Sustainable urban design – a (draft) framework

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To cite this article: Nico Larco (2015): Sustainable urban design – a (draft) framework, Journal of Urban Design, DOI: 10.1080/13574809.2015.1071649

To link to this article: http://dx.doi.org/10.1080/13574809.2015.1071649

Published online: 01 Oct 2015.

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Sustainable urban design – a (draft) framework

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ABSTRACT
This paper provides a roadmap or guide to help urban designers and researchers understand the elements and topics in urban design that should be considered when addressing sustainability. It describes – within the realm of urban design – what is to be sustained, the metrics for this and the urban design elements that contribute to those metrics. A matrix organizes the urban design elements by topic and scale to help urban designers and researchers relate these disparate aspects, identify areas of synergy and serve as a basis for comparison when trade-offs are present.

Introduction
Cities and urban design are intimately linked to sustainability goals. More than half of the world’s population now lives in urbanized areas, with these areas accounting for approximately two-thirds of global energy use (International Energy Agency 2012) and expanding into approximately 10 million acres of natural and rural land yearly (Seto, Guneralp, and Hutyra 2012). With this, the organization and design of urban areas has an ever-increasing role in affecting the sustainability of the planet as a whole.

The link between urbanism and sustainability is well established (Beatley and Manning 1997; Frey 1999; Wheeler 2000; Jabareen 2006) and is primarily based on the effect of urban form on transport, water quality and recharge rates, habitat, equity concerns and pollution. While sometimes used interchangeably, the term ‘sustainable urbanism’ encompasses topics of sustainability related to the entire process of city development and management, while sustainable urban design sits somewhere within that. Sustainable urban design is not necessarily a clearly delineated subset of sustainable urbanism, but instead can be thought of as focus area within it that is concentrated around issues of design while still maintaining strong links to the other realms such as planning, engineering, real estate and policy.

As commented by Alex Krieger, urban design itself is a discipline with an “absence of a simple definition” (Krieger and Saunders 2009, viii). On the one hand, it “articulates the physical form and programmatic components of urban situations” (Marshall 2009, 40), but the complexity of this task places urban design at the nexus of several other disciplines (Carmona 2010). While architects initially claimed the term and discipline (Barnett 1982; Mumford 2009), the list of engaged and associated disciplines has expanded due to the
complexity of urban development. This list initially included disciplines such as land use and transportation planning, landscape architecture, civil engineering, real estate and public policy. Today, as urban areas tackle sustainability related concerns, the disciplines directly related to urban design have expanded even further to include areas such as ecology, plant and wildlife biology, and environmental engineering to name a few.

For the purposes of this paper, urban design is defined as the design and organization of urban form and uses and includes the design of public space, transportation systems, open space, platting and buildings insomuch as they shape the public realm. While there are a number of regulatory structures, policy and process questions that guide the development of cities, the focus of urban design in this paper is more concerned with the physical manifestation and design of urbanized areas.

This broad definition and the mix of contributors described above, now intrinsic to the discipline, is indicative of the complexity of sustainable urban design and the breadth of topics it must address. Many have tackled the theoretical (Carmona 2009; Cuthbert 2012) and historical (Mitlin 1992; Wheeler 2000; Barnett 2011; Mehaffy 2011) underpinnings of sustainable urbanism and urban design specifically, have suggested models of sustainable development (Jabareen 2006; Lehmann 2010), or have focused on the process of conceiving sustainable development (Steiner 2000, 2002). However, what is still lacking is a framework for sustainable urban design that can act as a guide to practitioners and evaluators that begins with what is to be sustained, extends into the specific components or elements of how that might be achieved, and provides a means of relating these different components.

While discussion of sustainable urban design has thankfully moved beyond monotheistic discussions to include the breadth of related disciplines and topics, much of the literature on sustainable urban design still lacks grounds for holistically relating the different aspects of urban design. Density of development is treated as a completely distinct issue from habitat connectivity, which is in turn treated as separate from issues of urban heat island effects. While identifying the different broad categories of sustainability in urban design is an important first step, the lack of a means for comparison or coordination between specific components or moves causes problems for the evaluation and design of sustainable urban environments.

In the design process, it is helpful to understand the range of issues across sustainability goals that need to be addressed at any given scale and to understand how decisions at one scale will affect outcomes or potentials at the larger and smaller scale. Any development often includes both trade-offs and fortuitous moments of synergy in terms of sustainability. An overarching framework for sustainable urban design can provide a medium for weighing these trade-offs and identifying moments where a single design move can support multiple aims.

A major barrier to creating an overarching framework is the early state of research linking specific aspects of urban design to sustainability as well as linking one aspect to another. While there is growing consensus on how some specific elements of urban design affect sustainability goals – the connection between density and energy use for instance (see Newman and Kenworthy 1989, as well as the meta-analysis of Saelens and Handy 2008; Ewing and Cervero 2010) – many other aspects are still energetically debated. The reasons for this lack of clarity are in part due to a lack of research in some areas and in part to the endemic complexity of the topic in other areas. In terms of transportation mode choice, for example, human behaviour in something as varied as an urban context is hard to predict.
This makes it quite difficult to prove causality between any specific urban design element and outcomes. In addition, it is arguably a mix of urban design elements that lead to any one sustainable outcome. Analyzing the full combination of these elements at any one time is understandably difficult, but at the same time analyzing these elements separately often produces inconclusive results.

Data are often a problem in this area of research as many aspects of urban design are fine grained, qualitative in nature and difficult to quantify (Schwartz 1999; Forsyth 2012). Even when these aspects can be quantified, the data necessary for the fine grain scale of analysis needed is most often not readily available and is both cumbersome and costly to capture.

That said, the lack of even a draft framework has left the description of what sustainable urban design should address at a broad and vague scale that does little to help guide practitioners and researchers. A framework created at this time and with the research currently available will inherently include speculative aspects. At the same time, there is remarkable unity in many of the urban design elements that are currently considered – although arguably not unequivocally proven – to relate to sustainability goals. This paper is an attempt to both compile that list and then arrange it in a form that allows urban designers and researchers to relate disparate elements and can help guide sustainable design as well as future areas of research.

Unlike previous attempts to categorize sustainable urban design, this approach is not focused on models of urban form or design (such as the green city, compact city, etc. – Jabareen 2006; Barnett 2011), but instead on the specific elements and topics within urban design that affect sustainability. While discussion of overarching models is helpful, these models often give little guidance at the moment of design or evaluation of specific urban design projects. At the same time, it is rare that such models are ever definitively applied in any given project.

There are a number of sustainability focused urban scale rating systems such as LEED-ND, BREEAM Communities, STARS (arguably the broadest approach) and SITES (mostly focused on built landscapes and green infrastructure) that are excellent distillations of various aspects of sustainable urban design (US Green Building Council 2009; BREEAM 2012; Star Communities 2012; Sustainable Sites Initiative 2014). While the specifics of these rating systems are often hotly debated, the systems have been at the forefront of identifying critical design elements that need to be addressed in urban scale projects and have been tremendously important to the profession.

The proposed framework builds on these systems, adapting and incorporating many of the same elements they identify. The significant differences are that the proposed framework focuses specifically on design related issues (as opposed to planning, programme implementation or policy), that it attempts to be clear about the relationship of overall sustainability goals to specific elements (BREEAM and STARS are much clearer than LEED-ND and SITES on this front), and that it comprehensively organizes the critical sustainable urban design elements by scale and resource goal. These differences help clarify the role of urban design, make it possible to easily relate the disparate elements of sustainable urban design, and allow an easier consideration of trade-offs and synergies between these elements.

The intent with the framework is to introduce a fine scale mechanism that is flexible to diverse contexts and scales, identifies critical elements, allows comparison of these elements across scales and sustainability goals, and can serve as a guide in both the design and the evaluation of sustainable urban design projects.
What to sustain?

Researchers and practitioners (Hough 1984; Calthorpe 1993; Frey 1999; Wheeler 2000; Wheeler and Beatley 2004; Jabareen 2006; Kenworthy 2006; Farr 2008; Ritchie and Thomas 2009; Condon 2010) have proposed a number of concepts, issues and elements that constitute sustainable development and its subset of sustainable urban design (see Table 1). Because these lists include the broader category of sustainable development as well as sustainable urban design, they invariably include issues that relate to, but fall outside of the realm of, what urban design affects specifically (for example, systems of governance or economic structure). That said, what is readily apparent in this compilation is the variability in a few specific topics on the one hand, and the relative agreement on a number of topics on the other.

Even some of the lists that portend to focus directly on urban design are surprisingly broad. For example, urban design has fairly limited control over an individual’s material consumption or waste production. It also has limited power to decide how large, utility-scaled energy is produced (coal, nuclear, gas, wind, hydraulic) or which industries use that energy and how. While arguably urban design has some sway in these examples, it is limited.

Many lists also include some version of green building design and many of the sources, even those focused on sustainable urban design, speak at length about the use of photovoltaics – the seeming poster child and signifier of sustainability. While urban design decisions of block orientation and size may affect the potential for use of solar panels on buildings, the discussion in these sources focuses more specifically on the characteristics and application of the panels themselves, something that is generally more central to architectural design.

These lists occasionally mix elements more focused on what is to be sustained (for example, energy) with specific tactics that can help achieve this (reduce automobile use, density and sustainable transport), while some lists conflate these two categories, mixing in the same list what is to be sustained and how to achieve it. Many of the lists are dominated by energy and transportation concerns and give relatively limited attention to other issues.

Looking beyond the specifics described and focusing instead on the underlying targets of what is to be sustained, these sources and lists have remarkable unity. Nearly all of these attempts to define sustainable development include the goals of minimizing energy use and greenhouse gas production (GHG) as well as some version of ‘greening’ the city and protecting/providing habitat. A number also include issues of water quality (sometimes included in discussions of habitat) and many include the desire to protect social equity as well as protecting and creating areas that have a strong identity or ‘sense of place’.

The proposed framework builds from the commonalities in these lists – the current state of understanding on what sustainable urban design touches – and similar to many of these lists, focuses primarily on the sustainability of natural resources aspects identified (energy, air, water, habitat) and includes aspects related to equity and health.

As represented in many of these sources, in organizing an overall framework for sustainable urban design it is critical to separate the energy use/GHG production related to transport from the energy use/GHG production related to non-transport sources such as buildings and urban lighting. These need to be dealt with individually because they are distinct forms of energy use and they have significantly different and largely unrelated requirements and parameters for optimization.
Table 1. Compiled sustainable urbanism lists: concepts/issues/elements. (Source. List title and elements). Some lists are adapted/interpreted from the text, others appear specifically as lists within these sources and are simply copied here. Some of the lists have been slightly modified for clarity since they standalone in this table, away from explanatory text found in the original sources.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Climate and the urban heat island effect</td>
<td>Ecology and habitat</td>
<td>Containment (compact urban form)</td>
<td>Compact urban form</td>
<td>Land use and urban design</td>
</tr>
<tr>
<td>Water</td>
<td>Commercial and residential areas</td>
<td>Density</td>
<td>Preservation of open space and sensitive ecosystems</td>
<td>Transportation</td>
</tr>
<tr>
<td>Plants in the urban context</td>
<td>Parks, plazas, and civic buildings</td>
<td>Mixed use</td>
<td>Reduced automobile use</td>
<td>Urban ecology and restoration</td>
</tr>
<tr>
<td>Wildlife and habitat</td>
<td>Street and circulation system</td>
<td>Adaptability to changing social conditions</td>
<td>Reduced waste and pollution</td>
<td>Energy and material use</td>
</tr>
<tr>
<td>The city and farming/food relationship</td>
<td>Pedestrian and bicycle system</td>
<td>Public transport / reduced traffic</td>
<td>Reuse and recycling of materials</td>
<td>Environmental justice and social equity</td>
</tr>
<tr>
<td>Connections and integrated design</td>
<td>Transit system</td>
<td>Hierarchy of services</td>
<td>Liveable/community-oriented human environments</td>
<td>Economic development</td>
</tr>
<tr>
<td>Parking requirements and configuration</td>
<td>Parking requirements and configuration</td>
<td>Access to public and private open space</td>
<td>Decent, affordable and appropriately located housing</td>
<td>Green architecture and building</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pollution, noise, congestion, accidents, and crime-free env.</td>
<td>Improved social equity</td>
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<tr>
<td></td>
<td></td>
<td>Self sufficiency and a symbiotic relationship of city and</td>
<td>Development of a restorative local economy</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>country</td>
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<td></td>
<td></td>
<td>Social mix</td>
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<td></td>
<td></td>
<td>Local autonomy</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Imageability and sense of place</td>
<td></td>
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</tbody>
</table>

Notes: (Adapted from chapter organization. While not claiming to be a comprehensive sustainable urbanism approach, this early text covered a number of key sustainability areas.) (Adapted from list linked to Maslow's Hierarchy of Needs. Items from original list have been grouped here for clarity) (Adapted from introduction and chapter organization)
Table 1. (Continued).

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Compactness</td>
<td>Compact, mixed use urban form</td>
<td>Defined center and edge</td>
<td>Urban planning and design (compact, walkable, mixed use and integrated communities)</td>
<td>Restore the streetcar city</td>
</tr>
<tr>
<td>Sustainable transport</td>
<td>Well-defined higher-density development</td>
<td>Compactness</td>
<td>Sustainable transportation</td>
<td>Design an interconnected street system</td>
</tr>
<tr>
<td>Density</td>
<td>Human-oriented centres</td>
<td>Integrated land use and transportation</td>
<td>Environmental building design</td>
<td>5-Minute walk to commercial areas, transit, and schools</td>
</tr>
<tr>
<td>Mixed land uses</td>
<td>Superior non-auto transport systems</td>
<td>Sustainable neighbourhoods and corridors</td>
<td>Sustainable energy sources</td>
<td>Locate good jobs close to affordable housing</td>
</tr>
<tr>
<td>Diversity</td>
<td>Minimal road capacity increases</td>
<td>Biophilia – connecting humans and nature</td>
<td>Materials and their environmental impact</td>
<td>Provide a diversity of housing types</td>
</tr>
<tr>
<td>Passive solar design</td>
<td>Protection of natural areas and food prod. Capacity</td>
<td>High-performance buildings</td>
<td>Water sources and use</td>
<td>Create a linked system of natural areas and parks</td>
</tr>
<tr>
<td>Greening</td>
<td></td>
<td>High performance infrastructure</td>
<td>Waste, resources, and recycling</td>
<td>Invest in lighter/greener/cheaper infrastructure (stormwater syst.)</td>
</tr>
</tbody>
</table>

Notes: (Adapted from longer, more detailed list) (Adapted from Chapter 'Sustainable Urbanism: The Grand Unification') (Adapted from individual chapters on each topic)
Transport related energy use is affected by elements such as transportation networks, compactness, land-use mix, parking and street design, while building related energy use is more focused on building typology and orientation that affect building operations through the degree to which thermal control is necessary and daylighting is present in a building.

In addition, to a larger degree transport is a direct source of GHG production (through the combustion engine), while buildings and urban lighting primarily use energy-produced offsite, which can have many sources and is largely outside the realm of urban design. This is by no means universal as some forms of transport use off-site energy sources (for example, electric vehicles and electric forms public transport) and some GHG’s are directly produced in buildings (such as oil and gas furnaces), but this differentiation largely holds. In addition, unlike transport, buildings have the potential to produce their own renewable energy and this production is largely affected by the parameters of a building’s urban context. All of these issues differentiate the way urban design affects these two forms of energy use and GHG production, and are therefore kept separate in the proposed framework.

With this distinction, the proposed framework includes five primary focus areas of sustainable urban design:

1. Energy use and GHG emissions (based on transport related uses);
2. Water quality and recharge;
3. Habitat and ecological quality;
4. Energy use and production (based on non-transport related uses);
5. Equity and health;

**Sustainable urban design metrics**

Looking at the metrics of each of the primary focus areas identified above is a first step towards identifying the urban design elements that support sustainability. Researchers and public and private agencies have been developing sustainable development metrics and rating systems for decades (Sustainable Seattle 1993; Mega and Pedersen 1998; US Green Building Council 2009; BREEAM 2012, and see Maclaren 1996; Brandon 2005; Lynch et al. 2011; Sharifi 2013 for overviews and compilations).

While these metrics often encompass a wide range of sustainability aspects, their number is significantly reduced as the indicators are edited to those related specifically to urban design. A list of these most common metrics, separated into primary and related metrics, are listed in Table 2.

Primary metrics are those that directly translate the sustainability foci into a measurable form. The related metrics are ones that many of the indicators use as proxies for the primary metrics. For example, given the existing state of combustion engine technology and the dominance of the automobile in most urban areas, vehicle miles travelled is a key indicator for the amount of energy used and GHG emitted by the transportation sector. Density, land-use mix, the degree of network connectivity and the trip mode split are also indicators that affect the frequency and distance of trips, which in turn affect the amount of energy consumed and GHG’s produced.

These metrics are the basis for many of the specific urban design elements that affect the targeted sustainability foci.
Sustainable urban design matrix: getting to elements

While identifying what is to be sustained and the metrics related to this is helpful and suggests a direction for sustainable urban design and evaluation, it still leaves the practising urban designer and researcher at a loss for the more tangible elements they must address, as well as how disparate elements might be related. The matrix (see Table 3) aims to fill that void and provides, if not a complete list, then at least a roadmap of the elements that designers and researchers interested in sustainable urban design should consider and how these elements are related.

The matrix includes the sustainability foci on one axis and geographic scales on the other. The geographic scales include typical urban design project scale distinctions – the Region, the Neighbourhood/District, the Block/Street and the Project/Parcel. While the actual size of these relative scales is variable, they represent discernable scales of focus and related elements.

Arguably the most ambiguous scale is the Project/Parcel. While a parcel is typically a smaller unit within streets and blocks, due to variations in development patterns it can also represent large developed areas that are between streets yet have their own internal urban structure (e.g. large multifamily housing developments, large commercial areas). In these examples, the parcel may start to act more like a Block/Street or even a Neighbourhood/District. That said, the interest is in distinguishing those elements that affect sustainability but are located within private parcels.
Table 3. The sustainable urban design framework matrix.

<table>
<thead>
<tr>
<th>Energy use/GHG (transp./land use)</th>
<th>Regional</th>
<th>District/ neighbourhood</th>
<th>Block/ street</th>
<th>Project/parcel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robust transit network</td>
<td>Small and defined blocks</td>
<td>Multimodal street design</td>
<td>Engaging public realm design</td>
<td></td>
</tr>
<tr>
<td>Robust bicycle networks</td>
<td>High building/housing density</td>
<td>Engaging pedestrian realm</td>
<td>Dense and street activating</td>
<td></td>
</tr>
<tr>
<td>Vehicular networks</td>
<td>High network connectivity</td>
<td>Robust bicycle infrastructure</td>
<td>Building typologies</td>
<td></td>
</tr>
<tr>
<td>High land use mix (Macro scale)</td>
<td>Macro parking mgmt/design</td>
<td>Design for transit</td>
<td>Engaged building/street relationship</td>
<td></td>
</tr>
<tr>
<td>Compact development (for density/proximity)</td>
<td>High land use mix (micro scale)</td>
<td>Limiting auto impact</td>
<td>High internal and external connectivity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dense and street activating</td>
<td>Micro parking mgmt/design</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>building typologies</td>
<td>Parking for density</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Avoid flood prone areas</td>
<td>Robust stormwater mgmt. network (distributed/on-site recharge)</td>
<td>High surface permeability</td>
<td></td>
</tr>
<tr>
<td>Compact development (for limited impact on nat. systems)</td>
<td>Robust stormwater mgmt. network (distributed/on-site recharge)</td>
<td>High surface permeability</td>
<td>Extensive green stormwater infrastructure (GSI)</td>
<td></td>
</tr>
<tr>
<td>Ecology/habitat</td>
<td>Avoid ecol. sensitive areas</td>
<td>High surface permeability</td>
<td>Extensive urban forest canopy</td>
<td></td>
</tr>
<tr>
<td>Robust and connected macro ecological systems and networks</td>
<td>Ecological corridors/pockets</td>
<td>High vertical complexity</td>
<td>Rainwater capture/re-use</td>
<td></td>
</tr>
<tr>
<td>Compact development (for limited impact on nat. systems)</td>
<td>High urban forest</td>
<td>Native vegetation</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Daylight/restore waterways</td>
<td>Mitigating habitat disruption</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Non-polluting lighting design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy use/production (non-transp.)</td>
<td>Compact development (for limited embodied energy in infrastructure)</td>
<td>Dense/energy efficient building typologies</td>
<td>Infill development</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Block size/street orientation for microclimate mitigation</td>
<td>Microclimate mitigation</td>
<td>Dense/energy efficient building typologies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High building/housing density</td>
<td>Low albedo surface materials</td>
<td>Increase local energy production (solar/wind)</td>
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<tr>
<td></td>
<td></td>
<td>Urban forest and robust vegetation</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>High street ht./width ratio</td>
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<tr>
<td></td>
<td></td>
<td>Efficient street lighting design</td>
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<tr>
<td></td>
<td></td>
<td>Plating for density and solar exposure</td>
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</tr>
<tr>
<td>Equity and health</td>
<td>Equitable distribution of employment, housing, human services, open space, education facilities, and healthy food options</td>
<td>Active/attractive open space (for activity and quality of life)</td>
<td>Mix of unit types</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equitable distribution of employment, housing, human services, open space, education facilities, and healthy food options</td>
<td>Lighting for safety</td>
<td>Active/attractive open space</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limit location of point source pollution and toxins</td>
<td>Site design for ownership and surveillance</td>
<td>Lighting for safety</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Affordable housing typologies</td>
<td>Site design for ownership and surveillance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Complete streets for ped safety</td>
<td>Affordable housing typologies</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban forest and robust veg. (for pollution sequestration)</td>
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</tr>
</tbody>
</table>
An additional scale that is not directly reflected in the matrix is the Campus scale. These are large, often single ownership, projects that lack a finer grained organizing street system. Examples of campus developments are university campuses, hospital campuses and corporate campuses. While the campus is in some ways a distinct project scale, with regard to the matrix it acts as a combination of the Block/Street scale and the Project/Parcel scale.

Within each cell of the matrix is a list of individual urban design elements or issues that relate to the given scale and sustainability foci. These are meant to be specific enough so that they can be easily linked to actual urban design decisions and practices.

The following section is organized by the five sustainability foci and describes the elements and issues related to each focus area at greater length. Where possible, this section includes technical references and sources that describe how to design or apply the topics being discussed.

**Energy use and GHG emissions (based on transport related sources)**

Until auto technology radically advances, independent auto travel – per passenger mile – is the most energy consuming and GHG emitting form of urban transportation (Schafer and Victor 1999). While areas that have relatively poorly utilized transit systems, such as many areas in the United States, are exceptions to this (Davis et al. 2009), it is clear that areas with robust transit systems and a high degree of walking and biking utilize the least amount of transportation energy per capita. Because of this, one of the basic sustainability questions for urban design is simply how to shift travel mode so that it reduces the number of auto trips and increases the share of less energy intensive modes such as walking, biking and transit.

The relationship between urban design and mode choice seems self-evident on the one hand and utterly complicated on the other (Cervero 2002; Ewing and Cervero 2010). As urban design includes decisions regarding the distribution of land use, the networks of connection between these uses, and the quality and character of the paths that make up that network, then trip lengths, modes and frequency would seem to be directly affected by urban design. What is less evident is how and if specific changes in urban design individually or cumulatively affect changes in energy use and GHG emissions. Some areas of research on specific urban design elements are discussed below.

When faced with which mode to use for a trip, individuals quickly and unceremoniously weigh the time, energy, comfort and financial costs of making the trip by different modes (Gardner and Abraham 2007; Frank et al. 2008). One of the most basic ways urban design can affect this decision is by reducing the distance to a destination. At the regional scale, this is done by creating compact, dense development that has a rich land use mix that distributes uses relatively near potential users. Less compact, lower-density and single-use development – the definition of suburbia – puts greater distance between uses and potential users, makes efficient and robust transit networks difficult and often makes the private car the preferred travel option (Ewing, Pendall, and Chen 2003). A fine grain land use mix that puts daily uses near residences for example supports daily trips not having to be auto trips (Cervero 1996).

Even when destinations are at a reasonable distance as the crow flies, district and neighbourhood scale urban design decisions, such as street patterns, block size and connectivity, can have dramatic effects on trip length and hence mode choice (Giles-Corti and Donovan 2002; Saelens, Sallis, and Frank 2003; Badland and Schofield 2005; Frank et al. 2006; Lee and Moudon 2006; Forsyth et al. 2007; Forsyth et al. 2009). Walking, biking and transit use...
are sensitive to small-scale changes in trip length (Krizek and Johnson 2006; Ewing and Cervero 2010), making these design decisions critical to mode choice. Reduced block sizes are more inviting to pedestrians (Hess et al. 1999) and a well-connected street, bike and pedestrian network allows the shortest possible route between locations (Handy, Paterson, and Butler 2003).

In addition to the distance to a destination, the quality of a route can also play a role in mode choice. Auto dominated streets that do not have sidewalks or do not protect pedestrians or bicycles from fast moving traffic are deterrents to walking and biking. Multimodal street designs, or ‘complete streets’ (see McCann and Rynne 2010 for a description and guide), address and balance the needs of all modes. This includes reducing or mitigating auto traffic speeds, providing buffers between modes, providing adequate street enclosure, providing adequate and protected crossings, and including shading and protection from the weather.

As individuals who walk, bike or use transit must interact with the public realm more directly than someone traveling in a car, the quality and perceived safety of the public realm also plays a role in mode choice.

The platting (or organizing of lots) of an area can affect mode choice as it often dictates possible building typologies and, in turn, the relationship of buildings to the street. How a building interacts with the street, the uses as well as the extent and distribution of entrances, windows and service areas on the first floor affect the level of activity and perceived ‘eyes of the street’ as described by Jane Jacobs (Jacobs 1961). (See US Green Building Council 2009 for a guide on how the design of building frontages can support active streetfronts.)

As mode choice decisions are based on a comparison between available modes, the ease of using the automobile is as important to mode choice as the way the built environment invites less energy intensive modes. Higher auto speeds with fast moving lanes of traffic encourage auto use (Frank et al. 2008) while they create inhospitable areas for pedestrians and cyclists. Similarly, ample, free and easily available parking located directly in front of destinations creates a ‘pull’ towards auto use and can create barriers and uninviting conditions for pedestrians and cyclists (Shoup 2005). The distribution of parking and whether it is allocated to single uses, shared between uses or pooled in central locations affects the dominance of the automobile and the amount of land dedicated to it. In addition, the actual design of parking areas themselves – their size, how they front the street and whether they include landscaping or are barren wastelands – also affect how inviting the public realm feels (Ben-Joseph 2012).

As mentioned previously, the direct effects of urban design on mode choice are highly debated. First, a number of other issues such as culture, habit, socio-economic status, climate, transit management, transit frequency and general safety, to name a few, also play roles in mode choice (Aarts, Verplanken, and van Knippenberg 1997; Bhat 1998; Bamberg and Schmidt 2001; Johansson, Heldt, and Johansson 2006; Bamberg, Hunecke, and BL’baum 2007; Gardner and Abraham 2007). In focusing specifically on built environment attributes, many studies have supported the issues described above while a few have either found no effect or negative effects. Meta-studies that have attempted to compare effects across studies have found a few more definitive effects. Of a wide range of urban design related issues reviewed by Ewing and Cervero’s meta-analysis, trip distance, access to transit, intersection density, connectivity and land use mix/diversity seemed to consistently have an effect on mode choice (Ewing and Cervero 2010). Although the effect of any individual trait was small, in combination the effects seem to be robust. Another meta-analysis by Saelens and Handy
found similar results (Saelens and Handy 2008). As is evidenced by these studies, human behaviour and decision making is a complex task, with a wealth of factors contributing to it. This is an area thick with research and yet still remains in need of extensive future work.

**Water quality and recharge**

Of all of the diverse water systems that exist in an urban context – potable water, waste water, grey water, stormwater and rain water (see Sarté 2010), urban design plays the most significant role in the handling of stormwater. The use of potable water, grey water and wastewater, while critical, is primarily related to architecturally scaled decisions, private landscaping, the culture/habits of water use and not specifically to the realm of urban design. While urban design can affect some water use directly based on whether irrigation is necessary for specific plantings within the public realm, this is typically a small proportion of the overall water use of any given area.

The guiding strategies to a sustainable stormwater approach are first to reduce run-off and second to mitigate the run-off that is created. Because of the large number of impervious surfaces and channelling often found in urbanized areas, the rate of direct recharge of stormwater into the earth is often greatly reduced. Urbanized areas typically have decreased water concentration times and increase the volume and speed of stormwater run-off (Rose and Peters 2001). Because of this, urban development often causes increased erosion and an increased amount of sediments and pollutants within run-off. Due to channelling and increased heat in urbanized areas, stormwater coming from these areas is also typically warmer than stormwater in adjacent rural or natural areas. (see Booth, Hartley, and Jackson 2002; Brabec, Schulte, and Richards 2002 for an overview of urban stormwater issues). All of these issues are problematic in terms of sustainability in that they reduce water quality, can lead to deterioration of aquifers and can affect the viability and strength of surrounding ecologies.

The urban design elements that affect the quantity and quality of run-off in an area are the degree of compact development, the ratio of permeable surfaces and the extent of natural vegetation and the urban forest. At the regional scale, simply creating compact development can minimize the total amount of impervious surface (due to reduced road lengths) and reduces the disruption of natural stormwater drainage and infiltration (Pyke et al. 2011). While compact development can create increased run-off within developed areas, it keeps more land in its natural state and hence reduces the overall impact urban development will have on stormwater recharge.

At the block/street and the project/parcel scale, the extent of the tree canopy and surface permeability greatly affect run-off generation. Trees along streets and in open spaces (the urban forest) can dramatically reduce the rate at which stormwater reaches the ground by as much as 27% (Xiao et al. 2000; Xiao and McPherson 2011).

The ratio of permeable to impermeable surfaces will affect the amount of stormwater that is directly recharged into the ground versus being kept along the surface as run-off. Compared to rural or natural areas, urban areas with more than 75% impervious surface can see a more than a five-fold increase in surface run-off and less than one-third the amount of infiltration and recharge (Schueler 1994). As approximately a quarter to a third of the surface area of a city is typically directly within the public realm, urban design can have a significant effect on the amount of impervious surface within any given area. As the number of
impervious surfaces increase, recharge rates are dramatically reduced and run-off increases (see Federal Interagency Stream Restoration Working Group 1998 for in-depth review of urban stormwater issues).

One way of reducing the amount of rainwater that needs to be treated as stormwater is by harvesting rainwater for potable or grey water use. While potable water harvesting practices are emerging and effective at the building scale, neighbourhood or city scale approaches are hampered by numerous logistical and legal barriers and are still in early phases of implementation (Farahbakhsh, Despins, and Leidl 2009; US EPA 2014).

If water quality and recharge are key concerns of urban design, the primary goal with run-off that is generated is to slow it down (retention and detention), cool it (often through retention and detention), clean it (filtration) and if possible have it recharge into the ground or atmosphere as close as it can to where it originally fell (on-site infiltration or evapotranspiration). At the district and neighbourhood scale, the strategies for doing this involve the development of stormwater management networks that preference on-surface water distribution and on-site recharge. This is largely preferred over mixing stormwater and wastewater or the underground channelling and the direct dumping of concentrated, warm and polluted stormwater into larger, natural bodies of water. In addition to incorporating on-surface drainage networks, part of this strategy can also include daylighting and restoring pre-existing waterways to approximate their natural state so that they can assist in stormwater detention, filtration and infiltration (see Federal Interagency Stream Restoration Working Group 1998 for a guide on stream restoration issues and practices). This approach needs to include efforts to mitigate inflow to the waterway during large events so that added impervious surface due to urbanization does not overwhelm streams or create flooding (Walsh, Fletcher, and Ladson 2005).

Once on the ground, the speed, volume and temperature of stormwater can be mitigated by the use of Green Stormwater Infrastructure (GSI) (also called Sustainable Urban Drainage Systems: SuDS) such as stormwater planters, rain gardens, green gutters, swales and retention basins or ponds (see San Mateo Countywide Water Pollution Prevention Program 2009 for guide on stormwater sensitive street and parking lot design). Reducing impervious surface ratios by minimizing the total area of hardscape, for example, streets and parking lots, dramatically reduces on-surface run-off.

All of these approaches slow water down, allow on-site recharge and minimize the damaging effects of the channelled and concentrated typical stormwater management approaches (see Butler and Davies 2011 for overview of sustainable urban drainage issues).

**Habitat and ecological quality and extent**

Urban development is, almost by definition, a substantial disruption and strain on natural systems, habitat and ecological cycles. As it replaces natural or agricultural areas, it removes or displaces plant and animal species, modifies water drainage and movement, compacts and confines soils, restricts plant community structure and limits ground level access to light (Hough 2004). Urban development is often a source of pollutants and toxins that affect neighbouring air and water quality and, due to the heat island effect, often increases local temperatures. Except for the few species that thrive in these environments, all of this leads to a general and severe reduction of biodiversity and the degradation of species vitality (Alberti 2005).

The goal of sustainable urban design, as it relates to habitat and ecology, is to limit these negative effects of urban development. This is achieved by limiting the amount of natural
habitat that is disrupted, by mitigating the inevitable disruption that occurs when development happens, and where possible by creating habitats and ecologies that are robust in areas where human presence is dominant.

Creating urbanized areas that preserve, protect and incorporate healthy ecologies and habitat — ‘biophilic cities’ — are not only a benefit to various species and natural cycles, but also directly benefit humans. Natural areas and nature in urbanized areas help us understand natural processes, build empathy towards natural systems and generally improve our quality of life and mental health (Beatley 2011).

At the regional scale, the most effective means of limiting habitat disruption is simply to practice compact development and avoid sensitive or high value habitat areas. By containing urban development, less overall land is affected and more natural, or even agricultural, habitat and ecologies can be preserved. While some have recently argued for lightly touching the land through lower density development that allows natural areas to exist between and within urban and suburban development, this approach generally creates vast areas of limited ecological value with reduced species diversity and vitality (Hansen et al. 2005).

Even within compact development, not all areas are ecologically equal and certain areas should be prioritized. Urban development often grows near sensitive, high value areas such as wetlands, waterways, migration routes and unique habitats. These areas often hold increased species diversity, play a significant role in larger scale ecologies and, as famously advocated by Ian McHarg, should be identified, mapped and protected from development (McHarg 1969). Sensitive areas that have been previously developed or modified, such as streams within urban areas, can be daylighted, revitalized and/or restored.

Patches of habitat – even smaller ones at the district scale – can be maximized as species diversity increases exponentially with increased size (Andren 1994; Hough 2004). Species often require continuous areas of habitat or at least significant patches that are well connected. Creating robust, resilient and ample connections between habitat patches can have a dramatic effect on the health of species (see Dramstad, Olson, and Forman 1996 for general strategies).

Around these areas and wherever urban development comes into contact with natural habitat, adequate ecological buffers are critical to limiting contamination and pollution as well as increasing species diversity and health (see McElfish et al. 2008 for a guide to how this can be achieved). While the overall effect will vary depending on design and target species, buffers as small as 3 meters can affect the movement of sediment, phosphorous and nitrogen, while buffers larger than 10 meters can positively affect wildlife vitality (Phillips 1989; Vitousek et al. 1997; Mayer 2005).

While these guides serve to protect existing habitat and set the location of urban development, there is also opportunity to improve ecologies within developed areas where human presence is dominant—much of the field of Urban Ecology is focused on exactly this issue (Gaston 2010; Pickett et al. 2011). At the block and parcel scale, developed areas should mimic the complexity and biodiversity of natural systems instead of instilling monocultures with little variety in plant community structure. Limiting the extent of lawns, the dominant landscape element in urban areas, and creating areas that have are layered and diverse vertical plant structural improves biodiversity and vitality. Plantings within the city should not be considered as singular street trees, but instead as part of the urban forest that can increase biodiversity and species vitality (see Town and Country Planning Association 2004 for overview on designing for biodiversity).
It should be noted that not all species are equally affected by human development or have the same habitat needs; therefore effective approaches are not often generalizable. Because of this, collaboration with disciplines such as biology, botany and wildlife ecology is critical. Engaging with this topic requires a site-specific analysis of existing and potential species in the area as well as the size, character and structural needs of those species' viable habitat (see appendix in Kennedy, Wilkison, and Balch 2003 for a reference guide to the needs of various common species).

Sustaining ecology and habitat is intimately linked to other goals of sustainable urban design. For example, reducing auto trips not only reduces energy use and GHG emissions, but also reduces the amount of pollutants such as heavy metals that are released into the environment. Similarly, reducing the ratio of impermeable surfaces and mitigating the negative effects of urbanization on stormwater management also reduces the strain on ecologies surrounding waterways (Klein 1979; Walsh, Roy et al. 2005).

**Energy use and production (based on non-transport related sources)**

In addition to transportation related energy use, urban design also affects energy use through three non-transport related sources: building energy use, energy use through street lighting and the embodied energy of infrastructure. While transport related energy use is the larger share of the energy use affected by urban design, these additional areas can cumulatively be substantial.

**Building energy use**

The energy used in buildings for heating, cooling, lighting and ventilation is based not only on the building design, but also on the urban design context of that building. Before a building design has even begun, there are a number of urban design factors that will predetermine the ease and overall potential of reduced building energy use. Solar orientation, which is critical to building heating and cooling loads, can be largely dictated by urban design scale decisions about the size, shape and orientation of blocks and individual parcels. These same decisions will also affect the degree to which a building can – depending on the season and energy needs – take advantage of or minimize the cooling and ventilation potential of wind.

Parcel size and shape along with height limitations often set both density and building typologies. For example, studies have quantified how, in a cool climate, at a building energy use level, lower density, detached buildings typically use significantly more energy than higher density, attached buildings (Walker and Rees 1997; Newton, Tucker and Ambrose 2000; Norman, MacLean, and Kennedy 2006; Ewing and Rong 2008; Dettling et al. 2010). Urban design examples that allow denser typologies that reduce surface to building area ratios can also help reduce overall energy use (Chalifoux 2008). Building depth, largely defined by parcel size, can also have a dramatic effect on energy use for lighting and for ventilation, with deeper buildings typically requiring more energy than thinner buildings (Steemers 2003). The trade-offs between compact building form with limited envelopes (beneficial for reducing heating needs) and reduced building depth (beneficial for daylighting and natural ventilation) will depend largely on the specifics of the local climate.

In addition to parcel characteristics, the organization and design of the public realm can also have a dramatic effect on building energy use as it is largely affected by the
microclimates created by a building’s immediate context. Urban design can limit or accentuate urban heat island effects through the organization of streets and their solar exposure (Kruger, Minella, and Rasia 2011), through the width of streets and the degree that buildings can shade one another (Sharlin and Hoffman 1984; Givoni 1998; Futcher and Mills 2012), through the shading characteristics and distributions of trees (Shashua-Bar and Hoffman 2000; Stone and Rodgers 2001; Robitu et al. 2006; Tsiros 2010), through the quality and distribution of vegetated parks (Papangelis 2012), and through the types, colours and heat absorption qualities of materials used in the public realm (Akbari, Pomerantz, and Taha 2001). All of these elements contribute to the temperature of the urban environment and hence the degrees to which buildings need to use energy to cool or heat themselves.

Outdoor lighting

Lighting used for streets and parking accounts for approximately 8% of the total energy used for lighting in the United States. As the design, organization and type of lighting fixtures used are often developed in consultation with urban designers, this creates the opportunity for substantial energy savings. Inefficient and ‘over lit’ designs use unnecessary energy and often create areas of excessive glare. The types of fixtures used is also critical as studies have shown that 40% of the energy used for street lighting could be saved if street lights were changed to more efficient forms such as LED’s (Navigant Consulting 2011).

Embodied energy

Urban design affects the total embodied energy of development through its effect on infrastructure needs and through the selection of materials. Embodied energy is the total energy required to produce, transport and install any material or product.

Compact development not only affects energy use based on transportation mode choice as described previously, but it also directly affects the total amount of infrastructure needed in any given area. Spread-out and sparse development patterns inherently require longer lengths of infrastructure (sewers, roads, electrical transmission, etc.) to maintain similar populations. The increase in the overall amount of infrastructure also increases the total embodied energy required for the production and installation of that infrastructure. Compact development therefore often translates directly into a savings in embodied energy use.

Material designations can also affect embodied energy use. Highly energy intensive materials, such as aluminium, require up to six times more energy for production than less energy intensive materials such as steel (Hammond et al. 2011). In addition, the distance materials have to travel between their production sites and where they will be installed also affects embodied energy use. By selecting local products that require low levels of energy to produce, urban designers can reduce the embodied energy needs of a development.

Equity and health

As described in the Brundtland Report, social equity is central to the social aspects of sustainability (United Nations World Commission on Environment and Development 1987). The goal of ‘Equity and Health’ is to provide all residents with equal access to a high quality of life. While much of this goal is dependent on issues outside of the design of cities (larger
There are distinct areas of the physical environment that affect a resident’s equity and health. Namely, urban design can affect accessibility, affordability, safety and degree of physical activity. Each of these issues is part of larger, complex systems.

Accessibility is a measure of how easily individuals can reach goods, activities and services (Morris, Dumble, and Wigan 1979) and is largely correlated to many of the metrics listed under Transportation Related Energy Use and GHG Production described previously (Litman 2014). While this equity-based goal is not focused on energy use, equitably accessible areas have ease of walking, biking and transit to basic necessities and hence the same underlying variables affect resident accessibility as well. For example, density, the mix, and therefore proximity, of uses, connectivity and multimodal street design all directly affect equitable access. The framework matrix represents this connection as a large bar crossing over all scales of the Equity and Health focus area.

In addition, equitable access also includes the equitable distribution of employment, housing, human services, open space, education facilities and healthy food options. While overall accessibility increases the relative ease of getting to destinations, it is their equitable distribution that guarantees fair access by all residents. This access has a dramatic effect on quality of life and health.

Affordability is often dictated by international, national and regional forces, as can be easily seen by the changes in affordability that occur in different cities and different areas of the city with relatively little change to the built environment. That said, urban design can play a role in the relative cost of housing and transport based on the distribution of uses, accessibility, building and unit typologies employed (Aurand 2010), and the amount of parking required (Litman 2009; Aurand 2010). At the project/parcel scale, a range of building density, unit types and sizes in any given area helps create a broader swath of housing prices (Blair et al. 2004) and at the regional, district and block scale, increased accessibility and equitable distribution of destinations reduces transportation costs (Litman 2013).

While these elements can affect affordability, design alone is often not effective in controlling costs as improved and desirable districts are often gentrified, which greatly raises prices (Dale and Newman 2009). In order to be effective, urban design for affordability must be accompanied by policies that protect vulnerable populations.

Urban design’s role in safety covers three primary areas: safety from crime, safety from accidents, and safety from pollution and toxins. In terms of safety from crime, Jane Jacobs first described the importance of ‘eyes on the street’ and how the built environment directly affects safety (Jacobs 1961). These ideas have been largely expanded and built upon since then through ideas such as ‘Defensible Space’ (Newman 1972) and Crime Prevention Through Environmental Design (CPTED) (Jeffery 1977). These movements emphasized the now proven notion that creating areas that promote a sense of ownership, provide easy opportunities for surveillance and are well-lit help improve safety (Cozens, Saville, and Hillier 2005).

In terms of safety from accidents, related to urban design, the most vulnerable population are pedestrians and the typical aggressors are automobiles. At the block and parcel scales, creating multimodal street designs that calm traffic, create buffers between pedestrians and vehicles, and increase the visibility of pedestrians not only encourages walking and biking, but also protect the pedestrians and cyclists and can dramatically reduce accident rates (Retting, Ferguson, and McCartt 2003).
Safety from pollution and toxins includes limiting the existence or amount of overall pollution and toxic substances in urban areas and, where they do exist, being careful about their location to limit human and habitat contact. Sources of pollution and toxins in urban areas include exhaust from the transportation and energy sectors, contamination, by-products and waste from manufacturing, inclusion of toxic elements in construction, and simply the household uses of certain materials. While limiting some of these sources is outside of the realm of what urban design affects (transportation related pollution being the notable exception), the distribution and location of pollution and toxin sources — and their contact with people, proximity to habitat and ability to contaminate ground water — is definitely controlled by urban design. In addition, urban designers can limit the use and distribution of toxic materials used in the construction of the urban environment through design specifications used for streets, plazas and open space (see Atlee 2010 for a review of tools related to non-toxic material selection).

Finally, urban design has a direct effect on increasing both utilitarian and recreational physical activity (Heath et al. 2006). Again, across all scales, the energy-focused elements that help transition automobile trips to more active modes such as walking and biking increase physical activity for utilitarian purposes (Handy et al. 2002). These same elements along with the regional and district based increased access, size and attractiveness of open space can significantly increase residents’ amount of recreational physical activity (Giles-Corti et al. 2005).

Environmental justice is an important aspect of all of the topics described above as it focuses on assuring adequate representation by all stakeholders in decisions that can affect the equity and health of an area. Too often, decisions that affect access, affordability, safety and health have been made without the participation of marginalized groups and have placed undue burdens on these groups.

Uses of the matrix

As described previously, the proposed sustainable urban design matrix should be seen as a draft. Much research is still needed to fill out the topic areas as well as to substantiate the relative role of one topic over or in conjunction with another. That said, even in its early state, the matrix can have utility in that it gives an overall frame of what is included or needs to be addressed in sustainable urban design and, importantly, it provides a path towards relating the different aspects of sustainable urban design.

Organizing by goals, it allows a practitioner or researcher to trace the different aspects that contribute to any single goal. To address transportation related energy and GHG emissions, an urban designer must consider, to name only a few aspects, the existing or potential transit network at the largest scale, block size, connectivity and land use-mix at the district scale, street design and building typologies at the block scale, and the building to street relationship at the parcel scale. If the specific urban design project only works at one of those scales, it allows the designer to identify whether the elements at scales above and below the scale they are working at exist now or will exist. This can lead to more directed design decisions and more focused efforts.

As the matrix is also organized by scale, it allows a comparison of how different goals are manifest in the same scale. This is critical as the design process typically occurs at specific scales of work. The neighbourhood or district scale is typically considered at one moment,
followed later by the block and street scale, etc. While design is an iterative process and occasionally jumps between scales, the sequence of looking from larger to smaller scales is fairly consistent.

This matrix allows a designer to consider the different goals and their specific elements that are salient at any given scale, allowing a comparison of how one element might support multiple goals. For example, the distribution and selection of street trees is shown to affect the quality and how inviting a street is for walking and biking, the need to slow down the speed of water concentration in stormwater recharge, the possibility to create microhabitats for indigenous birds, mammals and insects, and the ability to provide shading that can mitigate the heat island effect and reduce building cooling needs.

The matrix also makes evident the trade-offs that should be considered when a single element is affecting multiple goals. For example, density is highly valuable in reducing both transportation and building related energy use and GHG emissions, but at the same time it often increases the amount of impermeable surface and limits habitat within an urban area. The matrix makes these trade-offs evident so that they can be discussed, weighed and considered by stakeholders.

While the current framework, as shown in the matrix, presents elements equally, not all elements are similar in terms of their ease of modification over time. In considering trade-offs, urban designers should consider the relative difficulty or ease of implementing certain elements in the initial versus later life of an area. For example, some basic elements such as block size and platting are fairly resilient and unchangeable over time and therefore initial design decisions are critical, should be carefully considered and fought for, and will persist.

On the other hand, other elements such as the extent of the urban forest or complete street design, while potentially not simple are relatively easier to modify. For these elements, design decisions that are untenable based on current political or financial issues can be revisited in future renovations or redesigns. This is an area for further research.

The matrix should also help prevent monothematic approaches that overly preference one aspect (for example, solar orientation or protected habitat for instance) over all others. These approaches often aim to completely maximize the sustainability of one area but in turn often have a deleterious effect on other critical areas of sustainability. A key impetus for the creation of this framework is to present a more balanced and holistic approach to addressing sustainability in urban design and to make the relationships between various goals more transparent and actionable.

It should be emphasized that this framework is meant to help define the topics that need to be addressed, not necessarily how they are addressed as this is determined in part by local conditions. For all of the issues described above, context is critical and what works in one area of the world with its specific parameters, culture and climate will not necessarily be transportable to another area. This framework is hence meant to act as a guide and not a stamp.

**Place and identity**

Place-making and vitality, both key domains of urban design, are critical to sustainability as places that lack identity or are not valued by their inhabitants will inevitably be neglected. This often leads to areas that fall into ruin and become obstacles to the very resources that are the target of the proposed framework. The European Commission’s Green Paper on the
Environment specifically identified the loss of vitality and sense of place in cities as two of the underlying root causes of environmental degradation (European Commission 1990).

‘Place’ is a complicated and contested concept that combines the physical attributes of a location with an applied meaning (Tuan 1974; Relph 1976; Carmona 2010). In a sense, place is socially constructed as it is individuals that assign meaning to locations and these meanings are often multiple, overlapping and even contradictory (Massey 1994). Related to this, vitality is a measure of the daily activity, events, celebrations and use of an area (Montgomery 1998).

In relation to the role of urban design, it is clear that the built environment is by no means the sole determinant or sufficient to create place – far from it given the social construction of place. Place is multifaceted, socially constructed and context specific so that it cannot easily be assigned to or associated with specific design elements. With the proposed framework, however, we are interested in the aspects of the built environment that can help affect place or ‘place potential’ and how the built environment supports vitality.

Urban design can assist with the definition of place in that it helps create discernable objects or locations that can be repositories for meaning. Kevin Lynch identified this concept as ‘imageability’: “… that quality in a physical object which gives it a high probability of evoking a strong image in any given observer” (Lynch 1960, 9). His five key physical elements of imageability were Paths, Edges, Districts, Nodes and Landmarks. Although seemingly simple, these elements actually often overlap and do not adhere exclusively to any single scale.

In addition to creating the discernable locations that help create place, urban design can help foster or sustain social narratives. For example, historic preservation of key buildings, building types, materials or urban fabric can help to sustain a social narrative through time. The maintenance or highlighting of the patina of time on spaces can also help preserve and solidify social narratives (Lynch 1972).

Place and vitality is a broad topic that can be seen as an overlay to many of the elements described in the framework matrix. For example, the creation of walkable districts, the character of an area based on the use of visible and distinct stormwater systems, or the identity of an area based on the broad extent of natural and preserved habitat can all contribute to a definition of place. In addition, many of the elements that contribute to increased walking, biking and transit use – mixed use, active street fronts, density and connectivity – also help create vital and active places (Montgomery 1998). Place and vitality are complex arenas, ones critical to sustainability, and ones in need of further research.

**Urban design and economic sustainability**

An issue that overlays the entire matrix and framework is the complex and multifaceted question of economic sustainability. Part of the difficulty with this topic is that while the term ‘economic sustainability’ has been used somewhat ubiquitously, a set definition is unclear. Throughout the literature on this topic, the term is interchangeably used to refer to the creation of economics value, an increase in economic activity and/or substantial cost savings. Similarly, the key beneficiaries or targets of economic sustainability can also vary considerably, with studies and reports focusing on benefits to some subset of businesses, residents, property developers, consumers, municipalities and/or society as a whole.

Although there is much need for additional research, there has been substantial work generally showing the economic benefits of sustainable urban design in terms of value, activity and cost saving and for a wide breadth of beneficiaries. It should be noted that while this
paper describes a broad range of urban design elements that contribute to sustainable urban design, a disproportionate amount of the existing economic research has focused mostly on only a few of these elements, namely compact development, elements that contribute to walkability and the use of green stormwater infrastructure. Below is a review of studies that have looked at the effects of these elements on economic value, activity and cost savings.

The creation of economic value refers to the increase in the market value of projects and is measured through higher rents and residential sale prices. A number of studies have looked at how areas that have implemented smart growth strategies and improved walkability have higher economic value compared to typical suburban and car-oriented development. This has included more walkable areas experiencing a nearly 75% increase in office rents (Leinberger and Lynch 2014), nearly a 50% decrease in commercial vacancies (NYC Department of Transportation 2012), and between a $4000 and $34,000 increase in housing sale prices (Cortright 2009).

In terms of economic activity, walkable areas have shown increased commercial absorption rates and retail revenue (Leinberger and Alfonzo 2012). In addition, compact, dense and walkable development is related to increases in productivity and innovation as these design qualities are correlated with an increase in an area’s access to educated and skilled labour, access to suppliers and the frequency of face-to-face interactions (see Kramer and Sobel 2013 for a review of related literature).

A number of studies have looked specifically at the cost savings related to sustainable urban design strategies. One of the key areas of research in this area is on cost savings related to infrastructure. Studies from the 1970s up to the present have shown that compact development significantly reduces the cost of water, sewer and transportation infrastructure (Burchell 2001; Bartholomew et al. 2009). If implemented nationally, these savings are estimated to be “$12.6 billion in water and sewer infrastructure costs and $110 billion in road building costs between 2000 and 2025” (Kramer and Sobel 2014, 8). This cost saving for municipalities can extend beyond infrastructure to include savings due to reduced service delivery costs of fire, police, emergency services and trash and recycling services (Bollinger, Berger, and Thompson 2001; Coyne 2003).

Individuals themselves also see significant cost savings related to sustainable development including lower transportation costs and health costs. As walkable areas lead to reductions in vehicle miles travelled, individuals save on costs associated with auto use including car ownership (especially a household’s second or third car), fuel and maintenance (Litman 2004, 2013). Increased walking and biking and reduced auto travel also provides health benefits that reduces healthcare costs borne both by individuals and by insurers (Boarnet, Greenwald, and McMillan 2008).

While the economic benefits described above seem to paint a rosy picture of sustainable urban design, this is in conflict with the observation that sustainable strategies are often not pursued specifically due to economic concerns. The overriding issue with this lies in how economic benefits are captured by the entities that fund sustainable developments or the infrastructure that supports them. While economic benefits can affect a wide range of people and groups, if developers, owners or municipalities cannot directly capture these benefits, the initial funding for sustainable developments can prove difficult. This is a large barrier in increasing amounts of sustainable development and requires the implementation of incentives and financial models that can help fund projects upfront while capturing long term and often dispersed economic benefits (Cotugno and McArthur 2007).
Additional issues and future research needs

An overarching issue related to all of the design elements in the framework is the issue of resilience. Resilience is “the ability of a system to adapt and adjust to changing internal or external processes” (Pickett, Cadenasso, and Grove 2004, 373). A key aspect of resilience is the notion that urban areas not be considered as separate from surrounding natural ecologies and instead be considered a single, integrated entity (Alberti and Marzluff 2004).

There are two critical time dimensions of resilience in that an urban area needs to be able to adapt and thrive through long-term, slow moving transformations such as climate change, economic shifts, technological advances or lifestyle changes, as well as through short-term, catastrophic events such as earthquakes, fires or floods.

Inherent in many of the urban design elements described in the proposed framework is a direct link to resilience as these elements increase accessibility, reduce the energy needs of cities (allowing for minimized disruption during events that limit energy availability), and work to minimize the strain on natural ecosystems while making strong connections between these ecosystems and urban areas. All of these things increase the flexibility of urban areas and facilitate adaption through both long-term and short-term changes. This is an area in need of future research.

Additional issues that are relevant to the framework are those that are salient at the larger urban design scales, but are not the primary realm of urban design. District energy and recycling programmes, for example, can play vital roles in the sustainability of an area, but, aside from needing a parcel or minimal space within the streetscape, they have little effect on urban design itself. The reasons these deserve mention is that decisions about these systems often occur in parallel with urban design decisions and hence urban designers can assist in their inclusion, if not their design and implementation.

Within the topics that are addressed in the proposed framework, there are substantial needs for future research. As mentioned previously, because of the complexity of urban design, human behaviour and natural systems, an overarching framework that only took into account each individual urban design element that had been quantitatively proven to affect a sustainability metric would be a thin list at best. That said, current research is helping us understand the complexity of these relationships and the interaction between various elements and their effects on sustainability goals. As more empirical evidence becomes available and studies are able to better deal with the complexity that is sustainable urban design, this framework will need be modified.

Conclusion

The proposed Sustainable Urban Design Framework attempts to define and relate the various aspects of urban design that contribute to sustainability. The aim is that this can serve as a roadmap of issues that need to be addressed in sustainable urban design and can help deter monothematic approaches to both the design and evaluation of areas ascribing to sustainability goals.

Because of the current state of research and the complexity of the topic, the framework has speculative aspects, but the attempt has been to ground all aspects as much as possible in currently available research. Urban designers, planners and researchers need to act and are acting in their pursuit of sustainable environments. If not definitive, then at least this...
framework can help organize the various elements and topics that are ‘in contention’ to affect desired sustainability goals.

**Disclosure statement**

No potential conflict of interest was reported by the author.

**References**


