Investigating the economic value of green infrastructure in urban development and planning

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I, Dominic Rolfe, hereby confirm that this Master Degree by Research thesis, titled "Investigating the economic value of green infrastructure in urban development and planning", has not been submitted for a higher degree to any other university or institution. All sources used in the thesis have been referenced and any other material is original work by me. Ethics approval has been sought and was granted on 27 May, 2016 (Ref number: 5201600281).

ABSTRACT

The term Green Infrastructure (GI) is being increasingly used in both policy and urban development settings. Covering everything from green roofs, permeable pavements and living nature strips to smart parks, increased tree coverage and water harvesting and recycling, it has been touted as a solution to making increasingly dense urban environments more liveable. But many development projects in Australia show varying levels of success in truly bringing the concepts of GI into planning policy and construction. While there is a growing body of literature showing the benefits of implementing GI, there is a dearth of research focused on the economic case of GI and its role in the decision-making process.

This research aims to partially address that lack of knowledge around how and why GI is, or is not, incorporated into the decisions of the planning and development community. Through a mixed-methods approach of literature review and qualitative and quantitative research techniques including semi-structured interviews of key participants, who have an impact on the planning, approval and construction of large-scale urban developments, this paper examines where and how GI is incorporated into those decision-making processes.

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1. INTRODUCTION

Australia is one of the world's most urbanised countries, with almost 90% of the population living in urban areas (World Bank, 2016) and two thirds living in capital cities (ABS, 2016). But as the population of Australia's major cities grows on ever more finite holdings of land, there is a need for sustainable solutions that make higher density living a driver rather than a brake on innovation, economic activity and social wellbeing. Increasing densities in cities is not confined to Australia; urbanisation is a global trend with the proportion of the world's urban population projected to rise from 54% in 2014 to 66% by 2050 (UN, 2014). Coupled with an estimate that 60% of urban areas projected to exist in 2030 are still to be built (Secretariat of the Convention on Biological Diversity 2012 in Kabisch et al, 2016), there are significant opportunities, both nationally and internationally, to influence and establish new approaches to urban design and development.

Approaches to urban land use planning have, however, been far from static. The past few decades has seen a shift from a preservation model (establishment of greenbelts, protection of areas of outstanding natural beauty such as national parks) distinguished by "islands of protection" (Owens and Cowell, 2011 in Scott et al, 2013, p 9), towards "a more holistic ecosystems approach, which includes not only protection but also enhancing, restoring, creating and designing new ecological networks characterised by multifunctionality and connectivity" (ibid, p 10). Urban policy and development in Australian cities reflects these changes and challenges. Notably Australian planners have become "increasingly concerned with infrastructure costs, environmental issues related to fringe development/urban sprawl, healthy cities, and the socio-spatial polarisation of our population" (Coffee et al, 2016, p 515).

Yet, the evolution of urban planning is beset by tensions flowing from competing development interests. "The planner must reconcile not two, but at least three conflicting interests: to 'grow' the economy, distribute this growth fairly, and in the process not degrade the ecosystem" (Campbell, 1996, p 297). A practical response to these theoretical tensions is exemplified at a local level by the three planning pillars used by the Greater Sydney Commission – productivity, liveability and sustainability (GSC, 2016, p 6). Hoping to square these competing interests while concurrently seeking to achieve a balanced and holistic approach, a number of recent developments in the urban planning sphere "that promise to reconcile environmental protection and economic growth in a way that is mutually beneficial" have emerged (Cowell and Owens 2006 in Lennon, 2015, p 957). Among them is the relatively recent emergence of the term "green infrastructure" (Lennon, 2015, p 958).

Green infrastructure (GI) has been promoted as a way of enabling urban development planners, policymakers and practitioners create more sustainable land use practices in our cities (Hansen and Pauleit, 2014, p 516). Taking in a broad spectrum of concepts that can range from green roofs and walls to linked green spaces, living nature strips and stormwater treatment, GI advocates maintain that this new approach has the potential to increase progressive planning policies and bring about myriad benefits for both urban communities as well as the natural environment (see, for example, the discussion of smart growth and GI in Benedict and McMahon, 2002, p 13).

But development projects in Australia show varying attempts to bring concepts of GI into the planning, design and building phases, from begrudging, lowest-level efforts to more complete, enlightened GI integration. One aspect contributing to the resistance in embracing GI is the dearth of empirical work evaluating the economic worth or otherwise of implementing GI, in either a policy or practical sense. Some other reasons for the patchy application and valuation of GI can be explained by the sweeping collection of benefits that are often ascribed to this approach. The Victoria Institute of Strategic Economic Studies, for instance, published a Green Infrastructure Economic Framework noting that GI systems operate across *various* scales, are *multifunctional* and have *multiple* benefits (Symons et al, 2015, p 4, emphases added). Other studies have also highlighted the multi-dimensional nature of GI (e.g. Ely and Pitman, 2012; Norton et al, 2015). The European Commission (2013, p 2), drawing a distinction between green and grey infrastructure notes, in heavily qualified language, that "compared to single-purpose, grey infrastructure, green infrastructure has many benefits. It is not a constraint on territorial development but promotes natural solutions if they are the best option. It can sometimes offer an alternative, or be complementary, to standard grey solutions." Such uncertainty is anathema to long-term planning and construction decisions.

It is also worth briefly reflecting that beyond the policy and planning world there are also other, wider conceptions of GI, such as that of the UK Green Investment Bank (GIB). The GIB, set up by the UK government (and recently acquired by Macquarie Bank), defines GI projects as including renewable energy, waste management and energy efficiency projects. It represents a departure from most of the academic definitions of GI and is markedly silent with respect to its inclusion of ecological and biological elements. It is notable, moreover, that the GIB sets out their sole "operating segment" as being "investment in green infrastructure", reinforcing the idea that in the corporate world, such a broad interpretation of GI has strong currency, albeit framed within their own definitional constraints.

The multiple conceptions of GI mean, ipso facto, that the definition of GI is sometimes contested (Symons et al, 2015, p 7). As a consequence, just as GI is being promoted, definitional vagueness is emerging as a potential barrier (Kambites and Owen, 2006, p 483). Others, meanwhile, have surmised that this vagueness is nevertheless a positive (e.g. Sussams et al 2015, p 192). In Australia, Pakzad and Osmond note that despite approaches to GI still being "at an early stage and not fully understood in the consistent way, practitioners, government agencies and academic researchers … are considering ways to both introduce GI and evaluate its performance" (2015, p 12). Intrinsically linked to the problems of definitional consistency is the lack of a sound, coherent and clearly enunciated economic argument for the use of GI (e.g. Symons et al, 2015, p 27).

In the absence of strong policy levers, the market, or parts therein, has been largely left to define and determine the value of implementing GI into new and existing urban contexts. This has meant consistent economic modelling is left languishing between piecemeal industry solutions and regulatory stasis. The value proposition for GI becomes even more clouded as the beneficiaries of any costs and benefits also remain undefined. For example, developers who are looking to sell on completion of a project tend to have a capital cost focus, those that maintain a stake in the development may have more of a life-cycle approach, while post-construction owners often look at amenity and comfort with some thought for maintenance costs. This is often described as "the principal-agent problem" (e.g. Persson and Grönkvist, 2015, p 298), and is another potential reason that the longer term benefits of GI have remained unmeasured.

Adopting an economic approach to the benefits of GI has been proposed to clear a way through this thicket of problems. As Matthews et al (2015, p 158) note, an "economic conceptualisation of green infrastructure underscores its character as a form of critical *natural capital*, able to generate a flow of material *benefits*, rather than being an ecological or social ideal." Moreover, in a real-world environment "dominated by fiscal constraint, this conceptual shift potentially enables planners to invoke the multiple benefits of green infrastructure, improving policy traction" (ibid).

The lack of data coupled with a sustainability-focussed regulatory environment that has generally not moved beyond the energy and water efficiency measures, means that any additional benefits, or indeed costs, that GI affords, are not being adequately captured and brought into the design and construction decision-making process. As Matthews et al (2015, p 157) note in looking at the barriers and drivers for adopting GI note (admittedly, through a climate adaptation lens), "unfortunately, researchers have tended to privilege the biophysical dimensions of green

infrastructure over socio-cultural and political-institutional concerns, so we know little about the latter". Thus, the impediments in making a value proposition for the inclusion of GI initiatives in urban projects is an area that is ripe for examination.

This research attempts to investigate the roadblocks hindering the uptake of GI through a longitudinal analysis of decisions behind medium-to-large urban projects across the planning, financing and construction sectors. In particular, it contemplates what may be required to facilitate the uptake of GI and particularly how economic data and financial modelling might provide extra incentives, in a regulatory as well as an industry and development context. The research also looks at what is most needed to transition to greater use of GI and seeks to test the different conceptions and definitions of GI in the space where the academy meets reality.

2. METHODOLOGY

2.1 Background

The aim of the research is to help in the development of an evidence-based position for government and industry to promote GI across environmental, social and, particularly, economic grounds. It does this through identifying and uncovering reasons for, and opportunities around, current barriers or blockages of GI that exist within the planning to delivery phase of major projects. The research also hopes to identify evidence for the strategic value of investing in GI by the development sector, which in turn would feed back into key decision-making points in project management.

Against this background, adequately capturing the sweep of opinions and valuations relating to GI is suited to a mixed-methods research methodology. By employing a mixed-methods approach, there is scope to unearth themes and discussions from interviewees, allowing for spontaneous narratives to emerge while developing data that is both contextual and rigorous (Creswell, 2003, p 211). As Greene and Caracelli (1997, p 7) note, the underlying rationale for mixed-method inquiry is to understand more fully, to generate deeper and broader insights, and to develop important knowledge claims that respect a wider range of interests and perspectives.

The ability to elicit spontaneous answers from the interviewees is a critical part of the discovery process, especially given the sometimes nebulous nature of GI. While some themes can be pre-identified through initial research and subsequent literature review, there needs to be scope for other themes to develop organically. In a paper discussing the rationale behind integrating qualitative and quantitative research methods, one reason for the open-ended nature of multi-strategy questions is that this type of research "provides such a wealth of data that researchers discover uses of the ensuing findings that they had not anticipated" (Bryman, 2006, p 110). Moreover, as is noted in Green and Caracelli (1997, p 7), the mixed-methods is intentionally designed "to gather different kinds of information".

The research problem also lends itself to a mixed-methods typology with a "concurrent embedded strategy" (Creswell, 2003, p 214). In this method, the quantitative research plays a supporting role to the larger qualitative component. It allows for the simultaneous collection of both types of data in order to "gain broader perspectives as a result of using the different methods as opposed to using the predominant method alone" (ibid, pp 214–215). The quantitative data seeks to undergird the research, even though it plays a minor role to the more fulsome qualitative data, while also providing additional qualitative data. The quantitative data comes from a four-part ranking question

related to the key factors for including GI. By placing these components within the qualitative data arising from the semi-structured interview questions, and towards the end of the question sequence, the relative views of people in different sectors and various management levels, who are making decisions at different points in a project, can be more richly analysed.

The qualitative data, meanwhile, is subject to constant refinement and informed by each interview and emerging lines of enquiry. It is critical to understand that the qualitative data doesn't seek to compare responses from the perspective of them being "wrong" or "right". Rather, the research forms an overall composite assessment of the problem that has multiple components and operates along the entire scope of a project's decision-making process.

2.2 Building the research method

The initial phase of investigating GI in urban development and planning in Greater Sydney specifically, as well as the broader domestic and international context, began with a comprehensive desktop survey. This enabled the identification of the most important sectors involved in considering GI projects, predominantly within the urban development industry and government. From this catalogue of industries, a broad list of potential interviewees with expertise in GI projects or related policy, as well as people involved in financing urban development or the design, construction and transfer of medium-to-high density property in Sydney, was then built.

At the same time, an initial survey of the available literature on GI projects was undertaken. This survey revealed that a large amount of research had focused on the efficacy of specific GI elements such as green roofs and walls, the effect of GI on the urban heat island, the effect of open space in developments and so on. Less research had been undertaken with reference to how GI elements enter or leave an urban development project, from concept and design to execution, construction and maintenance or transfer. There was also little available economic data on the relative value of the GI projects, either in and of themselves, or through hedonic pricing.

Having identified a research gap, it was apparent that a longitudinal set of interviewees was needed to understand the reasons why (or why not) and when the sweep of GI elements were considered during the decision-making process, and what the value of those elements was. Given the relatively small sample size (reflecting the constraints of the Masters program), it was determined that the interviewees would cover the entire decision-making process (from design, finance, policy, regulatory, investment and transfer/maintenance perspectives) and, ideally, have experience in more than one aspect of the decision-making process or worked in difference sectors. It was also critical

that they had as dispassionate a view as possible of GI, while still having a relevant understanding of the area. Key to gaining the deepest possible insights were the relatively long interviews that were undertaken, each lasting close to an hour. In this way, a longitudinal picture of the life of a project could be built rather than diving into specific sectors that might only join a project at certain junctures.

Industry representatives and policymakers were contacted to ascertain more detailed information about GI in Sydney. They included: the Green Building Council; Infrastructure Sustainability Council of Australia; UrbanGrowth NSW; NSW Office of Environment and Heritage; City of Sydney and other local governments; major development and investment representatives such as Lend Lease, Mirvac and Meriton; consultants, architects and landscape architects; sustainable finance sector representatives such as the Investor Group on Climate Change and the major banks. From this list, 11 participants a range of backgrounds agreed to be interviewed (see Table 1).

Table 1. List of interviewees and backgrounds

Interviewee number	**Role**	**Industry/Institution**
1	Senior bureaucrat and policymaker	NSW State government
2	Senior ESG property analyst	Investment advisory
3	Head of sustainability	Large property developer
4	Sustainability GM/Green Infrastructure analyst	Engineering consultancy
5	Senior policy officer	NSW State government
6	Senior urban designer/Landscape architect	Design consultancy
7	Sustainability manager/former government policymaker	Large property developer
8	Sustainable finance executive	Major bank
9	Senior environmental policymaker	Local government
10	Development director	Large property investment firm
11	Senior architect/landscape architect/board member	Government/Urban design consultancy

The interviewees were chosen with the intention of covering, as noted above, the longitudinal breadth of the development process, rather than testing the depth of a discrete part of the process

(the design or construction phases, for example). The selection of interviewees was skewed to the private development of medium to large built assets, such as buildings rather than, for example, green spaces. This approach reflected the research design and questions to uncover reasons for the inclusion, or not, of GI and the contribution of public policy of the decisions made within the private sector realm. This reflects the aforementioned approach of looking to impediments in finding the economic value of GI initiatives in urban projects, rather than policy or regulatory impediments.

2.3 Qualitative design

For the qualitative data, a semi-structured interview technique was chosen to enable the responses to reflect the diversity of understanding of a nascent industry, while still maintaining a coherent and comparable set of answers. Semi-structured interviews allowed the research to provide "some structure based on the research interests and interview guide but working flexibly … [to] allow room for the respondent's more spontaneous descriptions and narratives" (Brinkmann, 2014, p 1008).

At present there is a wide variance in how industry evaluates GI elements or projects, how those projects are defined in relation to the notion of GI, and what can be done to promote greater uptake of GI initiatives. It was determined that a useful way to understand at least some of the valuation of GI was to critically test Matthews et al's (2015, p 157) "economic conceptualisation of green infrastructure" outlined in the introduction.

Flowing from this, the qualitative data provided an insight into the most important questions in GI decision-making: the definition, impediments, benefits, where GI enters and leaves the process and the economic proposition of GI. The set of questions is set out below.

2.4 Questions

Question 1. What aspects of a project would you consider to fall under the banner of GI?

Question 2. What do you think are the benefits of GI, if any?

Question 3. What are the major impediments to the greater uptake of GI (with specific reference to Greater Sydney region)? (e.g. government policy v private industry/any new policies?)

Question 4. At what point in the decision-making process are the financial aspects of GI first considered, if at all (with specific reference to Greater Sydney region)? Why? If the idea of GI was considered but not realised, at what stage did it drop out and why?

Question 5. Were the economic benefits of GI modelled? If yes, how were they modelled and what effect did this have on the decision-making process? If not, why not?

Question 6. [The quantitative question from below is sequenced here]

Question 7. Are there other economic/financing solutions that could have a strong positive or negative effect on the uptake of GI e.g. considerations of intergenerational equity/resilience bonds/green bonds?

An iterative process followed, whereby answers from the first four participants was analysed to test for emerging themes and outcomes. Following the analysis of the responses by the initial interviewees minor adjustments were made to the grouping of the responses to elicit richer information on strong themes that were emerging, while still allowing for organic and unexpected answers. For questions 3, 4 and 5, it was quickly apparent that many of the answers overlapped and, as such, have been incorporated into one section for analysis with the major themes that emerged from those three questions being pulled out for discussion. The groupings below emerged from the initial answers.

Defining the scope of GI – *Question 1*
Benefits of GI – *Question 2*
What are the major drivers and barriers for GI in the decision-making process – *Questions 3,4,5 and 6*
What is important in GI decision-making – *Question 7*

2.5 Quantitative design

The quantitative data questions are drawn from earlier research into the decision-making aspects of GI by Matthews et al (2015). The authors of that paper argue that decision-making in GI:

> "must account for prevailing political sentiments, fiscal pressures, the attitudes, values and training of bureaucracies and the perceptions, needs and concerns of local residents. These socio-political factors have to be taken into account in assessing the (institutional) capacity

for using green infrastructure for adapting cities to climate change" (Matthews et al, 2015, p 162).

The questions were taken from this and ranked by the interviewees to determine which of those factors are the most important in decision-making and why. This gives rise to the following that was embedded as the penultimate question:

Question 6: In the decision-making process, how would you rank the following in terms of importance for projects involving GI:

a. political sentiments
b. fiscal pressures
c. the attitudes, values and training of bureaucracies and
d. the perceptions, needs and concerns of local residents

Why are they ranked like that?

Along with the ability to compare answers and draw some early conclusions about what most impacts the decision-making process across different sectors (e.g. government, finance and construction), the answers also yielded contextual qualitative data that allowed for a richer data set.

3. LITERATURE REVIEW

3.1 Green infrastructure: A slippery concept

Green infrastructure (GI) is a concept that as yet has no broadly accepted meaning, neither internationally nor locally. As GI has entered land use planning, it has created both confusion and uncertainty around what it is and its ability to add value and be valued (Pankhurst, 2010, p 8). For some it is urban greenery, for others it is physical infrastructure that has some environmentally friendly aspect. Others, still, combine the two, with many current definitions incorporating both the "green and blue spaces in the urban setting" (Symons et al, 2015, p 7), while a few such as the Green Investment Bank noted earlier, see GI as synonymous with large renewables projects. As the literature below also illustrates, the definition can split along sectoral lines as well as having some geographic distinctions. There is some evidence that the Australian approach is aligning more closely with the European definition, though the multiplicity of views makes a definitive conclusion hard to draw.

3.1.1 International Approaches to GI

In the United States, The American Society of Landscape Architects refers to GI as standalone and strategically networked environmental features designed for environmental, social and economic benefits (Matthews et al, 2016) (examples include permeable surfaces, green walls, green roofs and street trees). Similarly, an influential work by Benedict and McMahon (2006, p 5) from the US-based Conservation Fund, defines GI as an interconnected network of natural areas and other open spaces. Elsewhere in the US, there are tighter definitions. The US EPA, for example, maintains a narrow focus on GI as "a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits" (EPA, 2016) (this reflects the US focus on sustainable urban drainage systems analogous to the Australian terminology of Water Sensitive Urban Design (see for example, Fletcher et al, 2014, p 532)).

In Europe, however, there is a tendency to define GI more widely. The European Commission defines GI as a strategically planned network of natural and semi-natural areas with other environmental features such as water purification, air quality, space for recreation and climate mitigation and adaptation (EC, 2016). In a paper prepared for the EU-based but internationally-focused OECD (Kaminker et al, 2013), the authors take the definition of GI to be far broader than the definition used by many urban planners and policymakers. Beginning with the premise that GI investments "generate various benefits for human health, the environment and the economy" (ibid), the report indicates that GI could then include energy efficiency projects, smart grids, new transport

technologies, floodplain levees, sustainable agriculture and water infrastructure (Kaminker et al, 2013, p16).

3.1.2 Australian approaches to GI

In Australia, what constitutes GI is still not settled and, as a result, "is still not understood in a consistent way" (Pakzad and Osmond, 2015, p 12). Some highlight the urban network effects while others take a more eco-centric view, with the plurality of definitions below indicative of a still less than consistent approach. Despite this, Pakzad and Osmond suggest that "practitioners, government agencies and academic researchers are considering ways both to introduce green infrastructure and evaluate its performance" (ibid).

In a 2014 report for the Botanic Gardens of South Australia, Ely and Pitman (2014) note that their definition of *green* infrastructure as distinct from *grey* infrastructure is linked to the extra dimensions of multifunctionality and connectivity that GI delivers:

> "Green Infrastructure is the network of green places and water systems that delivers multiple environmental, social and economic values and services to urban communities. This network includes parks and reserves, backyards and gardens, waterways and wetlands, streets and transport corridors, pathways and greenways, farms and orchards, squares and plazas, business and institutional green areas, roof gardens and living walls, sports fields and cemeteries" (Ely and Pitman, 2014, p 3).

The Australian Institute of Landscape Architects' Strategy 2015–2020 document puts GI at the forefront of their government advocacy work (AILA, 2015). Like Ely and Pitman above, their definition of GI also focusses on the interconnected natural spaces:

> "The network of natural landscape assets that 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. Individual components of this environmental network are sometimes referred to as 'green infrastructure assets', and these occur across a range of landscape scales – from residential gardens to local parks and housing estates, streetscapes and highway verges, services and communications corridors, waterways and regional recreation areas etc" (AILA, 2015, p 8).

In New South Wales, the Office of Environment and Heritage (OEH), on their Climate Change website, considers GI through the lens of urban green cover: "Trees and vegetation (sometimes called green infrastructure) reflect heat, and they cool and clean the air by evapotranspiration. Other benefits are better health and well-being for urban-dwellers, more biodiversity and wildlife, and regulation of localised flooding" (OEH, Green Cover). They consider green cover to include bushland, private and community gardens, parks, greenways, habitat corridors, street trees, roof gardens and plant-covered walls, as well as reflective and permeable walls, pavements and other surfaces (ibid).

In a report for the NSW OEH looking, in part, at what urban policy settings can encourage the incorporation of urban ecology into planning for NSW, Davies et al (2017, p 14) noted the "full range of available green infrastructure, such as green roofs, green walls, urban agriculture, and other more commonly considered green spaces such as parks, should be used in developing corridors and patch frameworks that enable species to persist in the urban matrix and ecosystems to continue functioning." In related report, Davies et al (2017, p 29) note that GI is "an adaptable term used to describe an array of products, technologies and practices that use natural systems – or designed systems that mimic natural processes – to enhance environmental sustainability and human habitability (quality of life)." They also note that GI is the means by which urban ecology is incorporated into an urban setting. Taken together, these definitions seem to advocate a more eco-centric view of GI in potential local policy settings.

While the NSW Government's Greater Sydney Commission (GSC) did not specifically refer to GI in its draft District Plans, the final Greater Sydney Region Plan released in March 2018, noted GI both in the Chief Commissioner's introduction and throughout the Plan. They noted in the introduction (2018, p 6) that "Green infrastructure such as urban tree canopy, green ground cover, bushland, waterways, parks and open spaces will be valued for its economic, social and environmental benefits and will help to establish the Greater Sydney Green Grid, a network of walking and cycling links that will become increasingly important in daily travel arrangements improving sustainability and the wellbeing of residents." Later in the document (p 146) they define GI as: "the network of green spaces, natural systems and semi-natural systems that support sustainable communities. It has connected elements: waterways; urban bushland; urban tree canopy and green ground cover; parks and open spaces."

The Sydney Green Grid, noted above, is a proposal by the NSW Government Architect's Office to form an interconnected network across the city of "shared green pathways and open spaces" (NSW

Planning and Environment, 2016). In promoting the Sydney Green Grid, the Department of Planning and Environment remarks that it is the "ultimate green infrastructure, design-led strategy" (ibid). It is notable, however, in this proposal, that the concept of GI is predominantly concerned with the natural environment such as parks and playgrounds rather than, for example, the greening of buildings and other so-called "grey" infrastructure.

The definition has also been cast with climate change adaptability as a key element of GI's fundamental nature (Ely and Pitman, 2014, p 16). Some have seen the addition of GI's ability to adapt to climate change as a planning and management tool that can overcome the institutional barriers (e.g. cross-departmental coordination) to GI (see, for example, Matthews et al, 2015). In this vein, GI has also been defined as "a multi-purpose infrastructure solution for climate adaptation, versus single purpose engineered resiliency" (Rosenzweig, 2015, p 16). While noting GI's climate change adaptation benefits – mitigating the urban heat island effect; flood risk management; and ecosystem resilience – alongside all the other proposed benefits, some remain cautious about the widespread advantages of such an approach (Sussams et al, 2015, p 190). Indeed, the "lack of a static, universal definition could result in a lack of consistency in its application and, in turn, a lack of clarity in its comprehension" (ibid). Moreover, it has been argued that GI's inherent multifunctionality can drive confusion and some misconception between practitioners (ibid, p 189).

Such divergent views of GI have led to planners and policymakers remaining uncertain as to what constitutes GI (Matthews et al, 2015). While a number of projects concerning climate change in urban green areas exist and have been implemented, the absence of "a shared knowledge base in general and particularly for urban areas continues to be lacking because of uncertainties on how to best share information and regarding the drivers and constraints of implementation" (Kabisch et al, 2016, p 44). It has also been suggested that there are other crucial missing elements such as mechanisms for putting GI at the centre of the planning process and "practical guidance for those working at the local and regional level as to how to turn such conceptual thinking into useable planning tools" (Mell, I, 2009, p 77).

Compounding the complexity is the potential of GI to be not only a possible aid to adaptation but itself potentially be vulnerable to changes in climatic conditions. Kendal et al (2015, p 2) notes that GI in the form of urban green spaces can provide resilience to cities by "ameliorating external shocks and changes, [but] green spaces themselves must also be managed to be resilient in the face of external change."

Yet, despite the problems of definition and multi-layered issues, there is a hope that GI can shift contemporary planning "from conventional approaches to land conservation and natural resources protection because it looks at conservation in concert with land development and man-made infrastructure planning" (Benedict and McMahon, 2006, p 2). Similarly, the delivery of GI is seen to necessitate "a departure from conventional administrative arrangements wherein 'ritual and routine tend to predominate in the definition and handling of problems'" (Lennon, 2015, p 960).

These disconnected attempts at GI formulation, research and implementation, have, as a consequence, resulted in a lack of strong economic data that could be used to assess the costs and benefits of GI in Greater Sydney and other urban spheres. The 202020 Vision, for example, which aims to increase the amount of green space in Australia's urban areas by 20% by 2020, outlines a number of barriers to implementation, including a lack of measurement of the benefits, a robust business case and a lack of priority for green space in decision-making. Taken together, it is clear that the absence of evidence-based research into the economic costs and benefits is a potential impediment to the greater use of GI as it limits the arguments that policymakers, urban planners, designers and developers can use when contemplating new GI policies and projects.

3.2 Why economic benefits flowing from GI are important

Assessing the economic benefits of GI is a task complicated not only by the protean definitional issues but also by the multiplicity of ways that GI can produce social, environmental and economic outcomes. Unlike "grey" infrastructure that is generally thought of as man-made, constructed assets and solutions (Davis, 2010, p 1) primarily concerned with engineering resilience, GI projects are often seen as having multiple benefits from long-term climate change mitigation and health benefits to providing stormwater pollution management solutions and thermal insulation. Nevertheless, if GI is to be used, "policymakers … want to know whether these green investments can have a considerable economic return on both regional and community scale" (Vandermeulen et al, 2011, p 199). While this quote relates to a European context, in Australia, Jones et al (2015) from the Victoria Institute of Strategic Economic Studies note that there is a "lack of available data in Australia to measure green infrastructure benefits with confidence." When read in conjunction with IPART NSW's Better Regulation Principles, that require clear objectives of any government action and an understanding of the impact of government action that considers the costs and benefits of a range of options, including non-regulatory options (DFSI, 2017), this lack of data clearly has implications for both policy formulation as well as market acceptance.

Not only is there a dearth of economic analysis for GI, the nebulous nature of valuing the *benefits*, that are often assessed in purely qualitative (Naumann et al, 2011) or non-market terms (Baker and Ruting, 2014), contrasts markedly with valuations of the *costs* of "establishing and maintaining green infrastructure [that] are known for most projects" (Naumann et al, 2011, p 4). As an example, Foster et al (2011) note that within the realm of green technologies and infrastructure solutions, and reflecting US definitions of GI predominantly associated with the term Low Impact Development (LID), these are "often implemented with a single goal in mind, such as managing stormwater or reducing local ambient heat, and the costs and benefits are often evaluated in the same way." However, as they note, the full net-benefit of these solutions "can only be realised by a comprehensive accounting of their multiple benefits. For example, trees filter water, slow runoff, cool local and regional urban heat effects, and clean air" (ibid, p iii).

Presenting a strong economic argument for GI will turn on the valuation of these extra benefits that GI imparts compared to more traditional "grey infrastructure", such as mitigation of the heat island effect, higher property prices, increased thermal properties or brand recognition. The valuation of GI is also beset by questions of how biodiversity and ecosystem services can be properly valued in an economic sense. The economic benefits of ameliorating the Urban Heat Island effect, for example, have not been widely studied in Sydney (Sidiqui et al, 2016; Sharifi and Lehmann, 2014). While a handful of studies have shown that the Greater Sydney Region was found to have "urban areas [that] face daytime UHIs which are more evident in hotter months in a year with maximum intensity reaching up to 10°C or more" (Sidiqui et al, 2016, p 4), no economic outcomes were discussed. Adams and Smith, likewise, found that if an area in Greater Sydney Region with no vegetation was replaced by typical parkland (i.e. 70% photosynthetically active vegetation), land surface temperature would be reduced by 3.48°C (Adams and Smith, 2014). It is not an inconceivable leap to see how such studies could be built upon to show potential economic benefits of GI. And as Jeffrey Bruce in Living Architecture Monitor (2016, p 6) suggests, even though the economic benefits of GI may still not broadly understood, it is critical to provide as many financial benefits for implementing the GI design element to avoid it being engineered out.

In an Australian environmental policy context, local, state and federal governments rely implicitly or explicitly on a cost-benefit framework to assess the value of changes to environmental policy (Baker and Ruting, 2014). However, while some of the costs are relatively easy to quantify, estimating the benefits is complicated by two factors: an "incomplete understanding of ecological processes and behavioural responses to policy" (ibid, p 3); and a "particular difficultly where values are not reflected in market prices (so called 'non-market' values)" (ibid). The fact remains that

empirical evidence is necessary not only for continuous and reliable evaluation but that evaluation is necessary for better policy. This is backed by the NSW Government's seven principles of Better Regulation that include these points: the objective of government action should be clear; the impact of government action should be properly understood by considering the costs and benefits of a range of options, including non-regulatory options; government action should be effective and proportional (DFSI, 2017). This reinforces the need for metrics and performance measurements of GI to be consistent, replicable and effective and based upon a clear definition of GI from a policy and regulatory perspective that industry and government can rely on.

Some local attempts have been made to overcome the problems associated with the economic analysis of GI. In 2015, the Victorian Institute of Strategic Economic Studies released a paper titled "Assessing the Economic Value of Green Infrastructure" (Jones et al, 2015), that developed a framework for local government breaking down the benefits of GI into its major components. This approach laid out the monetary as well as the social and environmental benefits and values, sorting them into individual, community and institutional benefits. They adopted this approach with the "ultimate goal of … putt[ing] investment in green infrastructure at the local government level on a more even footing with investment in grey infrastructure" (Jones et al, 2015, p i). Acknowledging that being able to better define and then value GI from a multi-dimensional perspective that also considers the various co-benefits, is, according to the authors, critical to furthering the acceptance of GI. "[Green Infrastructure] is an investment that, once established will, in most cases, increase in value … This framework aims to provide greater understanding of the value of green infrastructure, in a way that is practical and works with current operational processes. Green infrastructure offers many opportunities because it is an area of innovation that has yet to reach its full potential" (ibid, p 5).

3.3 A collection of GI's potential economic benefits

The notion of taking an economic approach to GI that is agnostic to its countless definitional arguments is appealing. Not only does it avoid leaving GI mired in semantics but it is hoped that it will provide a way through to more practical outcomes, many of which are based on a traditional cost-benefit approach by those who are ultimately building, preserving or incorporating GI.

Typically, research around the economic benefits of GI has focussed on discrete elements of GI rather than considering the benefits as a whole. Apart from the VISES report (2015), much of the research also lacks a thread linking these economic outcomes back to questions of real world decision-making and barriers that can be overcome by well enunciated financial outcomes of GI.

Nevertheless, the brief review of literature below has been undertaken to show the number of ways that economic benefits of GI can and have been modelled (often, however, with reference to specific GI elements).

3.3.1 Higher property and leasing values

One of the main economic arguments for the use of GI is the increase in both sale and leasing prices. It has been suggested that more aesthetically and environmentally desirable buildings, containing GI assets such as green roofs and walls, can obtain premium prices in residential and commercial scenarios, as well as yield other economic benefits (from lease and property value to better employee recruitment). In the US, buildings with green ratings have substantially higher rental rates, effective rates and show a 13% premium in sale prices (Eichholtz et al, 2010, p 6). One research paper in Canada suggested that recreational green roofs on buildings achieved an around 11% increase in property value, and those with views onto green roofs had a 4.5% increase in property value (Tomalty and Komorowski, 2010). In Japan, researchers found that while the price difference for a new green apartment in Tokyo was initially negative compared to a conventional apartment, within two years the price difference becomes positive because of the longer-life designs of Japanese green condominiums (Yoshida and Sigiura, 2014, p 431). One note of importance, however, was that while long-life design and energy and resource efficiency were considered key to the price differential, the effect of "planting" on a building's prices was seen as small and insignificant" (ibid, p 428). Planting in this context was defined as: "A larger area of planting; planting on the wall and roof of the building; optimal mix of shrubs and trees; coordination with surrounding green areas; attention to the local eco-system."

In Australia, the leasing or selling of commercial buildings over 2000 m^2 requires evaluation under the National Australian Built Environment Rating System (NABERS). The six-star rating system ranks buildings on their energy efficiency, water efficiency, waste management and indoor environmental quality and commuter transport facilities. Critically, it does not make any specific reference to GI. The rating has, however, been shown to have considerable effect on both increased premiums in building valuations and net effective rents, especially as it applies to stars given under the energy banner. Analysis of more than 360 office buildings in Sydney and Canberra CBDs found that a 5-star NABERS energy rating had an additional value premium of 9.4% compared to 4.1% for a 4-star NABERS energy rating (the lowest rating of 2-2.5 stars showed a 1.1% discount) (Newell et al, 2014, pp 362-363). Likewise, rental premiums for 5-star properties in the same markets showed a 6.7% premium versus 2.9% for a 4-star property (2-2.5 star properties showed a 0.8% discount).

Green Star, a voluntary rating tool developed by the Green Building Council of Australia (GBCA), ranks buildings according to their environmental design and construction. As with the NABERS program, the GCBA ratings make no reference to GI and, as such, are indicative rather than reflective of the impact of GI elements. The same study (Newell et al, 2014, p 366), looked at a smaller cohort of office buildings (n=23) with 4, 5 and 6 Green Star ratings and found an 11.8% green premium in values and 6.6% green premium in net effective rents.

Broadening the notion of GI to green space more generally, the amount of urban open space can positively impact on the value of housing. Poudyal et al (2009, p 982) found that a 20% increase in the current average size of parks in Roanoke, Virginia (14.22 hectares to 17.06 hectares) resulted in a consumer surplus of US$160 per household, equating to a total surplus of US$6.5 million for the 40,984 households within 1.6km of the park. In closed "club" communities in Shanghai, researchers found an 8.7% premium on the sale prices of properties for each additional unit of the green space ratio (Xiao et al, 2016, p 445). In publically accessible green space, there was a premium of 2.6% of the house price for every kilometre closer to a city park (controlling for size) (ibid).

3.3.2 Health benefits

When GI is characterised as parkland and street trees as well as local, connected green areas, economic benefits have been shown to flow from health savings through increased levels of exercise as well as enhanced mental health outcomes. In a 2015 paper published in *Nature*, Kardan et al (2015), looked at neighbourhood greenspace in the urbanised environment of Toronto, Canada. They found that "having 10 more trees in a city block, on average, improves health perception in ways comparable to an increase in annual personal income of US$10,000 and moving to a neighbourhood with US$10,000 higher median income or being 7 years younger" (2015, p 1). They also concluded that "having 11 more trees in a city block, on average, decreases cardio-metabolic conditions in ways comparable to an increase in annual personal income of US$20,000 and moving to a neighbourhood with US$20,000 higher median income or being 1.4 years younger" (ibid).

Numerous studies show greater rates of activity by a range of demographic groups who have access to urban green spaces. For example, children who have access to urban green spaces, most notably in the access and use of urban parks, show considerable increases in health outcomes (Wolch et al, 2014, p 235). In another study, in Adelaide, Sugiyama et al (2008) reported that that the link between neighbourhood greenness and physical health was non-significant but there was a significant link between greenness and perceptions of increased mental health. The report

postulated, however, that the link between greenness and physical health was more associated with recreational walking than the greenness itself, which is potentially an argument for more connected, open and engaging green space to be developed in urban areas. A study of 3144 senior citizens in Tokyo underlined this position finding that proximity to "greenery filled public areas … that are easy to walk in" (Takano et al, 2002, p 913) positively influenced the longevity of those citizens. Increased urban green cover was also shown to have economic benefits through potential long-term reductions in mortality (Villeneuve et al, 2012).

3.3.3 Multidimensional benefits and co-benefits

There are also a number of postulated public benefits from GI elements. The most heavily researched and implemented elements are green roofs. In 2016, for example, San Francisco became the first US city to mandate green roofs and/or solar panels on new construction projects that meet certain requirements. As part of their policy argument, they noted that green roofs provided US$30 of public benefits per square foot (US$2.78 per square metre) compared to black roofs (Tam, Weeks and Zigas, 2013, p 2). Further work assessing the costs and benefits of San Francisco's 2016 Living Roof Policy (Weeks and Lilauwala, 2016) went beyond standard life-cycle benefits, such as reduced stormwater and energy costs, to include multi-dimensional benefits accruing from biophilic benefits, the living roof's effect on real estate values, worker productivity increases, increased neighbourhood real estate values as well as accounting for increased maintenance. While conservative estimates were used to overcome complexity, they found that the value to the city in taxes had an NPV of US$22.30/sq ft (US$2.07/sq m).

According to a report by the American Society of Landscape Architects, by 2035 there will be 110 billion square feet (10.2 billion m^2) of commercial real estate in the United States, an increase of 54% over 2003 levels. Using National Oceanic and Atmospheric Agency (NOAA) heating and cooling data, the authors argue that if green roofs had been built on all of these new structures since 2003, business and property owners could save a total of approximately US$95 billion dollars a year in avoided heating, cooling and roof replacement costs (ASLA, 2012, p 18).

In Toronto, which has a bylaw mandating green roofs on commercial, industrial and residential buildings with a floor space over 2000 m^2, a life-cycle cost analysis prepared for the city (Peck and Lilauwala, 2016) showed that "payback periods for green roofs are extremely long, and likely beyond the time horizon of most developers. Payback periods of 17 years or more are likely only appealing to building owners with a long-term outlook and a favourable view of sustainability" (ibid). The analysis notes that it does not take account of the multiplicity of public benefits that they

believe flow from green roofs, such as increased property values and rental income, improved employee productivity and occupant health. The analysis does, however, include annualised public benefits of reduced Urban Heat Island effects amounting to CA$5.69/$m^2$, CA$1.21/m^2 for improved stormwater management, CA$0.37/$m^2$ for increased air quality and one time benefits for improved biodiversity of CA$4.31/$m^2$ and avoided stormwater equipment costs of CA$44.53/$m^2$. Interestingly, the authors note that while Toronto doesn't charge for stormwater as many other jurisdictions do, including in Sydney, the annual maintenance costs of a green roof could be offset if such a charge was included.

The co-benefits flowing from decreased stormwater runoff include "utilising GI in place of environmentally and economically costly grey infrastructure for reducing impacts of stormwater on urban drainage systems therefore lowering the risk of surface water flooding" (McPhearson et al, 2015, p 153).

In Australia, the Royal Institution for Chartered Surveyors produced a guidance note on green roofs and walls (2016, p 19). While careful not to take a position either way, they noted the debate over whether green roofs or walls add or subtract value to property due to maintenance costs and the appearance of a visual cue to deter buyers or tenants versus increased amenity and the value of attractive green spaces, respectively.

3.3.4 Ameliorating the Urban Heat Island effect

Reducing the impact of the Urban Heat Island effect is another of the benefits attributed to GI. In a study of greenspace in the UK city of Manchester, researchers found that GI (referred to as "urban greenspace") could have important ameliorative effects on the heating of the city (Gill et al, 2007). Increasing green cover by 10% in high-density residential areas and town centres was responsible for keeping "maximum surface temperatures at or below 1961–1990 baseline levels up to, but not including, the 2080s High" (ibid, p 122) (The "2080s High" is the UK high emissions climate change scenario modelled by Hulme et al (2002)). The modelling suggests this additional cover equates to a 3.3°–3.9°C cooling effect. In Glasgow, increasing green cover by around 20% could eliminate a third to a half of the expected extra urban heat island effect in 2050 (Emmanual and Loconsole, 2015). Meanwhile, a study for the City of Melbourne, showed the NPV costs of heat events between 2012–2051 were assessed to be $1860 million, of which almost $300 million was attributable to the Urban Heat Island effect (Van Raalte et al, 2012, p 44). However, it should be noted that there is some debate over the usefulness of green roofs in reducing the UHI effect. For

example, a study of reflective (high albedo rated) or green roofs in high rise buildings found that the expected climatic impact and mitigation potential is limited (Santamouris, 2014).

3.4 Barriers to GI projects

While there are a number of benefits to GI, there are also a number of barriers to implementing GI in the urban environment. Confusion about the nature and definition of GI is the threshold problem. Another is how GI can be integrated into existing urban landscapes. As Gill et al (2007, p 127) notes, in many existing urban areas where the built form is already established, it is not feasible to create large new greenspaces. This, the authors argue, means "greenspace will have to be added creatively by making the most of all opportunities, for example through the greening of roofs, building façades, and railway lines, street tree planting, and converting selected streets into greenways" (ibid).

Barriers to financing GI is also varied. A paper prepared for the OECD (Kaminker et at, 2013, p 12) estimated of the "cumulative investments in green infrastructure [are] in the range of US$32–46 trillion between 2012 and 2030" (ibid, p 15). They also noted that there were "regulatory and policy issues, lack of project pipeline and quality historical data, risk/return imbalances and unpredictable, fragmented, complex and short duration policy support" (ibid). According to the World Economic Forum (2013), if sectors beyond traditional infrastructure, are "greened to secure future growth," for example transport vehicles, buildings and industry, agriculture and forestry, the additional investment required is around US$700 billion per annum (Inderst, 2013, p 13).

In 2012 the UK Green Investment Bank (GIB) investigated barriers to invest in GI and became the first bank in the world set up to "finance infrastructure projects that are green and profitable" (GIB, 2016, p 8). While they have worked to price the outcomes of GI, their definition of GI is somewhat different to many others, focusing on renewable energy, waste management and energy efficiency projects (see for example, GIB, 2016, p 26). Likewise, a paper prepared by the World Bank and the Australian Agency for International Development (AusAID), titled *Green Infrastructure Finance: A Public-Private Partnership Approach to Climate Finance* (Baietti, 2013), noted, without offering an explicit definition of GI, that as for the GIB, GI was seen as being "green projects [such as] solar, hydro, biomass and wind energy" (ibid, p 3). One of the paper's main aims was developing a new "framework" for investment "to bring clean investments towards a more familiar financing environment and to distance them from the charged political debate that has adversely affected the progress in international climate change discussions for over a decade" (ibid, p 2).

Nevertheless, the GIB acknowledges that investments in the "UK's green economy remain well below what's required." By taking on the more difficult infrastructure projects, de-risking new sectors and helping to lower the cost of capital for green projects, the GIB is implicitly acknowledging the lack of a comprehensive market-led approach to financing GI. Moreover, they developed a "green impact" methodology to assess, monitor and report on the outcomes of the projects they finance. While admitting that the area is relatively new to banking and that they are acting as a "market leader", the lack of formal measurement and outcome tools suggests that the market has not yet developed or considered the true economic impact of what they consider to be GI.

Another significant barrier to GI investment is its definitional bias towards the ecological or biophysical aspects of GI (albeit with a climate adaptation focus), rather than looking at the "socio-cultural and political-institutional concerns" (Matthews et al, 2015, p 156). This in turn, creates its own barrier to further implementation because of the lack of economic data that is "easily understood by stakeholders and the community as well as being a unit of measurement that can be used across a range of factors" (Symons et al, 2015, p 27).

There is also the problem of "path dependence" created by institutions and industries who are disinclined to take on new ideas or implement innovative solutions. There is some evidence to suggest that this is a significant barrier in implementing GI (Matthews et al, 2015, p 158). Moreover, there needs to be a means of halting GI from becoming yet another byword for broader sustainability efforts. As Matthews et al (2015, p 158) note, "A key challenge for planners … is how to utilise green infrastructure as a new and innovative form of planning, not just re-branding existing initiatives as somehow being 'green'." The authors also found (op cit, p 160) that the planners they "interviewed identified path dependence as a key barrier to the planning-led provision of green infrastructure."

It is also important to note that while there are many benefits to GI, there are also potential negative impacts that can arise from GI. In the case of urban green cover, for example, Kendal in Kendal et al (2016, p 19) notes the "ecosystem disservices" that could be a barrier to increased GI take-up. "Disservices can be generated directly by green spaces (e.g. bushfire), or indirectly as an outcome of management (or lack of it), e.g. negative aesthetics. Some disservices may be reduced with appropriate management and design. However, there is a risk that the desire to avoid disservices will lead to reduced provision of green space elements such as trees."

3.5 Summary

As the literature review makes clear, the barriers to GI are multifaceted and interlinked. The first challenge confronting the use of GI is the lack of a clear and widely-accepted definition. As noted by Sussams et al (2015, p 190), this engenders inconsistent application of GI and, thus, introduces uncertainty into the decision-making process. This lack of a universal definition then feeds into the regulatory environment that, in NSW, like other regulatory environments, relies on a cost-benefit framework built on clear and properly understood objectives and costs of government action. This further underscores the challenge of industry and policy transfer which is beholden to economic analysis to quantify benefits. The subsequent patchy economic modelling of GI is, then, another key barrier to its greater use. However, it could be argued that if clear and decisive modelling is built, the potential exists to include it in future projects, whether driven by market forces or policy action. It is these two main barriers – definitional and economic – that the research aims to test.

The barriers to GI can also arguably be said to mirror in broad terms two main approaches to GI. At their simplest, GI can be broken into definitions that (i) are related to "living" or "vegetated" aspects of a city, or (ii) are related to the environmental performance of urban elements. It is, therefore, critical to note this distinction when analysing the qualitative data on GI, due to the definitional fluidity.

4. RESULTS AND DISCUSSION

4.1 Themes from Question 1 – What aspects of a project do you consider fall under the banner of GI?

Key findings

- GI has no broadly accepted definition and can often be a fluid term
- Key elements of GI are virtually synonymous with broader sustainability elements such as water and energy efficiency measures
- An encompassing definition is the clearest way to deal with divergent thematic and sectorial interests for policy and implementation
- GI climate change adaptation benefits did not form a significant part of the range of definitions

Investigating the notion of GI begins with the basic threshold question of what GI means to those who are discussing it. But the definitional issues around GI, as elucidated in part by the literature review, are often fraught. This, in turn, colours the answers as to how the economics of GI are formulated and modelled, as well as how industry determines they interact with more conventional decisions made during the development process, ie decisions that have an emphasis on cost and compliance driven decision-making having primacy over the values based co-benefits but not quantified benefits of GI.

When asked what aspects of a project are considered as GI, three main definitional themes emerged: a definition that either wasn't fixed or was so broad as to effectively defy definition; a definition that was underpinned by infrastructure with natural elements such as vegetated components or green spaces; and a definition that strongly noted elements that had a specific climate change adaptation component. During the interview process, it was notable that the definition of GI was often somewhat malleable, with many of the 11 respondents shifting across definitions as the interviews went on. This reinforced the fluidity of the definition in the absence of any formal policy structures or industry norms.

4.1.1 No definition/broad definition

The lack of a definition seemed to be determined by two things – an admitted lack of knowledge about the specifics of GI or, despite knowing the term, having a broad, top-line view of GI. Comments about the lack of understanding were often in the context of participants following their

responses with a general remark wondering whether that definition was the correct one. Four of the interviewees noted that they couldn't succinctly define GI, even though it was a term they were familiar with and had used before. One high-level policymaker and bureaucrat noted that "there isn't a fixed definition [of GI], it's trajectories." As the interviewee clarified, "trajectories" refers to GI being largely subsumed by moves toward more sustainable practices in the urban development sector and that having a fixed definition was less important than a continued push towards more "sustainable" outcomes. His comments were echoed by a property analyst who signalled that GI is "anything that's built that is not done in a traditional way and instead done in a way that reduces its environmental impact." The analyst also noted that he had abandoned producing an internal discussion paper on GI as it had too many dimensions to cover.

4.1.2 Definitions that contain reference to natural elements

More than half of the interviewees defined GI with specific reference to vegetated components of a building or, more broadly, the urban environment. All of this set of interviewees also added that the vegetated components they were referring to delivered more than simple aesthetic benefits and instead had implications ranging from better maintenance of stormwater to increased biodiversity. A sustainability executive from a large developer distilled their understanding of GI into three categories: energy; water; and landscaping and biodiversity.

Two of the more parsimonious definitions came from an engineering consultant with GI technical research experience who said that GI is "introducing vegetation into buildings or into any project". In a similar vein, a senior government policymaker offered this succinct definition: "GI means the living elements of the built environment." More expansive definitions of GI included a list of elements given by a consultant in the area, suggesting that [GI is] everything from rain gardens, roof gardens and green facades to internal greenery, street trees and podium landscapes. This definition also included energy production from solar and wind, and energy savings from elements such as green roofs for cooling buildings and reducing the urban heat island effect. Another participant who had worked for both large developers as well as in local government noted that GI is about using plants in a "thoughtful and interesting way to get better operations out of the buildings, better human health, better bio-diversity."

4.1.3 Definitions that included specific climate change or greenhouse gas mitigation elements

While many of the definitions did refer to the general environmental benefits offered by GI, just two interviewees made explicit reference to the climate change adaptation effects of GI. This is notable because much of the literature surrounding GI focuses on the benefits of GI for climate

change or greenhouse gas mitigation. The senior government policymaker noted that green cover or vegetated, reflective and permeable surfaces within the built environment had climate adaptation benefits. The interviewee also noted, that specifically for Sydney, GI is "about heat mitigation". Another senior government official said that GI was about design and functional elements that were directly aimed at reducing overall energy and water consumption and greenhouse gas emissions generation. They listed a number of GI elements including smart meters, co-generation turbines and large water storage and re-use infrastructure. It is notable that both of the interviewees that mentioned climate change adaptation came from the policy sector, potentially pointing to a larger theme around different definitions emerging from different sectors.

4.2 Discussion

Many interviewees tended to use to the notion of GI and sustainability interchangeably or synonymously. It still appears as though GI is a term that causes confusion and, as such, suffers from the lack of a clear and compelling idea. For those who define GI in broad terms or encounter it without much background knowledge, there was a tendency to revert to using it as a proxy for general sustainability efforts. These efforts were most often framed with reference to water and energy efficiency efforts. Counter to this, however, were the frequent references to elements that can be broadly summed up as living elements in the urban environment, and, more specifically, buildings.

Overall, it was apparent that while GI as a concept was broadly understood, there is still no firmly accepted definition among key decision makers at a project level such as property analysts, financiers and investors. In a way, it reflects Hansen and Pauleit's (2014, p 517) findings that while GI has enjoyed widespread recognition in scientific publications, "little development of its theoretical foundation can be observed". In other words, those that have a design or policy interest in GI might broadly understand what it means but there is a lack of a wider, more embedded approach to GI that is woven into all aspects of real world decision-making. This is most clearly shown by Black et al (2016, p 11), who noted in relation to planning and design of Sydney roadways, that "most participants defined 'green infrastructure' as green roofs and walls rather than an interconnected network of green assets on a broader scale; therefore, it is of little surprise that Australian road authorities are a long way from integrating green infrastructure principles into guidelines and practice." In essence, because those that are involved in the engineering, design and implementation of the project have no clear concept of what GI is, real-world decision-making can easily overlook the incorporation of GI elements. This points to the need for an encompassing

definition of GI that draws both on thematic and sectorial interests as the clearest way through to a clear and succinct notion of GI.

4.3 Themes from Question 2 – What are the benefits of GI?

Key Findings

- The main economic benefits of GI are seen through increased rental yields and sale/resale values
- A coherent and widely accepted 'economic conceptualisation' of GI has not been achieved
- Other benefits such as health, environmental, climate adaptation and corporate branding are understood anecdotally but their financial outcomes have not been widely modelled

Responses to this question fell broadly into the "environmental, social and economic values and services" categories outlined by Ely and Pitman (2014). It is critical to note that while the answers have been grouped into different themes, almost all have some link to economic benefits. It is also interesting to note that for a number of interviewees, the economic benefits flowing from GI, often defined with respect to broader sustainability efforts, were contingent upon whether the project was commercial, residential or retail. The starkest illustration of this was in the increased rental yields accumulating to commercial buildings that have a higher rating, whether Green Star or otherwise. Summing up the difference, one interviewee from a property investment firm wryly noted:

> "On commercial buildings, there's definitely a benefit: a certain corporate tenant base as well as government tenants will only go into buildings with four or more green stars, four star NABERS. And when you're selling a [commercial] building, people will pay more for a building with a five star than for a zero-star building. However for retail and residential, there's not much of an economic benefit. You get a bit of feel good factor and people want to see it in the marketing brochure, but it's really just a box they want to tick and it's on page 27 of a 30-page brochure. What buyers really want to know is: does it have a view, does it have a car space?"

Other commercial implications of including GI in urban projects were also revealed, with GI being seen as a valuable addition for the "brand" of a building or project. Beyond this, the PR (public relations) value of GI on one project was seen as applicable to, or transferring to, other projects being undertaken by the same developer or financier. This also suggests an incentive to create a

high-level of awareness around the GI on one project to garner attention and then leverage that in the branding for other projects that have lower levels of GI.

4.3.1 Economic benefits

Perhaps the most compelling economic argument was revealed by the development manager from a property investment firm who noted that from a commercial perspective, there was a strong benefit to involving more GI elements into a building that lead to higher rated projects. Both corporate and government tenants "care about green star ratings" with many only occupying buildings with "four Green Stars [from the Green Building Council of Australia] or four star NABERS." They also noted that people will pay more for a building with a five star than for a zero-star building because of the higher yields and returns on investment, "which is probably why green infrastructure gets done more on commercial buildings than it does on the others." In addition to increasing the supply of tenants, the development manager also noted that higher-rated buildings command a higher rental yield, underscoring the economic arguments for GI.

Two caveats must be applied to this economic argument, however. First, that while this response was framed in the context of questions about GI, the answers should be read as being virtually synonymous with wider sustainability efforts that are captured by the building rating associations rather than associated with specific GI elements. And second, as foreshadowed in the introduction to this section, the economic benefits seem to partially fork when the distinction is drawn between commercial and residential buildings. This is, again, an important consideration for policymakers as the effect of policy changes may have different consequences depending on a building's end use.

Other economic benefits of GI were seen particularly through the lens of savings from energy and water efficiency outcomes. For most interviewees, they saw that lower operational costs were a natural result of having components such as green roofs and walls or stormwater retention and reuse. The sustainability executive from a large developer also saw future economic benefits, noting that energy efficiency measures at a large residential development level could lead to reduced upstream infrastructure costs such as smaller substations. However, for these upstream infrastructure costs to be considered as part of development decisions, the current infrastructure capacity would need to be reaching capacity. This, however, might presage the valuing of more localised and district planning, as opposed to site-by-site planning, because the economic benefits from localised infrastructure and development outcomes could accrue to that district.

4.3.2 Environmental benefits

When asked about potential benefits, most of the interviewees referenced the expected environmental benefits, through outcomes such as reduced resource consumption and stormwater management to potential air quality improvements and noise mitigation. Many of these benefits also have an economic dimension, however improved environmental outcomes, in and of themselves, were also seen as a benefit.

There were, however, a wide range of ways that respondents thought GI could deliver environmental benefits. This is partly due to the manifold understandings of GI initiatives. For example, the high-level policymaker noted that on the input and output side, the carbon dioxide output in construction is rapidly decreasing. This could indicate that some include construction materials and techniques in the basket of GI initiatives or perhaps that the concept of GI is being used more synonymously with broader sustainability and carbon reduction initiatives. In a similar vein, the sustainable finance executive from a large bank also noted that GI could help reduce the reliance on fossil fuels in an urban environment, though was at a loss to explain exactly how this might occur, beyond reduced air conditioning loads. Again, GI in this instance, was seemingly lumped in with other more nebulous efforts to bring about environmental change far broader than that contemplated by most GI practitioners. In one sense, this may be seen as emblematic of the divide in the understanding of GI that exists between the academy, policymakers and GI practitioners compared to higher-level industry players at the development and financial coalface. It might also correlate with definitions held by entities such as the Green Investment Bank, that consider investments in GI as including offshore wind, onshore renewables, energy efficiency and waste and bioenergy.

The research interviews also revealed more conventional understandings of GI, including the environmental benefits flowing from the potential to clean stormwater, to “soak up” more extreme weather events, increase bio-diversity in the urban environment, provide thermal and noise mitigation benefits to buildings, and air quality improvements. All these benefits are those that could be expected to emerge from GI initiatives such as green roofs and walls as well as verge gardens and increased urban green space. Naturally, many of the environmental benefits also have financial effects, most notably the water and energy efficiency dividend associated with green cover’s ability to retain and clean stormwater as well as the heating and cooling benefits that it can also entail. The multilayered notion saw some environmental benefits bleed into more anthropocentric values with the biophilia hypothesis, noise mitigation, providing a connection to nature and visual amenity mentioned. These could be considered economically advantageous in

commercial and, to a lesser extent, residential projects if potential lessees and buyers consider those values as creating a more desirable environment to work or live in.

4.3.3 Health/social benefits

Just over half of the participants noted the health benefits of GI elements in the urban environment. This was largely in the context of plants being closely linked to improved human health and behaviour. Interestingly, this is where the notion of GI as an element that adds a living dimension to an urban project was most apparent. The participant who had worked for both large developers as well as in local government believed that the benefits of plants in an urban environment was "massive" and inadequately understood, especially in areas of increased urban density. For example, the interviewee noted that plants had "biodiversity implications, for which I think there's very little generally understood information about just how important biodiversity is for the earth's health but also for human health and wellbeing." They also believed that in addition to green roofs and walls adding to "health and wellbeing", GI extended to recreational green spaces that supported similar health benefits. These green spaces also added to "a sense of community", which was believed to have a health benefit.

Again in the commercial building space, the sustainable finance executive noted that they had recently moved from an older building to a highly rated green star building, saying that "it's night and day in terms of the environment and the temperate, the space, the air quality". While it's anecdotal, this is evidence that employees are actively aware of how some GI initiatives, broadly defined, could positively impact their work. Certainly, some employers and developers are aware of the benefits to staff, with the participant who had worked for both large developers as well as in local government noting that "there is a lot of movement around indoor environmental quality and how that affects staff. There is green infrastructure in terms of internal air quality going in because the value is seen as keeping staff healthy. It actually is vital to keeping costs down for a big business." Two other participants noted the productivity benefits flowing from the biophilia hypothesis of certain living GI elements. A consultant in the area listed human wellbeing improvements, productivity, reduced sick days and reconnecting with nature as health benefits. They also noted the social benefits of urban agriculture and food production particularly when associated with large scale urban projects. In large projects, though, the economic outcomes of these may be seen as marginal, apart from the branding. The senior government policymaker also noted the increasing evidence base for the psychological and the social benefits of GI. They were careful to point out that arguments such as "if there's a park then people are likely to walk and then

they won't have diabetes" were "getting into the realm of tertiary benefits. They're a bit of a long bow and they're a bit harder to measure."

4.3.4 Branding and PR value

In the World Green Building Council's report on the Business Case for Green Buildings, "corporate image and prestige value" is noted as one of the key reasons owners, developers and tenants consider a "green building" (WGBC, 2013, p 11). While this just one element of GI as a whole, responses to the research questions revealed how the reputational element of GI projects is a large motivator. The reputational benefits that can come from including GI elements within a project are largely intangible, meaning the real value comes from enhanced corporate standing – whether through product differentiation, competitive advantage or simply enhanced brand value – which is ultimately economic in nature. The development manager from the property investment firm noted that "[GI] also helps the brand of the building, and the brand of [large developers], the people who were involved on the project. You very quickly develop a reputation from buildings. There are good buildings, bad buildings and that [reputation] does stick."

The rationale for incorporating GI as a public relations and branding exercise was viewed as cynical by some but there was a recognition that it was also a way of increasing the uptake and incorporation of GI more broadly. The development manager for a property investment firm noted that there is "definitely a corporate imperative to be a good corporate citizen and that gets driven both at a corporate level and at a personal level". They also noted that it is something that some of the bigger property companies do better than others. "It's definitely increasing. I've been doing this sort of property stuff for twenty years. It definitely went through a transition where ten years ago, it was a conversation. Generally we are a point now where green infrastructure is just a given." Beyond sheer brand recognition, another interviewee noted the brand benefits of being able to use GI as an opportunity for product differentiation.

A third of the participants noted that the benefits of many GI elements were in fact uneconomic but that the flow on effects of PR value and the more intangible impacts of good corporate citizenship meant that a project could incorporate the increased capital outlays perceived to be associated with GI. This was especially true when the cost of GI elements could be "washed through a billion-dollar project".

4.4 Discussion

The research revealed a range of opinions on the economic benefits of GI. In terms of understanding how GI can potentially become part of the decision-making process, one of the most salient points was the difference between commercial projects, where GI is seen as an advantage, and residential projects, where GI is seen as having no clear benefit. In part this was reflected in the length of time a developer or financier may have an interest in the building. Commercial buildings were seen as longer-term assets with the interests of their future owners linked to ongoing leasing returns and occupancy. By contrast, residential properties are built and sold in much shorter timeframes, with the developer typically having an interest only to the point of sale.

A wide range of environmental benefits reflected the different conceptions of GI that the interviewees held. The research seems to suggest that if GI is to be included in policy formulations, and a framework developed for assessing the economic outcomes for GI elements, it is critical that each benefit be clearly demarcated so that opportunities for confusion or developing an incoherent approach are recognised and avoided. Similar outcomes were apparent for the health and social benefits of GI, which rarely left the realm of perceived benefits.

Notably, even though there is some academic research showing this, none of the interviewees had actively modelled or sought economic arguments for increasing GI elements in an urban project on either environmental or health and social bases. Similarly for the brand and PR value, while GI was seen as feeding into good corporate citizenship, there was little evidence that the benefits for branding had been actively modelled to show economic outcomes. The lack of interest in creating a solid economic model would suggest that GI is not yet being mobilised as a significant goal in and of itself, especially as a driver of value within a development project. Moreover, the responses from a number of the participants that represent the financial stage of building development, that saw GI as being a byword for more "green" efforts in the urban space (for example the mention of Green Star and indoor air quality), also seem to suggest that beyond the world of specialist consultants or those who have a more precise or sectoral understanding of GI, that GI is seen more as another concept on the sustainability continuum rather than recognised as something that drives significant environmental performance.

4.5 Themes from Questions 3, 4 and 5 – What are the major drivers and barriers for GI in the decision-making process?

Key Findings

- Cost uncertainty with GI

- Economic imperative of a development and its decisions
- GI is an up-front cost
- Lack of integration across planning, design, construction and financing
- Lack of education, understanding and capacity to build/maintain GI a barrier from finance to construction
- GI requires commitment throughout the life cycle of the concept, design and construction aspects being removed or 'falling through the cracks'

In construction projects, the long-term outcome is essentially the product of myriad decisions made before, during and after the process. As Winch (2010, p 3) suggests, management of a construction project is "principally a problem in the management of information and its physical embodiment in an asset … [and] conceived as a progressive reduction of uncertainty through time." At each stage, from concept and design to construction and sale or ongoing maintenance, most elements of a project can be cajoled into or out of being. For GI, there are a number of key decision themes that prevail on whether those elements are included or not. The bifurcation is most obvious in relation to the positive outcomes that GI engenders in a commercially tenanted buildings versus the more indifferent or negative perceptions that are held within the residential sector (see for example, Ristimäki et al, 2013, p 177). This reinforces the sense that GI has different drivers within the two different markets and could point to a potential "forking" of policy.

The role of regulation was also seen as another important theme in the process. From the interviews, however, perhaps the most surprising theme was the low perceived capacity levels within not only our bureaucracies but also in the construction and development industries, to successfully incorporate or deal with any potential GI elements. These "perceptual barriers" to GI are similar to those outlined by Baptiste et al (2015, p 2):

- "Lack of understanding and knowledge of what green infrastructure is and the benefits that it provides;
- Deficiency of data demonstrating benefits, costs and performance;
- Insufficient technical knowledge and experience; and
- Lack of design standards, and best management practices."

4.5.1 Cost

GI was seen as being able to contribute favourably to the overall financial position of a project but there were also concerns about the upfront and ongoing costs imposed by those elements. As Vandermeulen et al (2011, p 199) notes, "economic valuation [includes] not only the classical

elements of economic value, related to the produced goods or services … but also the value generated by the … creation of the green infrastructure. It can be the costs for purchasing land, the costs for designing and constructing the green infrastructure or the income generated through the start-up and exploitation of the green infrastructure."

The most significant barrier to increased use of GI was the perception that it introduced significant costs into a project. One participant who had held senior sustainability roles with local government and major developers, noted that design conversations are generally centred on the maximisation of yield and less on environmental considerations: "When push comes to shove, no one is talking about greenery or about bio-diversity. The agenda is that our big projects are going to get people jobs and they don't want them to be held up by a frog or a plant. The language [around development] is incredibly value laden against maintaining the natural environment or some version of it." This same interviewee also noted that developers and building designers were reluctant to include GI elements because, even if they did, they were unsure how much they would cost to install and then maintain. Moreover, the developers and designers would be required to price systems that they hadn't used before and potentially deal with a new set of suppliers, which introduced a range of technical uncertainties as well as unwanted complications.

A senior government policymaker put it more baldly, noting that the notion that a developer or builder would choose something green over more leasable floor space, is "a revolutionary and some would say heretical idea. Perceived cost is, I think, possibly the greatest barrier." For the engineering consultant with GI technical research experience, "it's almost more the perception of cost than the actual cost. Often including GI doesn't have to add any costs at all, if you build it in from the start and do it well."

For the development manager for a property investment firm, the financial pressures are constant and pervasive. "Ninety percent of the decision is made on economics. [GI] is never not in the conversation but it's never 'We're just going to do it.' It's always how much does it cost? What does it do? Can we afford to do it?" For this interviewee, GI clearly seems to be seen as something that has up-front costs that need to be absorbed by the project rather than being something that has long-term positive value. It is here in the decision-making process that the longer-term, intangible and historically un-modelled benefits (e.g. health, environmental and social) meet the more available tangible costs of including GI.

A sustainability executive with a large developer noted that a focus on capital costs and not on life-cycle costing (LCC) is the biggest impediment to greater take-up of GI while the lack of early modelling to demonstrate cost effectiveness robustly over long-term (10 and 20 year) timeframes, was also seen as a key barrier.

As Cole and Sterner (2000, pp 371–2) note, there are manifold reasons why life cycle costing (LCC) is not taken up, including:

- "A general lack of motivation to use LCC;
- A number of contextual factors that restrict its use [such as the reluctance of design teams to include it unless formalised in contacts, LCC being just one cost consideration among many and internal bureaucratic structures];
- A host of methodological problems and limitations [such as the complexity of comprehensive LCC for complete buildings, lack of universal methods, standard formats and useful software, and one-of-a-kind nature of buildings]; and
- Access to reliable data."

For respondents, the question of who bears responsibility for introducing LCC into developments was beset by similar factors, even though some recognised that they themselves had some onus to develop and encourage them. For example, the sustainability executive said that some of the responsibility might reasonably be seen as falling to the developers themselves and leading customers to contemplate or incorporate GI into the development through life-cycle costings is one way that GI could gain greater traction. This is especially true for customers who might not know the economic arguments of including, for example, a green roof or wall on a commercial building, with the flow-on thermal benefits leading to lower energy consumption. The sustainability executive, though, pointed out the problems of split incentives in LCC. "Some clients will say, 'it's going to cost me an extra half a million dollars but I'm not going to get a direct benefit because I'm the landlord, the tenants are going to get the benefit.' It then becomes a difficult commercial argument to mount." A more optimistic tone was struck by the senior architect and landscape architect who believed that "there is a shift towards life-cycle modelling, which is critical. It is the direction that modelling needs to go in order to demonstrate the real benefits of GI within projects."

4.5.2 Regulation, policy and ratings tools

Some argue that the complexity of GI clouds regulatory intervention and that not understanding the "inter-relationships, tradeoffs and synergies between GI's impacts … [restricts] GI from being a genuinely strategic policy intervention" (Sussams et al, 2015, p 192). To take just one element from

the GI quiver, even if it is obvious that the theory suggests "green roof policies would encourage green roof installations" (Carter and Fowler, 2008, p 162), it is unclear, for example in the US, "whether green roof policies have resulted in more on-the-ground projects" (ibid). The authors argue that "without adequate education and on-the-ground examples, the regulated community may have a difficult time changing established roofing practices."

This ambivalence between market and policy drivers was reflected by the respondents. A high-level policymaker and bureaucrat, for example, thought that urban development in Australia was not operating in a performance environment but a regulatory environment, noting that "we've limited, by regulation, the quality of the output." A somewhat alternative view expressed by the sustainability executive from a large developer was that "industry leads government when it comes to innovation, change, sustainability, pretty much anything." Combined, these thoughts suggest that industry-led innovation may precede regulation and where regulation is introduced it serves to discourage leaders and begrudgingly raise the performance of the laggards. As the engineering consultant with GI technical research experience stated: "Regulation will help at the bottom end but you need things at the top and the middle as well to pull the whole curve up because if you just go for regulation, everyone will move down to that and it will actually get worse as an average which we have seen in other industries."

Perhaps the most illuminating comment was from an interviewee who had worked for both large developers as well as in local government. Formerly, when they were working in the government sector, they believed that regulation was too burdensome for businesses. However, this opinion has shifted since working for a large developer: "Over the last couple of years, I've come to the point where I think we actually need to mandate some minimums. It will annoy people. We'll get some poorly constructed [projects] but fundamentally it will shift the understanding of why it's important. I do think the industry is at a point where it can deal with it. I'm not sure that it was five years ago." This remark, in effect, signals that industry needs regulation to provide a more certain direction.

4.5.3 Role of the finance sector

In part related to the costing of any GI is the financing of urban projects. For those looking at financing a new building or project, one of the major considerations is the capability to repay. For commercial buildings, this turns on the building's ability to attract and hold tenants. For residential buildings, the costings are shorter term, as the sale of the dwellings within the building is the major consideration for profitably returning the costs of building it.

For commercial buildings, the sustainable finance executive for a large bank noted that it was less a matter of "green getting kicked out, especially at the big end" (though, again, this related to green star ratings rather than specific GI initiatives). "In terms of access to finance, if we had a [major developer] come to us and say 'We need funding for a three and a half star building in Sydney', that's just not going to happen. We wouldn't fund it because we'd be concerned about tenancy, about environmental impact or lack of environmental impact and the long-term proposition of where legislation is going." However, this view is tempered by the views of a high-level policymaker and bureaucrat with international experience who believes that the complexity in financing means that financing new GI systems is fraught. Just as life-cycle costings have not reached a state of widespread use, the interviewee believed that there is "no vocabulary in the banking industry for financing a green or a mixed-use building with green infrastructure. For the past 30 years, I should have been teaching bankers instead of urban planners."

4.5.4 Problems of risk, capacity and behaviour

One of the more unanticipated themes to emerge from the interviews was the lack of capacity to design, construct and maintain urban projects that include GI. For many of the interviewees, the institutional inertia or path-dependence created by reverting to well-known processes can cruel more innovative building design (this is also reflected in some literature, for example, in Sandström et al, 2011, p 53). Yet, even when a new design is proffered, without a strong focus on championing it throughout an iterative design process, there was a suggestion that GI initiatives often fall through the cracks. This is a position backed up by the seasoned development manager for a property investment firm, who noted that there still needs to be a focus on maintaining an adherence to GI throughout the design and construction phases. "You need someone whose job it is to make GI happen because the other people are just looking after pouring concrete and putting windows in. If no one actually does it then everyone else just does their normal job and then just as we get to the end of the building we go, 'Oh what happened to that? We talked about it but no one did anything about it.'"

In the design phase, the high-level policymaker and bureaucrat believed that the form of a building takes precedence over performance, meaning that significant attempts to improve how a building operates is given less precedence than what it looks like. Furthermore, the lack of skills within the civil engineering cohort leads to fewer attempts to be "creatively green". "Green infrastructure isn't promoted by engineers because you can't do it simply by the numbers. You have to actually pull out your spreadsheets, redo them and reimagine structures. And they often don't have the skills or

willingness to do it." For the GI consultant, this translates to a "business as usual" approach. "They revert to civil design that they understand and already have a cost sheet for."

This view was backed up by the sustainability manager who has worked for large developers as well as in local government: "It's easier to go, 'We're not going to deal with green because it's too complicated'." This perception of complex systems and dealing with "greenery that isn't linear", noted by the same interviewee, leads to "a perception that you can't predict how it acts and you need to get in specialist help because it's not part of the current processes." There is also the problem of ensuring collaboration at the project management level, especially if engineers and landscape architect are working together on the same project. As the senior government policymaker noted, "[GI] involves planning, financial incentives, health benefits and other benefits being factored in. In other words, it involves an integrated planning approach that rarely seems to occur."

Further muddying the ability to encourage GI, even if many of these institutional behaviours can be overcome, there then appears to be a real problem for developers finding enough skills within the building and construction community. The high-level policymaker and bureaucrat noted that even if developers wanted to implement innovative GI elements, builders are often resistant both from a skill and financial perspective. "Developers regularly tell me that the builder doesn't know how to do [GI], meaning they'll charge a 'motza'. Suggesting new techniques often gets the response, 'Stuff you, mate, my guys only do this and this is the only thing they know how to do.' There is no upskilling and it is a huge problem."

Likewise, for the property analyst, GI was often talked about at the beginning of a project and as being part of the core requirements of a project. However, as the project moved towards the real-world design, it was harder to keep GI in. "You start grabbing the lower hanging fruit such as high-performance glazing, low energy lights, water efficient taps. It became not just a cost but the actual products and materials, the cost of installing GI, the time it took to procure the materials and then how well they knew how to use that product and install that product as well."

According to the senior government policymaker, designing buildings that incorporate GI is not the norm because of the high level of technical and design uncertainty: "It's not a conventional way of designing a building. As experts across the world have told me, to successfully use GI in urban development, from buildings to street trees, you need to consider the ongoing maintenance and costs of managing a living system when you work out what you want that living system for. It's

turning projects on their heads by first considering the very, very end of the project line." Again, this underlines the inherent tension with respect to expectations, obligations, roles and responsibilities between policy and application: at a policy level there is the focus on reconciling benefits over the long term while at a developer level this is less of a concern. For the policymaker, the shift can be summed up as: "Designing a building is now just bricks and mortar – we need to make it bricks and mortar, trees and water."

Intimately related to this is developing a risk profile for undertaking new modes of construction and development. As a nascent industry, risks are inherent in the supply chain, sourcing of the product, technical implementation as well as the question of performance and maintenance. For the sustainability executive from a large developer the "main reasons GI leaves the process is predominantly around commercial and technical risk. How do we know that this will even work?" And, as noted by Alexander and Tomalty (2001, p 407), the "untested" nature of GI can have the perverse consequence of increasing the cost due to developers also installing traditional systems as back-up to reduce their perceived technical risk profile.

4.6 Discussion

Costs, both real and perceived, emerged as a significant barrier to whether GI was considered or not. From a political-institutional viewpoint, it is arguable, then, that if much of the decision-making turns on an economic argument, the lack of readily available and comprehensive economic data to answer questions of cost and, thus, allay any perceptions, will only stymie further consideration of GI. In addition, without a long-term or lifecycle view of a project, there is little incentive to explore the different ways that the benefits of GI can offset any extra initial capital outlays. Moreover, there were differing views of the economics of GI depending on the end use of the buildings.

Developing a repeatable, broadly-accepted means of introducing the costs and benefits of GI into urban projects, is also, it would appear, a way off. This is a view enunciated by the development manager for a property investment firm. They believed that while things such as energy efficient lighting can be readily modelled – "they use X kilowatts, kilowatts cost this much per hour" – the impacts for less tangible GI benefits are almost too difficult to quantify: "What's the PR value? What's the added feel good factor? If the tenants really like the building, does it affect the staffing? There is an impact for all of this but you don't model it. I don't think you will ever be able to model it exactly." Just as Symons et al (2015) note in their conclusion to a report on the value of GI, "while many tools have been developed to evaluate these benefits in the literature, further research

and application is justified in order for these economic values to become accepted within conventional economic analysis" (2015, p 40).

Alongside the problem of costs, the research also indicated that regulation and notions of "path-dependency" were also significantly hindering the uptake of GI. While the interviewees noted a range of opinions on the role of policy and regulation, reflecting their range of experience and capacity, the comment from the respondent with considerable experience in both government and industry sectors, would suggest that some mandated minimum levels of GI are needed to overcome the "business as usual" approach. Regulation or policy standards might also serve to drive the development of capacity in GI that is also inhibiting its inclusion. Less clear is what would be mandated and thus form a practice-based definition of GI in terms of what is important (minimum) and what is desirable or optional.

The research also indicated that providing education and clear, reputable data to all those within the GI decision-making chain is integral to increasing its incorporation in the urban landscape. At the same time, an education process would need to occur at all levels from policy and finance through to design and construction.

At an institutional level, the need to ensure ongoing collaboration presents a persistent problem for bringing GI into the decision-making process as well as maintaining it in that process. In addition, the research revealed that low levels of experience and skills in the construction sector also hampers greater GI uptake. Also, until the use of GI is widespread enough for customers and other building users to be actively asking for the information, there is an argument that developers should be promoting these types of solutions along with those that have an inherent long-term economic proposition. Finally, building financial modelling with clear, quantitative data indicating the economic benefits or other benefits such as environmental and social, that have an economic positive over time is key to engaging with the perceived costs argument and a critical research point for policymakers.

4.7 Themes from Question 6 – The relative importance of key factors in GI decision-making

The interviewees were asked to rank the importance of four key "socio-political factors" per Matthews et al (2015, p 162), in the following question. They were also asked to why they ranked them in such a manner.

QUESTION: “In the decision-making process, how would you rank the following in terms of importance for projects involving Green Infrastructure:

a. political sentiments

b. fiscal pressures

c. the attitudes, values and training of bureaucracies and

d. the perceptions, needs and concerns of local residents.”

4.7.1 Summary of answers

Rankings by interviewees:

A, c, b, d

C, b, a, d

B, c, a, d

B, d, c, a

B, a, d, c

A, d, b, c

B, c, a, d

B, a, c, d

A, c, b, d

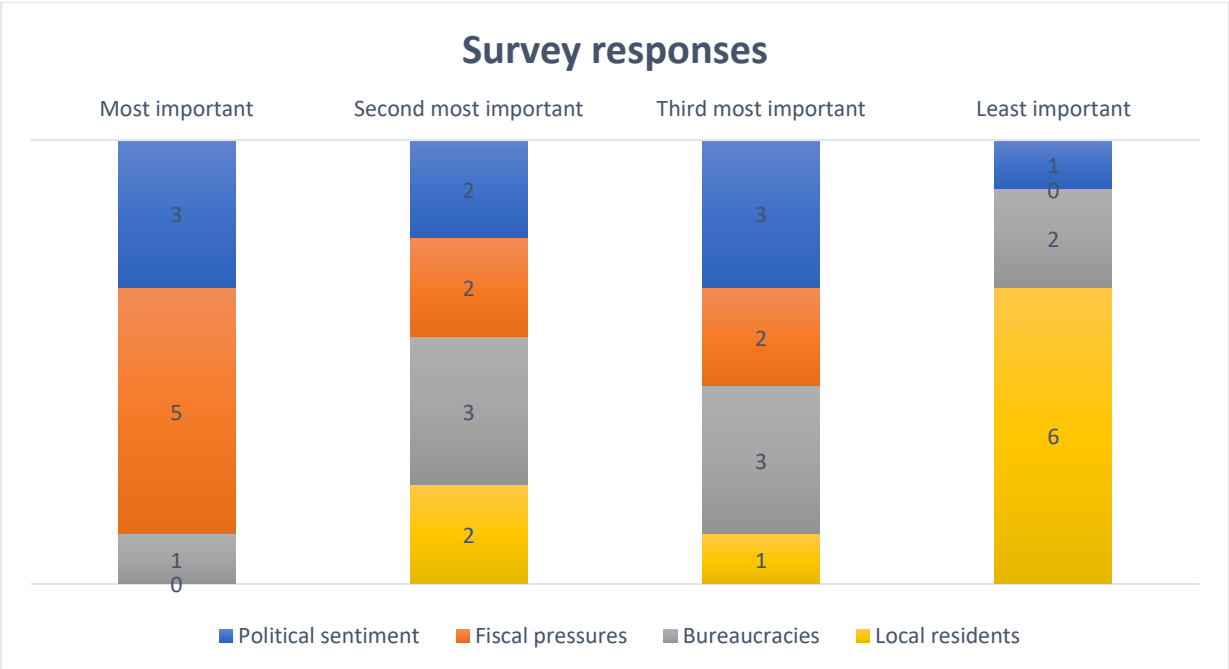

Chart 1: Responses to rankings

4.8 Discussion

Nine respondents ranked the importance of key decision-making points as set out by Matthews et al (2015, p 8) and two declined to rank them as they felt as though they weren't qualified to speak on all aspects of the survey. As Matthews et al note, "much of the green infrastructure literature reduces decision-making about greening to simply implementing 'a good idea' or evaluating a set of cost-benefit parameters that can be readily aggregated on a ledger. In reality the situation is a lot more complex and messy. As we show in our model, decision-making must account for prevailing *political sentiments, fiscal pressures, the attitudes, values and training of bureaucracies and the perceptions, needs and concerns of local residents*" (ibid, italics added).

Taking this as the starting point for the survey, some trends were identifiable that reflect the institutional structures of the interviewees. The fact that fiscal pressures were ranked as the most important factor underscores the findings throughout the research that cost was a major element in the consideration of GI, however it was defined. Interestingly, five of the six respondents who worked for the corporate sector, either as a consultant or with large developers or financial institutions, chose fiscal pressures as the main consideration. It was also notable that two of the three respondents who ranked broader political sentiments as the most important were part of government institutions. One of them noted that: "We currently have strong support for GI, but this can change when politicians change."

At the other end of the scale, it was also clear that the residents or the users of the buildings and amenities that might include GI were at the bottom of the pile. In fact, a number of respondents noted that users were generally not considered. This was countered by the sustainability executive from a large developer who said that local residents as end-users and customers of their projects were a major focus when considering GI.

4.9 Themes from Question 7 – What else can help the transition to greater use of GI?

Key Findings

- Lack of centralised, repeatable collection of GI research that can be used on a range of projects
- The project concept stage is where GI needs to be introduced as a viable consideration
- Being the "First-mover" or GI pioneer is not always seen as an advantage
- Many discussions of GI revolve around already understood notions of sustainability
- GI needs to be pushed by planners, designers and architects rather than from the sustainability team

- An internal or external champion is one of the most effective ways of driving GI
- The tipping point for including GI in industry norms is still unclear
- Key to any transition is the development of data and metrics
- Currently research and data collection is inefficient and uncoordinated

There are a number of barriers that are impeding the greater use of GI, or even an acknowledgment that it is a design consideration, from the perceptions of added cost, path-dependency, capacity and complexity shown above. But there are also a number of pathways that can start to bring it into mainstream consideration. Some of these are simple efforts that require little more than well-considered communication strategies; others are at the scale of multi-year research programs that aim to bring data and rigour to underpin arguments for GI. Effecting change to the status quo comes from all points in the decision chain, from the policymakers and the peak bodies to the developers and builders themselves, as enunciated in Benedict and McMahon's (2006, pp 21–24) influential work on GI. They argue that adhering to the principles of GI relies on key strategies that include: "working with all levels of government and private landowners; drawing from a variety of disciplines in designing green infrastructure systems; making it a primary budgetary item; documenting and promoting the benefits of green infrastructure; and engaging key partners and the general public."

While the initial formulation of the questions about further drivers of GI was framed in economic terms (e.g. intergenerational equity/green bonds), these were almost wholly subsumed by the interviewees' views on the need for better education and more comprehensive data around GI. Unfortunately, there are few relevant examples of research into real-world GI implementation in Australia. One related study looked at mainstreaming GI for Australian public road reserve design (Black et al (2016, p 10). Interestingly, the authors pointed out the problems of capability and aptitude of designers and construction teams, arguing that initially, road authorities should look at "capacity building and professional development of the involved professionals". They also noted the interaction with policy, arguing for the modification of existing guidelines "based on a holistic approach to the planning and design of high-density urban development around transport nodes that includes green infrastructure principles" (ibid, p 11). It needs to be noted that given government provision of road infrastructure, there was no discussion of how to transition to GI in a market-based milieu.

The consideration of GI by private interests (as opposed to public government interests) could, however, potentially be driven through changing consumer behaviour creating demand for better

designed homes that incorporate relevant GI elements (per Benedict and McMahon's (2006, p 24) final note about engaging the general public). As an example, Kennedy et al (2015, p 7757) noted, in research looking at climate-related lifestyle needs of people living in apartments in subtropical cities, that "residents … overwhelmingly prefer natural ventilation over continuous air-conditioning to manage thermal comfort in their dwellings." While this research is not encompassing of all GI efforts, this is an indication that latent consumer-driven demand exists and, with changes such as increasing energy prices, may be another future driver of more GI design. As the highly-experienced architect and landscape architect noted, in the interviews: "If we're talking about bringing about changes to thinking across the city, with green infrastructure, it's policy through to regulatory, down to fiscal, down to the community. I think it gets down to consumer awareness, which is like the green commercial building revolution that started around green stars but which is now being driven by tenant advisors who are wanting to give the best deals to tenants and so therefore are pressuring the building owners. The same thing can essentially happen in the residential sphere."

Still, there are hurdles to overcome if public awareness is to reach a tipping point whereby they demand increased GI. While climate change adaptation is just one part of what GI aims to achieve, the senior policymaker pointed to a survey on the assessment of vulnerability to climate change in Sydney that might explain some of the ambivalence: "We found the biggest impediment to action was low risk perception. The people living here in high rises or suburbia, don't look at the sky to find out if it's going to rain, they look at an app. They're not connected to what's going on outside or to natural elements or natural resources."

4.9.1 Education/Communication

In the preface to Benedict and McMahon's "Green Infrastructure Monograph" (2006, pp 3–4), GI is held as a "new framework that provides a strategic approach to land conservation" and urban development. Towards the end of the preface, they note how important communication and education is. "We need to build the capacity of our movement embracing the concepts of training, education and lifelong learning. We also need to educate the public about the benefits derived from green infrastructure" (ibid).

Three interviewees noted that at the concept and design stage, GI needs to be introduced as a viable concept. For the sustainability executive from a large developer, the ability to bring GI into the initial concept turns on "being able to get buy in early, and getting people believing in why you want to do something." This in turn means liaising with customers and, for the executive,

explaining “that it has benefit now or in the future. After that, the commercialities set in and you need to look at whether you can make it work within your feasibility. So there is definitely a role for developers and landlords in educating the market.” Unpacking this comment, there are clear junctures where the communication of GI needs to take place. In this development scenario, the education process happens first with internal stakeholders (for example, Kambites and Owen, 2006, p 491) before moving to the external sphere. Because GI is still an emerging approach, especially for those within large development companies, there is some reluctance to be the pioneer. While some, for example, have argued that note there might be a first-mover advantage (e.g. Leiberman and Montgomery, 2013), some have also noted that there are distinct disadvantages, especially in complex systems (e.g. Querbes and Frenken, 2017, p 68). When dealing with a complex, multifaceted system such as GI, any first-mover advantage that might be used to demonstrate market leadership or design capture, is potentially diminished by followers who need to see demonstrable results and who can coattail and refine new systems. As the sustainability executive noted: “Often people don’t want to be the first to do something. Even within a large national business, just because you’ve done it in one [place] doesn’t mean you can carry it across to the others. Concepts are a nice sketch on a page. Getting down to the depth of soil or media in order to put the planter boxes and how often it needs to be replaced, that’s when people think it’s too hard. But when people believe in a concept, they will do what it takes. Communicating and getting belief in the concept is probably the biggest thing.”

Driving change through communication also resonated with a landscape architect and GI consultant, even though the interviewee was aware that the relative youth of the GI industry creates its own limitations. “We’re still in the education phase here. There are not enough on-the-ground success stories to take businesses-as-usual operators to and there are not enough good news stories that you can point to in Australia. There’s also the communication of what it’s actually doing for the general public as an educational piece which I think is really important in getting the advocacy out.” For the sustainability executive from a large developer, even if internally there is a belief in a sound economic case for GI, you still need to “convince customers that it’s not about pure upfront costs, you’ve got to take them through the life cycle. It’s not that hard. It’s just about having really simple tools for people to communicate.” There is, however, a sense that conversations around GI are now being had in those crucial early stages and, albeit coming off a low base, rising. The critical caveat here, however, is that, as noted in previous sections, those GI measures generally relate to conventionally understood energy and water efficiency measures.

This caveat is borne out by a comment from another sustainability executive who works for a large developer and has worked in local government. They note that often, "[large] developers pride themselves on being at the top of global real estate index in sustainability, and that is largely driven around energy and water efficiency and carbon not greenery. As a consequence, these discussions [around GI] are pushed from a sustainability perspective, from the sustainability professionals and it is easy to label them as 'green and hippy and weird'. I think they need to be coming from the planners, the designers, the architects and not from the sustainability team."

The engineering consultant with GI technical research experience also noted that successfully transitioning to a new model meant overcoming problems of being a first-mover and using a clear and persuasive plan to help unmoor the business-as-usual approach. "It's a paradigm shift because you're changing the whole way the development phases work and it might actually be cheaper and better but you've got to think through how you change the system to get that benefit."

A number of the interviewees also noted that a champion from within the organisation or project is the most effective way of driving new processes relating to GI. The development manager for a property investment firm noted that "GI gets a lot more traction [when] you [have] those champions who make it happen as opposed to just doing what you always do. You do need the commitment because it does cost time and it does take more money." As an example of where a so-called champion might sit within the organisation, the interviewee used the case of another large developer they had partnered with that had specifically hired an engineer to oversee a new GI process. "He reported to people at a high level which meant he couldn't just be ignored. He wasn't just the guy that we needed to tick a few boxes. He was actually the guy that had power." The notion of a champion was also seen as a powerful driver, even within organisations that have broadly committed to GI practices. As the same interviewee noted: "There is definitely a corporate imperative just to be a good corporate citizen and that gets driven both at a corporate level and I think it also gets very much driven at a personal level as well. I think that's something that some of the bigger property companies do better than others."

4.9.2 Developing better data/research

Another key to the mainstreaming of GI is the development of economic data and metrics that can be called upon when communicating the benefits of new building methods that include GI. As the engineering consultant with GI technical research experience noted, because the benefits are "often a multitude and they're synergistic, if things are going to change, it's up to us to be innovative and explore those and understand those better." For the development manager for a property investment

firm, without decent metrics, “you’re really just picking numbers out of the air.” This only serves to reinforce the definitional and analytical problems around the measurement of the success or otherwise of GI initiatives, as well as highlighting the potential for gains off a low base.

There is some evidence that customised metrics are being built to help transform the landscape but this is still piecemeal. For example, according to the sustainability executive from a large developer, “we’re trying to improve the metrics around energy, health and wellbeing, water and materials. One of the things that we are lacking at the moment is really good metrics around bio-diversity. We’re now asking questions such as ‘How do you measure bio-diversity?’” However, there is a desire for greater research that goes beyond just the bespoke. This attitude was summed up by the GI consultant and landscape architect who noted that “there’s no collection of this research into one simple usable place. Research has to be done every time. It’s inefficient, it’s uncoordinated, it’s just not there yet.”

4.10 Discussion

Where the tipping point sits for making GI part of industry norms still seems unclear. This transition, however, will be propelled by increasing efforts to include or embed GI in projects, whether that is broader sustainability efforts that have arguably already begun to happen in commercial buildings (linked to green star building) or the emerging elements such as green walls, roofs and verges and connected green spaces. The research revealed, though, that data from local cases for GI isn’t sufficiently developed to present compelling evidence for wholesale change. At the margins, there seems to be a willingness to engage with the notion of GI but it’s difficult to conclude that a transition is any more than in its infancy.

This lack of locally-based examples with transparent and relevant data quantifying the direct economic benefits and indirect co-benefits remains arguably the key barrier. Deeply coupled to this, the data, as contributing to the justifiable case, must resonate with the variety of principal-agents involved across the development spectrum, that would include but not be limited to the policy maker, lender, developer, owner, investor and the party responsible for maintenance/replacement. Cost-driven decision making is revealed as most important to the broader ‘development’ sector and motivations around this depend on the type of development (commercial, retail or residential), scale and location.

As has been noted above, in relation to capacity, education and communication, as well as increasing the number of use cases demonstrating GI in a practical sense, the transition to wider GI

implementation will be bumpy. In a sense, it mirrors the increase in “green building”, noted by Bond (2010, p 17) in a study of the drivers and barrier to sustainable development in Australia. Building from limited local examples, leaders in the field took risks with subsequent development learning from those examples. Cost as a perceived barrier reduced as case studies emerged and a holistic approach to design was used, even though uncoordinated regulatory barriers persisted (ibid). The engineering consultant with GI technical research experience echoed this normative change, noting that “it’s a generational shift which you can speed up by getting more and more case studies [of GI] and having more buildings with GI around them.” Case studies emerge as important elements in increasing the industry’s technical capacity and reducing risk and uncertainty. They also play a critical educational role across multiple sectors or principal-agents, forming powerful visual communication roles and enabling the transition to a new normative position.

Encouraging more research and use cases, is however still in question. Is it the role of governments to mandate data collection for all buildings or just those that incorporate some elements of GI, as they do for NABERS ratings in large buildings? Or as the market develops metrics that show the economic argument for including GI in projects, will that create its own momentum? Perhaps the answer will lie in future use cases on new projects that utilise broad, live data sets gained from innovations such as the Internet of Things. Or as the engineering consultant with GI technical research experience noted: “I think there is a role for governments to be putting in a policy that GI should be included, particularly on larger developments, and then doing background studies to provide that information for people. If you get coordination, it actually isn’t that hard to get a group developing those metrics and then build on that knowledge base.”

5. CONCLUSION

The research set out to look at the factors hindering the uptake of GI in Greater Sydney and, more broadly, Australia, as well as looking at the efforts to use economic modelling as a means of driving GI uptake. As noted, it was skewed to participants who had experience in development across the breadth of private sector medium to large built assets, rather than green spaces so that reasons for the inclusion, or not, of GI in the private sector realm, and the contribution of public policy to their decision-making, might be ascertained.

The threshold question of what defines GI was the first significant finding. From the interviews and analysis, a clear, coherent and broadly-applicable definition of GI remains unresolved. Moreover, current definitions of GI appear to be strongly sector-based, and carry with them their own inherent biases. As a result, the sector-based definitions reinforce a lack of consistency and coherency that may explain policy paralysis to-date.

Sector definitions are being reinforced (in their own policies and practices) to reflect specific industry perspectives including that of their membership. For example, landscape architects have a greater emphasis on living elements, the property sector is focused on sustainability/green star ratings, while the financial sector seems to link GI with large-scale renewable projects. Overcoming this by defining GI broadly may give policymakers an increased ability to create industry movement (in other words, a narrow definition may leave policymakers with little room to move and stifle innovation, inclusiveness and creativity).

In terms of practical implementation of GI, the residential and commercial sector have split incentives to incorporate GI that relates in part to the principal-agent problem and may reflect the particular demand-driven property markets. The construction of medium-to-large residential developments is most often driven by minimising capital costs and any long-term benefits of GI are not accrued to the developer thus offering little incentive for their inclusion. Commercial projects, meanwhile, that include GI can demand higher rents or leases and are consequently factored into design and accepted as a capital positive inclusion. The strong caveat here is that GI, again due to definitional variability, is often lumped in with broader sustainability initiatives, especially as it relates to energy and water efficiency. There is also some indication of path-dependence that could explain the lack of GI entering a project. However, in the case of the decision-makers that were interviewed, the lack of good case studies and, thus, the nebulous nature of the cost and risk profile of a project often precluded inclusion or expansion of GI efforts.

The second part of the research set out to divine where in the decision-making process GI entered and left and, whether economic modelling had been done for GI, as a way of arguing for it on a cost-benefit basis. While there were no strong outcomes for where GI entered or left a project, there was agreement that bringing GI into a project as early as possible was the optimal approach. Having a person driving that approach was also seen as being advantageous. In addition, the research found that the different conceptualisations of GI create little incentive for consistent and repeatable economic modelling of GI's benefits, especially as it relates to less tangible outcomes such as increased health, climate change adaptation, noise insulation, urban biodiversity, storm-water mitigation and biophilia. As such, no broadly applicable economic modelling was uncovered that could be used more widely. If consistent economic modelling and costing was available, however, it could be a powerful tool to use in the decision-making process (by all sectors).

Designing and constructing innovative GI is also stymied by a lack of willingness to include GI because of risk and uncertainties. This applies to the cost, technical elements (such as lack of industry standards) and availability of experienced and skilled contractors to implement and maintain GI. In fact, this latter point around the lack of capacity in the workforce is perhaps one of the most critical factors in the future development and uptake of GI. In addition, regulation or policy could also drive the development of GI, however what the mandated minimums would be, and what would be optimal, was less clear.

It is recommended that future research must involve a clear and widely-accepted definition of GI if it is to become a critical part of development decisions. Economic modelling needs to follow from the definition if it is to enter the decision-making process. And, as a potentially larger issue, the usefulness of the term GI and its associated benefits needs to be assessed with a clear eye to the real-world impact and its broad applicability, especially with those who are involved in the key business decisions, as well as in the education process.

References

ABS. 2016. *Regional Population Growth, Australia, 2016* [Online]. ABS (Australian Bureau of Statistics). Available: http://www.abs.gov.au/AUSSTATS/abs@.nsf/mf/3218.0 [Accessed].

ADAMS, M. P. & SMITH, P. L. 2014. A systematic approach to model the influence of the type and density of vegetation cover on urban heat using remote sensing. *Landscape and Urban Planning,* 132**,** 47-54.

AILA 2015. The Next Five Years: AILA's Future Strategy 2015-2020. AILA (Australian Institute of Landscape Architects).

ALEXANDER, D. & TOMALTY, R. 2010. Smart Growth and Sustainable Development: Challenges, solutions and policy directions. *Local Environment,* 7**,** 397-409.

BAIETTI, A. 2013. Green Infrastructure Finance: A Public-Private Partnership Approach to Climate Finance. *World Bank, AUSAid*.

BAKER, R. & RUTING, B. 2015. Environmental Policy Analysis: A Guide to Non-Market Valuation. *In:* PRODUCTIVITY COMMISSION, S. W. P. (ed.).

BAPTISTE, A. K., FOLEY, C. & SMARDON, R. 2015. Understanding urban neighborhood differences in willingness to implement green infrastructure measures: a case study of Syracuse, NY. *Landscape and Urban Planning,* 136**,** 1-12.

BENEDICT, M. & MCMAHON, E. 2001. Green Infrastructure: Smart Conservation for the 21st Century.

BLACK, J., TARA, K. & PAKZAD, P. 2016. Mainstreaming Green Infrastructure Elements into the Design of Public Road Reserves: Challenges for Road Authorities. *International Journal of Environmental Protection***,** 1-8.

BOND, S. 2010. Best of the Best in Green Design: Drivers and Barriers to Sustainable Development in Australia.

BRINKMANN, S. 2014. Encyclopedia of critical psychology. Springer New York.

BRUCE, J. 2016. The Business Case: How to Avoid Projects Being Value-Engineered Out! . *Living Architecture Monitor*.

BRYMAN, A. 2016. Integrating quantitative and qualitative research: how is it done? *Qualitative Research,* 6**,** 97-113.

CAMPBELL, S. 1996. Green Cities, Growing Cities, Just Cities? Urban Planning and the Contradictions of Sustainable Development *Journal of the American Planning Association*.

CARTER, T. & FOWLER, L. 2008. Establishing green roof infrastructure through environmental policy instruments. *Environ Manage,* 42**,** 151-64.

COLE, R. J. & STERNER, E. 2010. Reconciling theory and practice of life-cycle costing. *Building Research & Information,* 28**,** 368-375.

CRESWELL, J. 2003. Advanced mixed methods research designs. *Handbook of mixed methods in social and behavioral research.*

DAVIES, P., CORKERY, L. & NIPPERESS, D. 2017a. Urban Ecology: theory, policy and practice in New South Wales, Australia. *National Green Infrastructure Network.*

DAVIES, P., CORKERY, L., NIPPERESS, D., BARNETT, G., BISHOP, M., HOCHULI, D., HOSE, G., JOEI, L. C., LIN, B., KEANE, A., OSMOND, P., PELLERI, N., STAAS, L., THRELFALL, C., VAN DEN BERG, F. & WILKINSON, S. 2017b. Blueprint for Living Cities: Policy to Practice. National Green Infrastructure Network.

DAVIS, M. 2010. Case Analysis 6 - Grey Infrastructure Mitigation.

EC 2013. Green Infrastructure (GI) — Enhancing Europe's Natural Capital. EC (European Commission).

EC 2016. Green Infrastructure. EC (European Commission).

EICHHOLTZ, P., KOK, N. & QUIGLEY, J. 2010. The Economics of Green Building. Berkeley Program on Housing and Urban Policy.

ELY, M. & PITMAN, S. 2014. Green Infrastructure: Life support for human habitats.

EMMANUEL, R. & LOCONSOLE, A. 2015. Green infrastructure as an adaptation approach to tackling urban overheating in the Glasgow Clyde Valley Region, UK. *Landscape and Urban Planning,* 138**,** 71-86.

FLETCHER, T. D., SHUSTER, W., HUNT, W. F., ASHLEY, R., BUTLER, D., ARTHUR, S., TROWSDALE, S., BARRAUD, S., SEMADENI-DAVIES, A., BERTRAND-KRAJEWSKI, J.-L., MIKKELSEN, P. S., RIVARD, G., UHL, M., DAGENAIS, D. & VIKLANDER, M. 2014. SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal,* 12**,** 525-542.

FOSTER, J., LOWE, A. & WINKELMAN, S. 2011. The Value Of Green Infrastructure For Urban Climate Adaptation. The Center for Clean Air Policy.

GIB 2016. Annual Report and Accounts 2015–16. GIB (UK Green Investment Bank).

GILL, S., HANDLEY, J., ANNOS, R. & PAULEIT, S. 2007. Adapting Cities for Climate Change: The Role of the Green Infrastructure. *Built Environment,* 33**,** 115-133.

GREENE, J. & CARACELLI, V. 1997. Defining and Describing the Paradigm

Issue in Mixed-Method Evaluation. *New Directions For Evaluation,* 74.

GSC 2016a. Draft Central District Plan. GSC (Greater Sydney Comission).

GSC 2016b. Towards Our Greater Sydney 2056. GSC (Greater Sydney Comission).

HANSEN, R. & PAULEIT, S. 2014. From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. *Ambio,* 43**,** 516-29.

INDERST, G. 2013. Private Infrastructure Finance and Investment in Europe. *In:* 2013/02, E. W. P. (ed.).

JONES, R., SYMONS, J. & YOUNG, C. 2015. Assessing the Economic Value of Green Infrastructure: Green Paper Victoria Institute of Strategic Economic Studies

KABISCH, N., FRANTZESKAKI, N., PAULEIT, S., NAUMANN, S., DAVIS, M., ARTMANN, M., HAASE, D., KNAPP, S., KORN, H., STADLER, J., ZAUNBERGER, K. & BONN, A. 2016. Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society,* 21.

KAMBITES, C. & OWEN, S. 2006. Renewed prospects for green infrastructure planning in the UK 1. *Planning Practice and Research,* 21**,** 483-496.

KAMINKER, C., KAWANISHI, O., STEWART, F., CALDECOTT, B. & HOWARTH, N. 2013. Institutional investors and green infrastructure investments: selected case studies", OECD Working Papers on Finance, Insurance and Private Pensions, No 35.

KARDAN, O., GOZDYRA, P., MISIC, B., MOOLA, F., PALMER, L. J., PAUS, T. & BERMAN, M. G. 2015. Neighborhood greenspace and health in a large urban center. *Sci Rep,* 5**,** 11610.

KENNEDY, R., BUYS, L. & MILLER, E. 2015. Residents' Experiences of Privacy and Comfort in Multi-Storey Apartment Dwellings in Subtropical Brisbane. *Sustainability,* 7**,** 7741-7761.

LENNON, M. 2015. Green infrastructure and planning policy: a critical assessment. *Local Environment,* 20**,** 957-980.

LIEBERMAN, M. & MONTGOMERY, D. 1988. First-mover advantages. *Strategic Management Journal,* 9**,** 41-58.

MATTHEWS, T., AMBREY, C., BAKER, D. & BYRNE, J. 2016. *Here's how green infrastructure can easily be added to the urban planning toolkit* [Online]. Available: https://theconversation.com/heres-how-green-infrastructure-can-easily-be-added-to-the-urban-planning-toolkit-57277 [Accessed].

MATTHEWS, T., LO, A. Y. & BYRNE, J. A. 2015. Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. *Landscape and Urban Planning,* 138**,** 155-163.

MELL, I. C. 2009. Can green infrastructure promote urban sustainability? *Proceedings of the Institution of Civil Engineers - Engineering Sustainability,* 162**,** 23-34.

NAUMANN, S., DAVIS, M., KAPHENGST, T., PIETERSE, M. & RAYMENT, M. 2011. Design, implementation and cost elements of Green Infrastructure projects: Final report to the European Commission, DG Environment.

NEWELL, G., TIM DIXON, P. S. B. A. P., MACFARLANE, J. & WALKER, R. 2014. Assessing energy rating premiums in the performance of green office buildings in Australia. *Journal of Property Investment & Finance,* 32**,** 352-370.

NSW DEPARTMENT OF FINANCE, SERVICES AND INNOVATION 2016. NSW Guide to Better Regulation.

NSW DEPARTMENT OF FINANCE, SERVICES AND INNOVATION. 2017. *Regulatory Impact Assessments* [Online]. Available: https://www.finance.nsw.gov.au/better-regulation/regulatory-impact-assessments [Accessed].

NSW OFFICE OF ENVIRONMENT AND HERITAGE. 2017. *Green Cover* [Online]. Available: http://climatechange.environment.nsw.gov.au/Adapting-to-climate-change/Green-Cover [Accessed 2017].

NSW PLANNING AND ENVIRONMENT. 2016. *Green Grid wins AILA 2016 national award* [Online]. Available: http://www.planning.nsw.gov.au/News/2016/Green-Grid-wins-AILA-2016-national-award [Accessed].

ODEFEY, J., DETWILER, S., ROUSSEAU, K. & TRICE, A. 2012. Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide.

PAKZAD, P. & OSMOND, P. 2015. A Conceptual Framework for Assessing Green Infrastructure Sustainability Performance in Australia.

PAKZAD, P. & OSMOND, P. 2016. Developing a Sustainability Indicator Set for Measuring Green Infrastructure Performance. *Procedia - Social and Behavioral Sciences,* 216**,** 68-79.

PECK, S. & LILAUWALA, R. 2016. Life-Cycle Cost Analysis for Green and Cool Roofs in Toronto - Appendix C Financial Modelling. City of Toronto.

PERSSON, J. & GRÖNKVIST, S. 2015. Drivers for and barriers to low-energy buildings in Sweden. *Journal of Cleaner Production,* 109**,** 296-304.

POUDYAL, N. C., HODGES, D. G. & MERRETT, C. D. 2009. A hedonic analysis of the demand for and benefits of urban recreation parks. *Land Use Policy,* 26**,** 975-983.

QUERBES, A. & FRENKEN, K. 2017. Evolving user needs and late-mover advantage. *Strateg Organ,* 15**,** 67-90.

RICS 2016. Green roofs and walls. RICS (Royal Institution of Chartered Surveyors).

RISTIMÄKI, M., SÄYNÄJOKI, A., HEINONEN, J. & JUNNILA, S. 2013. Combining life cycle costing and life cycle assessment for an analysis of a new residential district energy system design. *Energy,* 63**,** 168-179.

ROSENZWEIG, C. 2015. Confessions of a Green Scientist. *Living Architecture Monitor.*

SANDSTRÖM, U. G., ANGELSTAM, P. & KHAKEE, A. 2006. Urban comprehensive planning – identifying barriers for the maintenance of functional habitat networks. *Landscape and Urban Planning,* 75**,** 43-57.

SANTAMOURIS, M. 2014. Cooling the cities – A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar Energy,* 103**,** 682-703.

SCOTT, M. 2013. Delivering ecosystems services via spatial planning – reviewing the possibilities and implications of a green infrastructure approach.

SHARIFI, E. & LEHMANN, S. 2014. Comparative Analysis of Surface Urban Heat Island Effect in Central Sydney. *Journal of Sustainable Development,* 7.

SIDIQUI, P., HUETE, A. & DEVADAS, R. 2016. Spatio-Temporal Mapping and Monitoring of Urban Heat Island Patterns over Sydney, Australia using MODIS and Landsat-8. *2016 Fourth International Workshop on Earth Observation and Remote Sensing Applications*

SUGIYAMA, T., LESLIE, E., GILES-CORTI, B. & OWEN, N. 2008. Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? *Journal of Epidemiology & Community Health,* 62**,** e9-e9.

SUSSAMS, L. W., SHEATE, W. R. & EALES, R. P. 2015. Green infrastructure as a climate change adaptation policy intervention: muddying the waters or clearing a path to a more secure future? *J Environ Manage,* 147**,** 184-93.

SYMONS, J., JONES, R. N., YOUNG, C. K. & RASMUSSEN, B. 2015. Assessing the Economic Value of Green Infrastructure: Literature Review. Climate Change Working Paper. *Victoria Institute of Strategic Economic Studies, Victoria University, Melbourne.*

TAKANO, T., NAKAMURA, K. & WATANABE, M. 2002. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *Journal of Epidemiology & Community Health,* 56**,** 913-918.

TAM, L., WEEKS, K. & ZIGAS, E. 2013. Greener and Better Roofs. an Francisco Bay Area Planning and Urban Research Association.

TOMALTY, R. & KOMOROWSKI, B. 2010. Curb appeal. *Living Architecture Monitor.*

UN 2014. World Urbanization Prospects: The 2014 Revision, Highlights. United Nations, Department of Economic and Social Affairs, Population Division.

US EPA. 2017. *What is Green Infrastructure?* [Online]. Available: https://www.epa.gov/green-infrastructure/what-green-infrastructure [Accessed].

VAN RAALTE, L., NOLAN, M., THAKUR, P., XUE, S. & PARKER, N. 2012. Economic Assessment of the Urban Heat Island Effect City of Melbourne.

VANDERMEULEN, V., VERSPECHT, A., VERMEIRE, B., VAN HUYLENBROECK, G. & GELLYNCK, X. 2011. The use of economic valuation to create public support for green infrastructure investments in urban areas. *Landscape and Urban Planning,* 103**,** 198-206.

WEEKS, K. & LILAUWALA, R. 2016. Cost Benefit Supports San Francisco Green Roof Policy and Quantifies biophilic Tax Benefits. *Living Architecture Monitor.*

WGBC 2013. Business Case For Green Building Report. WGBC (World Green Building Council).

WINCH, G. 2010. *Managing Construction Projects: An Information Processing Approach*, Wiley-Blackall.

WOLCH, J. R., BYRNE, J. & NEWELL, J. P. 2014. Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. *Landscape and Urban Planning,* 125**,** 234-244.

WORLD BANK. 2016. *Urban Population (% of total)* [Online]. Available: https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2016&locations=AU&start=1960&view=chart [Accessed].

XIAO, Y., LI, Z. & WEBSTER, C. 2016. Estimating the mediating effect of privately-supplied green space on the relationship between urban public green space and property value: Evidence from Shanghai, China. *Land Use Policy,* 54**,** 439-447.

YOSHIDA, J. & SUGIURA, A. 2014. The Effects of Multiple Green Factors on Condominium Prices. *The Journal of Real Estate Finance and Economics,* 50**,** 412-437.

Appendix 1: Ethics Approval Letter

Dear Dr Davies

RE: Ethics project entitled: "Investigating the economic value of green infrastructure in urban development and planning"

Ref number: 5201600281

The Faculty of Science and Engineering Human Research Ethics Sub-Committee has reviewed your application and granted final approval, effective 16/05/2016. You may now commence your research.

This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site:

http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.

The following personnel are authorised to conduct this research:

Dr Peter Davies
Mr Dominic Rolfe

NB. STUDENTS: IT IS YOUR RESPONSIBILITY TO KEEP A COPY OF THIS APPROVAL EMAIL TO SUBMIT WITH YOUR THESIS.

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).

2. Approval will be for a period of five (5) years subject to the provision of annual reports.

Progress Report 1 Due: 16/05/2017
Progress Report 2 Due: 16/05/2018
Progress Report 3 Due: 16/05/2019
Progress Report 4 Due: 16/05/2020
Final Report Due: 16/05/2021

NB. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

5. Please notify the Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:
http://www.mq.edu.au/policy/

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have final approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of Final Approval to an external organisation as evidence that you have Final Approval, please do not hesitate to contact the Ethics Secretariat at the address below.

Please retain a copy of this email as this is your official notification of final ethics approval.

Yours sincerely,
Human Research Ethics Sub-Committee
Faculty of Science and Engineering
Macquarie University
NSW 2109