

## Designing the twenty-first century urban park: design strategies for a warming climate

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**Abstract:** With 2014 considered the hottest year on record, the implication of climate change on the liveability of cities is becoming ever more apparent. Accordingly, the role of open space is emerging as a pressing issue, with clients increasingly demanding evidence of design performance. In 2011 for example the New York City Department of Parks & Recreation in collaboration with the Design Trust for Public Space released *High Performance Landscape Guidelines: 21<sup>st</sup> Century Parks for NYC*. As Deborah Marton the former Director of the Design Trust comments, this type of document reflects a major shift in the conception of open space, ‘from park as end-product to park as work in progress’ (Carlisle and Pevzner 2012). This paper explores how two contemporary designs for open space in Asian cities have engaged with environmental simulation to increase the performative attributes of open space. Through the comparison of Singapore’s Gardens by the Bay and Taiwan’s Phase Shifts Park we highlight the different philosophies and technical challenges presented in these ambitious designs and conclude with a wider reflection on the technological manipulation of natural phenomena.

**Keywords:** performance; open space; climate change.

### 1. Introduction

Environmental and civil engineering have a long tradition of testing design performance through physical modelling (such as wind tunnels or hydrological models) or digital simulations. Increasingly accessible software capable of modelling the fluid dynamics of wind, water, tides, heat, humidity and pollution present new opportunities for embedding temporality and change into design processes. Simulations and real time data offers techniques for introducing an evidence-based metric into design processes, heightening the performative ambitions of spaces and providing quantitative and qualitative arguments for the value of parks, gardens and green infrastructure.

*Cities Alive: Rethinking Green Infrastructure* published by Arup in 2014 uses social, environmental and economic benefits to argue for green infrastructure. Tom Armour (2014), Global Landscape Architecture Leader at Arup, highlights the significance of metrics in the current economic context,

stating ‘we need to get the value out of landscape’ by demonstrating its potential in lowering pollution and air temperature levels, reducing carbon and contributing to healthier cities. Similarly, Stephanie Carlisle (2014) environmental researcher and designer at Kieran Timberlake Architects, comments that ‘if we want to have projects built we have to be able to argue about what they are and what they do.’

Climatic challenges and environmental health risk such as the Urban Heat Island (UHI) phenomenon affect millions of people around the world as cities become warmer due to human activities. Conditions in many Asian megacities prove particularly challenging due to the combined factors of high temperature, humidity and poor air quality, which prevent citizens from engaging in outdoor activities, calling for actions to increase the resilience of cities. Awareness of UHI as significant health risk has emerged for instance in Japan since early 2000, leading to increased planting of street trees in addition to promoting low-tech means of cooling the streetscape with the support of local residents. These activities include planting fast growing annual climbers as shading devices (e.g. in front of windows or entire façades) or manually watering hot street surfaces utilising the cooling effect of evapotranspiration. Recently, this strategy has been adopted in building technologies, for example, in the so called Bio Skin design for the Sony City Osaka building in Tokyo designed by Nikken Sekkei, where a water-filled exterior façade system constructed of porous ceramic pipes extends across the entire height of the building. Utilising rainwater the Bio Skin responds to the hot southern winds prevailing in the summer months and has the capacity to cool adjacent outdoor spaces by two degrees Celsius.

Low latitude countries, such as Singapore and Taiwan, are exposed to even more challenging conditions with constant high temperatures elevated by high humidity levels and low average wind speed. (Yang *et al*, 2013; Chang and Roth, 2006; Lin, T-P, 2009). This is paired with a cloudy environment of subdued light and decreased efficiency of solar energy, supporting further dependency on fossil fuels and high air pollution levels (National Climate Change Secretariat. 2012). Within this context a significant and explicit shift towards improving the performance of buildings, parks and cities is evident. This paper discusses two projects that actively engage with these challenging conditions to provide comfortable and healthy outdoor environments, beginning with Singapore's Gardens by the Bay followed by the Phase Shifts Park (known post competition as Jade Eco Park) in Taichung, Taiwan. This comparative analysis draws on interviews with designers and reviews of competition and design documentation. Embedding environmental simulations in the design process has provided a crucial strategy to test, control and predict conditions such as solar radiation, temperature, humidity, and air pollution in order to develop innovative schemes for the twenty-first century urban park.

## **2. Gardens by the Bay, Singapore**

Singapore's Gardens by the Bay emerged from an international design competition for a 54-hectare public garden. In 2006 the Bay south competition was won by the multi-disciplinary collaboration of Grant Associates (landscape architects), Wilkinson Eyre Architects and the engineering firms of Atelier One (structural) and Atelier Ten (environmental). The project's success relied on the establishment of a successful growing environment for a range of plants within Singapore's cloudy environment of subdued light and high humidity levels. Significantly this ambition was to be achieved within a carbon neutral energy system.

The design of the two feature biomes conservatories was particularly challenging. At close to 20,000 square metres, and up to 58 metres in height, the conservatories are some of the largest in the world. The challenge within the Singapore context was to adequately ventilate, cool and dehumidify the equatorial environment, while meeting horticultural lighting requirements and limiting the carbon footprint'. For 95 percent of the year, Singapore's equatorial tropical climate maintains temperatures

between 24 and 32 Celsius with humidity measuring between 17-21 g/kg (Davey *et al*, 2010, p.141). *The Cool Moist (cloud mountain) Dome*, designed for species from the mountainous tropical regions, requires mild air temperature night and day combined with an almost saturation level of humidity, while *The Cool Dry (flower) dome* replicates the Mediterranean springtime of mild dry days and cool nights.

A combination of physical and digital prototyping was used to develop this complex growing environment. In an important precursor to the competition, National Parks Board of Singapore (NParks) staged a multi-year research project with CPG consultants (Singapore) and German climate engineers Transsolar (Stuttgart) to identify the required growing conditions for the conservatories. Six prototype glass houses informed the initial briefing documents for the winning team. During the design process these prototypes continued to be used to test glass and equipment specifications, and understand their effect on plant growth. For the designers it was critical to identify annual and peak light levels to support plant growth, combined with specific temperature and humidity levels which would vary over the course of the day and year to simulate the dynamic change of plants within their natural environment (Bellew & Davey, 2012, p.38). A combination of proprietary software such as Ecotect and Radiance and bespoke software generated by Atelier Ten, facilitated the evaluation and comparison of various proposals. Daylight simulation techniques assessed the availability and quantity of daylight for the inhabited volume for each hour of a typical year (Bellew & Davey 2012, p.49).

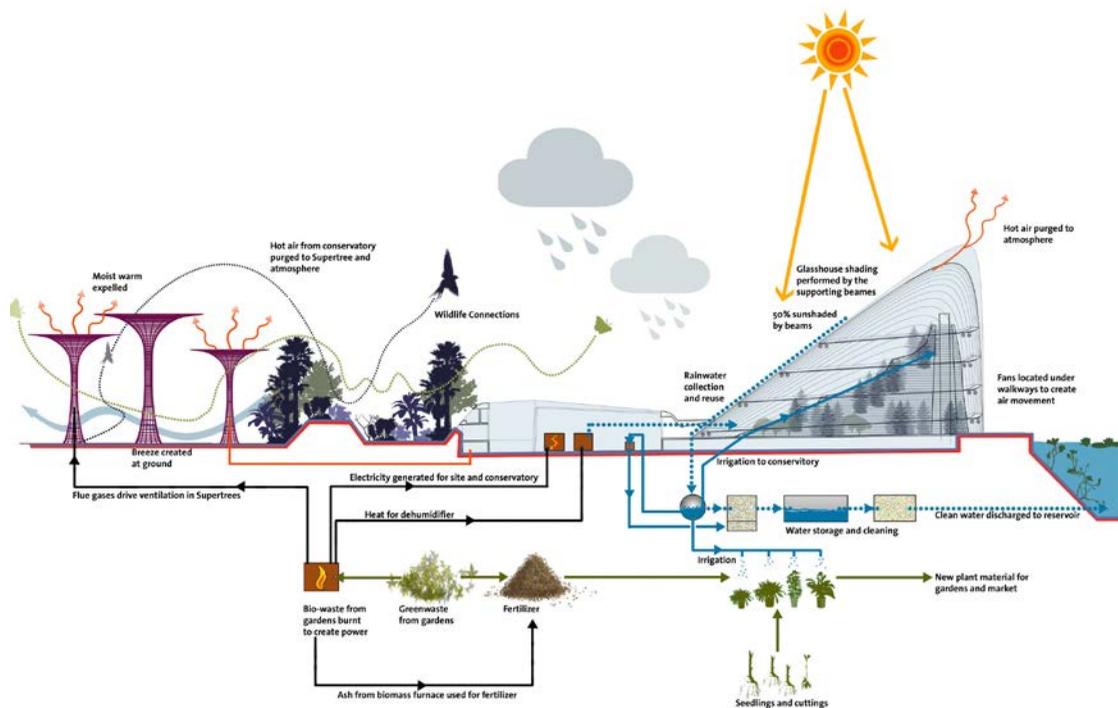


Figure 1: Diagram from the competition submission showing the environmental system, which is fueled by green waste and a bio-mass boiler (Source: Grant Associates)

A dynamic shading structure, responsive to the changing solar environment, emerged as an important solution for achieving the desired growing environment. Internal light levels with and without shades were modelled for a complete reference year. The final scheme comprises 419 individually controlled external shades, featuring ‘an intelligent self-learning algorithm’ that adjusts shades in response to the sun paths, the geometry of the internal spaces and the external cladding (Bellew & Davey, 2012, p.56). Initially solar was assumed as the energy source for the environmental systems however the cloudy nature of Singapore reduces its efficiency. Discussions with NParks revealed that the city regularly prunes several million trees, generating extensive green waste largely incinerated or sent to landfill (Ferguson, 2014, p.27). Plans altered to include a bio-mass boiler fuelled by the city and garden’s horticultural waste. Steam from the boiler feeds a turbine to generate electricity. Remaining ash is used as fertiliser, while surplus energy is fed back into the grid.



Figure 2: Planting panels on the Supertrees and the suspended walkway of the Supertree Grove (source: Walliss)

The iconic Supertrees shown in Figure 2 perform an essential role in this complex energy system, which was conceived as a larger symbiotic relationship that included the conservatories and gardens, through an exchange of energy, air, water, nutrients and water cycles. This cycle is depicted in Figure 1. These spectacular tree like structures are multi-functional ‘environmental engines’ designed to disperse hot gases generated by the biomass boiler and the desiccant process, generate energy through photovoltaic solar panels and provide shade for the public areas below as well as extensive valuable habitat for birds and insects. *The Gold Cluster* of Supertrees, which is located near the entrance, conceals the major chimney from the energy centre’s boiler, discharging non-toxic flue gases high above any occupied areas. The steam turbine powers the electric chillers, producing chilled water to cool the domes. Adopting principles of thermal stratification, chilled water runs through pipes within the floor slabs, while the rising warm air is vented out at higher levels or is captured to harvest heat. CFD modelling allowed the engineers to analyse and optimise this airflow and accurately predict outcomes (Ferguson, 2014, p.30).

Any waste heat is used to regenerate the liquid desiccant, necessary to de-humidify the air for the *Flower Dome* (the cool-dry biome). Conventional cooling of humid air requires an energy intensive

process; chilled water removes water vapour through condensation, followed by reheating to the desired temperature (Ferguson, 2014, p.28). In contrast this system uses liquid desiccants to remove water vapour from the air through a chemical process; leaving the air temperature similar but drier. Used in conjunction with conventional cooling systems, this technology requires less energy, while the desiccant is recycled through treatment from waste heat from the biomass boiler. *The Silver Cluster* of Supertrees, masks the hot moist air discharge from the regeneration unit of the liquid desiccant dehumidification system.

This complex environmental system encompassing the entire garden facilitates a number of ‘virtuous cycles’ involving either the reuse of resources or the maximization of their use (Davey *et al*, 2010, p.142). The Supertrees however were designed as far more than environmental infrastructure. Their inspiration, states landscape architect Andrew Grant (2014), are the monumental karri forests of Western Australia (which feature a sky walkway) and the 1997 anime film *Princess Mononoke* depicting a young warrior’s encounter with forest gods and those wishing to destroy the forest resources and beauty. Rising 50 metres to match the monumental scale of the conservatories, the structures were conceived as a magical ‘other worldliness of space,’ including a unique night time experience. The largest configuration forming the *Supertree Grove* are particularly immense, supporting a 135m long aerial walkway suspended over twenty metres above the gardens, shown in Figure 2, with the tallest structure featuring a bar and viewing gallery.

The landscape architects worked closely with structural engineers Atelier One, led by Neil Thomas to develop the Supertrees. First versions, state Grant (2014) were very ‘clunky’ which ‘looked like bits of the Eiffel tower.’ Slowly the form evolved through a process of testing structural form and exploring environmental efficiency through physical and sectional analysis and three-dimensional studies. The geometries of the structures were established parametrically, and emerged as two repetitious modules that reinforce each other as ‘doubly curved anticlastic surfaces’ with the form developing structural stiffness (Bellew & Davey, 2012, p.99). Planting panels were designed to attach either directly to the concrete core, or to the steel skin covering the core. This novel typology challenged Singapore’s existing building codes, raising questions for authorities and engineers on how to classify them. Should they be considered buildings or bridges?

In contrast, to the Gardens by the Bays focus on developing optimum growing environments for plants, Taiwan’s Phase Shifts Park designed by landscape architect Catherine Mosbach and architect Philippe Rahm aimed to produce a more inhabitable environment for people. The park is currently under construction, expected to be completed in 2016. The scheme aims to give back the outdoors to the public by developing exterior spaces that diminish the experience of Taichung’s subtropical warm and humid climate. The park proposes a healthier and more comfortable outdoor environment, which emerges through the superimposition of two overlapping strata; lithosphere developed by Mosbach comprising soils, topography and rain-water, and atmosphere explored by Rahm which focuses on the effects of heat, humidity and pollution. CFD modelling was used to understand the existing atmospheric conditions and inform a spatial and experiential structure for the park based on extending the atmospheric range.

### 3. Phase Shifts Park, Taiwan

Philippe Rahm’s interest in atmosphere lies in its performative potentials. He aims to embrace climate within the domain of design, as distinct from controlling climate from a functionalist perspective to achieve optimum efficiencies. The design competition for Taichung Gateway Park provided Rahm the

opportunity to expand his explorations of atmosphere from the scale of the exhibition and architecture into an urban scale, whilst maintaining his focus on the human experience. This intent is signaled in the diagrams featured so prominently in the competition entry that depicts human physiological reactions to heat, humidity and pollution.

Mapping the climatic variations of the site through CFD modelling formed the starting point for the conceptualisation of the atmospheric strata. This modelling develops an understanding of the fluctuating conditions of heat, humidity and pollution, including the impact of the future architecture on the park's edges. The models were developed by German firm Transsolar who used ANSYS Fluent software combined with weather data from the Taiwanese central weather bureau's measuring device located close to the site (Frenzel 2014). From their models, the designers developed three graduation climatic maps that documented the intensity and variation of heat, air humidity and atmospheric pollution. These maps were overlaid and intersected to create a diversity of conditions, conceived as a series of Coolia, Dryia and Clearia 'climatic lands.' Rahm (2014) stresses that this approach is not a Modernist or functional response.

The aim is not to modulate conditions, for instance making the hotter areas cooler. Instead the scheme maintains and even extends the graduation of conditions, increasing qualities where areas are naturally cooler, less polluted and less humid. Consequently, this tactic is more than a pragmatic response, instead reflective of Rahm's interest in designing space through voids, particles and atmospheres rather than lines and forms. A polarity of conditions is established, with hot spaces necessary to establish cool ones thereby 'creating spaces by acting on difference' (Rahm 2014). Space emerges through the transformative boundaries of atmospheres and conditions, not as hard spatial delineations. This concept extends into the graphic representation of the park as points and dots, where space is communicated through a graduation of light and colour rather than sharp demarcation of form. The Coolia, Dryia and Clearia establish an atmospheric structure for the park as shown in Figure 3, with circulation systems conceived to link similar climatic lands. These distinctive climatic conditions offer the rationale for siting major program and activities. Sport, for example, is sited within areas of low pollution and humidity, water games placed in high humidity areas and indoor programs.

The insertion of climatic devices at strategic points is arguably one of the more controversial elements of the park. The devices offer 'a contemporary extension of traditional furniture of parks,' operating like the pavilions, grottos, trellises and niches found in older parks, and providing a texture of sensory experiences of refuge, delight and interest (Taichung Gateway Park International Competition Overview, 2013). These devices are designed to augment the existing conditions and offers a 'tool box' of approaches including ultrasonic speakers to keep mosquitos away, artificial water devices such as rain fountains for evaporative cooling, dry clouds for removing humidity from the air, depollution techniques and passive cooling techniques.

These technological interventions are supported by detailed planting regimes, featuring plants with particular performative attribute. For heat reduction, *Acer serrulatum Hayata* were selected for their large and dense canopy which provides maximum shading, for pollution the conifers *Calocedrus formosana* were nominated for their ability to absorb particulates from air, while for humidity *Ficus microcarpa* were chosen for their capacity to capture water by arial roots. Together these design strategies merge technological and biological performance to propose a twenty-first century response to climate change.

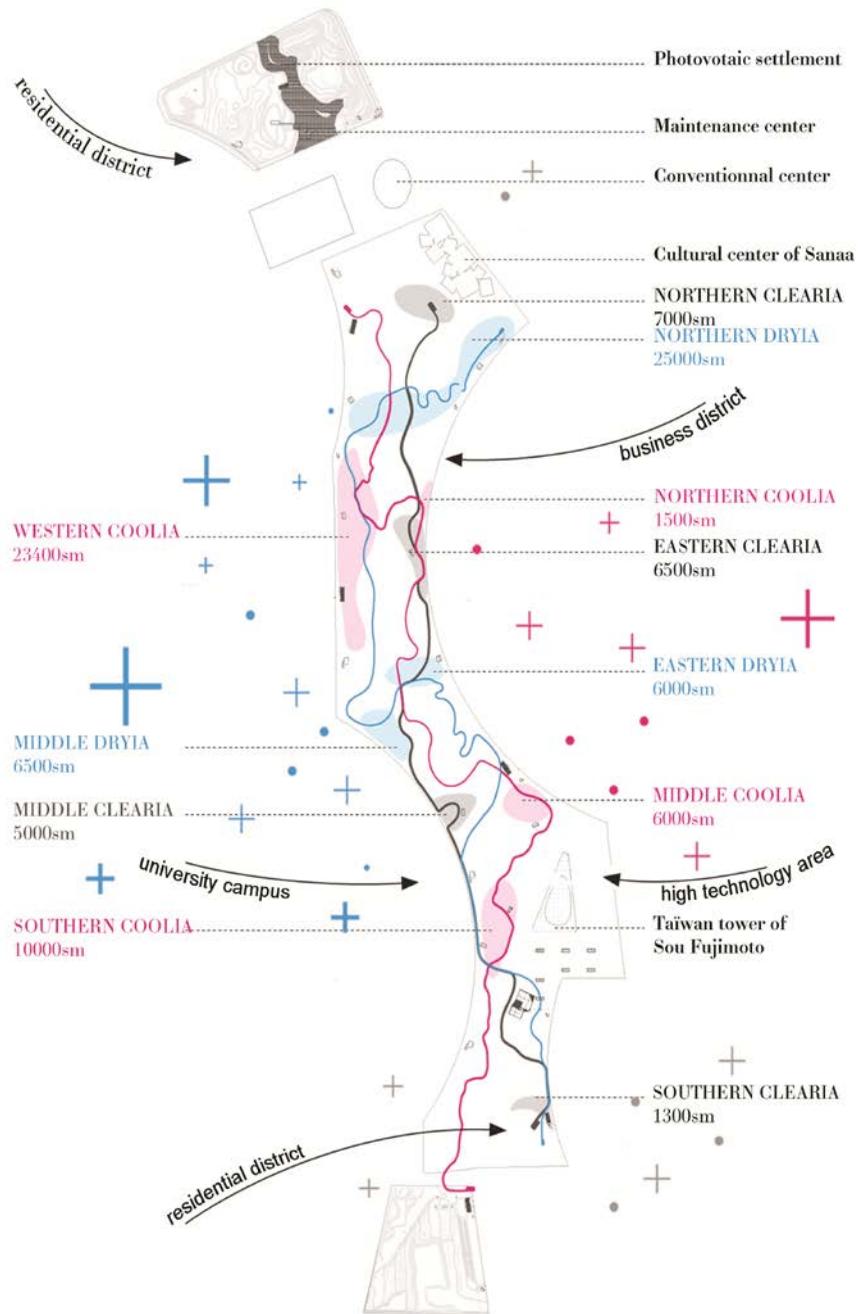


Figure 3: The 'Climatic Lands Structure' for the Park emerged through the intersection of the thematic masterplans developed from the simulations (Source : Taichung Jade Eco Park, Taiwan, 2011-2016/ Philippe Rahm architectes, Mosbach Paysagistes, Ricky Liu & Associates)

## 4. Technology and Nature

Such an explicit manipulation of climatic phenomena, as demonstrated in Phase Shifts Park is rare in the design of open space. For Rahm, working with external conditions presented a very different design challenge to engaging with architectural spaces. In his previous work, states Rahm (2014) ‘the decision about temperature was not mine,’ instead determined by regulations, ambitions for energy consumption or comfort indexes. In the case of the park, the design team proposed a ‘graduation of place’ with wind speed the only parameter that could be definitively controlled by the climatic devices. Standing under the Anticyclone device shown in Figure 4 for instance it was possible to experience a reduction of temperature by up to six degrees in June, producing a temperature of 29 Celsius compared to 35 Celsius in surrounding space. This reduction however is not a baseline standard, instead always relative to the fluctuating external conditions.

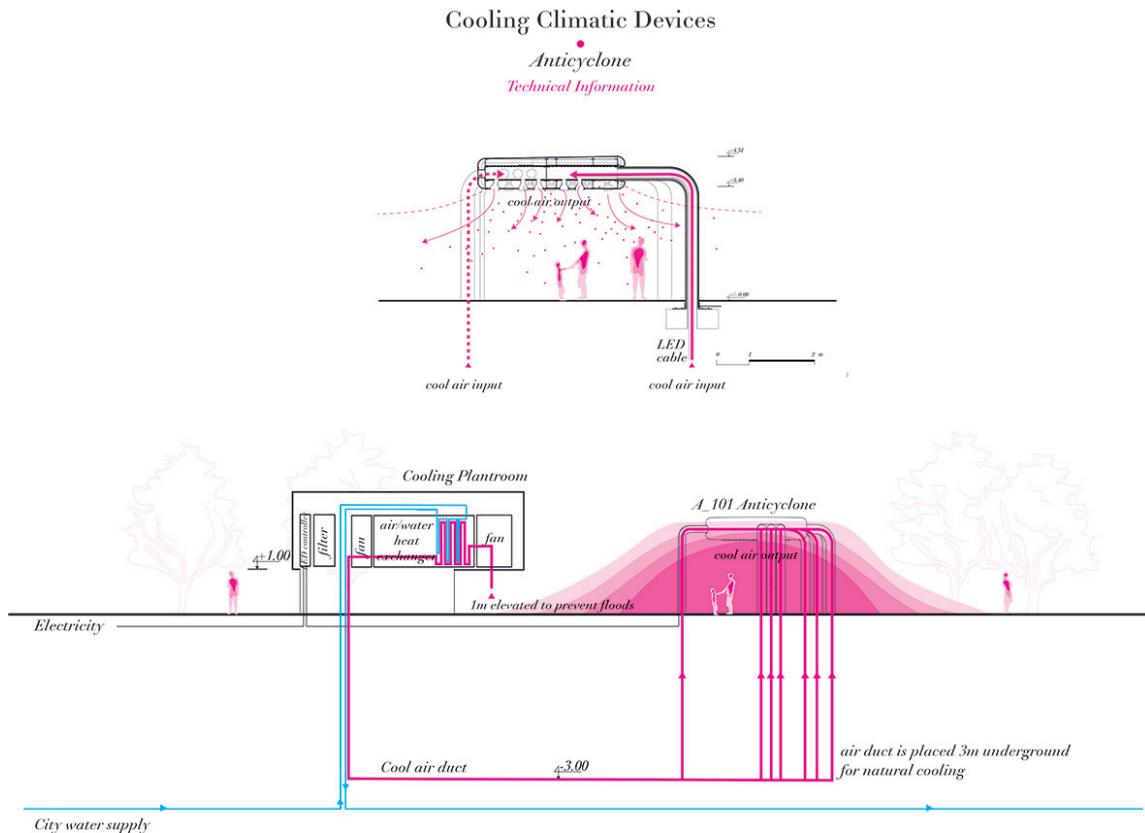


Figure 4: Cooling Climatic Device (Source : Taichung Jade Eco Park, Taiwan, 2011-2016/ Philippe Rahm architectes, Mosbach Paysagistes, Ricky Liu & Associates)

Here we begin to see clearly the different design tactics regarding atmospheric performance that underlie the Gardens by the Bays and Phase Shifts Park. In the case of the park, the external conditions are constantly evolving, with any design manipulation understood as a factor of graduation rather than absolutes. While design interventions can offer a relative improvement of conditions, it is impossible to definitively achieve performance criteria. Further the added value of combining biological performance with technological intervention will only become apparent over time as the living system becomes more established. In contrast, the smart environmental infrastructure driving the design of the biome conservatories and the Supertrees presents a more prescriptive outcome, with the processes of digital simulation offering more accurate predictions of performance.

Of further interest are the different responses to the use of technologies within the schemes. Whereas the design of the biome conservatories is championed for its design and engineering excellence, including winning the 2012 World Building of the Year, Rahm's climatic devices attract mixed reactions, despite their reliance of renewable energies (solar) and passive cooling principles. The insertion of what are perceived as 'non-natural elements' into a landscape is viewed with hesitancy, whereas conversely the application of sustainable technologies within a more explicit architectural program is championed. Yet are these not the same thing? Both are delivered in an energy efficient sustainable manner, one to improve the comfort of external space for people, the other to develop a more contained space appropriate for plants.

We argue that these contrasting responses reflect larger anxieties concerning the application of technology as a dystopian replacement to nature. Why replicate nature when you can simply plant a tree, and further isn't technology the primary cause of environmental issues in the first place? This argument is not without merit. For example Dutch artist Daan Roosegaarde's *The Smog Free Project* (2014) uses patented ion technology to make the 'largest air purifier in the world' to create the cleanest park in Beijing. The project is accompanied by the marketing idea of creating souvenir Smog rings from the particles captured from the air, with each ring representing the cleansing of 1000m<sup>3</sup> of polluted air. Much emphasis is placed on the development of a 'smog free movement' promoted through exhibitions and public events. Nowhere in the extensive promotional material however is there mention of the energy requirements and energy source necessary for the purification process. This raises questions over whether the energy source remains brown coal, which creates the irony of the purifier both cleaning and contributing to air pollution. But beyond this question of energy, the *Smog Free Project* also presents a very limited response to the broader question of pollution and the performative role of open space in the Chinese City.

## 5. Conclusion

As we have highlighted in this paper, Gardens by the Bay and Phase Shifts Park demonstrate a comprehensive engagement with environmental conditions and phenomena, using technology to enhance design processes and the performance of constructed spaces and systems. Importantly these design approaches introduce a new aesthetic into the design of open space, merging the artificial with the natural as reflected in Rahm's climatic devices and the iconic Supertrees. Rahm (2014) sees no difference between trees and machines, and is comfortable with the interaction between the natural and artificial, such as the potentially surreal experience of the park visitor uncovering a strange machine within a wild forest. In a similar response Andrew Grant (2014) states that the Supertrees should not be considered as a replacement to nature, nor design 'elements' to be reproduced in other locations. Instead, he highlights their origins in a very specific design context, emphasising their value in re-

conceiving infrastructure to operate intelligently to address environmental issues and limited energy resources. While some critics might react to the insertion of technology into what they perceive as a 'natural landscape,' we argue that the future of the twenty-first century urban park in the mega-urbanism of the Asian city lies at the very intersection of biological and technological performance.

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