Paper 3 Week 1

FORMS OF SUSTAINABILITY MEASUREMENT IN CITIES

In principle, sustainability outcomes are able to be interpreted through an assessment of the sustainability performance against objectives. In practice, assessment is done with indicators, both qualitative and quantitative. To gain an appreciation of the types of indicators and measurement methodology, it is useful to explore thinking from a cross section of research and practice.

In a review of literature presented at the 1998 and 2001 World Conferences on Transport Research (cited in Black, *et al.*, 2002a), it was found that academic research during the period had not progressed the development of indicators at the urban scale.

Most of the practice reviewed however, did show indicators to help assess the economic, social and environmental implications of scenarios or policy were beginning to be applied in Europe; some were aimed at specific elements of sustainability such as environmental capacity and sustainable accessibility and mobility. There was a large number of suburban scale literature, much of it from North America, none of which was focused on targets or performance indicators, however none of the indicators connected through to higher level goals of the system.

A 2001 review by the Institution of Engineers Australia NSW Transport Panel (cited by Black, *et al.,* 2002a) concluded that transport sustainability indicators and analytical techniques were little progressed since the concept of sustainable development was formulated.

The next sub section looks specifically at the approach of the European Commission leading into the practical applications referred to in Black, *et al.*, (2002a).

Observations of the 1996 Expert Working Group on the Urban Environment

The Expert Working Group (Expert Group on the Urban Environment, 1996) observed that indicator choice is more than purely a technical choice, but also a matter of policy choice. Indicators have important consequences and should be accountable to policy processes. Their work states that ‘sustainability indicators are seen as definable, measurable features of the world whose absolute levels or rate and direction of change are intended to reveal whether the world (or a city) is becoming more or less sustainable’(section 2.8, point 2) . The process involving indicators was seen as two way. Indicators are implied by policy aims, but indicators also help to define and mould policy aims.

The process of defining indicators influences notions of what is sustainable development. In many policy areas, proposed indicators can be judged against a clear and secure prior understanding from experience. ‘Deficient, or an unbalanced set of sustainability indicators, may devalue, or distort, the understanding of sustainable development, rather than put the worthiness of the indicators into question’ (section 2.8, point 5). The Working Group concluded that ‘any process of choosing sustainability indicators should be explicit, open and transparent, and that the reasoning behind the choice should be made clear to all those with an interest’ (section 2.8, point 6). Involvement of local communities is a particularly important response to the problem of choice in sustainability.

A tension exists in selecting between indicators that have ease of measurement and policy significance. Indicators have to be both practically useful and related to policy aims. Weighting minor or irrelevant factors, simply because they are easy to measure was to be avoided. The Expert Working Group concluded that advantages of indicators are:

> directing information collection, and making it accessible to decision-makers and the public; helping decision making by providing quantifiable measures to guide the application of institutional mechanisms and operational tools, particularly in relation to specifying targets; allowing for comparison over time and space; allowing effectiveness to be measured and progress to be assessed; providing a vision and a range of signposts for a desired future state;
>
> (section 2.8, point 8)

A typology of indicators, was described by the Expert Working Group, focusing firstly on environmental indicators and then on quality of life indicators. Environmental quality indicators and environmental performance indicators are of the first type. Also known as primary indicators they measure condition of key environmental features (such as impact e.g. CO_2 emissions or scarcity). Alternatively, features that are indicative of overall measure of quality or basic trends are desirable.

Environmental performance indicators instead measure the influence of human activities on the environment. Environmental performance indicators can be divided into two types. Secondary indicators measure basic quality by proxy and general effectiveness of policy. Tertiary indicators assess direct effects of particular policies, for example, the level of economic activity, public opinion and so on.

In summary, environmental quality indicators quantify sustainability impacts and environmental performance indicators monitor the outcome of policy decisions.

Another type of environmental indicator concerns integration of environmental issues in economic policies. The Expert Working Group identified these as environmental accounting indicators. Economic valuation on environmental costs and benefits is one form; the other is a system of natural resource accounts to measure quality.

Quality of life indicators are the second main group within the typology of sustainability. They convey attributes of sustainability to the community by translating 'technical' environmental indicators to help generate and facilitate community involvement. Quality of life rather than environmental indicators are seen to be of most interest in engaging community into local Agenda 21 strategies. A particular form of quality of life indicator is reported to be the indicator of sustainable lifestyle options. These are an attempt to measure more qualitative elements of sustainability. Subjective values such as personal growth, education, aesthetics and so on are their basis.

The Expert Working Group in the following statement left a standing challenge for practitioners in planning:

> There is an urgent need for experiment and diversity in sustainability policy and practice. Cities are complex enough to display the full range of problems, yet small enough to make changes relatively quickly - and for problems to be containable. Many European cities have already developed innovative approaches. The environmental problems linked to global sustainability, in

particular, have diverse causes and require diverse solutions at the level of the individual or household. Many innovative projects have been developed at local community level, and it is important that cities establish policy frameworks to foster these. It will be immensely valuable for policy makers to be able to compare (say) a city which keeps building roads to a similar one which actively restricts traffic.

(Expert Group on the Urban Environment, 1996, Chapter 4, p. 113)

(http://ec.europa.eu/environment/urban/pdf/rport-en.pdf, Jan 2008)

To illustrate the breadth of sustainability performance assessment approaches, a discussion on a cross section of examples follows:

Indicators and Metrics

A distinction can be made between indicators and metrics. Blakely (2006), highlights the difference. He notes that both metrics and indicators are used in society today to assess the direction of social, economic or natural condition of a metropolitan system. Metric is a term that means an objective measure of condition and process trend, whereas indicator is a judgment of performance. The metric tells only about what has changed and does not contain subjective interpretations of cause within the measure. As such, it provides a consistently quantifiable baseline each year, from which subjective interpretations can then be made. Blakely (2006) points out that good metrics have these characteristics:

- Addresses fundamental components of a regional system that can be measured over time.
- Clear and understandable.
- Can be tracked with regularly collected data from reliable sources.
- Easy to communicate graphically and in text
- Measures outcomes and not inputs.

(p. 7)

European Sustainability Indicators

The sustainability indicators in practice in Europe in 2007 are based on ten themes. The framework for the sustainable development indicators reflects key challenges of the sustainable development strategy, as well as the key objective of economic prosperity, and guiding principles related to good governance. The themes focus upfront on an economic dimension and then progress through social, environmental and institutional dimensions. The indicator set is built on three levels. The three levels of indicators reflect the structure of the strategy with overall objectives, operational objectives and actions and also respond to different kinds of user needs. The headline indicators have the highest communication value. These three-levels of indicators are complemented with contextual indicators, which provide valuable background information but which do not monitor directly the strategy's objectives (see Eurostat, http://epp. eurostat. ec.europa.eu, Jan 2008). The ten themes are shown in Table 2.2.

Table 2.2 European Commission indicator themes 2007

1.Socio economic development	6.Climate change and energy
2.Sustainable consumption and production	7.Sustainable transport
3.Social inclusion	8.Natural resources
4.Demographic changes	9.Global partnership
5.Public health	10. Good governance

(Source: Sustainable development indicators, http://epp.eurostat.ec.europa.eu, Jan 2008)

Seven of these themes correspond to the priority areas of the 2001 Commission Communication "A sustainable Europe for a better World" and the 2002 Communication on Global Partnership, while Production and Consumption Patterns and Good Governance arise from the Plan of Implementation of the World Summit on Sustainable Development.

These were revamped following the 2006 renewed European Sustainable Development Strategy (http://eur-lex.europa.eu /LexUriServ/site/en/ com/2005/ com2005_0658en01.pdf, Jan 2008; http://www.consiliu m.europa.eu/ueDocs /cms_Data/docs/pressData/en/ec/90111.pdf, Jan 2008).

Sub-themes and 'areas to be addressed' are a further division of the themes (see example Figure 2.11). The sub-themes mostly monitor progress towards headline objectives while the ´areas to be addressed` facilitate more detailed and diversified analysis of background factors in each theme. The sub-themes can also address ‘slow burning’ concerns that may need a very long time to reverse.

THEME 7: SUSTAINABLE TRANSPORT

(Key SDS challenge: Sustainable transport)

Access to data collection for Sustainable transport

Level 1	Level 2	Level 3
	Sub-theme: TRANSPORT GROWTH	
	2. Modal split of passenger transport	4. Volume of freight transport
	3. Modal split of freight transport	5. Volume of passenger transport (*data not yet availabe*)
	Sub-theme: TRANSPORT PRICES	
1. Energy consumption by transport mode	6. Road fuel prices	...
	Sub-theme: SOCIAL AND ENVIRONMENTAL IMPACT OF TRANSPORT	
	7. Greenhouse gas emissions by transport, by mode	9. Emissions of ozone precursors from transport
	8. People killed in road accidents	10. Emissions of particulate matter from transport
		11. Average CO_2 emissions per km from new passenger cars

THEME 8: NATURAL RESOURCES

(Key SDS challenge: Conservation and management of natural resources)

Figure 2.11 Example of European Commission indicator sub themes 2007

(Source: Theme 7, sustainable development indicators, http://epp.eurostat.ec.europa.eu, Jan 2008)

Australian Sustainability Indicators

The Ecologically Sustainable Development Transport Working Group1991 reported with many recommendations but did not provide any suggestions on analytical tools, evaluation methods or sustainability indicators. The Australian Government State of the Environment Reporting system provides reporting against the Ecologically Sustainable Development National Strategy and that supports Australia’s commitment to Agenda 21 for Sustainable Development and the OECD environmental performance reviews. In 1998, the Australian Government began the evolution of the reporting system with the aim to develop a set of environmental indicators that when properly monitored, would help track the condition of Australia’s environment and the human activities that affect it. A process to develop State of the Environment (SOE) indicators saw the commissioning of reports to recommend indicators for each of the following major themes: human settlements, biodiversity, the atmosphere, the land, inland waters, estuaries and the sea, natural and cultural heritage. The "Human Settlements" report provided an extensive review of the indicator options for urban form and urban transport, suggesting indicators shown in Table 2.3.

Table 2.3 2001 SOE sustainability indicators for Australia

Transport and accessibility

Indicator 4.1:	Access to Public Transport Stops
Indicator 4.2:	Car Ownership
Indicator 4.3	Perceived Residential Density
Indicator 4.4:	Driving Licence Holders by Age and Sex
Indicator 4.5:	CBD Parking Supply and Charges
Indicator 4.6:	Fuel Pricing and Taxing
Indicator 4.7:	Average Speed by Mode and Distance
Indicator 4.8:	Mode Choice by Trip Purpose by Area
Indicator 4.9:	Total Time and Distance Travelled
Indicator 4.10:	Perceived Daytime Density
Indicator 4.11:	Economic Costs of Road Accidents
Indicator 4.12:	Fuel Consumption per Transport Output
Indicator 4.13:	Costs of Congestion

(source: Newton, *et al.*,1998, p. 90)

Table 2.4 State of the environment (SOE) 2006 sustainability indicators

HS-20 Journey to work modal split Data on the modal split of journey to work assists in understanding the pattern of private and public transport use. This pattern depicts how accessible public transport is and how well public transport meets the need of commuters. This pattern is also related to the traffic congestion in inner city areas and to localised air pollution.	CO-30 Length and area of coastal and estuarine foreshore altered for human purposes The impact of human settlements on coastal habitats and ecosystems depends considerably on the form of that urban development.
HS-76 Vehicle kilometers travelled Kilometres travelled is an indicator of the accessibility of work and services required by settlement residents.	HS-06 Population density patterns in major cities Population density in major cities is an aspect of settlement patterns that has major implications for the environment of settlements.
A-35 Projections of motor vehicle travel and pollutant emissions	HS-30 Average size of new residential lots in capital cities

Motor vehicle projections are an indicator of trends in the reliance of the community on motor vehicle transport.	The average size of residential lots in capital cities is a surrogate indicator for density patterns in cities. The balance between residential lot size, dwelling floor size and population size contribute to the population density in settlements.
LD-15 Area and proportion of land surface occupied by human settlements, structures and activities that support human settlement The amount of urbanised area and changes in this area over time is an indicator of the level and rate of use of land by human settlements.	HS-51 Average floor area of new dwellings The size of newly built dwellings is an indicator of the liveability of human settlements. This indicates the amount of living space that is available for the inhabitants and will have an effect on settlement density, resource use and energy use.
HS-78 Housing demand (see note1) Demand for housing is an indicator of the pressure to build more housing, placing increasing pressure on the environment through the direct displacement of habitats and as a result of increasing other pressures of human settlements.	note1: Estimated using median house prices (capital cities) and the Real Estate Institute of Australia (REIA) housing affordability index (ratio of median family income to average new loan repayments).

(source: http://www.environment.gov.au/soe/2006/publications/drs/indicator, Jan 2008)

However, when it comes to specific urban planning and urban transport focused sustainability indicators, these are not as well considered given that the role of urban and transport development rests largely with state governments.

The 1998 Organisation for Economic Cooperation and Development (OECD) report (section 2, p. 8) pointed out that while Australia has a well developed strategy, there is a need to press on with increasing the intergovernmental co-operation and into implementation (http://www.environment.gov.au/commitments/oecd /publications/pubs/ oecd.pdf, Jan 2008).

In 2001, the Australian Government endorsed a set of headline sustainability indicators in response to the Ecologically Sustainable Development Strategy. Twenty four indicators were selected to collectively measure Australia's national performance against the core objectives of the Strategy (NSESD). These are reported through to the United Nations Commission for Sustainable Development and to the OECD. Some of the twenty four indicators selected, came from the State of the Environment (SOE) theme indicator recommendations, however, none were specifically for urban form and urban transport. The SOE theme indicators for “Human Settlements” were introduced to the SOE reporting in 2001 (see Table 2.4).

Approach by OECD Environmental Policy Committee's Task Force on Transport

The Organisation for Economic Co-operation and Development (OECD) Environmental Policy Committee's Task Force on Transport initiated a project on Environmentally Sustainable Transport (EST) in 1994.

Six environmental criteria for the transport sector were developed for the EST initiative as being the minimum number required to encompass the wide range of health and environmental impacts from transport. They include the greenhouse gas criteria which have global effects, local criteria which have a direct effect on health and amenity, together with other environmental stewardship criteria related to biodiversity and intergenerational aspects of the environment. (http://esteast.unep.ch/default.asp?community=est-east&page_id=5E423E42-1FFA-4B5F-9749-B4C414CC92CF, Jan 2008). Table 2.5 lists the criteria and provides quantitative goals for each.

Table 2.5 Agreed list of OECD environmental criteria and targets for environmentally sustainable transport

CO_2 Climate change is prevented by reducing carbon dioxide emissions so that atmospheric concentrations of CO_2 are stabilised at or below their 1990 levels. Accordingly, total emissions of CO_2 from transport should not exceed 20% to 50% of such emissions in 1990 depending on specific national conditions.	***NO_x*** Damage from ambient NO_2 and ozone levels and nitrogen deposition is greatly reduced by meeting WHO Air Quality Guidelines for human health and eco-toxicity. This implies that total emissions of NO_x from transport should not exceed 10% of such emissions in 1990.
VOCs Damage from carcinogenic VOCs and ozone is greatly reduced by meeting WHO Air Quality Guidelines for human health and ecosystem protection. Total emissions of transport-related VOCs should not exceed 10% of such emissions in 1990 (less for extremely toxic VOCs).	***Particulates*** Harmful ambient air levels are avoided by reducing emissions of fine particulates (especially those less than 10 microns in diameter). Depending on local and regional conditions, this may entail a reduction of 55% to 99% of fine particulate (PM_{10}) emissions from transport, compared with 1990 levels.
Noise Noise from transport no longer results in outdoor noise levels that present a health concern or serious nuisance. Depending on local and regional conditions, this may entail a reduction of transport noise to no more than a maximum of 55 dB(A) during the day and 45 dB(A) at night and outdoors.	***Landuse/Landtake*** Land use and infrastructure for the movement, maintenance, and storage of transport vehicles is developed in such a way that local and regional objectives for air, water, eco-system and biodiversity protection are met. Compared to 1990 levels, this will likely entail the restoration and expansion of green spaces in built-up areas.

(Source: OECD, 2002b, p. 45)

PROPOLIS Approach

A part of the European Commission's 5th Framework was the "City of Tomorrow and Cultural Heritage" under the Programme for Research and Technology Development. A key initiative was the development of the Planning and Research of Policies for Land-Use and Transport for Increasing Urban Sustainability (PROPOLIS) in 2003.

At the time PROPOLIS was proposed, there were a range of policies and instruments being put in place. All were aimed at contributing to sustainability improvement. However the different policies, including transport, land-use, regulatory, investment, fiscal and pricing policies were not stopping the decrease of sustainability of European cities. The interactions of these varying policies and their overall effect were not able to be clearly judged. It was suspected that some policies may even be working against other polices. PROPOLIS was aimed at improving the transparency of the direct and indirect, the short-term and long-term effects to give better capability to assessment of policy impact and policy evaluation.

To meet this goal, the PROPOLIS approach included integrated land-use, transport and environmental modelling as well as indicator, evaluation and presentation. For the first time, linking transport, land-use and environmental, social and economic modelling in the one process (Spiekermann and Wegener, 2003). This approach is shown in Figure 2.12.

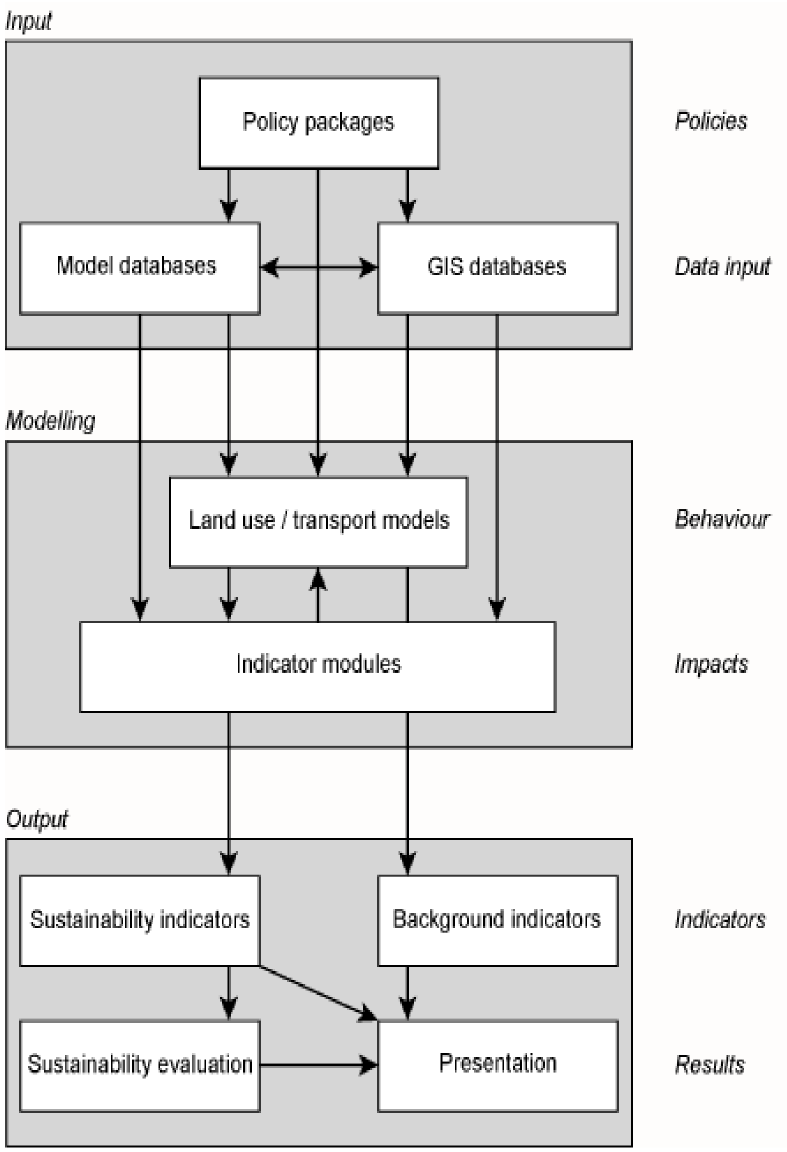

Figure 2.12   The PROPOLIS approach

(source: Lautso, *et al.*, 2004, p. 73)

Table 2.6   The PROPOLIS indicators

	Theme	Indicator
Environmental indicators	Global climate change	Greenhouse gases from transport
	Air pollution	Acidifying gases from transport Volatile organic compounds from transport
	Consumption of natural resources	Consumption of mineral oil products, transport Land coverage Need for additional new construction
	Environmental quality	Fragmentation of open space Quality of open space
Social indicators	Health	Exposure to PM from transport in the living environment Exposure to NO_2 from transport in the living environment Exposure to traffic noise Traffic deaths Traffic injuries
	Equity	Justice of distribution of economic benefits Justice of exposure to PM Justice of exposure to NO_2 Justice of exposure to noise Segregation
	Opportunities	Housing standard Vitality of city centre Vitality of surrounding region Productivity gain from land use
	Accessibility and traffic	Total time spent in traffic Level of service of public transport and slow modes Accessibility to city centre Accessibility to services Accessibility to open space
Economic indicators	Total net benefit from transport	Transport investment costs Transport user benefits Transport operator benefits Government benefits from transport Transport external accident costs Transport external emissions costs Transport external greenhouse gases costs Transport external noise costs

(source: Lautso, *et al.*, 2004, pp. 46-47)

The PROPOLIS indicators are established on a modelling basis rather than a basis in monitoring. They comprise environmental, socio-cultural and economic dimensions. Key indicators were identified using this set of criteria:

> *Relevance:* The indicator should be relevant for describing important aspects of sustainability.

> *Representativeness*: In order to keep the indicator system manageable, not each suitable indicator can be included, the focus is on key indicators representing different domains of sustainability.
> *Policy sensitiveness*: Only indicators that are sensitive to the policies investigated are of interest.
> *Predictability*: There exist a large number of indicators suitable for monitoring but, as the objective is to model future policy impacts, it is essential that the indicator values can be forecast into the future by the model system.
>
> (Spiekermann and Wegener, 2003, p. 3)

The PROPOLIS indicator system is shown in Table 2.6. The three sustainability pillars are subdivided into themes and the indicators are related to these themes. Nine themes and thirty-five key indicators were defined to measure the three pillars of sustainability.

The PROPOLIS sustainability indicators are modelled (i.e. can be forecast) and are not based on monitoring approaches in which the quantities in question are directly observed or measured. The indicators were chosen as near as possible at the tail-ends of causal chains. For example, vehicle kilometres or average travel times are not presented as indicators for sustainability but emissions or numbers of residents in the most polluted areas are included.

Quality of Life Approach

Hayashi and Sugiyama (2003) conceptualised packaging of separate objectives and their indicators under a higher goal of “quality of life”. This is shown diagrammatically with the link to a set of performance indicators, Figure 2.13.

From this conceptualisation, innovative research by Hayashi, Kato and Kachi, (see, Kachi, *et al.*, 2005; Kachi, *et al.*, 2007) produced a model for analysing sustainability in cities is as shown in Figure 2.14. This figure shows the framework for target oriented modelling for restructuring urban form based on a livability maximising approach. Quality adjusted life years (QALY) is used as an index for quality of life. Three types of components of the QALY and three types of constraint conditions are considered in the model. The three component types of the QALY are accessibility, amenity, and hazard. The three constraint types are economic, equity, and global environment.

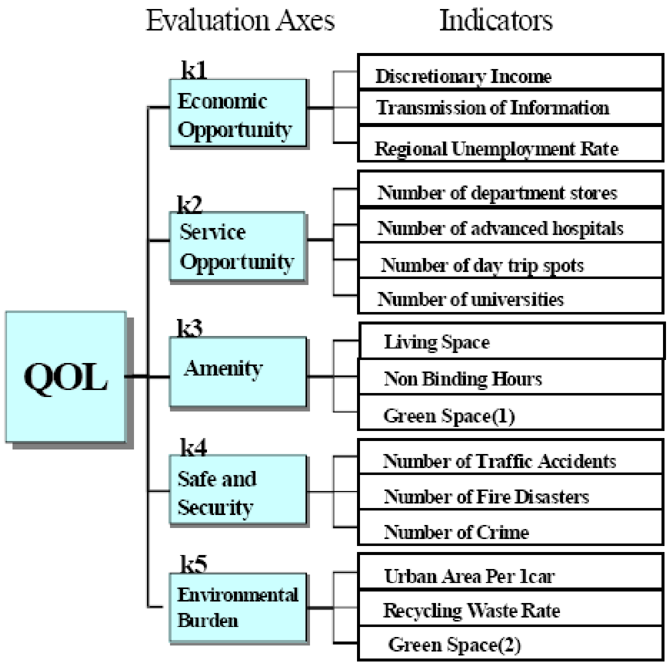

Figure 2.13 Overall Quality of life(QOL) – Its component objectives and their goal indicators

(source: Hayashi and Sugiyama, 2003, p. 12)

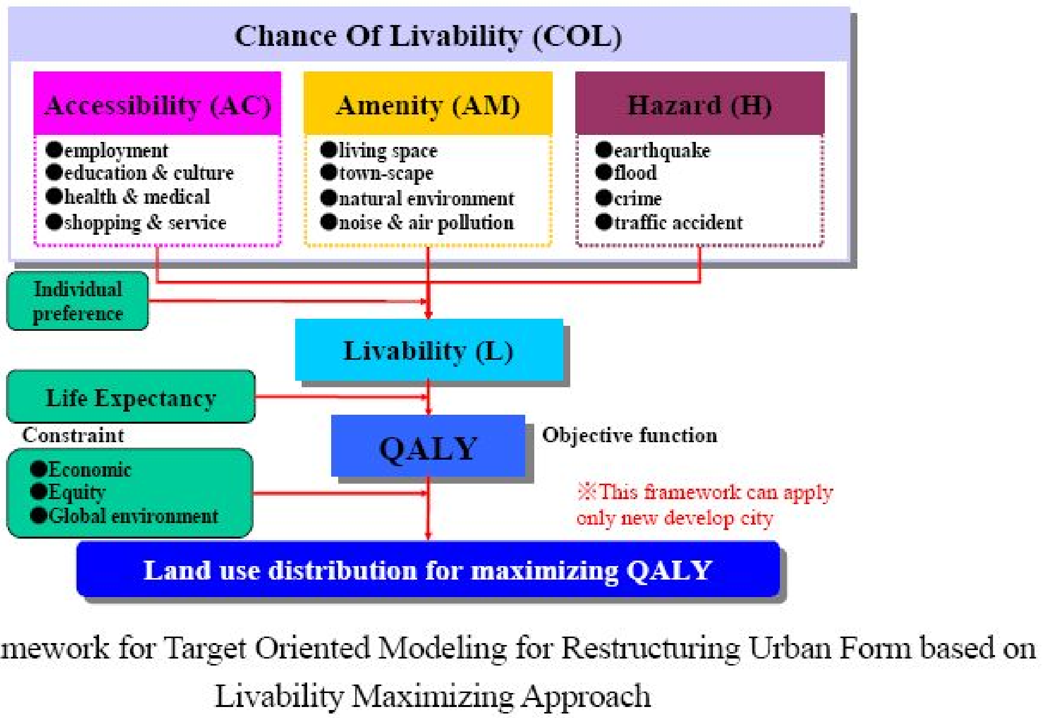

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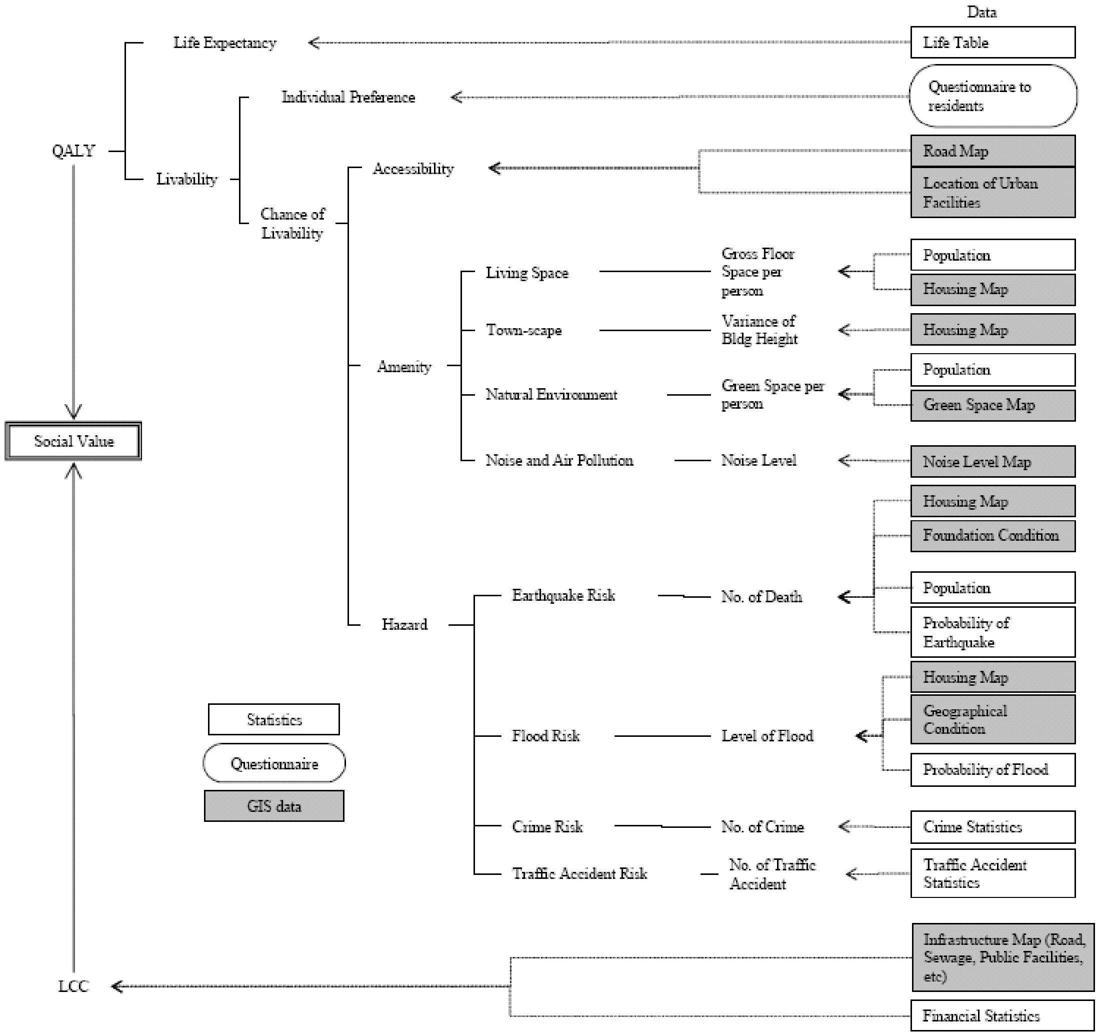
Figure 2.14 Structure of the QALY model

(source: Kachi, *et al.*, 2005, p. 3826)



. Data for the Calculation of Social Value

Figure 2.15 Inputs to calculation of social value

(source: Kachi, *et al.*,2005, p. 3832)

Liveability is defined as the chance of liveability based on the urban system characteristics of accessibility, amenity and hazard mixed with individual choice under the constraint conditions of economic, equity, and global environment limits. This approach promises a more objective integrated assessment of sustainability than can be expected from an individual assessment of indicators.

Kachi, *et al.*, (2005) also defined a social value term, observing that it is a more applicable term for existing urban forms. The social value term permits a maximisation of increase in rate of quality of life against life cycle cost of the change. This approach, shown in Figure 2.15 is more able to be assessed in existing urban forms. Kachi, *et al.*, (2005) found that this approach to measuring sustainability has practical advantages in combining a number of inputs.

The relationship between QOL elements and the three pillars of sustainability are also presented by Doi, *et al.*, (2007), in an alternative conception, shown in Figure 2.16. The concept shows the possible hierarchical structure and causal relationships between the five elements and the sustainability outcomes.

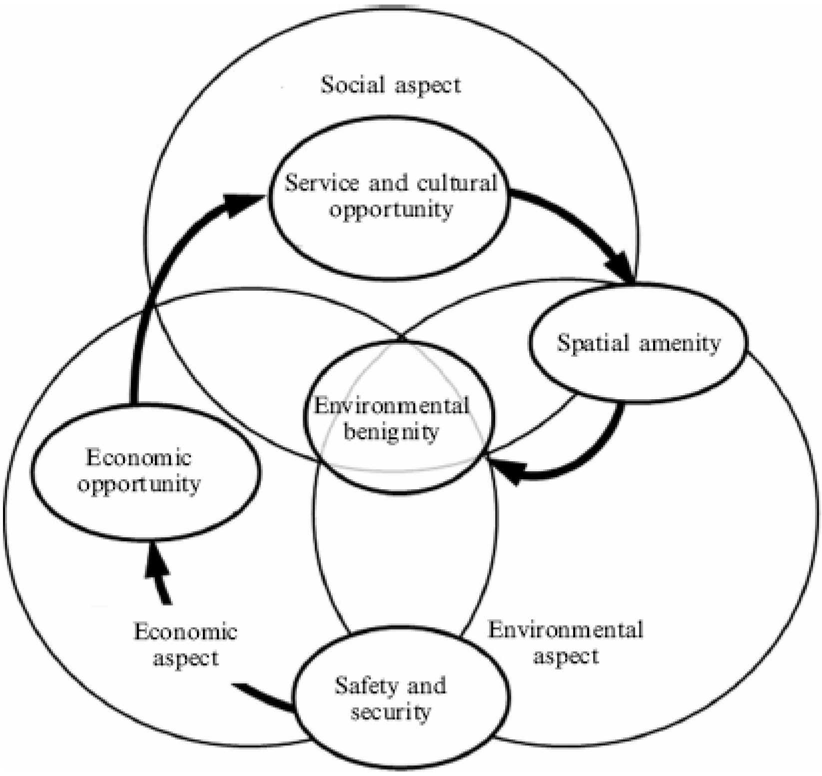


Figure 2.16 QOL elements and relationship to sustainability pillars

(source: Doi, *et al.*, 2007, p. 3)

Material Flow Account Indicators

Using material and energy flows in society, an additional indicator set known as stocks and flows indicators were derived in 2005 as part of the Australian Government SOE development process. (http://www.environment.gov.au/soe/2006/publications/technical/stocks/index.html, Jan 2008). Material and energy flows are concluded to be key determinants of ecological sustainability and also relevant to the social and economic pillars of sustainability. In a case study of the South East Queensland (SEQ) urban area of Brisbane and its hinterlands, analysis of material and energy flows were seen to provide indicators suitable for policy assessment and to inform of progress towards sustainability at local, regional, national and global scales. Inputs and outputs are shown in Figure 2.17.

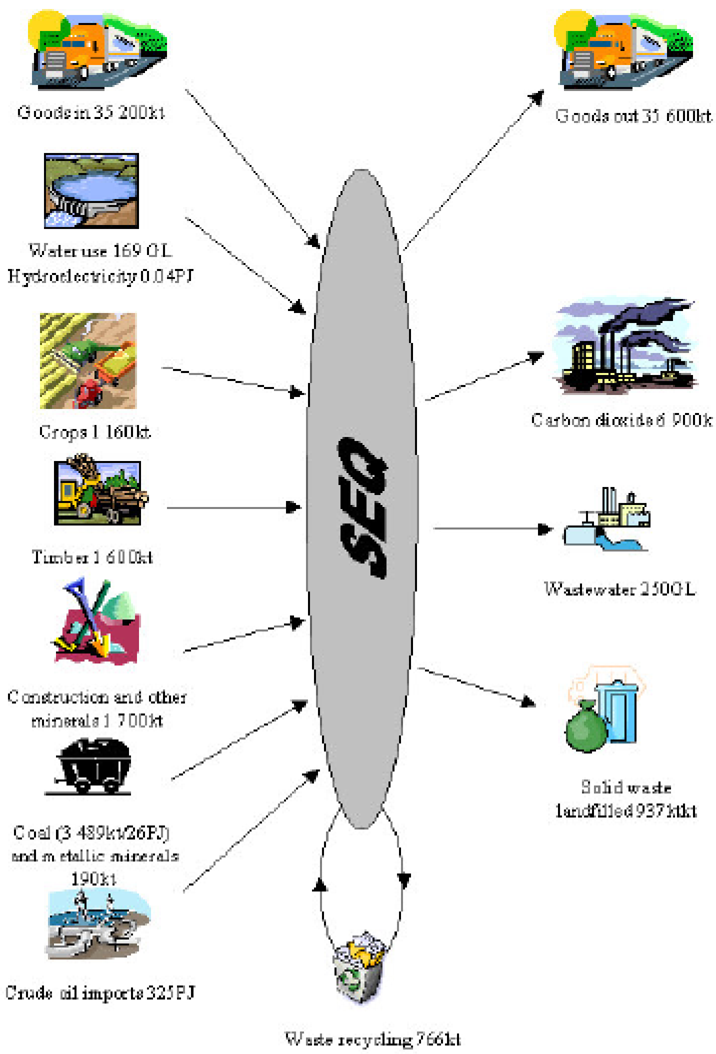


Figure 2.17 2006 SOE stocks and flows indicators

(source: Lennox and Turner, 2005, p. 17; http://www.environment.gov.au/soe/2006/publications/technical/stocks/pubs/stocks.pdf , Jan 2008)

Material flow account derived indicators are also planned for use in Europe. A methodological guide (European Commission, 2001) was prepared in 2001 (http://epp.eurostat.cec.eu.int/cache/ITY_OFFPUB/KS-34-00-536/EN/KS-34-00-536-EN.PDF, Jan 2008). The Eurostat statistical programme has these type of indicators listed as a key priority for development in 2007 (http://epp.eurostat.ec.europa.eu, Jan 2008).

These approaches relate also to the principles of "Ecosystems Thinking", developed in Europe in the early 1990's. This methodology views the city as a complex system, characterised by flows as continuous processes of change and development. (see Brugmann, 1992; Tjallingii, 1992, 1994; cited in Expert Group on the Urban Environment, 1996). Aspects such as energy, natural resources and waste streams are regarded as chains of activities which required maintenance, restoration, stimulation and closure in order to contribute to sustainability of the city. Other elements of the ecosystem thinking approach are regulation of traffic, urban development and consideration of the city as a social ecosystem.

The Australian Government Human Settlement theme report (Newton, *et al.*, 1998) provided a useful summary figure of the inputs and outputs of the physical material flows and the community dynamics. Figure 2.18 (http://www.environment.gov.au/soe/publications/indicators/pubs/settlements.pdf , Jan 2008).

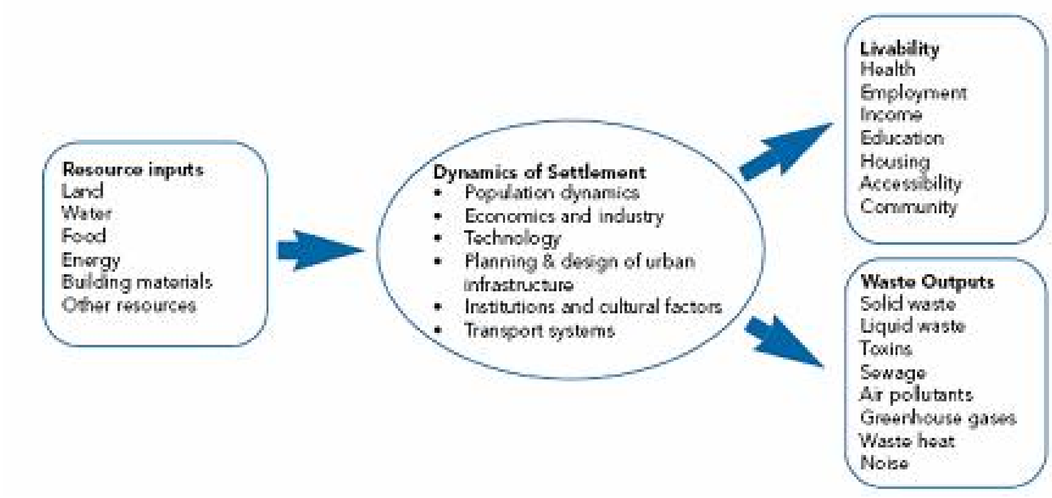


Figure 2.18 1998 Newton Concept for Sustainability Indicators

(source: Newton, *et al.*,1998, p. 10)

The Human Settlement theme report (Newton, *et al.*, 1998) in describing development of suitable indicators mapped the process from physical inputs through dynamics of settlement, to sustainability outcomes (Figure 2.18). The pillars of social equity and economic efficiency can largely be related to the livability portion of the figure. The waste outputs and resource usage mix relate to the environmental stewardship pillar of sustainability.

The relationship between each of these inputs and outputs are further illustrated in Figure 2.19, the DOMAIN model for transport (cited in Newton, *et al.*, 1998). Noticeable in this figure is the relationship of outputs to impacts, a connection between urban dynamics and the three pillars of sustainability environmental impact, social and economic impacts. (http:// www.environment.gov.au/soe/publications /indicators/pubs /settlements.pdf, Jan 2008).

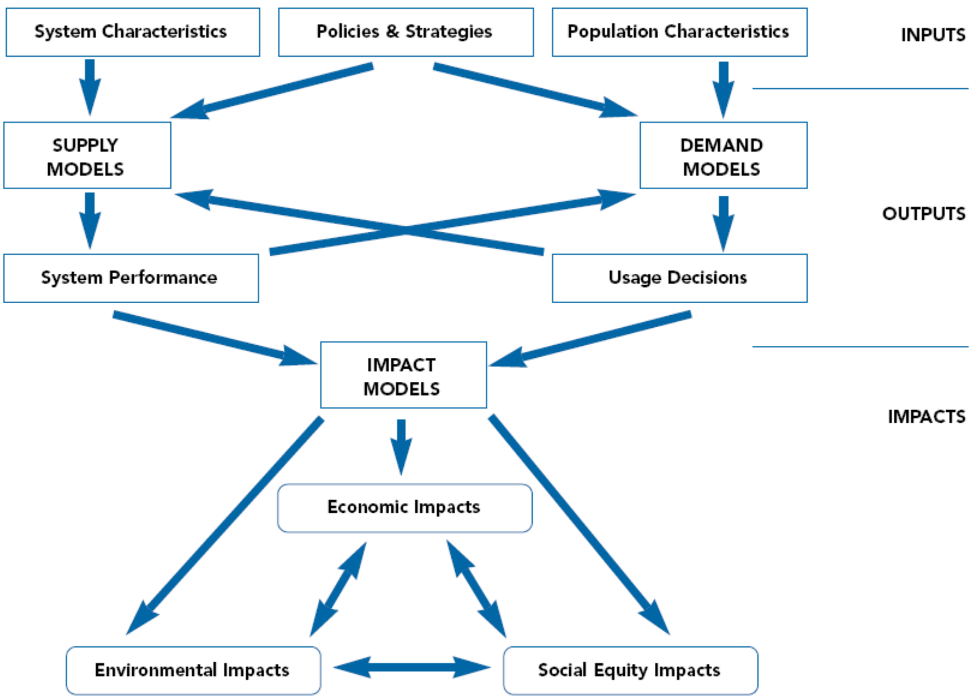


Figure 2.19 1998 Newton Domain model for transport sustainability indicators

(source: Newton, *et al.*,1998, p. 36)

Some New insights from WCTR and EASTS Conferences 2007

Wulfhorst (2007) advocates a systems thinking approach to sustainability to holistically link the urban system, its dynamics interactions with community and sustainability outcomes. Methods to evaluate multi criteria objectives require more development. Feng and Hsieh (2007) proposed an indicator framework which derives from links to the three pillars of sustainability. The concept is shown in Figure 2.20. Transport system characteristics give a performance that may or may not reach the goals set for the indicators of mobility, accessibility, safety and externality. The objective is to minimise the gap between performance and goals. The particular novelty is in the inclusion of goals which include a measure of transport diversity. 'Different transport stakeholders with diverse demands have different needs for transport infrastructures and services in an urban transportation system. To meet the objectives of sustainable transportation implies the trade-off consideration of benefits among different stakeholders' (p. 2)

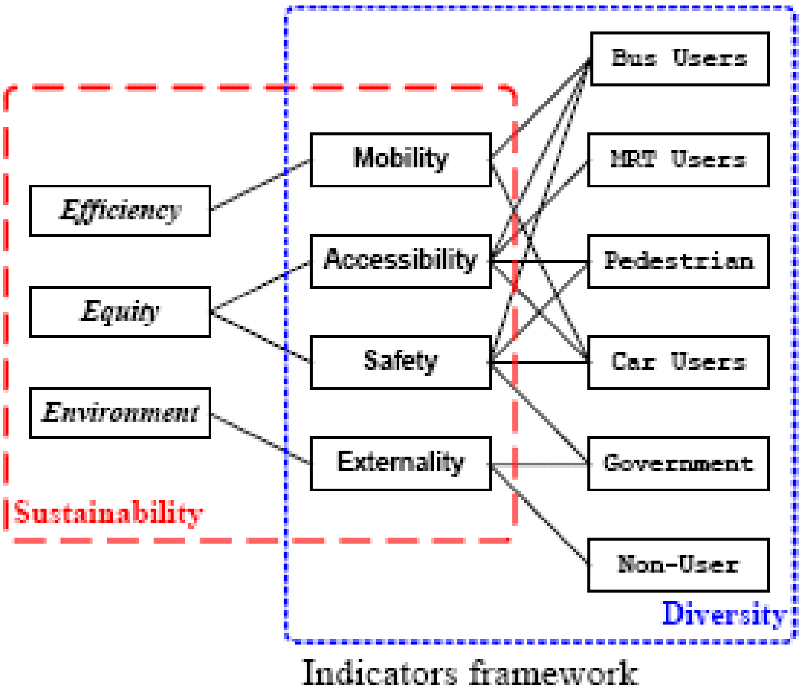


Figure 2.20 Linkage between sustainability and indicator framework

(source: Feng and Hsieh, 2007, p. 1241)

Morichi and Acharya (2007) concluded that while there is no question on the importance and role of the three pillars of sustainability in achieving a sustainable transport system, that in case of developing cities without providing a strong "foundation block", the above mentioned "three pillars" can not be well supported. They observe that 'unless an appropriate physical form of urban and transport system is put in place, is may not be possible to achieve sustainable urban transport system that ensures environmental efficiency, social equity and environmental soundness' (p. 8).

Zhang and Fujiwara (2007) explore a different approach to indicators of sustainability. Recognising that sustainability is effected by governance (government, firms, community) they package sustainability indicators as inputs to an assessment of governance by each of these actors. Zhang and Fujiwara (2007) identify a framework incorporating cause effect relationships. Policies for sustainability, are packaged into what is termed latent variables of land-use, transport supply and transport demand. They relate each of the governance actors to these as explanatory variables of the policy variables. A set of governance indicators are output, which show how much governance is in place for specific policy packages for each of the actors and how effective it is in producing sustainability outcomes. Giving an indication of where governance might constrain a cities sustainability performance.

European Commission Sustainability Indicator Interpretation and Integration Improvements

INSURE, a research project co-financed by the European Commission under the 6th Framework Program for Research and Technological Development concluded in 2007, with the development of a toolkit for regional scale application. The principal purpose was to move past the use of indicators that only show what is easy to see on the surface. The INSURE project (http://www.insure-project.net, Jan 2008) was aimed to get beneath the surface, to the underlying "system dynamics". Figure 2.21 shows this concept. Though, not applied to cities, it further highlights the need to understand the urban dynamics and provides a valuable development in this direction.

The renewed European Union Sustainable Development Strategy, the 6th Environment Action Programme and the related Thematic Strategies call for development of an integrated approach to assessment of sustainable development. The DECOIN and INDI – LINK projects commenced in 2006 as a priority response to this call and are due for completion in 2009.

An objective of the DECOIN project (http://www.decoin.eu, Jan 2008) is to carry out a detailed analysis on the inter-relationships between selected unsustainable trends and to provide a prototype tool for the analysis and for forecasting. A number of analytical frameworks are going to be applied in the project, including integration of biophysical, economic, social, demographic and land-use analyses. A life cycle cost analysis frames integration of resource use and environmental assessment aimed at a methodology to calculate consistent resource use efficiency and environmental performance indicators.

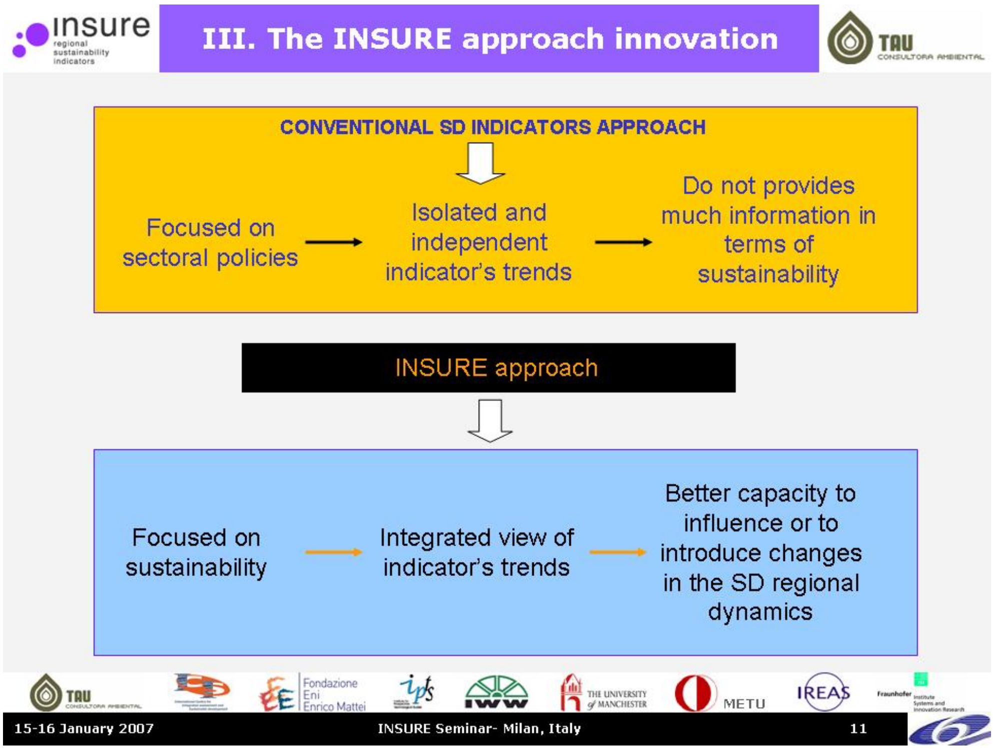


Figure 2.21 INSURE integration approach to sustainability indicators
(source: , Presentation 19/01/2007, http://www.insure-project.net, Jan 2008, p. 11)

The INDI-LINK project (http://www.indi-link.net, Jan 2008) is largely aimed at improving European Union sustainable development indicators and interlinkages between the different priorities of the renewed European Union Sustainable

Development Strategy. Objectives include identification of the most effective combinations of environmental, economic and social policy measures, focusing on the synergies and mitigation of potential trade-offs.

A particular focus is being placed on the consideration of inter-temporal interactions and intergenerational aspects of different sustainable development policies. No details of project results for either of these projects are yet available.

Observations on Accessibility from General Review of Sustainability in Cities

The principal meaning of sustainability was identified in the three pillars of sustainable development. These pillars of environment protection, equity and economy were observed to mean environmental sustainability or stewardship for future generations, equity in social opportunities and economic efficiency for a healthy economy.

A key to sustainability in cities is that all three pillars of environmental sustainability (stewardship), social equity and economic efficiency work together. An effective sustainability performance therefore requires all three pillars to achieve complementary outcomes rather than competing outcomes. Yet, there is a tension between the proponents of each pillar. This has sometimes resulted in particular perspectives on sustainability that give some subjective bias towards the pillar of most concern to the proponent. Some of the tensions relate to a perception that intergenerational equity coming from stewardship of resources and ecological capacity, economic efficiency for a productive durable economy; and equality of the social benefits of economy and environment between communities, are not able to be optimised in favour of all three pillars.

It is notable that there are many indicators to choose from, but individually they paint only a very limited picture of sustainable performance of a city. It was pointed out in the previous subsection, that indicators of sustainability need to be considered together to give a holistic picture of the sustainability performance of a city. In Paper 1 it was observed that the 2002 World Summit on Sustainable Development (WSSD) in

Johannesburg (United Nations, 2002) identified a need for a holistic approach to the three pillars of sustainability. A conclusion of the Summit was that there was no tool available for this integrated holistic type of assessment.

> The significance of a balanced and holistic approach to the three pillars of sustainable development was highlighted. It was pointed out that an integrated approach, while not a novel idea, needs further development. There is currently no internationally agreed tool for using an integrated approach in policy and programme planning and development. Efforts should be undertaken to address this shortcoming.
>
> (clause 15, p. 125)
> (http://www.un.org/jsummit/html/documents/documents.html, Jan 2008).

This prompts the question: "are there methodologies that have the potential to contribute in objectively measuring the performance of all of the pillars of sustainability?"

From the literature reviewed, we can draw out some important insights into how to answer this question. It was observed that the concept of accessibility is seen as one important characteristic of sustainability. For example, Europe's environmentally sustainable transport strategy (OECD, 2002a) included in the definition of sustainable transport 'provides for safe, economically viable, and socially acceptable access to people, places, goods and services'(OECD, 2002a, AnnexureII pp. 17). In this we see that the concept of access and therefore accessibility relates to social well being through the object of the access, being equity for all inhabitants and efficiency which relates to the economic well being of the city. The European Sustainable Cities Project (European Commission, 1996) selected sustainable management of natural resources, socio-economic aspects of sustainability, sustainable accessibility and sustainable spatial planning as the priority areas requiring a set of principles and tools needed to move cities towards sustainability. A primary objective of a city's transport policy was seen as reconciliation of the goals of accessibility, economic development and environmental objectives.

In a study on Chinese cities, Black (2001) concluded that accessibility plays an important role in the desire for a sustainable city form. Chinese cities like many Asian cities are under pressure to take on contemporary trends seen in western cities in the past 40 years. Under the pressure of increasing motorised transport and increasing separation between work and home, these cities are at great risk of suffocation.

The Dutch National Institute of Public Health and the Environment (Geurs and Ritsema van Eck, 2001) in their review of accessibility measures, determined that accessibility had a definitive role as both an indicator of social consequences and as an indicator of economic consequences. They pinpointed that activity and utility based accessibility indicators are the most appropriate, having sensitivity to both land-use and transport changes.

The Expert Working Group on Sustainable Urban Transport Plans (2004, pp. 17) affirmed this by including accessibility for all categories of inhabitants, commuters, visitors and businesses as an important objective for sustainable urban transport plans. They explicitly unpacked this to mean accessibility with social objectives (health, safety and security of citizens including the vulnerable in the community along with attractiveness and quality of urban environment), environmental objectives (minimising emissions and resource usage i.e energy consumption), economic objectives (improve efficiency and cost effectiveness of transport for persons and goods along with attractiveness and quality of urban environment). Academia has also incorporated accessibility in some newer approaches. For example, the framework shown in Figure 2.14 has accessibility as a key component, providing inclusion of social opportunity and economic opportunity arising from efficiency.

Thus, there is a well substantiated body of opinion that accessibility (as a measure of social well being, social equity and economic efficiency) has the potential to provide an important connection between these pillars and the environmental pillar called for in sustainable development. The European Sustainable Cities Project (European Commission, 1996) terms this potential as “sustainable urban accessibility” and nominates this to be a vital step in the overall improvement of the urban environment and maintenance of the economic viability of cities.

Wachs (address titled “Perspective of an outsider”; cited in Warren Centre for Advanced Engineering, 2003, pp. 1 -12, section 0) emphasised the role sustainability is playing in addressing equity and distributional issues in receiving the benefits of social capital. By drawing attention to the cities in the developing world he highlighted the challenge to consider the form of accessibility that can minimise the inequity in distribution of social and economic benefits to the developing world without the high environmental and resource cost experienced in the developed world.

This notion of sustainable accessibility has come as a match to the idea of a complementary outcome for the three pillars of sustainability. To explore this potential, it is first necessary to look more deeply into the concept of accessibility. Paper 4 begins this by focusing on the concept and looking carefully at the definition of accessibility.