1. Session: 1st Workshop on EeB KPIs - Key Performance Indicators

1.1. Visualising the 'Big Picture': Key Performance Indicators and sustainable urban design

T. Crosbie	TEESSIDE UNIVERSITY (TECHNOLOGY FUTURES INSTITUTE), MIDDLESBROUGH, UK	t.crosbie@tees.ac.uk
M. Crilly	TEESSIDE UNIVERSITY (TECHNOLOGY FUTURES INSTITUTE), MIDDLESBROUGH / STUDIO URBANAREA LLP, NEWCASTLE, UK	m.crilly@tees.ac.uk michael@urbanarea.co.uk
N. Dawood	TEESSIDE UNIVERSITY (TECHNOLOGY FUTURES INSTITUTE), MIDDLESBROUGH, UK	n.n.dawood@tees.ac.uk
J. Oliveras	FOMENT DE LA REHABILITACIO URBANA DE MANRESA, SPAIN	joliveras@forumsa.cat
N. Niwaz	RAMBOLL (ENERGY SUPPLY AND PLANNING), COPENHAGEN, DENMARK	ndn@ramboll.dk

Abstract

This paper explores the scope of key performance indicators [KPIs] used in urban development plans and international, national and local government policies and initiatives. The key focus of the paper is how KPIs may be used to support the delivery of carbon reduction initiatives and urban planning projects.

The work presented sets out the scope of sustainability KPIs used during the different procedural stages of a project brief. As such it illustrates how KPIs are used to assess the viability of a project's 'business case' and how KPIs can be used to inform the delivery and on-going monitoring and evaluation of a project.

More significantly, the paper also describes the connections between KPIs at different operational scales of statutory regulation. Drawing from a series of European case studies, it examines policy indicators used within the statutory urban planning and building regulation processes and how these are represented and modelled within currently available ICT decision-support tools. It is suggested that current practice in the use of urban indicators is largely scale dependent and reflects limited, or professionally-defined, remits that restrict the benefits similar KPIs can have over the course of a 'live project' from concept to completion.

The case studies describe scenarios made up of a series of measures seeking to optimise individual project stages rather than work holistically. They highlight some of the unintended consequences of approaches that inadvertently isolate and optimise individual stages of the urban development process. The paper concludes that there is potential to work more systemically and holistically, using existing data sources more effectively across different procedural actions and at different policy scales.

Keywords: sustainability, key performance indicators [KPIs] and urban development plans

The Scale of Sustainability

Over recent years there have been numerous initiatives and guides offering practical advice in the use of data for supporting sustainable communities, guiding new forms of urban design and adapting the existing urban structure. There has been advocacy for the use of urban models in the design of sustainable cities and layering information on a comparative spatial basis. There is a subtle underlying theme in this body of work about the use of appropriate data that could link, and integrate, some of the thinking at the different scales and levels of strategic urban design interventions. While central to thinking about sustainability is the effective integration of different physical and socio-economic systems, in real-world decision making it also relates to issues of the scale and the different project stages at which the decisions are made. It is dependent upon the remit of the stakeholder making decisions. In this practical context, sustainability and integration becomes more of a procedural concern than an imposed substantive solution. As such, the use of meaningful data, indicators and measures has a critical role in this process. Thus, the current stakeholder or 'practitioner' focus in the development and use of key performance indicators [KPIs] is around indicators used as procedural tools to support local and project decision-making.

> "Close examination of recent housing … standards … indicates a tendency to adopt a piecemeal approach that relies on outdated data sources and references … [a] process of cobbling together existing standards" (Milner & Madigan 2004 p.739).

Integration around sustainability and quality indicators is more than simply patching together separate topics that measure one of the elements of sustainability. Integration has to occur with regard to both the scale and scope of interventions.

Coordination and consistency between scales of intervention from the macro (city and region) to the micro (buildings and components) is a prerequisite of sustainable design. While it has been recognised that in practice, most work is undertaken at a multi-layer approach, seeking to integrate work at different scales of operation (Carmona 2001), this is not a straightforward task.

European and national governments and agencies have taken steps towards integration by setting, and then mandating, standards. They have attempted to lead by example (for instance, in establishing integrated standards for land disposal and funding eligibility, English Partnerships 2006) in the piloting, measurement and testing of standards. There have been studies looking at potential conflicts with localised requirements and site practicalities. There have been attempts to extend and develop many findings from pilot sustainability and low-energy projects. For example, the UK 'Carbon Challenge competition' sites included zero carbon homes plus sustainable considerations at each stage of the design and construction process from participation, planning, detail, lean construction and on-going neighbourhood management to "…. incorporate lifestyle features and designs for behavioural change so that residents may live low carbon lifestyles … (and) … demonstrate how such homes can be produced for the wider market"(CLG and English Partnerships 2007).

However, beyond the government supported exemplar projects and initiatives, the main mechanism proposed for integrating the different physical and technical systems for sustainable performance in the UK is the Code for Sustainable Homes (CSH) (CLG 2005, CLG 2010). This has a focus on individual properties and technical solutions with some limited potential for rescaling.

Property Scale KPIs - The 'Code for Sustainable Homes'

KPIs are extensively used as part of the accredited approach to assessment at the project design and post-completion stages. Within the CSH there is a combination of 'essential' and 'desirable' measures, each providing a score towards the overall standard. The 'desirable' elements are those left to the decisions of the design team to allow trade-offs between issues such as potable water use, site ecology and construction management processes. The 'essential' elements on energy and carbon dioxide emissions have implicit KPIs requirements that relate to *DER (dwelling emission rate)* and the *TER (target emission rate)* figures, These are measurements commonly used to calculate the *FEE (fabric energy efficiency)* within the UK's SAP (standard assessment procedure).

This cross referencing to existing KPIs described within statutory requirements, such as building regulations, does have the effect of common language and reference points for comparison and evaluation. At a localised scale, many planning authorities are now refining their own sustainability standards in the context of a *percentage improvement over the TER*. As such they are using the same KPI measurements and methods and sign-posting stakeholders towards CSH as one of the most appropriate sources for specification guidance.

With the exception of a limited number of urban scale KPIs, such as site density (*gross number of dwellings per hectare*) and development mix *(gross floor area by land use)* the CSH limit measurement to the dwelling scale. This is as much to do with confidence and availability of appropriate data at the neighbourhood scale, as it does with theoretical understandings of sustainable design.

It would seem that sustainability thinking as grounded in the *Code for Sustainable Homes* is still restricted to the dwelling or site rather than the neighbourhood or city scale. Consequently, the policy emphasis on the integration of technical systems at the scale of the individual building has led to less detail being available for measuring sustainability at the neighbourhood scale.

While there is significant work exploring the idea of typologies urban neighbourhoods within a climate context (Prasad et al. 2009 and Ewing et al. 2008) and a recurrence of thinking and planning at the scale of the neighbourhood, much of this work is also theoretical and hard to pin down with regard to setting specific objectives, measurements and assessment. For example, certain projects need 'outcome' assessments for their particular investment model that demand measurable social benefits. Igloo (a sustainable & social investment pension fund)"are in the process of improving [their] ability to quantify these, often hard to measure, benefits, in particular those that contribute to societal well-being" (Brown 2012 p.26). It is important to note that these do not have to be monetary or technically based KPI measurements.

There are also significant problems in scaling up technical solutions. For example, one of the most famous attempts at scaling up some of the innovative thinking on sustainable energy and water systems, buildings and lifestyles, Bedzed in Sutton in the UK, had serious operational difficulties (Slavin 2006 p.9). Many of these problems arose from the use of untested technologies at the neighbourhood scale (Slavin 2006 p.9). Perhaps somewhat unsurprisingly the greatest saving in carbon emissions for collective CHP, car clubs and other behavioural issues resulted from the high density form of the Bedzed development and the fact that the development attracted those with a concern for the environment to live there. Yet aspects of ***urban density*** and ***occupant preferences*** are not generally considered as sustainability KPIs.

There are additional concerns over the implications for larger scale densities and mix of land uses on local neighbourhood energy demand and the viability of different technical systems. This means that what seems optimal at the household scale is not necessarily the most appropriate solution at the neighbourhood scale. It is also suggested that there is a real issue about maintaining design quality and identity in the face of overpowering sustainability requirements and that these are as important as costs and construction issues (Elliot 2006).

Project Scale KPIs – New development in 'Copenhagen's North Harbour' and large-scale retrofit in 'Newcastle's Riverside Dean'.

Stakeholder scoping was conducted in three separate case studies. These included a mixed new urban quarter at Copenhagen's North Harbour and the large scale retrofitting of a social housing estate in the West End of Newcastle upon Tyne. This exercise identified a total of 62 separate KPIs (Niwaz *et al* 2012) intended to be generic and transferable to similar situations and project scenarios. These KPIs take the form of energy efficiency and CO_2 emission variables (Gallopín 1997), that are measurable and represent the operation of both neighbourhood and building scale energy systems.

These are overtly technical measurements that are used to calculate the high-level performance indicators. They are used as factors for establishing baseline energy demands (*Energy demand for final energy uses, Demand for different energy carriers, Energy distribution losses*), the proportion of this demand met by renewable sources (*Energy carriers from renewable energy sources, Renewable energy in the total electricity supply, Share of local electricity carriers from renewable energy sources, Share of local energy carriers from renewable energy sources*) and the resultant emissions (*CO_2 emissions and reduction compared to baseline*). Calculations including – income, socio economic considerations and energy costs provides indicators that support the evaluation *of energy efficiency options* and the assessment of *fuel poverty*.

These are typical of project-specific KPIs that concentrate on measurable outcomes set within the initial project briefs, be it the development of a zero carbon neighbourhood (North Harbour, Copenhagen) or the area-wide removal of fuel poverty (Riverside Dean, Newcastle).

Urban Scale KPIs - The Covenant of Mayors

This European cooperative movement involves local municipalities making corporate commitments to a target level of a 20% reduction in CO_2 emissions by 2020. These are generally delivered by Sustainable Energy Action Plans (SEAP) that rely on KPIs to measure a *1990 baseline level of CO_2 emissions* and a year on year *percentage reduction*. Actions within the individual SEAPs vary enormously between different cities and locations with each signatory municipality deciding on their own set of indicators and measures.

More localised KPIs generally relate directly to the contents of the SEAP and include *process indicators* around the effective implementation of SEAP activities. They include benchmarks relating to public lighting and facilities, transport, buildings, even behaviour and good manners. The benchmarks used in each individual case reflect the statutory responsibilities and areas of control via purchasing and public private partnerships etc. Therefore the appropriate indicators shown in a meaningful way to provide information for the appropriate stakeholders are important in moving the municipality towards their CO_2 emissions targets.

Integration also relates to KPIs measuring issues of ***occupancy*** and ***behavioural characteristics***. There are a growing number of studies highlighting the interrelationship between social factors such as demographics, levels of occupation and energy consumption (Energy Saving Trust 2012 and Crosbie and Baker 2010). These all show that when consumer concerns, preferences and attitudes are included, in any evaluation, things become more complex: And when consumer and occupancy concerns are scaled up, for example in Britain's *Green Deal*, so is the complexity and chaos associated with policy interventions.

National Scale KPIs – The 'Green Deal'

Nowhere has the need for an accurate understanding of upfront *capital costs* and *potential energy savings* from retrofitting work been as critical as with Britain's Green Deal (Guertler *et al* 2013). This 'pay to save' business model relies on assessed energy savings from a package of energy efficient works to the fabric and the energy systems of existing properties. KPIs relate to existing *carbon emissions*, *energy demand* (space heating, hot water, electricity) and potential *carbon and energy savings per annum* over a fixed period. It also has a calculated 'Golden Rule' making finance available for those with a *pay-back period* of less than seven years. Here, the process of assessment is particularly important regarding issues of trust in both the accuracy of the costs / predicted savings (Bioregional 2011) and those installing the works on behalf of those responsible for utility bills (not necessarily the property owner). Critical to the scheme in operation is a lack of effective integration between predicted energy savings and finance rates, with the result that "… the government's flagship energy efficiency programme … has become something of a shambles" (Brignall 2013 p.4).

Acknowledging the benefits of integration in its' broadest scope for sustainability, practice is still restricted in attempts at integrated design. Practitioners are still largely limited to the measurement and assessment of technical issues and scared by the complexity of human interactions, preferences, values, tastes and lifestyles when thinking at the scale of the urban designer and town planner.

> "The objective approach focuses on results, not the process by which results are achieved. ... (while) (p)rocess approaches see planning as much more than a technical process." (Marcuse 1976 p.271)

Yet sustainability isn't just about scale. It has procedural elements that incorporate the central idea of 'integrated design'. Thinking about sustainable systems requires different ways of collaborative and interdisciplinary working between professionals, politicians and community stakeholders with local ownership and involvement. It requires the early involvement of key professional skills in areas such as architectural design, energy strategy, materials and specifications, supply chain considerations and long-term management. The supply chain concerns are also significant where the design process has to be based on requirements and understanding of the construction, materials, and the full range of factors impacting on manufacture, assembly, management, repair and adaptation. Yet, there are seldom KPIs used to assess these stages in the project process.

In the real world of urban planning both process and outcomes are important areas for measurement and assessment.

'Outcome' versus 'process' indicators

Comparative studies of urban scale KPIs have stressed the need for constant review and evaluation of their use in practice. Their selection requires some degree of consistency suitable for international comparison (Shen *et al* 2010) as well as setting a useful baseline for local level monitoring (Munier 2011). Urban scale KPIs have to be measurable and relevant to urban planning outcomes; in that they reflect local objectives and priorities or processes (Zhang *et al* 2008) and ideally present a simplified view (Mega and Pedersen 1998) of a complex system. While this suggests pragmatism is essential in the use of any set of indicators (due to availability and cost of data, relevance to national and local policies), perhaps the key distinction is between 'process' indicators (measuring the implementation of policies or actions) and 'outcome' indicators (measuring the impact of the urban planning process).

Strategic 'outcome indicators' have been defined by the 'vision' of sustainable regeneration within central government (ODPM 2005) that in itself has been informed by earlier scoping studies (for example; Turok and

Kearns 2004, Housing Corporation and European Institute for Urban Affairs 2003). This work suggested a broader range of indictors within a toolkit of measures that reflect similar definitions of sustainable communities. This 'toolkit' approach was applied in the Housing Market Renewal (HMR) programme and found their way into the Egan review (Egan 2004) and became the core of those current indicators within urban planning and regeneration activities within the UK.

Urban Scale KPIs – the 'Housing Market Renewal Pathfinder' Initiative

The Housing Market Renewal Initiative was part of the national framework for urban planning, complementing the (mostly) southern growth areas with managed housing-led regeneration in the (mostly) northern urban conurbations. The aim was to stabilise local housing markets through planned interventions around a mix of demolition, refurbishment and new house building. The range of KPIs reflected this explicit economic bias with some weight given to softer measures relating to community cohesion.

Within this HMR programme, a review of the core performance measures (ECOTEC and Nevin Leather Associates 2009) shows that key performance indicators relate mostly to the targeted delivery of the business plan. They assessed the effective delivery of business plans rather than the actual impact of the business plans on the stability and sustainability of the local housing market. This review also found that business plans were placing the greatest weight on economic measures and noticeably missing any core indicator relating to environmental sustainability and energy efficiency performance. In practice, many of the significant outcome indicators were forgotten and there was a dominance of process indicators, where data was readily available. There were similar reasons in the limited use of locality specific indicators. While local key performance indicators generate diversity they also create a degree of inconsistency in measurement around the country makings comparisons and the development of national indices difficult. There were also often problems with locally self-defining indicators due to the availability of information at a small area basis (Bramley *et al* 2007). Even with the use of supposedly integrated indicators, there were unanticipated consequences, or displacement impacts, within other areas and housing markets that were not being directly recorded in any form of impact indicator (ODPM 2006).

In practice, many of the locality defined indicators relating to energy efficiency and sustainability are based on subtle variations around some of the nationally recognised standards and measures. Indeed this wider perspective of sustainability in urban planning and regeneration (as defined through the set of indicators and measures adopted) has been replaced with a smaller number of transitory indictors based largely on assessment of funding priorities. For example, the numbers of voids / empty properties and *percentage of properties abandoned per street*, HCA 2011. 'Process indicators' also relate to post-completion and occupancy stages. Practice based reviews (LCEA 2011) suggest that KPIs and information should be linked in some way to incentives or 'rewards' for behavioural change and reflect key actions within a behavioural change strategies, for example, *reductions in annual energy bills* and *uptake of energy efficiency improvements*. Most KPIs are derived from policy and their use in practice is either mandated or dependent upon national or local government funding. A condition or requirement of funding is what is generally meant when people talk about 'core indicators'. This is consistent with other areas of grounded-research (Innes & Booher 2000) that suggests there is no generic model or set of indicators for any city or region. They simply have to be fit for purpose regarding scale, cost, and rapid feedback and as such have to be framed with the user involved from the outset.

It also has to be remembered that the choice of KPIs is also a political decision, which sets both a definition of sustainability and an agenda for change (Crilly *et al* 1999). As the emphasis in the use of key performance indicators has moved towards more data-defined indicators; and a bias towards quantitative and economic indicators, the scope and importance of sustainability is diluted.

This perspective sets some interesting requirements and questions for KPIs and the framework from which they are selected.

- With regard to scale, can KPIs be used to assess household energy consumption? Is the data underlying a KPI suitable for aggregation and / or disaggregation and therefore suitable for informing decisions at a variety of different operational scales?

- With regard to stage and processes, is it possible to use the same set of KPIs in a technical brief right through to post-occupancy monitoring of properties and energy systems? Is there even a commonly recognised set of work stages between different professional disciplines working at different stages in any project? Are 'practitioners' limited in the choice of KPIs by their professional discipline?

- With regard to scope, do KPIs allow for comparison between economic costs, social acceptability and technical performance? Are the assumptions of achieving buildings and cities that are sustainable and affordable even achievable? Are we able to recognise the empirical bias of how KPIs are used to guide policy and practice?

- With regard to outcomes, can we make any clear associations between the impact measures and the success of policies if we are only measuring the policy implementation process?

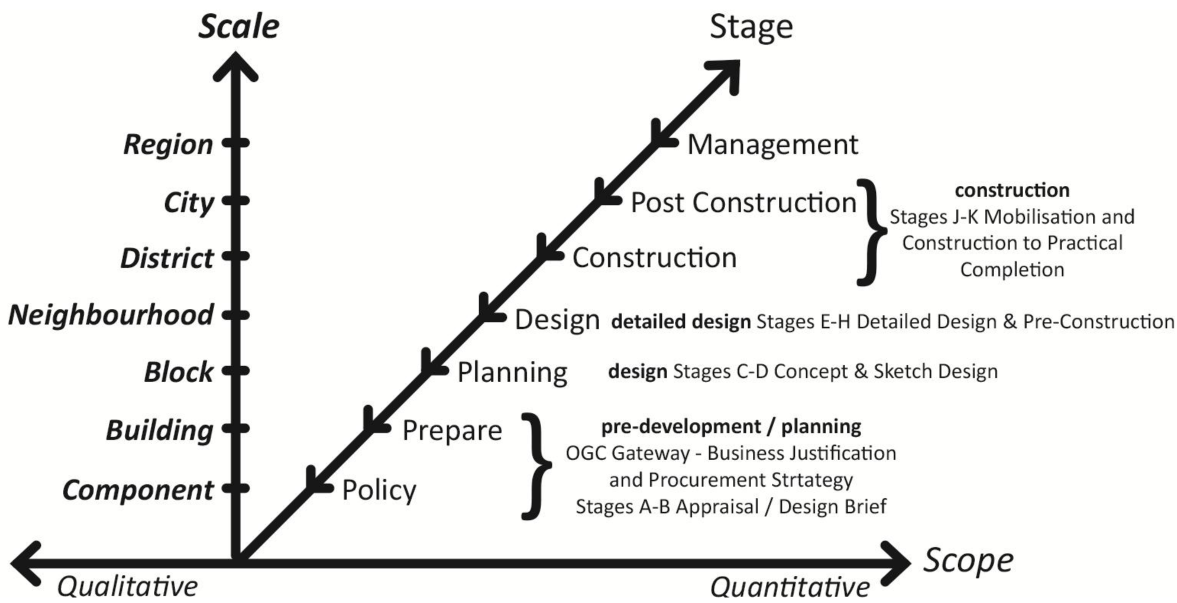

Figure 1. Alternative framework for integrated key performance indicators developed from the Stakeholder Capture Requirements exercise undertaken for the Semanco project.

Our response to these questions has been informed by an exercise in capturing stakeholder (decision-making 'agents' and technical 'users' of evaluation and assessment tools) requirements around the use of KPIs for sustainability and energy efficiency. This framework (figure 1) seeks to address the relationship between three 'dimensions' of sustainable design. Specifically (1) the scope of sustainability (integrating subjective and empirical measures), (2) the scale (detail / operational scale for potential interventions and / or initiatives to address energy efficiency and the reduction of carbon emissions), and (3) the stages of decision-making (related to professional disciplines).

The research underpinning this primarily concerns the identification of a conceptual framework or 'toolkit' of KPIs that are useful in practice to a range of professional disciplines working at different scales and at a variety of project stages. In mapping out the KPIs that are currently used regarding energy efficiency and carbon emissions, we can also begin to highlight gaps in themes, scales and work stages. In short, it can help to maintain a more holistic view – the bigger picture of what is happening.

Integrating Information and Data Modelling

One of the key factors influencing the choice of KPIs is the availability of meaningful and relevant data. In response, this section sets out some ideas for using a 'toolkit' approach to KPIs that begins to integrate actions at different scale and stages of project work and make the best use of available open-source data. The idea behind the integration of data is one of semantic modelling.

Integrated KPIs - Semantic Energy Modelling

The 'Semanco' project sets out to apply Semantic Energy Modelling, to support the calculation of a set of energy based KPIs within the practical context of limited data of the right format and sources. KPIs were defined by the stakeholders through a series of use cases. A summary of the project capture requirements (Crosbie *et al* 2013) highlighted significant implications for the selection and use of KPIs. Particularly regarding the appropriate use of metadata standards (e.g. sources, dates, sampling and accuracy) and protocols that provide comparison that require indicators in understandable units of measurement and which are referenced in national, regional or local policies or mandated standards. Here there has to be a recognition over the importance of high-level standards in informing more localised policy and thus the choice of any indicators used for measurement.

The collection of appropriate supporting data, considered the data format (spatial / three-dimensional) and the scale(s) of operation. This generally reflected the operational scale of the key stakeholders working in sustainability and energy efficiency. It considered the source of data, whether it was actual / monitored or modelled data and the cost-effective use of open-source public data. The developing semantic structuring of data is supporting KPIs in a 'toolkit' that is pragmatic around the best use of cost-effective data and sharing data at different scales of operation and stages within any project implementation. The stakeholder is able to self-select and visualise their own specific energy-related indicators using the platform developed as part of the SEMANCO project Madrazo et al (forthcoming).

The idea of semantic information being applied to urban planning and design is not new. Haken and Portugali (2003) suggested an approach based on pattern recognition and building geometry. Another applied example is pattern recognition in the size / density of settlements as part of a self-organising hierarchy (Samet 2013). This proposes some ideas for structuring data in a 'layered' manner that can be used in the formulation and application for suitable KPIs. Indeed, there are increasing numbers of examples of data-rich indicators that go beyond the principles and theory into how spatial data can be used to inform strategies and responses to urban resilience (Pickett *et al* 2013) and sustainability (Crilly and Mannis 2000). More recently, KPI data is being organised in three-dimensional geodatabases (Dalla Costa *et al* 2011) "... including geometry and semantics, later developed in CityGML standard format." (Dalla Costa 2013 p.27). In the same way, things have come a long way to the semantic modelling of building energy use (Grzybek *et al* 2011) for comparison and testing of options from an initial interest in thermal modelling, lighting, daylight and airflow (Eilers 1999).

Yet in such an approach to the use of KPIs, supported by computer modelling, there are errors and uncertainties associated with any data input. Indeed, there is a suggestion that there is an academic tendency for KPIs to be driven by the data (Ennis and Madrazo 2013). Whether this is due to practical availability or research interest, rather than the stakeholder requirements is unclear. In response, the emphasis in any application is on the consideration and evaluation of different options. This type of evaluation and 'agent-based' modelling (Portugali 2001) has been largely absent from most 'standardised' energy calculations. We have to be honest and say that semantic data doesn't yet support accurate predictive models rather it supports explanatory and exploratory models which provide 'ball park' predictions. However this does allow comparisons of the different options for increasing urban sustainability at different analytical scales to inform decision making.

Real World data is noisy

> "Networks are everywhere. It is a structural and organisational model that pervades almost every subject, from genes to power systems, from social communities to transportation routes" (Lima 2011 p. 73).

The implications of maintaining a 'big picture' through the use of a set of KPIs, are to do as much with the underlying conditions of the systems being measured as with any individual indicator or metric. In building up a picture that is holistic and representative of a sustainable system (neighbourhood, city or regional scale) there has to be some reflection of the complexity around the inherent conditions of that system. The system will be complex, unpredictable, self-organising and thus there has to be an understanding and appreciation of uncertainty, errors and risks in the use of any proxy measures in describing the behaviour of this system.

> "Complexity itself can be deceiving. Biogenic complexity constrains entropy flows with checks and balances. What we take to be man-made artificial complexity (technology) is, paradoxically, a simplification process that increases flows by editing away inefficiencies. ... Everything we identify with the man-made substitutes for natural bio-economies, that is, technologies, tend towards positive feedback, which is self-amplifying, self-reinforcing, and destabilizing, featuring the removal of constraints to entropy flows and leading to the certain eventual destruction of that system." (p191, 192, Kunstler 2005)

For example in relation to the assessment of energy and carbon emissions, there are errors relating to the data collection methods (uses of approximations standardised inputs etc.), the accuracy of open-sources data (for building geometry, property ages, methods of construction etc.) and the separation from any variable associated with occupants. What is available through specific KPIs is simply an abstraction of reality. It is simplified and standardised. However, they are still the most cost effective way of assessing the potential energy performance of a property/city/region independently from the difficulties of qualitative variables.

In writing about the pitfalls in the use of big data, Silver (2012 p.9) states "(t)he numbers have no way of speaking for themselves. We speak for them. We imbue them with meaning." It is similar when indicators and measures are used in calculations of climate and carbon emissions. They often ignore the importance of errors, and levels of uncertainty as part of making sense of the complex system. As planners and policy makers, we set the semantics for the data. This is why the SEMANCO project has developed front-end tools to facilitate end user involvement in the semantic data modelling underpinning the project and the exploration of semantically modelled data. In this way it ensures the outputs of the project are of value to end users (Madrazo et al Forthcoming).

Conclusions

Dealing with urban sustainability means addressing the procedural aspects and varying scales at which decisions are taken that impact on energy consumption and carbon emissions. Activities and KPIs at the urban design / neighbourhood and city scales need to be aligned with and supported by the regional and national governmental structure and cultures. Experience has shown that without consistency between scales of action there will inevitably be a 'gap' between policy and delivery. This will be the case, even allowing for some level of flexibility and creativity to achieve the important performance indicators at the local level. We need indicators not just to measure processes but as a reminder of the scope and definition of sustainable urbanism.

Addressing sustainability also requires thematic integration. It is clear that there are overlapping and complex relationships between spatial planning, urban regeneration, energy policy and technical standards. Many of the technical details and parameters also have systemic relationships with socio-economic systems. Central to these key associations are the economic implications for renewable energy strategies and issues of affordability (affordable warmth, fuel poverty and fuel security) of properties. In most cases, the significant KPIs are those relating to the 'triple-bottom line' and the need to demonstrate the cost effectiveness of using appropriate sustainable technologies. There has to be benefits on several levels, including the medium to long term cost benefits of management and maintenance. Thus any measurement of impacts and options for achieving carbon reduction without associated costs will not have any real practical application.

Finally we have to maintain the *bigger picture* with regard to urban sustainability. This might mean working outside of our professional restrictions to coordinate between different stakeholders, scales and stages of intervention. It also means being aware of the limitations of our own evidence, as defined by data and KPIs. It means being open to displacement effects and unexpected consequences of some policy interventions. KPIs can help to build a picture of how well things are being done ('process indicators') and the observable changes being effected ('outcome indicators'). However, used blindly KPIs can have unexpected consequences. Therefore even in the world of 'big data', it needs to be understood that KPIs must be used with caution. Planning and managing urban change is complex and contextually contingent. We have to accept that when planning sustainable urban change 'one size' does not fill all. However there is undoubtedly a potential to work more systemically and holistically, using existing data sources more effectively across different procedural actions and at different policy scales.

Acknowledgments

This paper is based on applied semantic modelling research work undertaken as part of the SEMANCO project. SEMANCO is supported by the Seventh Framework Programme "ICT for Energy Systems" 2011-2014, under the grant agreement Number 287534.

References

1. BioRegional (2011) *Helping to Inform the Green Deal: Green Shoots from Pay As You Save - Sutton Pilot Results and Evaluation Report* (BioRegional, Sutton). [online] Available at: http://www.bioregional.com/files/publications/Helping-to-inform-the-Green-Deal-green-shoots-from-Pay-As-You-Save.pdf [Accessed: 8 Jul 2013].

2. Bramley, G., Leishman, C., Kofi Karley, N., Morgan, J and Watkins, D (2007) *Transforming places: Housing investment and neighbourhood market change* (Joseph Rowntree Foundation, York).

3. Brignall, Miles (2013) "Go green? Why it's not a big deal". *Guardian Money* 29th June p4.

4. Brown, Chris (2012) "The Community is the Client". *Urban Design* 123 pp25-26.

5. Carmona, Matthew (2001) "Sustainable Urban Design – A Possible Agenda" pp165-192 in; Layard, Antonia., Davoudi, Simin and Batty, Susan (Eds.) *Planning for a Sustainable Future* (Spon, London).

6. Communities and Local Government (2010) *The Code for Sustainable Homes: Case Studies Volume 2* (Department for Communities and Local Government, London).

7. Communities and Local Government (December 2006) *Code for Sustainable Homes: a step change in sustainable home building practice* (Department for Communities and Local Government, London).

8. Communities and Local Government, English Partnerships (2007) *Carbon Challenge standard brief* (English Partnerships, London).

9. Crilly, Michael and Mannis, Adam (2000) "Sustainable Urban Management Systems" pp 202-214 in Elizabeth Burton, Mike Jenks and Katie Williams (Eds.) *Achieving Sustainable Urban Form* (E & FN Spon, London).

10. Crilly, Michael., Mannis, Adam and Morrow, Karen (1999) “Indicators for Change: taking a lead”. *Local Environment* 4(2) pp151-168.

11. Crosbie, Tracey., Crilly, Michael., Oliveras, Joan., Gamboa, Gonzalo., Niwaz, Nadeem and Lynch, David (2013) SEMANCO Project Deliverable 6.1 Stakeholder requirements analysis: The SEMANCO project is Co-funded by the European Commission within the 7th Framework Programme Project ICT 287534.

12. Crosbie, Tracey and Baker, Keith (2010) “Energy-efficiency interventions in housing: learning from the inhabitants”. *Building Research & Information* 38(1) pp70-79.

13. Dalla Costa, Silva (2013) ‘Energy indicators based on multi-source data and participation’. *Urban Design and Planning* 166 pp24-33.

14. Dalla Costa S, Roccatello E and Rumor M (2011) “A CityGML 3D geodatabase for buildings’ energy efficiency”. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXVIII-4/C21 pp19–24.

15. ECOTEC and Nevin Leather Associates (2009) *Wider performance measures for the housing market renewal programme: National evaluation of housing market renewal pathfinders* (Department for Communities and Local Government, London).

16. Eilers, Martin (1999) “Energy and Environmental Computer Modelling of Buildings”. *EcoDesign: The Journal of the Ecological Design Association* 7(2) p40-41.

17. Elliott, Jane (2006) “Achieving a Sustainable Consensus”. *Urban Design* 99 pp 12-13.

18. Energy Saving Trust (2012) *Powering the Nation – Household Electricity Using Habits Revealed* (Energy Saving Trust, London).

19. English Partnerships (2006) *Quality and Price Standards for use in development competitions and site disposal tendering* (English Partnerships, London).

20. Ennis, Chris and Madrazo, Leandro (Eds.) (2013) *Workshop Discussions Document: Analysing and visualising energy related data in our buildings, towns and cities*. [online] Available at: http://arcdev.housing.salle.url.edu/semanco/SEMANCO_Barcelona_Workshop_Outline_Discussion_Document_Public_Version_FINAL.pdf [Accessed: 8 Jul 2013].

21. Ewing, Reid., Bartholomew, Keith., Winkelman, Steve., Walters, Jerry and Chen, Don (2008) *Growing Cooler: The evidence on urban development and climate change* (Urban Land Institute, Boulder).

22. Gallopín, G (1997) “Indicators and Their Use: Information for Decision-making”. In: Moldan, B. & Billharz, S. (Eds.) *Sustainability Indicators. Report of the project on Indicators of Sustainable Development*. Scope 58.

23. Grzybek, Hubert., Shah, Hussnan, H., Wiafe, Isaac., Gulliver, Stephen R and Nakata, Keiichi (2011) “Modeling Building Semantics: Providing Feedback and Sustainability”. Paper presented to *World Renewable Energy Congress*, 8-11 May, Linköping, Sweden.

24. Guertler, Pedro., Robson, David and Royston, Sarah (2013) “Somewhere between a ‘Comedy of errors’ and ‘As you like it’? A brief history of Britain’s ‘Green Deal’ so far.” *ECEEE Summer Study Proceedings* pp153-164.

25. Haken, Herman and Portugali, Juval (2003) “The face of the city is its information”. *Journal of Environmental Psychology* 23(4) pp385-408.

26. Homes and Communities Agency (2013) *Quality Counts 2011/12: Results of the Quality Assurance and Impact Visits: Affordable Homes Programme 2011-12* (Homes and Communities Agency, London).

27. Homes and Communities Agency (2011) *HMR transition funding – DCLG/HCA bidding guidance* (Homes and Communities Agency, London).

28. Housing Corporation and European Institute for Urban Affairs (2003) *A Toolkit of Indicators of Sustainable Communities* (Housing Corporation, London).

29. Innes, Judith E and Booher, David E (2000) “Indicators for Sustainable Communities: A Strategy Building on Complexity Theory and Distributed Intelligence”. *Planning Theory & Practice* 1(2) pp173-186.

30. Kunstler, James Howard (2005) *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century* (Atlantic Books, London).

31. LCEA (2011) *The Missing Quarter: Integrating Behaviour Change in Low Carbon Housing Retrofit* (Low Carbon Economic Area LCEA Behaviour Change Retrofit Group, Manchester).

32. Lima, Manuel (2011) *Visual Complexity: Mapping Patterns of Information* (Princeton Architectural Press, New York).

33. Madrazo, L. Nemirovski, G. and Sicilia, A. (Forthcoming) Shared Vocabularies to Support the Creation of Energy Urban Systems Models, 4th Workshop on EEB Data Models 10th of September 2013 held in parallel with the 2013 ICT FOR SUSTAINABLE PLACES NICE | FRANCE

34. Marcuse, Peter (1976) “Professional Ethics and Beyond: Values in Planning”. *American Institute of Planners AIP Journal* July pp264-274.

35. Mega, Voula and Pedersen, Jørn (1998) *Urban Sustainability Indicators* (European Foundation for the Improvement of Living and Working Conditions, Dublin).

36. Milner, Jo and Madigan, Ruth (2004) “Regulation and Innovation: Rethinking ‘Inclusive’ Housing Design”. *Housing Studies* 19(5) pp727-744.

37. Munier, N (2011) “Methodology to select a set of urban sustainability indicators to measure the state of the city, and performance assessment”. *Ecological Indicators* 11 pp1020-1026.

38. Niwaz, Nadeem., Gamboa, Gonzalo., Cipriano, Xavi., Hvid, Jørgen., Lynch, David., Madrazo, Leandro., Sicilia, Alvaro., Ballarini, Ilaria., Nolle, Andreas and Crosbie, Tracey (2012) *SEMANCO Project Deliverable 2.2 Strategies and Indicators for Monitoring* CO_2 *Emissions*: The SEMANCO project is Co-funded by the European Commission within the 7th Framework Programme Project ICT 287534.

39. ODPM (2006) *Assessing the impact of Housing Market Renewal (HMR) pathfinder: interventions – displacement issues* (Office of the Deputy Prime Minister, London).

40. ODPM (2005) *Sustainable Communities: Homes for All. A Five-Year Plan* (Office of the Deputy Prime Minister, London).

41. Owens, S (1992) “Energy, Environmental Sustainability and Land-use Planning” pp77-105 in; Breheny, M.J (Ed.) *Sustainable Development and Urban Form* (Pion, London).

42. Pickett, S., Cadenasso, M.L. and McGrath B (2013) *Resilience in Ecology and Urban Design: Linking Theory and Practice for Sustainable Cities* (Springer, Dordrecht).

43. Portugali, J (2001) *Self-Organization and the City* (Springer-Verlag, Berlin).

44. Prasad, Neeraj., Ranghiere, Federica and Shah, Fatima (2009) *Climate Resilient Cities: A Primer on Reducing Vulnerabilities to Disasters* (World Bank Publications, Washington).

45. Samet, R.H. (2013) “Complexity, the science of cities and long-range futures”. *Futures* 47 pp49-58.

46. Shen, Li-Yin., Ochoa, J Jorge., Shah, Mona N and Zhang, Xiaoling (2010) “The application of urban sustainability indicators – A comparison between various practices”. *Habitat International* 35 pp17-29.

47. Silver, Nate (2012) *The Signal and the Noise: The Art and Science of Prediction* (Penguin, London).

48. Slavin, Terry (2006) “Living in a dream”. *Society Guardian* May 17th p9.

49. Turok and Kearns (2004) *Sustainable Communities: Dimensions and Challenges* (Office of the Deputy Prime Minister, London).

50. Zhang, K., Wen, Z., Du, W and Song, G (2008) “Study of indicators of urban environmentally sustainable development in China”. *International Journal of Sustainable Development* 6(2) pp170-182.