

A Conceptual Framework for Assessing Green Infrastructure Sustainability Performance in Australia

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Abstract: In recent years, as environmental issues increasingly permeate the urban discourse, the more holistic term “sustainability” has become a watchword internationally. Numerous appraisal frameworks, sustainability indicators and rating tools of varying effectiveness have been developed to gauge the effectiveness of sustainability interventions. Urban ecology is arguably one of the main approaches for formulating and assessing sustainable urban development, policy and management. Although there are several methods to evaluate urban ecosystems, an integrated assessment system which addresses the range of ecosystem services necessary to maximise sustainability outcomes remains elusive.

“Green” infrastructure, as distinct from conventional “grey” infrastructure, is an emerging concept linked to natural and designed ecosystems and the services they provide. While it is difficult to have one universal definition for green infrastructure, it is generally recognised as embracing all the natural, semi-natural and engineered networks of multifunctional ecological systems within, around and between urban areas at all temporal and spatial scales.

This paper proposes a methodology and a conceptual framework for evaluating green infrastructure performance, derived initially from the literature and adapted for the Australian context by incorporating the results from a semi-structured interview process involving twenty one selected Australian practitioners and researchers.

This proposed framework combines three key themes: ecosystem services, human health and well-being and ecosystem health. It helps to provide a basis for determining specific indicators to describe the measured phenomena pertinent to green infrastructure performance and serves as a foundation for a proposed indicator-based assessment model in future studies.

Key words: Green infrastructure, conceptual framework, urban ecosystem, ecosystem services, human health, ecosystem health

Introduction

Rapid urbanization is a phenomenon that has been taking place all around the world since the 20th century. This condition imposes a significant ecological footprint on the planet. It causes fundamental changes in land use, the landscape pattern and the ecosystem structure and function. The ultimate outcomes are landscape fragmentation, biodiversity loss, the creation of urban heat islands and increasing greenhouse gas emissions. There is also a decrease in human health and well-being among other negative outcomes, which when combined with the effects of climate change, has increasing detrimental effects on human life.

Green infrastructure has been identified as a greener alternative and less costly response for addressing some of these negative consequences and improving the sustainability of urban development (Ely & Pitman 2014; Laforteza et al. 2013). Sustainability in general refers to the capacity to be continued indefinitely. The most frequently cited definition refers to “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (WCED 1987). Sustainable development represents an approach in the context of three sustainability pillars or ‘bottom lines’ – ecological, social and economic. Ecologically sustainable development was defined by the Commonwealth of Australia (1992) as “...using, conserving and enhancing the community’s resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased”. Hence, the ecological perspective of sustainability applied in this paper embraces the integration of natural and living systems into urban design with the objective of supporting the wellbeing and health of society and ecosystems over time.

The Australian Institute of Landscape Architects (AILA 2012, 4) defines green infrastructure as "a network of natural landscape assets which underpin the economic, socio-cultural and environmental functionality of our cities and towns – i.e. the green spaces and water systems which intersperse, connect, and provide vital life support for humans and other species within our urban environments." The US Environmental Protection Agency (USEPA 2011) highlights the role of human intervention, defining GI as "an array of products, technologies and practices that are natural systems—or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services."

Over the last two decades the concept of green infrastructure has emerged as a new category of infrastructure and an effective response to challenges such as climate change adaptation and mitigation (Moore 2006; McPherson et al. 2009; Thom et al. 2009), urban heat island effect mitigation (Coutts et al. 2007; Loughnan et al. 2008; Livesley 2010; Loughnan et al. 2010; Philipp et al. 2015); sustainable water management (Wong 2011); carbon storage and sequestration (McPherson et al. 2013; Pakzad et al. 2015a); and supporting human health and wellbeing (Kent et al. 2011; Planet Ark 2011; Ely & Pitman 2014). Notably, green infrastructure as an ecological entity evolves over time at no cost to humans, so potentially it has lower capital, maintenance and operational costs (Jaffe et al., 2010). When the effectiveness of green infrastructure is compared to conventional or 'grey' infrastructure, that tends to be designed for single functions, green infrastructure can perform multiple functions whilst having less negative impact on the environment and potentially reducing the carbon footprint.

A study conducted by Black et al. (2016) evaluated the integration of green infrastructure into other urban infrastructure in USA, UK, Singapore and Australia in terms of comparison between theory and practice in these four case studies. According to this study, Australia road authorities are a long way from integration green infrastructure principles into guidelines and practice (Black et al. 2016).

However, new thinking is required to address the challenges of integrating green infrastructure planning into urban development towards more sustainable, resilient and healthy cities. This in turn will support effective intervention in terms of protection, management and restoration of urban ecosystems (Benedict & McMahon 2002). A broad conceptual framework is proposed here, derived from a synthesis of existing literature. This framework is refined through semi-structured interviews across a wide range of disciplines, including urban and landscape planning, architecture, environmental science and ecology as an essential first step to determine the associated key performance indicators of GI in future research.

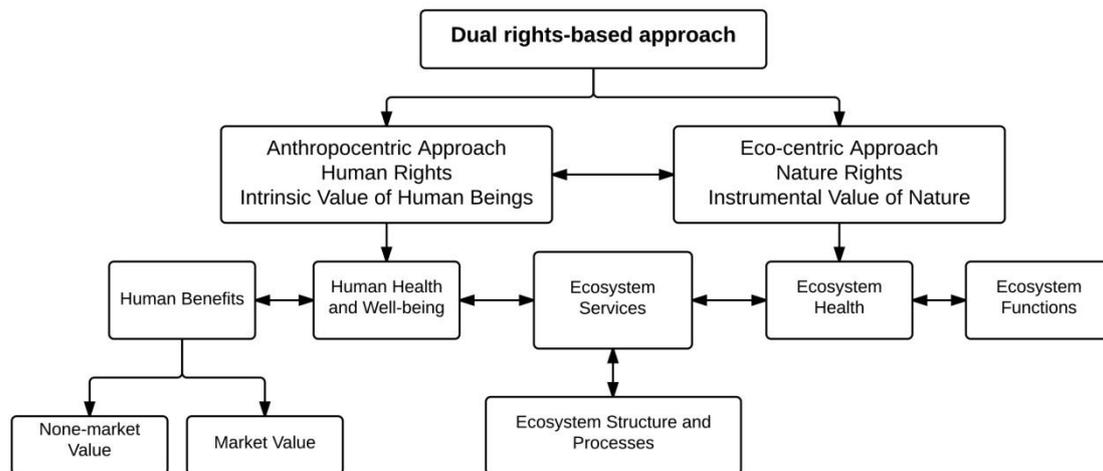
Background

Development of the green infrastructure concept and theoretical underpinning

Jabareen (2009) defined a conceptual framework as a network or interlinkage of various concepts that presents a comprehensive understanding of a phenomenon and illustrates the integral role of each concept in relation to the other. One major aspect which must be considered when developing a conceptual framework is the accurate collection and aggregation of data. The proposed conceptual framework in this study (Figure 2) is derived from a combination of two viewpoints, theoretical and practice oriented. The output is intended to contribute to the scientific discourse on green infrastructure as well as to inform practitioners on appropriate planning and design processes.

The key theory behind the green infrastructure concept is the moral relationship between humans and the natural environment, known as environmental ethics (Leopold 1948). Environmental philosophy is unsurprisingly contested ground. Among the many conflicts and disputes, anthropocentrism vs. ecocentrism is recognized as one of the most common ecological moral dilemmas (Kortenkampn & Moore 2001). Aldo Leopold's (1948) 'Land Ethic' represented an early approach to the eco-centric position. Other scholars such as McHarg (1969) developed a philosophy of 'Design with Nature', while James Lovelock addressed the self-designing capacity of nature in his 'Gaia' hypothesis (1969). Australian scholar John Passmore, (1974) in his book 'Man's Responsibility for Nature' emphasised the urgent need for changes in human attitudes concerning the environment and land ethics. The contradiction of advancing ecocentric and anthropocentric attitudes simultaneously explains the prevalence of paradoxical environmental ethical decisions. To evaluate decisions that equally consider humans' and nature's rights, stakeholders must weigh up the possible consequences and determine which one should take priority (MacKinnon 2007).

Figure 1 Dual rights-based approach (Source: Author).



From this ‘dual rights’ perspective, green infrastructure may provide the missing link between humans, nature and the built environment. For example, in order to determine the best use of land to support natural processes, ecosystems as well as recreational and other needs of settlement, green infrastructure systems at various scales can embody a dual rights-based approach, which incorporates both anthropocentric and ecocentric values (Figure 1). This is achieved by integrating interdisciplinary factors such as pollution mitigation, habitat and biodiversity, quality of life enhancement, food, energy, recreation and scenic values. Therefore, green infrastructure can be a cost-effective and efficient solution to address many issues simultaneously (Austin 2014).

Methods

Reviewing Existing Green Infrastructure Conceptual Models

Numerous social science research models address environmental effects on human mental and physical health (table 1). The physical characteristics of built environment including housing form, roads and footpaths, parks and other public amenities have significant impacts on mental and physical health (Freeman, 1984). In 2002, Henwood suggested a model that demonstrates a link between environmental stress and health. Pickett et al. (1997; 2001) proposed an integrated human ecosystem framework for analysing urban systems in relation to their social, biological and physical aspects. The two interconnected parts of this framework are:

1. The human-social system, which includes social institutions and cycles;
2. The resource system, which consists of cultural and socio-economic resources, and ecosystem structure and processes.

Grimm et al. (2000) revised Pickett’s human ecosystem framework based on land use and land cover changes in relation to the interactions between social and ecological systems. Even though these two models help to understand the concept of green infrastructure in general, they do not clearly address the relationships between ecosystems and public health (Tzoulas et al. 2007).

Based on Maslow’s hierarchy of human needs, Macintyre et al. (2002) proposed a framework for healthy neighbourhood which includes physical features (e.g. clean air and water, and protection from infections), socio-cultural services (e.g. education, recreation and community integration) and economic (e.g. work and transport) factors affecting health, but did not acknowledge the importance of biodiverse habitats in contributing to these factors.

The “Arch of health” is another integrated framework that was developed by the World Health Organisation (WHO 1998). This model explains the environmental, cultural, socio-economic, working and living conditions, community, lifestyle and hereditary factors of public health. Paton et al. (2005) combined the “arch of health” model with organisational development principles (social,

environmental, organisational and personal factors) and systems theory to enhance their approach within organisations.

In 2003, the Millennium Ecosystem Assessment body established a framework to assess global ecosystem changes and their impacts on human and ecosystem health. This framework links ecosystem services and human wellbeing through socio-economic factors. Under this framework, ecosystem services were classified into four categories: provisioning, regulating, supporting and cultural; and human well-being was classified into five categories: security, access to basic resources, health, good social relations and freedom of choice (MEA 2003, 78). Even though this framework is very broad and includes many parameters, it does not “explicitly distinguish between the biological, psychological and epidemiological aspects of health” (Tzoulas et al. 2007, 21).

A comprehensive and complex model developed by Van Kamp et al (2003) synthesised various factors that affect the quality of life including personal, social, cultural, community, natural and built environment as well as economic factors. However, the interrelationships between these factors were not clear.

Tzoulas et al. (2007) proposed a framework for green infrastructure in urban areas that provided the ground for linking ecological concepts such as ecosystem health to social concepts such as individual or community health. On this basis, Laforteza et al. (2013) described a framework for green infrastructure planning with five interlinked conceptual components: ecosystem services; biodiversity; social and territorial cohesion; sustainable development, and human well-being. In 2010 Abraham et al. conducted a scoping study reviewing over 120 studies examining the health-promoting aspects of natural and designed landscapes. The authors identified three dimensions of human health linked to Green Infrastructure: Mental well-being: landscape as a restorative environment; Physical well-being: walkable landscapes; Social well-being: landscape as a bonding structure.

Table 1 Models and theories linking ecosystem and human health aspects (Source: Tzoulas 2007; revised by author).

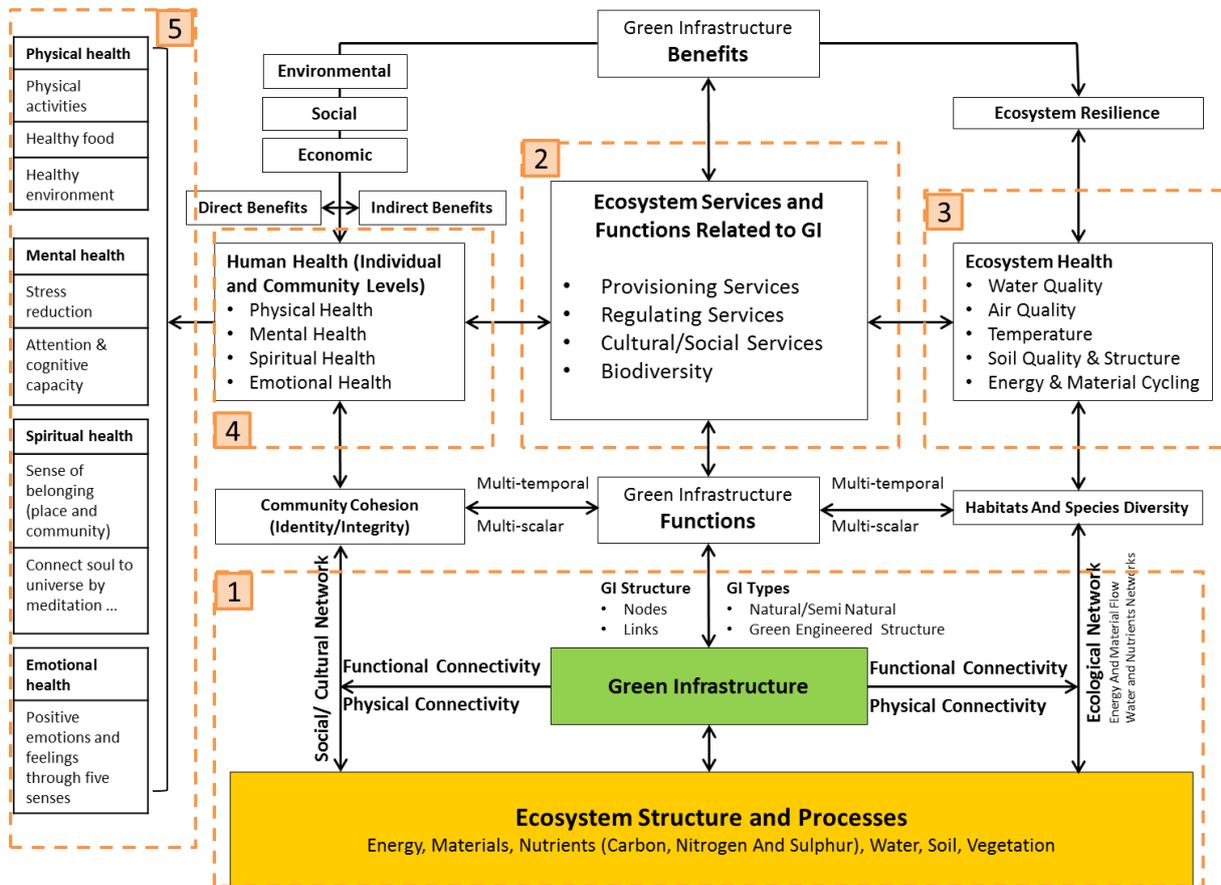
Author	Model/theory	Green infrastructure aspect	Human health aspect
Freeman (1984)	Model of Environmental Effects on Mental and Physical Health	Physical, social and cultural factors	Nervous system and illness
Henwood (2002)	Psychosocial Stress and Health Model	Physical poor environment	Chronic anxiety, chronic stress and high blood pressure
Pickett et al. (1997, 2001), Grimm et al. (2000)	Human Ecosystem Framework	Ecosystem structure and processes and cultural and socio-economic resources	Socio-ecological systems
WHO (1998)	Arch of Health	Environmental, cultural, socio-economic factors	Working and living conditions, community, lifestyle and hereditary factors
Paton et al. (2005)	Healthy living and working model	Environmental, cultural, socio-economic factors	Living and working conditions
Millennium Assessment (2003)	Links between ecosystem services and human well-being	Provisioning, ecosystem services, regulating and cultural	Security, basic resources, health, social relationships, and freedom of choice
Macintyre et al. (2002)	Framework based on basic human needs	Air, water, food, infectious diseases, waste disposal, pollution	Health and human needs (biological, personal, social, and spiritual)
van Kamp et al. (2003)	Domains of liveability and quality of life	Natural environment, natural resources, landscapes, flora and fauna, green areas	Health all aspects (physical, psychological, social)
Tzoulas et al. (2007) and Austin (2014)	Conceptual framework integrating Green Infrastructure, ecosystem and human health.	Ecosystem services and functions (air and water purification, climate and radiation regulation, etc.) and ecosystem health (air quality, soil structure etc.)	Socio-economic, community, physical and psychological health
Abraham et al. (2010)	Human health and wellbeing benefits of green infrastructure	Accessibility, walkability, Aesthetically appealing nature, environmental aspects (air quality and noise reduction), biophilia, restorative, social and cultural interactions	Physical, psychological and social health and wellbeing

Table-1 summarises the most recent frameworks, which indicates that the overall concept for the assessment of green infrastructure performance is based on concepts for services which are delivered by ecosystems with a social–ecological perspective (de Groot et al. 2010; Ernstson 2013). This conceptual framework respects both the philosophical anthropocentrism and the ecocentrism

approaches discussed above. The link between ecosystem services, ecosystem health and human wellbeing is very clear. Healthy ecosystems within green infrastructure environments have the ability to increase the delivery of ecological and cultural services. These services are provided through ecosystems to improve human health and wellbeing at both individual and community scales.

As an overview, Tzoulas et al. (2007) and Austin (2014) proposed a framework through the combination of three systems (ecosystem services, ecosystem health and human wellbeing), even though the methods are different in detail. Their framework explains the relationship between the ecological benefits of green infrastructure and the values for humans. These benefits lead to enhanced human health and wellbeing while conserving and maintaining the environment and natural resources. Based on these theories and existing models a conceptual framework which links green infrastructure, ecosystems and human health and wellbeing is seen as a fundamental requirement. This framework provides the basis to establish a composite indicator-based model for assessing green infrastructure performance (Figure 2).

Figure 2 proposed conceptual framework of green infrastructure. (Source: Author)



The top half of Figure 2 indicates the interactions between ecosystem services, the functions that green infrastructure provides and the aspects of ecosystem health and human health that these services influence and provide (Boxes 2, 3 and 4). The lower half represents green infrastructure types, the ecological processes and the two-way interactions between them. This is expressed as green infrastructure characteristics such as connectivity (Box 1). Natural or ecological cycles act as an input for the model which is influenced by ecosystems health, human activities and the structure of green infrastructure.

Box 1 outlines the types of green infrastructure, their structure and function. Ideally each of these elements should be structured with the network of green infrastructure which consists of nodes and links.

Boxes 2 and 3 have been adopted from the model of ecosystem services, developed from a combination of the Millennium Ecosystem Service framework (2005) and the ecosystem health model proposed by Lu and Li (2003) and employed by Costanza et al. (2007) and Austin (2014). Ecosystem

health relates to the quality, quantity, configuration and variability of ecosystem functions and services (Costanza et al. 2007).

Box 4 illustrates the impact of ecosystem services and the functions associated with ecosystem health on individual and community wellbeing, based on Gawain (1999) and Abraham et al. (2010). Green infrastructure and associated improvements in ecosystem health provide a balance across the four factors of human health (physical, mental, psychological and emotional) and create the environmental settings for community health. Community health also contributes significantly to the well-being of individuals (Troyer 2002; Westphal 2003). Community satisfaction and involvement, as well as community identity, are fundamental to the social well-being of both communities and individuals. The “arch of health” (WHO 1998) also recognises culture and lifestyle as determinants of health.

Box 5 indicates the four aspects for the fulfilment of human health and wellbeing.

1. Physical health relates to those physical activities that promote health and wellbeing.
2. Psychological health is considered in relation to the human contact with green spaces (Ulrich et al., 1991; Kaplan, 1995; Hartig et al., 2003).
3. Emotional health is the ability to experience life deeply, to relate to and have meaningful connection to one another and the surrounding environment.
4. The spiritual aspect refers to our inner essence, our soul, surrounded by time and space and connects our feeling to the universe.

Stakeholder Interviews

The proposed conceptual framework (Figure 2) emphasises the interrelationship between human health, at individual and public levels, ecosystem health and its parameters and ecosystem services which are delivered through green infrastructure elements across spatial and temporal scales. The outcomes from the pilot interviews conducted with industry representatives provide further justification for this framework in an Australian context.

This section presents the findings from a series of 21 semi-structured interviews with property and design industry professionals (Table 2). The purpose was to seek an understanding of the current perceptions and knowledge of green infrastructure in the Australian context and secondly to refine the draft conceptual framework discussed above to enable the derivation of indicators to evaluate the performance of green infrastructure in the built environment. The interviewees were selected from the following fields: design (landscape, architecture and urban planning); horticulture; urban policy makers; water management and environment from the private, academic and government sectors.

The interview questions were categorized into three sections:

1. To identify the interviewees’ knowledge of existing tools used for assessing the sustainability performance of buildings, landscape and infrastructure projects.
2. To appreciate their understanding of green infrastructure terminologies, concepts, structure and its components.
3. To identify their priorities for the conceptual framework parameters and interrelations within and between parameters.

The criteria for interviewee selection included their understanding and expertise in sustainability issues, in rating tools and in other assessment methodologies, and their interest and passion for the topic of the performance of green infrastructure.

Table 2 Interviewee profiles

Interview participant type		Interviewee numbers
Practitioners	Building Practitioners	3
	Landscape/urban planner/ environmentalist practitioners	10
Academics	Landscape and urban planner academics	2
	Building academicians	1
Government	Government official	5
Total		21

Semi-structured research interview design and data collection approach

The most widely employed method in qualitative research is the 'in-depth' interview where the interviewer can engage the respondent in a dialogue and to ask supplementary questions to clarify the respondents' answers. In-depth interviews are often divided into structured, semi-structured and unstructured according to the interview schedule and design. Prior to drafting the semi-structured interview questions the researcher conducted open question interviews with four stakeholders. These pilot interviews helped the researcher to identify issues that needed to be discussed in more depth with the larger sample. It also provided the opportunity to clarify any ambiguities and to establish more in-depth questions that would direct the respondent to provide further detail, to clarify or to explain answers.

With the knowledge obtained from the literature review and the pilot interviews, a set of 14 questions including additional probes were drafted (Table 3). Nineteen of the interviews were conducted face to face and two were by phone. The interviews lasted between 45 minutes to one hour and the recordings were supplemented with notes taken during the interview and the impressions, ideas and thoughts of the interviewer. All the interviews were transcribed and manually coded through an Excel spreadsheet. Repetitions, digressions and irrelevant materials were omitted from the transcripts before coding.

Summary of results

All transcripts were analysed and the frequency of responses for questions that required straightforward "Yes" or "No" answers were counted and tabulated in Table 3.

Table 3 Descriptive statistics of answers for Yes/No questions. Note: Only yes and No questions has been considered in this table.

Sector	Government	Academics	Practitioners
Section 1: Establish a general framework based on existing rating tools and assessment methods			
Q1: Are you familiar with rating tools?			
Yes (100%)	5 (24%)	3 (14%)	13 (62%)
Q2: Have you been involved in developing any rating tools?			
Yes (38%)	2 (9.5%)	2 (9.5%)	4 (19%)
Section 2: Characteristics of rating tools for green infrastructure			
Q3: Are you familiar with the term green infrastructure? Then their definitions			
Yes (100%)	5 (24%)	3(14%)	13 (62%)
Q4: Do you use any tools or methods for assessing landscape and open space performance as part of a design project?			
Yes (28.5%)	2 (9.5%)	0	4 (19%)
Q4.1 Are you familiar with SITES initiative rating tool?			
Yes(57%)	1 (5%)	3(14%)	8 (38%)
Q6: Do you think that landscape should be assessed as part of an integrated system (green infrastructure) and as an individual component (both)?			
Yes (62%)	4 (19%)	3 (14%)	6(29%)
Section 3: Define framework, categories, sub-categories and benchmarks			
Q8: Are you familiar with the term 'Triple-Bottom-Line' for sustainable development?			
Yes (100%)	5(24%)	3(14%)	13(62%)
Q8.3: Do you think that TBL can be an appropriate concept to create a framework for assessing GI performance?			
Yes (100%)	5(24%)	3(14%)	13(62%)
Q9: Are you familiar with the Millennium Ecosystem Assessment (MEA) framework?			
Yes (52%)	5(24%)	3(14%)	3(14%)
Q9.1: (After my explanation about MEA); Do you think that MEA can be an appropriate concept to create a framework for assessing GI performance?			
Yes (71%)	4(19%)	3(14%)	8(38%)
Q10: Do you agree with Combining two concepts of MEA and TBL for the measurement of GI performance?			
Yes (100%)	5(24%)	3(14%)	13(62%)
Q11: Do you think GI assessment framework needs to be benchmarked?			
Yes (100%)	5(24%)	3(14%)	13(62%)
Q12: Do you think benchmarks must be cover local government policies and strategies rather than national policies?			
Yes (19%)	1(5%)	0	3(14%)

Section 1: Familiarity with existing rating tools

The objective of the questions in this section was to establish whether the interviewee was familiar with any rating tool/s for assessing sustainability in buildings, infrastructure and/or landscape.

Eight out of 21 interviewees were involved in developing rating tools. Six had providing limited input data at the early stage of the development of a tool and two were involved in the whole development process. The academics had the widest knowledge of the tools available, including the theoretical and philosophical thinking behind them, but they rarely used or tested these tools in practice. Table 4 demonstrates the order of popularity for the knowledge of the tools.

Table 4 the most popular tools Note: G: Government; A: Academics; P: Practitioners

IS			GreenStar			SITES			NABERS			LEED			iTree			Others		
G	A	P	G	A	P	G	A	P	G	A	P	G	A	P	G	A	P	G	A	P
3	2	4	5	3	10	1	3	8	2	3	6	2	3	9	1	2	6	1	1	5
9			18			12			11			14			9			7		

Section 2: Understanding of the green infrastructure concept

- GI definitions

All of the participants were familiar with the term 'green infrastructure' and they were able to describe it in relation to their own field of expertise. While they were questioned about their understanding of the term, the subjects proposed nine quite different definitions. From these, four broader definitions could be derived:

- 1: Green infrastructure (GI) is a policy and strategic approach to land and species conservation.
- 2: GI is a network of energy, materials and species flows that maintains and improves ecological functions in combination with multifunctional land uses and provides associated benefits to human populations and ecosystems.
- 3: GI refers to the integration of ecological functions through natural and engineered networks into conventional infrastructure systems to enhance their functions, and it can significantly reduce their carbon footprint.
- 4: GI is an ecological solution underpinned by the concept of ecosystem services to improve the sustainability level of the urban and built environment. It embraces the idea of the triple bottom line – the social, economic and environmental aspects of the urban environment.

Table 5 GI definitions among three groups of participants Note: G: Government; A: Academics; P: Practitioners

D1			D2			D3			D4		
G	A	P	G	A	P	G	A	P	G	A	P
4	0	2	1	2	0	1	1	5	2	2	8
6			3			7			12		

Table 5 illustrates the frequencies of the preceding green infrastructure definitions among the three groups of participants. Some of the participants' definitions cover more than one category. Most participants defined GI as a solution to improve the sustainability level of the urban environment (definition 4). Interestingly, only three practitioners were aware of the Millennium Ecosystem Assessment (Table 3). However, eight of 13 of the practitioners embraced definition 4. Among government sector interviewees' definition 1, policy and the strategic approach, was favoured over other definitions.

- GI Components and Types

Green infrastructure types vary in terms of scale and functions. Responses from interviewees regarding GI types can be classified into six groups:

- 1- Green corridors(greenways/ street trees/bike ways)
- 2- Green roofs and green walls
- 3- Bio retention and infiltration (bio swales/rain garden/ permeable pavement)
- 4- Natural green areas(forest/woodland/grassland)
- 5- Water related components(rivers/ streams/ lakes)
- 6- Green square/parks/ gardens/ yards

Table 6 demonstrates that government sector participants have a broader perspective of GI types at the macro scale than other participants. They were able to name green networks and national parks

which have been influential in decision making and strategic planning. Practitioners mostly focused on the micro and meso scales such as green roofs and walls and bio-retention practices. Academics appeared to have a broader perspective across various types of green infrastructure implementation.

Table 6 Most well-known GI components

Sector	Practitioners	Academicians	Government
Green corridors	8	2	5
Green roofs and walls	13	3	1
Bio-retention	8	2	1
Natural green area	3	2	5
Water related components	2	1	3
Parks/Garden/Square	7	3	3

- GI Benefits and Functions

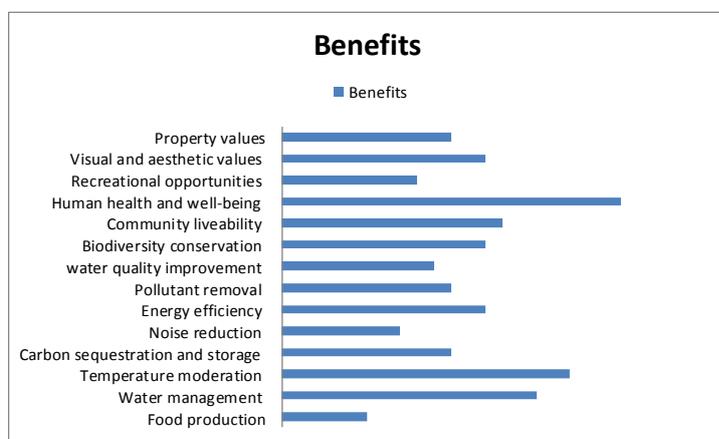
Green infrastructure can support numerous individual environmental or socio-economic functions. These include biodiversity, local distinctiveness, public health, sport and recreation, flood management, climate change adaptation and others. They can be 'multifunctional' meaning that different functions or activities occur on the same piece of land (TEP 2008, 9).

The interview participants were asked to indicate the benefits of GI that they were familiar with. Their responses were classified into 14 categories:

1. food production
2. water management (flow control and flood reduction)
3. temperature moderation
4. carbon sequestration and storage
5. noise reduction
6. energy efficiency
7. pollutant removal
8. water quality improvement
9. biodiversity conservation
10. community liveability
11. human health and well-being
12. recreational opportunities
13. visual and aesthetic values
14. property values.

Figure 3 illustrates the relative importance of the potential benefits of GI as designated by the interviewees.

Figure 3 Importance of potential benefits of GI which are designated by stakeholders.



Based on Figure 3 and the frequencies of participants' responses to identify the benefits of GI; Table 7 illustrates the weighting and degree of importance of each benefit.

Table 7 Weighting of GI benefits

Benefits	Weight
Food production	5%
Water management	15%
Temperature moderation	17%
Carbon sequestration and storage	10%
Noise reduction	7%
Energy efficiency	12%
Pollutant removal	10%
water quality improvement	9%
Biodiversity conservation	12%
Community liveability	13%
Human health and well-being	20%
Recreational opportunities	8%
Visual and aesthetic values	12%
Property values	10%

Several themes were consistent among all interviewees; the GI approach:

- is an imperative for national, regional and local policy regarding sustainable development
- brings economic and health benefits
- contributes to climate change mitigation and adaptation
- can offset the negative environmental and social effects of development
- improves the quality of life and the quality of place

- GI Structure

Interviewees were asked to explain the best scale at which green infrastructure should be applied, and to rate the importance of GI connectivity and networks.

Thirteen participants believed that GI assessment tools should be applicable at both individual and integrated scales and five said the tool should be able to assess GI performance as an integrated system. The remaining three suggested that due to lack of data, the individual component level is the best scale for assessment.

Table 8 GI structure Note: G: Government; A: Academics; P: Practitioners

Integrated components			Individual components			Both		
G	A	P	G	A	P	G	A	P
1	0	4	0	0	3	4	3	6
5			3			13		

Section 3: Establishing the framework

Participants were asked whether the proposed framework set out in Figure 2 was applicable to an Australian context or needed to be revised.

All interviewees were well-versed in the concept of sustainability, sustainable development and TBL of sustainability, but few were familiar with the concept of MEA (Table 3), although they identified that food, regulation and cultural services were delivered by GI.

Interviewees emphasised that the GI framework needs to be benchmarked. Table 9 illustrates that most interviewees agreed that benchmarks for each indicator should cover both local and national scales (top-down and bottom-up). This will enable the identification of projects at a local level that can deliver local benefits whilst also contributing to targets at higher levels.

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Table 9 GI benchmarking scale Note: G: Government; A: Academics; P: Practitioners

Local authority			National scale			Both		
G	A	P	G	A	P	G	A	P
1	0	3	1	1	2	3	2	8
4			4			13		

Six of 13 interviewees who advocated multi-scale benchmarking (Table 9), pointed out that establishing the benchmark at an international level is the most consistent way to evaluate the sustainability of green infrastructure projects.

Discussion

Analysing and coding the interviewees' responses revealed nine major concepts and themes that were consistent across all interviewees. These nine concepts can be classified into three categories: economic growth; environmental sustainability; and health and wellbeing (Table 10).

- ✓ Concept 1: Economic benefits
- ✓ Concept 2: Alignment with political issues and city strategies
- ✓ Concept 3: Climate change adaptation and mitigation
- ✓ Concept 4: Healthy ecosystem
- ✓ Concept 5: Biodiversity
- ✓ Concept 6: Water management
- ✓ Concept 7: Food production
- ✓ Concept 8: An active travel network (Human health and wellbeing)
- ✓ Concept 9: Enhance liveability (Human health and wellbeing)

Table 10 GI performance themes based on interviews' results (Source: Author)

Thematic concepts	Categories	Coding descriptive statements
Economic growth	Economic benefits	Increased property values Job productivity
	Alignment with political issues and city strategies	Effectiveness of GI implementation at local scale
Environmental sustainability	Climate change adaptation and mitigation	Temperature moderation
		Wind speed modification
		Carbon storage and sequestration
		Avoided emissions (reduced energy use)
	Healthy ecosystem	Air quality
		Water quantity and quality Soil structure (increase permeability)
Biodiversity	Habitat and species diversity	
Water management	Water purification Flow control and flood reduction	
Food production	Provide local food (community gardens)	
Human health and wellbeing	An active travel network (people-center) focus on GI connectivity characteristic	Physical wellbeing
	Enhance liveability	Social (social cohesion) wellbeing (Community liveability and sense of community) Psychological wellbeing

In another study which was conducted by Pakzad and Osmond (2015b), they used this thematic concept as a conceptual basis to establish an assessment framework to evaluate the sustainability performance of green infrastructure. This framework comprises of 30 indicators that were classified in four main categories including ecological indicators, health indicators, socio-cultural indicators and economic indicators.

Conclusions

This paper proposes and tests a conceptual framework which links green infrastructure performance into ecosystem services, ecosystem health and human health and wellbeing. This framework (Figure 2) provides the basis to establish a composite indicator-based model for assessing green

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infrastructure performance in future studies. Semi-structured interviews were conducted to validate this proposed framework and to demonstrate whether it is applicable in the Australian context.

Almost all interviewees agreed that sustainability and sustainable urban development are broad ideal concepts that link social, environmental and economic integrity. In addition, all agreed that the triple bottom line is a good concept for developing a framework for GI performance assessment. However, sustainable development is not the endpoint, it is a transition process that cities undertake moving toward a more sustainable and resilient future. A combination of TBL and MEA provides the most acceptable approach according to the interviewees. Table 10 shows how ecosystem services delivered by a green infrastructure can provide healthy environments and physical and psychological health benefits to the public and individual. In addition, healthy environment can provide socio-economic benefits for communities.

In conclusion, the approach to green infrastructure in Australia is still at an early stage and not fully understood in the consistent way, but the results of this study suggest that practitioners, government agencies and academic researchers are considering ways both to introduce GI and evaluate its performance.

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