GREEN INFRASTRUCTURE

USING VR TO ASSESS WILLINGNESS TO PAY FOR GREEN INFRASTRUCTURE IN SWEDISH RESIDENTIAL DEVELOPMENT

By **Prof. Sara Wilkinson, University of Technology Sydney** and **Dr Agnes Zajelska Jonsson, KTH Stockholm**

INTRODUCTION

It is said that we are experiencing more change in the current two decades than we have over the last three centuries. This change is not only climate-related, but is also largely technology focussed and this is impacting us socially, economically and legally. With this in mind, it is not surprising to hear about a project that uses Virtual Reality (VR) to assess willingness to pay (WTP) for an environmental benefit such as Green Infrastructure (GI). This article looks at residential development in Stockholm Sweden and a project that uses VR as a means of determining how much GI is economically optimum.

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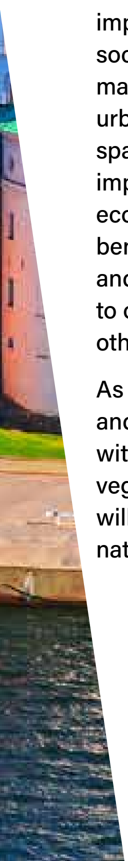
GI offers significant wide-ranging economic, social and environmental benefits. Green roofs, facades and walls contribute to these benefits, particularly in dense urban areas. Green roofs improve air quality, provide space for social interaction and relaxation, help manage urban stormwater, reduce the urban heat island (UHI) effect, provide space for urban food production and improve urban biodiversity. These economic, social and environmental benefits have led to GI uptake nationally and internationally. Some benefits accrue to owners and/or occupiers, whereas others provide wider societal benefits.

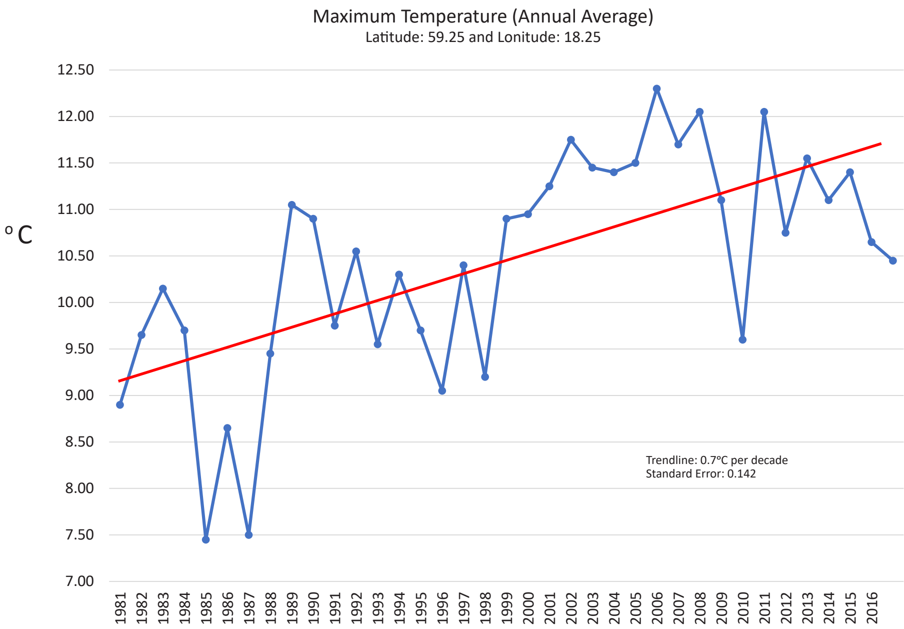


As global population grows, towns and cities expand and become denser with less area for green space and vegetation. Increasing urbanisation will have significant effects on the natural environment and the health and wellbeing of human and non-human populations. Green roofs, facades and green walls can mitigate some of these impacts. Swedish cities experience similar issues to Australian cities, with predictions for increased average temperature with more extreme heat events as well as increased rainfall, drought, fire, warmer oceans and sea level rise (CSIRO and Bureau of Meteorology 2016). Stockholm's annual average maximum temperatures from 1981 to 2017 (www.ClimateChip.org, 2019) show an increase from 9.2 oC to 11.7 oC (Figure). These increases are not discernible on a day to day basis but are clear in figure 1.

More alarming predictions are shown in Figure 2, where algorhythms of five climate centres predict temperatures to 2085. The HadGEM (UK Met Office) model is shown in red and in purple is NORES - the Norwegian climate model. The green shows the French Institut Pierre-Simon Laplace model prediction and the US GFDL NOAA model is the blue line. The orange line is the Japanese prediction - MIROC (University of Tokyo) model. The Japanese model forecasts an annual average maximum temperature increase from 10.2oC in 1992 to just under 17oC in 2085 representing a 6.8oC increase.

The most optimistic prediction, the US model, predicts 2085 annual average maximum temperature is just below 14oC. All models predict major temperature increase and changed weather patterns. Most existing buildings are not designed to function comfortably within these

Figure 1: Stockholm annual average maximum temperatures 1981 to 2017



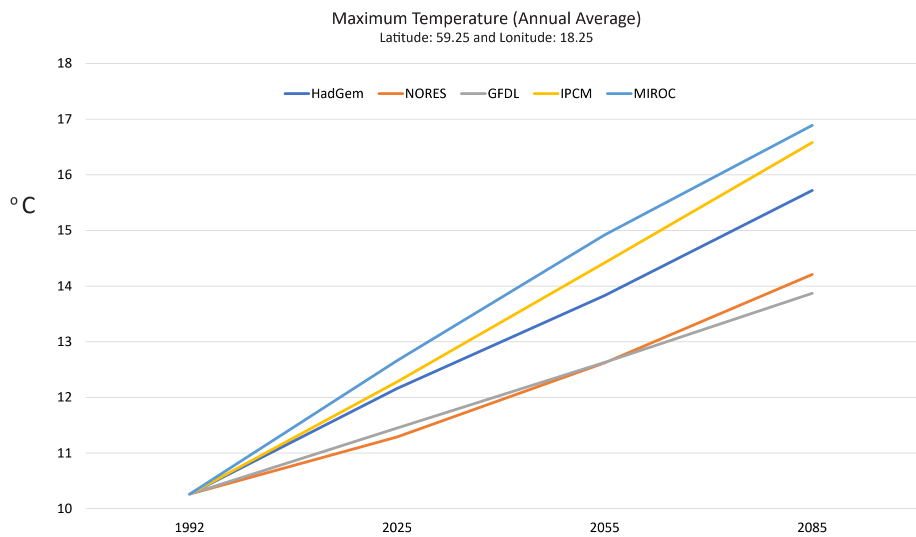
(www.ClimateChip.org, 2019)

parameters. Although temperature figures differ for Australia, we face similar issues with our building stock.

With the need to accommodate and adjust to higher temperatures, the value of incorporating GI into built environments bringing back lost nature in cities, recreating lost ground space, using roof and wall spaces, is clear. Green roofs and walls improve thermal and sound insulation of buildings, enhance stormwater management and air quality, increase property prices, create places for social interaction and community engagement, cool cities, and reduce energy consumption and greenhouse gas emissions (AECOM, 2017). The aesthetic qualities of cities are improved. Green roofs contribute to urban ecology or biodiversity protection and urban food production at commercial scales as rooftop urban farms.

Green roofs are an example of multifunctional GI (Dixon and Wilkinson 2016) with multiple social, economic, ecological, environmental, and public health benefits. These benefits are categorised into two types: public benefits, shared at wider community and government levels and private benefits, received by owners and occupants. The public and private benefits provide meaningful economic returns. The benefits are key drivers central to the uptake of living architecture practices (Hopkins and Goodwin 2011) and comprise a primary benefit which comes with co-benefits, shown in Table 1. Policy initiatives, government incentives and key national priorities significantly influence processes and guide the progress in implementing GI. The drivers vary with different land use zones such as residential, commercial and industrial (City of Sydney 2017) and various locations and at different densities with the city.

Figure 2: Stockholm predicted annual average maximum temperatures from 1992 to 2085



(www.ClimateChip.org, 2019)

We argue there is also an uplift in property value. AECOM (2017) estimated the value uplift of GI in a typical Sydney home to be AU$50,000 and Newell et al (2011) calculated the price premium in top quality commercial property for sustainability features to be circa 9%.

CHALLENGES FOR GI

A key concern is the high costs of green roof, wall and facade installation and maintenance (Downton 2013). Specialised knowledge and skills are needed for maintenance and care when green roofs, walls and facades are installed on high-rise buildings. Developers often consider other technologies (e.g. solar panels) more feasible. Continuing plant maintenance is an added cost and overall costs is a major barrier to the uptake of green roofs. Thus, it is vital to identify short and long term, multiple performance benefits, and economic and environmental values to establish the viability of GI. The capacity of the construction industry for GI is in a developing phase in most countries (Wilkinson et al, 2017). The GI industry needs to be able to supply skilled workmanship to withstand demand. Barriers are summarised in table 2.

STOCKHOLM

Stockholm is a metropolitan area housing over 20% of Sweden's population. There are three tiers of governance at national, municipal and county levels. The municipality is responsible for regulations affecting planning and building which is delivered through the Swedish Planning and Building Act. There are

Table 1: Green roofs - primary and co-benefits

Green Roof	Primary reason	Co-benefits	
Thermal	Improve insulation and reduce energy consumption	▪ Stormwater attenuation ▪ UHI	▪ Biodiversity ▪ Air quality
Stormwater	Attenuate pluvial flooding	▪ Thermal improvement ▪ UHI	▪ Biodiversity ▪ Air quality
Biodiversity enhancement	Increase local biodiversity	▪ Thermal improvement ▪ Stormwater attenuation	▪ Air quality ▪ UHI
Conservation of flora and fauna	Provide environment for endangered species	▪ Thermal improvement ▪ Stormwater attenuation	▪ Air quality ▪ UHI
Urban food production	Local food production	▪ Reduce carbon food miles ▪ Thermal improvement ▪ Stormwater attenuation	▪ Increase biodiversity ▪ Air quality ▪ UHI
Provision of social space	Amenity space	▪ Thermal improvement ▪ Storm-water attenuation ▪ Food production	▪ Air quality ▪ UHI

Source: Wilkinson & Dixon, 2016

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26 municipalities within Stockholm focussing on increasing densities and redeveloping land to accommodate a growing population.

Stockholm aims to be fossil free by 2050 and acknowledges the role of the built environment to attenuate and mitigate climate change and this is manifest in initiatives such as the Green Space Factor (GSF) (Clark, 2005). The GSF and Green Points system, which originates in the GRaBS (Green and Blue Space Adaptation for Urban Areas and Eco Towns) project is applied in urban regeneration. GRaBS is a network of pan-European organisations involved in integrating climate change adaptation into regional planning and development. Stockholm shares a number of issues found in Australian cities.

Table 2 Barriers to Green Infrastructure

Type of barrier	Description
Economic	▪ Perceptions of high installation and maintenance costs ▪ Lack of knowledge regarding value uplift of GI to capital and rental values
Environmental	▪ Plant lifecycle and replacement rates ▪ Additional water consumption ▪ Additional energy consumption ▪ Competition with other sustainable technologies e.g., rooftop solar PV
Social	▪ Occupational Health and Safety during installation and maintenance
Technological	▪ Structural capacity for retrofit ▪ Perceptions of leaks ▪ Reliability of systems – durability ▪ Reliability of systems – maintenance ▪ Access to roof for installation and maintenance ▪ Orientation (access to sunlight) ▪ Lack of guides for owners and property managers / facility managers ▪ Construction industry capacity

Source: Adapted Wilkinson et al, 2016

VR AND AR

VR is a 'scientific and technical domain that uses computer science and behavioural interfaces to simulate in a virtual world the behaviour of 3D entities, which interact in real time with each other and with one or more users in pseudo-natural immersion via sensory moto channels.' (Fuchs et al, 2011: 8).

VR has grown out of computer vision and 3D modelling and has gained significant momentum in the past decade with a range of devices available (Greenwald, 2018). VR technology has various hardware options from those that require a mobile phone (e.g. Samsung Gear VR) to those that can stand alone (e.g. Oculus Go). With Augmented Reality (AR) currently available, technology is primarily in developer mode such as the Magic Leap (Greenwald, 2018). There is hardware produced by Emoti, a head-up-display that includes a five or 14 channel electroencephalogram or EEG (EMOTIV, 2019). The use and validity of this device is found in the field of neuroscience (Argento et al., 2017). For some projects, researchers want users to be fully immersed, yet passive, and can use mobile headsets (for wider audience) or stand-alone headsets. If there are decisions to be made, additional controllers allow that functionality. From previous work on VR, psychology and human factors, the more intuitive and natural an environment the easier it is to focus on undertaking the tasks (Juliani, et al, 2016).

Architecture uses a range of drawn mediums to represent imagined spaces from paper and pencil, CAD, 3D models and now VR. Leovardis and Bahnă (2017) researched journalism architecture and advertising to see how VR would influence innovation. Virtual environments were described as the 'holy grail of architecture', as the process allows for changes to be made within the virtual space (Leovaridis & Bahnă, 2017: 167). Within creative industries VR is seen to be both cost effective and enhanced interactions, creativity and problem solving (Thornhill-Miller & Dupont, 2016). Recent studies demonstrate little difference in the judgement of the performance of a space, being in a physical space, looking at a photograph or a rendering (Acemyan & Kortum, 2018). Researchers at Stanford's Virtual Human Interaction lab explored how VR may increase environmental behaviours (Ahn, Bailenson, & Park, 2014). The potential of virtual 'being there' in places, allows us to explore future environments in real time. This approach was therefore deemed appropriate for our project to assess how people perceive and value GI in a Stockholm residential development. Though studies use VR to assess the property market (Wolf, 2018), it is said AR/VR will become ubiquitous, in conjunction with smart homes, the internet of things (IoT) and artificial intelligence (AI).

VALUE AND WILLINGNESS TO PAY (WTP)

Many economic, social and environmental benefits result from the installation of GI and are tangible (can be quantified) or non-tangible (cannot be quantified). The accelerating rate of investment into GI is indicative of the value created for stakeholders. A challenge to adoption is the clarity of the business case for specific investments, which are open to a wide variety of design choices affecting costs and benefits. Table 3, shown on the next page, summarises sources of value created from GI.

The economic benefits are divided into two categories:

1. Those that benefit owners/occupants/investors directly such as installation, replacement and repair, stormwater, increased property values, and energy savings leading to reduced operating costs for running less air conditioning in warmer months and less heating costs (through less heat loss through the external walls and roofs).
2. Other financial impacts such as greenhouse gas savings, market-based savings and community benefits.

A challenge in quantifying the value from GI is the variety of approaches to evaluate net value. The most common are cost-benefit analysis (CBA), triple bottom line (TBL), life cycle assessment (LCA) and life cycle costing (LCC). While these models enable analysis of the costs and benefits, they all are incomplete on some dimension, and are criticised for being insufficient to allow for reliable evaluation of trade-offs between economic and environmental performance. Economists argue conventional financial CBA is insufficient for investment analysis, as environmental costs and benefits are not included in the modelling.

With GI, this challenge is salient as there are substantial direct costs incurred by owners and investors (City of Sydney 2017), whereas the value created is shared by various stakeholders including tenants, and the local community and economy. Perhaps in recognition of the shared value, a range of subsidies could be implemented to compensate investors. While more recent attempts to evaluate the business case for GI have included attempts to identify and quantify the value created with respect to economic, environment, and community/social value (e.g. GSA 2011), a more compressive approach which includes a more comprehensive set of value drivers is needed.

WHERE WE ARE UP TO

This research adopts VR and EEG Technology as a means of assessing people's perceptions and reactions to various GI spaces, including green roofs and walls. We are working with a major Swedish developer. The results of the experiments and semi-structured interviews will provide a comprehensive understanding of GI. This understanding will be correlated and mapped with data on property capital and rental values, to determine various degrees of willingness to pay for GI. With this knowledge, developers in Sweden and in Australia will be able to make a more robust informed holistic business case for increased uptake of GI for more liveable healthy cities.

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Table 3: Summary of key sources of value from GI

Value drivers	Main category of value delivered		
	Economic	Environment	Social / community
Supply of products and services			
Sale of fruit and vegetables	☑	☐	☐
Sale of flowers and other non-edible products	☑	☐	☐
Other value-added products and services, such as provision of education services	☑	☐	☐
Direct cost savings			
Thermal energy saving leading to reduced demand for heating and cooling	☑	☑	☑
Roof longevity in some cases	☑	☑	☐
Air quality			
CO2e sequestration and absorption	☐	☐	☑
Removal of VOC (indoor and outdoor)	☐	☑	☑
Quality of life			
Mental Health benefits such as reduced anxiety	☐	☐	☑
Productivity benefits from increased amenity	☑	☐	☐
Stormwater management			
Absorption and storage of rainwater leading to reduced demand from water supply	☑	☑	☐
Absorption and storage of rainwater leading to reduced demand for stormwater services to manage urban water	☑	☑	☐
Reduction in urban water pollution such as through remediation of water quality	☑	☑	☐

Value drivers	Main category of value delivered		
	Economic	Environment	Social / community
Biodiversity			
Increased habitat		✓	
Increased diversity in flora and fauna		✓	
Urban Heat Island effect			
Reduce energy demand for cooling	✓	✓	
Acoustics			
Reduction of noise transfer			✓
Tourism			
Increased direct and indirect employment and other economic activity	✓		✓
Real estate value			
Increase in property value	✓		
Increase in surrounding property value	✓		
Increased rent returns and reduced vacancy rates	✓		
Increase in urban aesthetic			✓
Other economic value			
New jobs for building infrastructure	✓		
New jobs maintenance	✓		

Source: Wilkinson et al, 2017