# The Marriage of Built and Green Environments **Feasibility of Container Tree Planting in Urban Streets**

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The requirements of a tree are few and simple: healthy soil, air, water, and light (Yang et al. 2005). We all know that trees have grown without human intervention for thousands of years, but why are the trees that we plant in cities incapable of fending for themselves? Why does it take several years of care to be sure that an urban tree will survive its infancy?

Unfortunately, urban forests, towns, and cities have not been designed according to the laws of nature, but by those of human supply and demand (Ridder et al. 2004). Urban trees are included as amenities and established in an artificial habitat that usually falls short of supplying their basic needs. In an urban setting, trees are further stressed by pollutants and human-inflicted injuries. The need for care is necessary not only for their survival and well-being, but also to protect people and property from the hazards that trees can impose when abandoned in a hostile environment (Dwyer et al. 1992).

## Conditions of the Urban Habitat

The urban underground habitat is particularly ill-suited for healthy tree growth. Typically, the soil is a mixture of subsoil, bedrock, and construction wastes, compacted to a density that eliminates 80 to 90 percent of the soil porosity, through which air and water must flow. Drainage is frequently so poor that heavy downpours tend to result in a waterlogged environment, in which tree roots are unable to grow. Often, the nutrient levels are too low for normal tree growth or too high in sodium or trace elements, making them toxic to trees (Brack 2002).

In addition, urban trees tend to be planted close to concrete or asphalt surfaces. Compacted soil conditions and greater moisture and oxygen levels on the topmost surfaces of the soil encourage tree root growth to occur close to the surface, forcing the roots to grow near roadways and footpaths. When the man-made structure becomes damaged, the roots are often cut back or the tree is removed.

The urban habitat can be just as harsh above ground as it is below. Buildings and vehicular right-of-way often occupy the spaces where a tree branch normally grows. The consequential pruning may be performed with little regard for the structure or health of the tree (Urban 2008).

The light a city tree receives can vary from full sun to full shade. Trees next to buildings can be shaded for most parts of the day, or they can be subjected to full sun or light reflected from walls and windows. Furthermore, city trees are frequently doomed to a shorter lifespan as a result of improper management in the production nurseries.

One of the most common flaws in container-grown stock is circling roots. Trees that cannot develop a normal root system will be unstable or their roots may strangle another root and eventually kill the tree. It is commonly accepted that a good part of the root system in container trees is constrained by the size of the container, and this is likely to have an impact on the growth of the tree in general.

The pursuit of at least some degree of proficiency in container culture is therefore necessary to ensure success and take container tree growth to another level. The principles applied to conventional tree planting can, and in most cases should, be applied to containerised trees. Due to the small volumes of soil and restricted sizes of containers, the extent of the container tree culture's success will depend on knowledgeable selection, preparation, and manipulation.

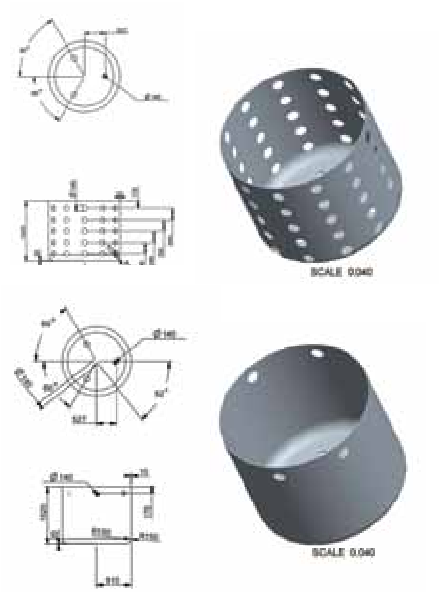
Container trees have been used predominantly in gardens. Therefore, expanding their application beyond gardens to streets and roadside verges is considered novel. Such unique applications are ideally suited for urban cities, where space is limited and the coexistence of grey and green infrastructure is becoming more critical in achieving a sustainable environment.

The benefits of greenery to any city landscape are well understood, and they extend beyond human comfort to the human psyche. However, for economic growth, the expansion of infrastructure is inevitable (Lee and Maheswaran 2011). These conflicting approaches may be overcome through the advent of green infrastructural solutions (Nowak and Dwyer 2007).

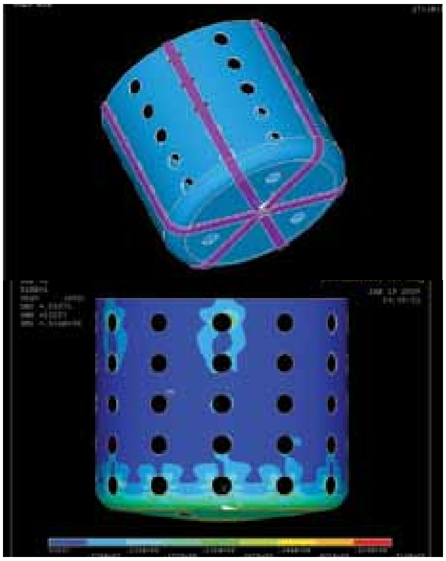
## Design and Development of Containers

In this research and development project led by the Centre for Urban Greenery and Ecology, large containers (with a diameter of 1.8 metres and depth of 1.5 metres) were developed with the intent of preserving large trees and keeping younger ones in place for several decades to allow extended periods of uninterrupted growth alongside large volumes of soils.

Apart from the overall growth of the tree, aspects of structural strength had to be carefully considered in the container design.



1. Two container designs (with [top] and without [bottom] drainage perforations) for below and above ground conditions respectively.



2. ANSYS is an engineering simulation software suited for simulated-driven product development.

The ANSYS simulation software was used to depict the load conditions and distribution within the geometry of the container, based on the assumption of a fully laden container weighing some 8,500 kilograms. This assisted with the material selection and design development. In addition, materials were studied using numerical modelling and accelerated age tests to identify the maximum loads and strains that each type of material could withstand.

The performance specifications focused on the infiltration characteristics of the soil as well as the drainage potential of the container. Drainage was envisaged to be achieved through the puncture of holes along the walls of the container. This was necessary to avoid waterlogged conditions, but care had to be taken at the same time to avoid excessive loss of water, which is detrimental to tree growth.

Therefore, an intricate balance of the flow of water in and out of the container had to be established to meet the desired expectations of infiltration. Related studies were conducted through the use of peziometers and tensiometers (devices used to measure liquid pressure in a system) placed at variable depths within the soil profile both inside and outside the containers.

Another desirable performance specification was container mobility. This was required to facilitate the relocation of trees as and when a site is compromised as a result of developmental works. The feature of mobility supports the objective of tree preservation when uninterrupted growth can be achieved despite relocation.

## Implementation

Since the inception of the study, two sites, primarily roadside verges, have been implemented with container trees between 2011 and 2013. The implementation of more trees is still ongoing. The lessons acquired have reinforced our need to better understand what works for urban trees and what does not. Aspects such as species selection, soil type, nursery stock, insects, and diseases have been shown to have strong influences on the success of this technology.

Circling roots, which tend to go unnoticed, will progressively lead to diminishing vitality. Trees that operate under such stressful conditions will become more susceptible to attack by insects or other bio-agents while the underlying cause of stress goes unnoticed.

Species with the ability to cope with higher soil water will thrive over species that cannot withstand waterlogged conditions. Soil types with a greater proportion of sand will be the key to ensure that moisture moves freely in and out of the container. However, to achieve this, the soil condition around (and/or surrounding) the container becomes highly relevant. While water may flow freely given the ideal soil conditions provided for within the container, the flow will be greatly limited if the surrounding soil conditions are not optimal (for example, if they are highly compacted).

Nevertheless, when the various criteria are carefully adhered to, the application of container trees will complement other forms of public greenery. Container trees can provide shade, improve the aesthetics of the space, and are advantageous to the human

3. Filling the large container during implementation.

4. Installation of large container for street tree planting.

5. Relocation of container trees.

6. One of the street sides where container trees were implemented.

sensory experience. Furthermore, well-planted trees not only are cost-efficient, but also benefit the overall ecosystem and bring psychological, physiological and economical benefits to the urban community at large (Choumerta and Salaniéa 2008).

The strategy for implementation has been multifaceted. For example, container trees have been designed in this research project for the Formula 1 Grand Prix race tracks, where the greenery along the tracks has to be moved annually to accommodate temporary seating and light fittings during the race season. Following the race, greenery is expected to return after the structures have been demolished. The key feature of container trees, their mobility, provides an elegant solution in this particular example.

By contrast, an alternative container design that allows the container to be buried in the ground has also been developed. The intent of this design is to facilitate long-term planting and provide for redevelopment that may result in the need for relocation.

Tree stability is a concern with container trees as well as trees planted in true ground. In fact, stability is even more important for container trees, given the limited space the roots have to explore (within the confines of the container). More importantly, the highly populated urban environments in which the container trees are likely to be deployed actually increases the need to ensure trees are stable inside the containers. The failure of a container tree in an urban environment will have serious implications on human safety, property, and activity. The risks of damage to people and property as well as economic losses warrant the need for scientific and empirical investigations in the field of container tree stability.

## Future Directions

While numerical and controlled studies have been undertaken in this project, the importance and relevance of tree stability in an urban environment necessitates new research beyond computational analysis and laboratory conditions. Field trials under naturalistic environments with a focus on stability and/or failure will be considered in future research. They should also be tested under urban microclimatic conditions.

The current methods of managing urban trees include pruning and visual assessments of mechanical strength by trained arborists. Such methods provide only limited data to assess tree strength and stability, and all methodologies stem primarily from a static approach to estimate loads (James and Haritos 2008).

More recent research on the measurement of dynamic wind loads and the effect on tree stability is giving a better understanding of how different trees cope with winds (James and Hallam 2013). Though all the work done has focused predominantly on trees grown in true ground, the empirical knowledge is relevant and applicable to container trees (Mattheck et al. 2003).

Clearly, the way we construct the urban environment has significantly impaired the success of new as well as existing plantings (Georgi and Dimitriou 2010). All too frequently, the site plan in an urban project is conceived based on the assumption that the trees are going to become very large and that the canopy will knit together so the full suite of benefits can be experienced. Most of the time, however, the trees do not make it to a size sufficient to achieve these effects (Niemelä et al. 2010).
It is important for us to be aware that the

natural model of tree roots are broad and flat (root systems of a tree are thin in depth but extensive in area), which often conflicts with typical urban planting schemes (Jim and Chen 2008). When trees are successful under urban conditions, it is usually correlated with a break out of the confined areas by the roots. Though these trees may grow to fairly large sizes, the roots would have used up much of the available soil, and the tree leaf area index is unlikely to have changed significantly despite the increasing tree mass. In essence, there will be the same number of leaves or the same leaf area required to support the increasing tree mass. Although the tree can continue for a very long time under such conditions, it will weaken over the long term and eventually will succumb to disease or drought that will end its life.

One potential approach to address this issue will be the establishment of mathematical formulas aimed at calculating the odds of success of any given tree from an engineering perspective. This would be ideally similar to an engineer who calculates how much water will flow through a pipe. The formulas should indicate the likelihood of the tree being sound and alive in the next 20 years (or more). Such information will be the key towards the unification of the built and natural environments (Morancho 2003).

Much research remains to be done given that the industry is not even close to having baseline data to build a formula on (McPherson 1992). However, the concept and actualisation of a container to accommodate large trees is a bold but necessary step and solution towards the creation of sustainable urban streetscapes.

Our recent scientific findings are important for revealing what it takes to optimise the survival and growth of trees in the urban streetscape. With this knowledge and with the application of some of the good science and innovative growing methods we have at our disposal, we can start to improve on the quality of tree care in urban environments for our future generations to reap the benefits.

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