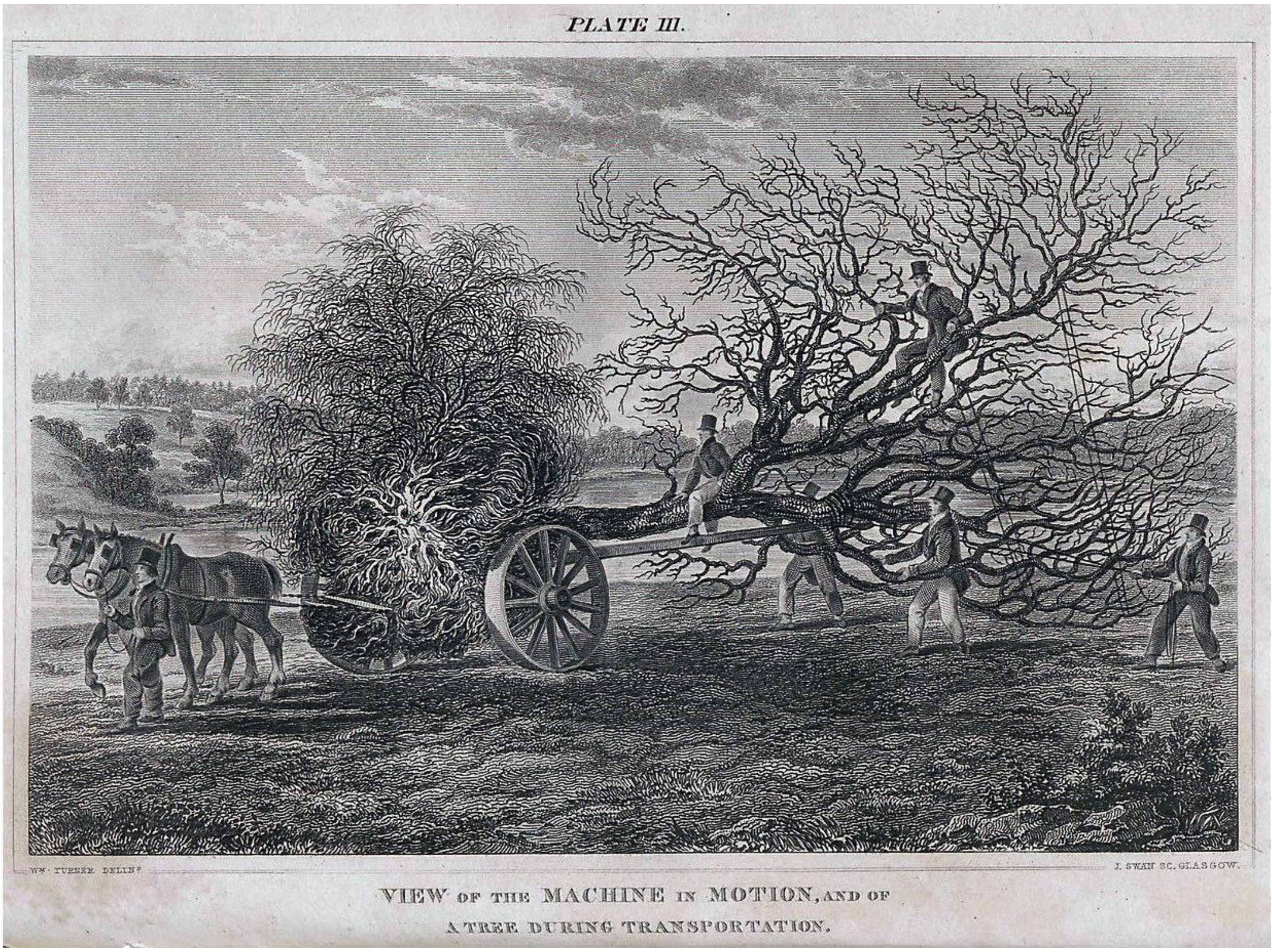


Illustration of a bare root tree transplanting in 1828 (Steuart, 1828)

The Development of Tree Transplanting in Hong Kong

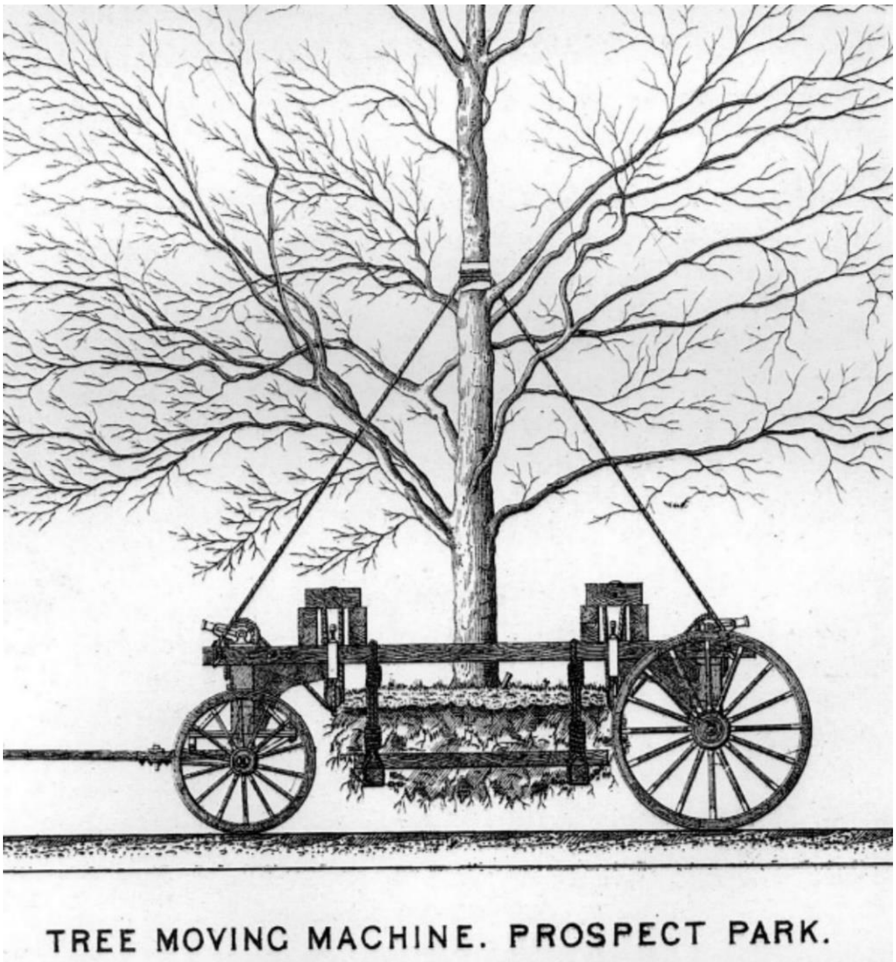
By Ian Robinson & Jonathan Picker

Part 1 - Ian Robinson

Transplanting of large trees is not a new idea. In 18th-century Britain, Charles Bridgeman, William Kent and Lancelot Brown produced landscapes on a large scale that required the clearance of vast tracts of land in order to create new grand vistas for their clients. This of course led to the felling of many trees. However, some were successfully transplanted using all sorts of interesting devices and contraptions featuring ropes and pulleys that generally called for transporting the trees in a vertical position. It was Lancelot Brown that first came up with the technique of moving trees in a horizontal position by the use of his ‘Tree Moving Machine.’ This still required the use of horse drawn vehicles and substantial manpower resources but the rich landowners calling for such services could easily afford it. However, the techniques may not have been quite as successful as everyone imagines. At least one 19th-century commentator has remarked, “Such trees for several years grow so slowly as to remind me of a stricken deer”.

Hong Kong

Fast forward then to Hong Kong where in the 1980’s, landscaping was being introduced on a grand scale to the New Towns and in infrastructure projects. A large number of existing trees in old estates needed to be felled to make way for the new developments. An alternative solution to the apparent waste was to transplant many of them instead. At that time,



From the 1861-1873 Annual Reports of the Brooklyn Park Commissioners

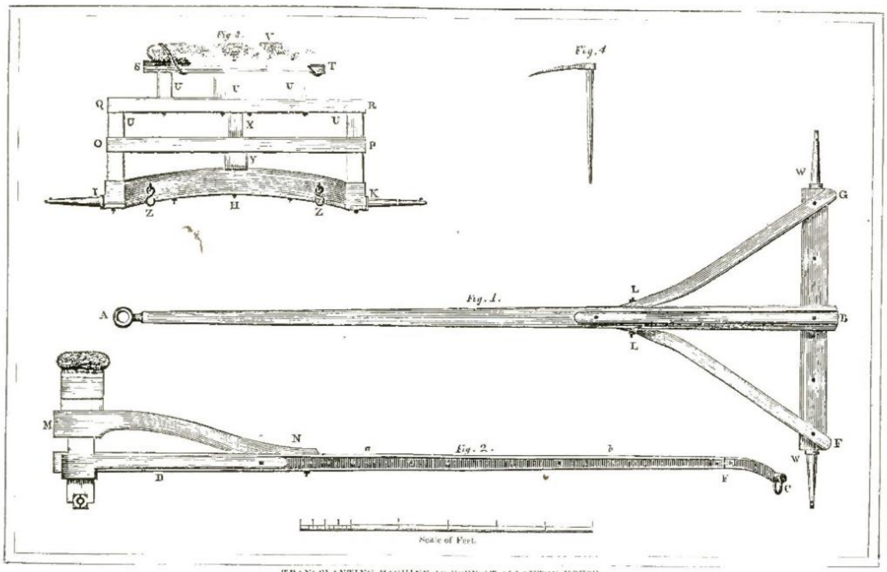
several General Specifications for Soft Landscaping were in development for new planting, Hydroseeding and other topics; but none really addressed the question of transplanting existing trees. It was generally assumed that the "gardeners" knew how to do it.

In 1991 an excellent SILTECH report, *Tree Planting and Maintenance*, produced by a government landscape architect Richard Webb (Webb, 1991), created a lot of new standards for the protection of trees on construction sites – how to plant and maintain new trees, etc. Practitioners and landscape architects alike welcomed this. The information it provided is still being referred to even now. I think most landscapers I know of from that era still have their own copy on their shelves. However, it had only a very limited section dedicated to "Transplanting" and really only addressed smaller trees and shrubs.

In the 1980's and 90's, the prices for relocating trees under the government term contracts were extremely low, barely more than the prices for new tree planting.

These were not just small trees, but trees with extremely large trunk diameters of 400mm, 600mm, 800 mm etc., that were expected to be transplanted for only a few hundred dollars. The point being that very little technical or practical consideration was being given to the topic at the time.

Another factor that came into play was the District Land Office's requirement for what many landscape architects and developers considered as extensive and unreasonable planting requirements in new developments by way of compensation for large numbers of trees that were being proposed to be felled. To combat this many more unsuitable trees were consequently labelled as "transplantable" during the design process.



TRANSPLANTING MACHINE AS USED AT ALLANTON HOUSE.

The Newman Tree Frame

Improper transplanting, incorrect species selection, poor quality specimens, and poor tree pruning techniques performed 30 years ago has resulted in many of the hazards that we now see in trees as they become older such as instability in storms, weak branch attachment, etc.

New Beginnings

The introduction of the International Society of Arboriculture (ISA) to Hong Kong around 2006 has had a remarkable and substantial impact on how new and existing trees are now managed and viewed, not only by landscape managers and arboriculture practitioners, but also on how the general public perceives trees.

In 2010, the establishment of the HK government's Tree Management Office (TMO) in response to tree failure incidents and has led to significant improvements in the dissemination of knowledge and best management practices to the industry using templates and guidelines imported from overseas.

Regarding tree transplanting, it is only, as recently as September 2014, that we have seen the introduction of some specifications and technical guidance notes on the topic that addresses some but not all of the issues.

Most practitioners would probably agree that almost any tree species and size could be transplanted provided that sufficient funds are applied to the process. This may occasionally involve transplanting whole ecosystems by capturing very high proportions, if not all, of a tree's root system. However, to relocate trees using this approach in Hong Kong is extremely expensive and several favourable situations need to present themselves for this to be a viable solution:

1. The donor and receptor sites need to be situated relatively close to one another
2. The donor and receptor sites preferably need to be located within the same construction site boundary
3. Transportation along public rights-of-way can be avoided
4. Access for large-scale mechanical plant and equipment and to their working area needs to be possible.

These types of situations are few and far between and each must be addressed according to its own merits – whether the tree relocation is for political or cultural reasons – and this may only apply to a few particularly sensitive tree specimens.

For all other trees, the current practice has been simply to increase the size of the root ball from what used to be a very minimal root area to now something close to 8-10 times the trunk diameter in order to retain more roots. The result has been the substantial increase in the volume of soil that needs to be transported with the tree. Consequently, the techniques for relocating trees involves ever-increasing sizes of plant and machinery to the extent that the transplanting exercise becomes much more of an engineering solution rather than an arboricultural one.

Of course, with the increase in complexity of the engineering solution the cost of relocation increases exponentially as well.

It is worth pointing out the enormous sums of money poured into the transplanting of some individual trees. Some sums, ranging from $250,000

to $4,000,000 per tree, can never be recovered from a purely economic cost-benefit analysis over the lifetime of the trees so there has to be another motive to do it.

The benefits of trees to the community as a whole have now been well documented elsewhere so I won't dwell on those here. However apart from the many intangible benefits provided to the community, there are numerous less obvious economic contributions that trees provide. Carbon sequestration, storm water management, prevention of erosion, contribution to the physical health of the community, reduction in respiratory ailments, pollution removal, and measurable increases in property values all represent measurable monetary value. However, most of these economic benefits only really start to be realized when the newly planted trees are over the age of 15 years. This is generally the break-even point after the initial cost of planting has been taken into account.

After this period the trees become net contributors of economic returns for the community. These become even more significant once the trees reach maturity as the return on initial investment is rewarded many times over perhaps 50-200 times ROI.

Therefore, it is essential that new trees must be given the optimal chance of surviving up to and beyond these early formative years in order to maximize the return on investment. Selection of quality nursery stock, correct planting, early pruning, and correct planting location can all help address this issue. For transplanting, given that the costs are so much higher than new planting and that the trees often take years to recover from the process, it is even more important that trees are given the best opportunity to survive over the longer term and that the implementation costs are kept as low as possible.

This means that we, as landscape managers and landscape architects, need to be very careful about which trees we select to become candidates for transplanting.

From my personal experience as an arboricultural practitioner in Hong Kong for almost 40 years, a significant factor contributing to the failure of the transplanting process is that far too many unsuitable trees are labelled as "transplantable" in the early-stage tree surveys of development projects.

There are many different reasons why trees should not be labelled as being suitable for transplanting any one of which should have resulted in them being classified for felling instead. For example,

the reason for rejection could have been based on size, poor form, structural condition, accessibility, species, age, poor health, angle of slope and many other reasons. Much more attention should be paid to this part of the process by field staff than is currently the case as this often predetermines the final recommendations proposed during the planning/design stage.

The desire to preserve as many trees as possible at this stage is understandable and commendable. However, the preservation of these trees through transplanting is a false economy with the long-term financial loss to the community being greatly underestimated since many of them will never reach full maturity, or will have significantly reduced amenity value, or are potentially dangerous.

Two common practices and one contractual problem that we have yet to overcome are:

1. Creation of the offsite temporary holding nursery;
2. Segmented or staged approach to advance root pruning preparation and;
3. The length of the Defect Liability Period (DLP) for transplanted trees.

Regarding item 1, the introduction of temporary holding nursery was seen as a way to reduce the number of trees that were being removed from development sites that would otherwise end up in the landfills. During the 1980’s and 1990’s many old areas of HK were being redeveloped into nice new public housing estates or luxury developments and these old areas had thousands of beautiful trees growing in them many of which were already perhaps 30-50 years old. Among the mix were many species such as *Delonix*, *Bauhinia* and *Albizzia* with wide spreading crowns as well as very tall *Aleurites* and enormous *Cinnamomum* trees, which, at their donor site, were all splendid trees. There was some pressure to retain these somehow but almost all of their initial high amenity value was lost as soon as they were moved offsite to these temporary holding areas. Many were extensively pruned to comply with the size limitations for transportation on public roads. In many cases these trees remained in the temporary holding areas for between 3-10 years pending a return to the development site while being held in makeshift small pits or even fabricated containers. Fortunately, this practice has been finding less favour in recent years. In my opinion this offsite nursery temporary holding area practice should be abandoned completely.

If sufficient space can be found within the boundary limitation of a development site – such that trees do not need to have their crowns pruned – this may be an acceptable alternative.

Regarding item 2, when roots are cut it does stimulate the production of new fine roots from the cut end. However, these newly regenerating fine roots are very fragile for many months following cutting and they do not contribute any substantial benefit to the transplanting process. Transplanting is already quite stressful for trees. The addition of root pruning stages prior to transplant results in additional stress. In fact, the energy put into creating this new growth depletes the food reserves which should be being deployed elsewhere. It also can lead to the decline of a tree's immune system and overall health. As a consequence, the tree simply has to spend more time in this temporary "limbo" situation than is good for it. By having these pruning stages we are only creating problems for the next generation to manage.

The results of research findings are conflicting as some indicate that the length of time between the pruning intervals had some influence on the outcome. It has been noted that for some species a longer duration between pruning stages was more successful. However, in other cases the reverse was seen to be more effective.

I have never quite understood the rationale for the staged pruning methodology that limits the root pruning intervals to 90 days or even less that we see in some current specifications in HK. If this period was to be extended for a whole growing season between stages this might then prove to be effective for root regrowth. I believe that we may have inherited this idea from some old British standards back in the late 1980's. Unfortunately, in Hong Kong the time constraints in development projects now call for much shorter time intervals between advanced root pruning stages in order to avoid costly delays to the construction programmes. This, together with the fact that many projects commence at inappropriate times of the seasonal cycle for root pruning when root pruning during periods of active shoot growth can prevent root regeneration or when root loss from root pruning during active shoot growth can suppress crown development suggests that this practice should be abandoned altogether.

More recent studies and practice in the USA now advocate transplanting trees in a single operation with no staged root pruning.

Regarding item 3, construction/ building contracts have a DLP of 12 months following completion. Arborists, however, understand that it can take several years for the impact of excessive tree root removal caused by trenching or excavation during the construction phase to become apparent in the tree as crown dieback. The current 12-month DLP is too short for latent damage to become noticeable. This period should be extended to 3 years after transplanting.

While we already know that individually selected large specimen trees can now be successfully transplanted for

substantial sums of money what has not really been addressed to date is how to handle the relocation of the significant numbers of trees in the mid-range size categories ranging from 150-400mm diameter that are probably between 10-30 years old without incurring these same prohibitive costs.

In the late 1990's we introduced the Newman Tree Frame to HK, which we obtained from Civic Trees one of the UK's best-known tree service companies. This device was designed to overcome the problem of how to ensure that the trees were lifted by their root balls and not by their limbs or trunk. This system had been used successfully for many years in the UK and Europe and is still used now but it did not find favour in HK at the time due to the need to insert a steel bar drilled through the trunk to help bear some of the load.

Contained Trees vs. Open Growth Trees

Some studies show that there is a strong correlation between the original donor locations and the degree of success for certain species.

Quite often trees which are situated in raised planters or restricted planters such as those growing on podium decks or some street tree pits can have a reasonable chance of survival after transplanting as the majority of roots can be captured.

For example, in the redevelopment of Pacific Place, Admiralty between 2008-2011 where all the existing trees had to be transplanted these had been growing in their own 'pots' or raised planter beds for over 20 years so it was comparatively easy to uplift and replant these trees without removing any roots and without experiencing any failures.

Most problems occur in establishing trees that have originally been growing in open ground or woodland areas where roots have been presented with opportunities to spread far and wide.

Consequently, too many trees transplanted in the conventional way experience "transplant shock". This is the tree's response to water stress arising from the sudden water imbalance within the tree that occurs as a result of the root-to-shoot ratio being altered after the loss of a substantial amount of the water-absorbing roots.

The proportion of these essential water absorbing fine roots (<2mm) retained during the traditional transplanting process is generally between 5-18%. (Gilman, 1988)

The reason for the removal of these essential water-absorbing roots – which are often located further away from the trunk – is the reduction of the overall soil volume, and consequently the weight in the root ball to facilitate ease of lifting and transportation.

The large woody roots of the root plate and outer root systems determine the overall size and shape of the whole root system; but it is those extremely fine roots attached to the fine non-woody roots that make direct contact with the soil which are critical for tree survival. These fine roots enable trees to uptake water and nutrients. These roots are generally only 1-2 mm in length or less than 1mm in diameter and are very easily damaged or broken during manual excavation. Such fine roots tend to stay very close to the soil surface. Different publications and studies will often state that 99% of tree roots can be found in the top 1.0 m of soil with 90% being located in the top 20-30cm. More significantly research shows that 99% of these fine roots can be found in the uppermost 10-13cm of soil with 74% located in the top 7cm and 67% of fine roots < 2mm being found within the top 5cm. (Dobson, 1995)

In Hong Kong where soil cover is actually very thin and generally based above an underlying granite subgrade these proportions could be even higher. In woodlands these fine roots can be found high up amongst the leaf litter. This being the case why do we still insist on creating these huge 1.0-2.0m deep root ball boxes to accommodate soil which contains little or no root mass?

We all know the adverse impact that compaction of the soil at the surface has upon the fine roots as they become starved of oxygen. Similarly, the loss of these fine roots by excavation, trenching, level changes are all damaging to the tree and one has to ask at what point does root such removal become fatal.

Since we understand the value of these fine roots, we must prioritize their retention during transplantation. This will require a review and adjustment of the current tree transplant methodology.

Looking to the Future

So what do we do now if we want to reduce the overall weight of the root ball so that smaller machines can be utilised for transportation while simultaneously still preserving as many of those water-absorbing fine roots as possible? How do we ensure that the transplanting process can be completed within a few days rather than over several months, as is the current practice?

Fortunately, there is some good news on the horizon. Bare root tree transplanting has been difficult in the past because there was no simple way to remove the soil from tree roots without severely damaging the fine roots. Practitioners in the USA have been using the airspade as a tool for aerating compacted soils for many years; but now the science has started to demonstrate that this can also be used for creating completely soilless root balls. Since research from several leading international tree experts over the last 5 years or so has reaffirmed this, we can now begin to apply these same principles to the transplanting of large trees in their bare root form. This has already been carried out in Hong Kong too and in the following section we will explain the process in more detail.

Part 2 - Jonathan Picker

Bare Root Tree Transplanting

Bare root tree transplanting is a method that involves the complete removal of all soil from a tree's roots prior to transplant. Recently, this method was used for the transplant of five *Ficus virens* in Hong Kong, ranging from 160mm to 300mm DBH. Using an airspade and airvac is a viable way of safely removing soil while retaining tree roots, including fine (<2mm diameter) roots. In this case, two airspades, one airvac, and two air compressors were utilised.

The airspade is a handheld device operated by one person. Its nozzle is designed to focus compressed air, increasing the rate to approximately 2,500km/h. During operation, high-speed air is forced between soil particles, effectively breaking them apart.

The airvac is similarly powered by compressed air. It is primarily used in combination with the airspade and allows for safe and efficient vertical digging without damaging objects such as tree roots or underground utilities.

Soil Condition

Prior to transplanting, the soil conditions were analysed for each tree and found that the soil layers were similar to those of many built environments. There was a layer of topsoil approximately 250mm depth on top of a layer of highly compacted soil (likely 95% proctor density). It was difficult to penetrate the soil with a handheld compaction tester. This signified that tree roots would equally have a difficult time growing through the soil. From this finding, it was concluded that the tree roots were likely growing primarily within the top 250mm layer.

Timing for Transplanting

The trees were transplanted in late October, early November when shoot growth is less active. This is in line with some published research that it may be better to transplant trees during the time that branch shoot growth is not active and therefore, the tree is not placed under further stress (Buckstrup & Bassuk, 2000). Since it is known that trees have a limited supply of energy that is used for all aspects of survival, it is important to allow the tree to

focus on one thing (root development) as opposed to multiple things (root development in addition to shoot growth).

"Transpirational demand of leaves and shoots is lower in fall than spring because ambient temperatures are cooler, days are shorter, shoot extension has ceased, and plant cells have lignified." (Good & Corell, 1982) When roots of fall-transplanted trees get a head start establishing before new spring shoot growth begins; root-to-soil contact is improved as a result. The roots of spring transplanted trees, by contrast, must compete for a tree's resources as shoot growth begins in spring (Buckstrup & Bassuk, 2000). (Hinesley, 1986) suggests that "fall-transplanted trees may do better because spring transplanting interferes with the production of root-produced hormones necessary for good shoot extension."

Branch Pruning

Since the trees would be transplanted in their natural vertical form, some minor branches were pruned to balance the weight distribution of the tree crowns during transport. Only these branches and dead branches were removed so as not to adversely impact the trees' health. This is important as trees have a limited supply of energy for all aspects of survival including branch growth, root growth, immune system, wound closure, and many other actions. Since a tree must allocate a significant amount of energy during transplanting and reestablishment, it is important not to burden them with excessive wound closure requirements due to pruning. Furthermore, it is important to retain as many leaves and branches as possible to maximize energy production.

Root Pruning

It is always better to retain roots rather than prune them. Using the bare root method, the majority of tree roots are retained during the process. This means that root pruning may not be required at all or if required, the diameter of roots requiring pruning is substantially reduced. Considering what is known about a tree's limited energy, it is highly recommended to carry out all transplanting works at the same time and move the tree immediately. This method will reduce the number of stressful periods for the tree from 3 (1st and 2nd stage root pruning and

Tree	DBH (mm)	Hong Kong Standard Specifications (10:1)		Bare Root Method		Root Area sqm % Increase
		Root Area Dimensions	Square Meters	Root Area Dimensions	Square Meters	
T1	300	3m x 3m	$9m^2$	6m x 6m	$36m^2$	300%
T2	160	1.6m x 1.6m	$2.56m^2$	4m x 4m	$16m^2$	525%
T3	280	2.8m x 2.8m	$7.84m^2$	5m x 5m	$25m^2$	218%
T4	300	3m x 3m	$9m^2$	6m x 6m	$36m^2$	300%
T5	200	2m x 2m	$4m^2$	4m x 4m	$16m^2$	300%

transplanting) down to 1 (transplanting).

In this case, some of the trees were growing in close proximity to each other and their interlocking roots needed to be separated prior to transplanting. A trench was dug between the trees using an airspade to expose the roots; and this allowed for proper pruning cuts by hand. Secateurs, lopper, or hand saw were used depending upon the root diameter. This also allowed for maximization of the root length retention for each tree while effectively separating the trees.

Root Characteristics

Tree roots are opportunists and grow where the environment is suitable for their development. During the airspade works, it was found that when roots came into contact with an obstruction, such as a kerb, they would turn a 90-degree angle and grow shallow along the edge of the obstruction. This likely occurs as required variables for optimal root growth were more available in the upper layer of soil than in the subsoil or underneath the obstruction. It was noted that shallow-growing *Ficus virens* roots would grow thick and woody. In addition, these specific shallow woody roots would send vertically downward growing roots called “sinker” roots. This finding is consistent with published research. Research has shown that, generally speaking, these sinker roots are present close to the trunk where woody buttress roots are present; however, it appears that in this case, these sinker roots were also present further away from the trunk (1-3 meters). One theory would be that trees growing in poor soil conditions form shallow woody roots and additionally also grow sinker roots from those woody roots likely to both support structural stability and increase water and nutrient uptake. It also may be a species-specific characteristic

or a combination of both. This would require further study to be verified.

Regarding the diameter and number of woody roots, this varied between the five trees and this, in part, may be related to soil quality and space. While one tree had large woody roots growing as far as 3-meters radius distance from the trunk, other trees had much fewer woody roots and much shorter distance from the trunk.

Retained Root Area

Assuming a 10:1 ratio, root area diameter to tree DBH (Anon., 2014), the retained root area diameter was doubled which led to an average of +328% increase in retained root square meter area for each of the five trees.

"The spread of woody roots and condition of fine roots moved with the tree are the major differences between traditional transplant and bare root transplant methods" (Watson & Hewitt, 2020). Regarding tree health, the most notable part was that bare root transplant, when done correctly, can retain more than 5 times the number of fine roots compared to the traditional transplant method.

Transport and Replanting

Due to the removal of soil, the overall weight of each tree was substantially reduced. A telehandler or crane lorry was utilised as needed to transport the trees approximately 1km to the receiving site. All of the trees were lifted from under the roots and the weight was displaced across most or all of the structural roots near the trunk at the same time. The trees were not lifted at the trunk in order to avoid cambial damage.

At the receiving site, shallow holes were dug by an excavator to match the dimensions (depth and width) of each tree's root system. The trees were placed and then thoroughly watered in to help the roots make contact with the new soil and begin reestablishment. A 10cm layer of mulch was applied for moisture retention and to promote prolonged soil quality.

Establishment Period

Studies have shown that "stress can reduce growth up to 40% during the initial years after [trans]planting while the tree is re-establishing its root system" (Watson, et al., 1986), and "can increase losses due to

drought stress and secondary pests and diseases, such as borers and canker diseases" (Watson & Hewitt, 2020). When a tree is under stress, its immune system is reduced. This can lead to secondary problems such as insect infestation or disease.

A higher retained root area also means a reduced period of establishment. The findings of (Watson & Himelick, 2013) and (Watson & Hewitt, 2020) show that in a 9-11 USDA hardiness zone [Hong Kong's subtropical climate is equivalent to zone 11], tree roots grow approximately 1.8m per year and the projected time to replace root spread for a transplanted tree is 2 years for a soil ball transplanted tree and 1 year for a bare root transplanted tree. This is, of course, assuming specific dimensions for root area as defined in those studies. However, considering a relative comparison between the two transplant methods, there is a clear pattern of 50% relative reduction in the reestablishment period. This has implications for improved tree health as well as reduced financial costs.

Traditional Transplanting Challenges

In (Pryor & Watson, 2016), they discuss a number of challenges that can be faced during traditional transplanting operations. One issue they discuss is that "moisture within a transplanted root ball can be depleted very quickly" (Watson, 1992). It is common that the soil of a root ball that is transplanted with a tree will likely be somewhat different or very different from the receiving site. Referred to as a "soil horizon", this differentiation of soil type can result in either too much (bowl effect) or too little amount of water retention. For example, if the surrounding soil at the receiving site is very dry, it may quickly draw the moisture out of the root ball.

During bare root transplanting, this problem is addressed by replacing all of the soil within the root area with existing soil from the receiving site resulting in no differentiation between the soil types. This may raise the concern that beneficial microorganisms and mycorrhizae may be absent from the new planting location soil. This is a reasonable concern; however, even transplanting a litre of soil from the originating site can soon populate the new soil. Proper site selection and soil conditioning are critical for success and can, when done correctly, even improve the long-term growth of a tree. Additionally, there are treatment methods available to further improve this need.

Another issue that (Pryor & Watson, 2016) addressed was that vibration during transport may also result in a detachment of the roots from the soil. This detachment could also potentially lead to root breakage. This is a non-issue for bare root transplanting as no soil is transplanted with the tree.

Questions About Bare Root Transplanting

One concern is that if all the soil is removed, fine roots need to connect with new soil after planting and may cause stress. This is true and may cause some initial stress while trees re-establish. However, this short duration of stress as well as short duration of overall re-establishment is still better than the alternative. It is also necessary to have a clearly defined method and schedule for watering. Ideally, a drip watering irrigation system should be installed across the entire root area and beyond to encourage new root formation.

Another concern about bare root transplanting is that roots and specifically fine roots are exposed to the air and sunlight during excavation and transplant works and may desiccate (dry up and die). While this is a reasonable concern, this issue is addressed by covering the exposed roots with hessian material and thoroughly wetting them a few times a day during the procedure. If the trees can be moved within a few days, the roots will survive. Research has shown that under some circumstances, “carefully handled fine roots may lose more than 70% of their water for a short period and remain alive” (Watson, 2009) suggesting most of them would survive. “Fine roots have a lifespan of a few months to a year and are regularly replaced” (McCormack, et al., 195(4)) so replacing fine roots should take place relatively quickly if lost (Watson & Hewitt, 2020).

Advantages of Bare Root Transplanting

To summarize, there are a number of technical advantages to utilising bare root transplanting including:

1. a larger overall retained root area including substantially higher retention of fine roots;
2. a reduced period of stress and hence reduced potential of secondary problems such as insect infestation or disease;
3. a reduced reestablishment period;
4. consistent soil type throughout the planting area;
5. the opportunity for soil improvement within the critical root zone;
6. roots can be visually assessed and pruned if needed
7. improved water balance;

New leaves forming two months after transplant

8. and overall improved transplant survival rate.

In addition to these technical advantages, financial advantages include:

1. reduced heavy machinery requirements;
2. no planter box construction;
3. reduced overall transplanting schedule and reestablishment period; and
4. potential significant reduction in the critical path for construction development programmes resulting in significant cost savings for developers.

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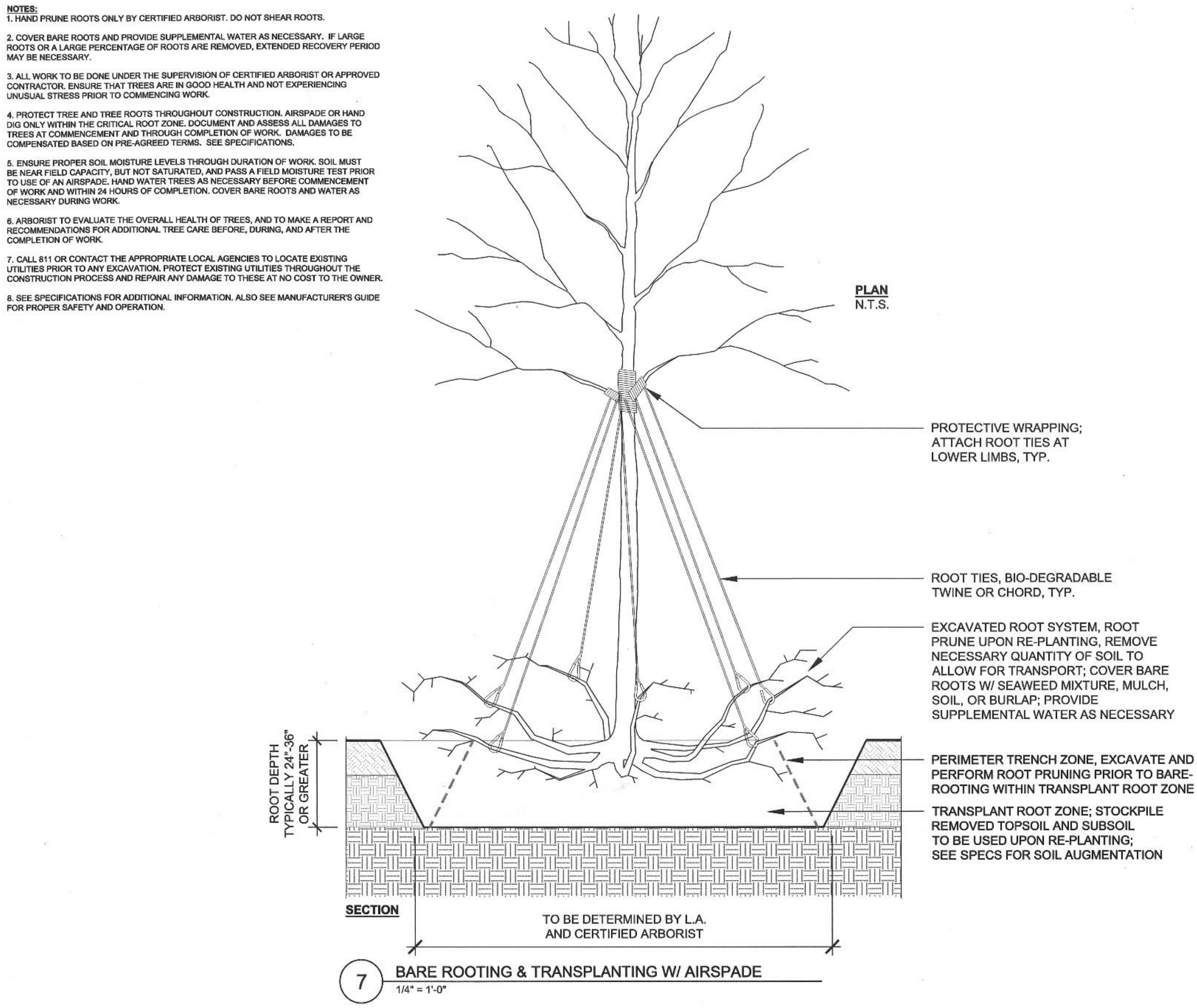

Example bare root transplanting diagram (Fite, et al., 2016)

References

Anon., 2014. *Guidelines on tree transplanting.* Hong Kong: Greening, Landscape and Management Section, Development Bureau, The Government of the Hong Kong Special Administrative Region.

Buckstrup, M. J. & Bassuk, N. L., 2000. *Transplanting success of balled-and-burlapped versus bare-root trees in the urban landscape,* s.l.: Journal of Arboriculture.

Dobson, M., 1995. *Tree Root Systems,* s.l.: Arboricultural Advisory and Information Service.

Fite, D. K. et al., 2016. *Airspade technical applications bulletin: Use of compressed air-powered excavation for arboriculture site works.* s.l.:Stephen Stimson Associates & Bartlett Tree Research Laboratories.

Fite, K. & Smiley, D. E. T., 2016. *Best management practices (BMP) - Managing trees during construction, second edition.* s.l.:International Society of Arboriculture.

Fite, K., Smiley, D. E. T., McIntyre, J. & Wells, C. E., 2011. *Evaluation of a soil decompaction and amendment process.* s.l.:Arboriculture & Urban Forestr.

Gilman, E. F., 1988. *Tree root spread in relation to branch dripline and harvestable root ball,* s.l.: HortScience.

Good, G. L. & Corell, T. E., 1982. *Field trials indicate the benefits and limits of fall planting,* s.l.: Am. Nurseryman.

Harris, J. R., Fanelli, J. & Thrift, P., 2002. *Transplant Timing Affects Early Root System Regeneration of Sugar Maple and Northern Oak,* s.l.: Hortscience.

Hinesley, L. E., 1986. *Effect of Transplanting Time on Growth and Development of Fraser Fir Seedlings,* s.l.: Hortscience.

McCormack, M. L., Adams, T. S., Smithwick, E. A. H. & Eissenstat, D. M., 195(4). *Predicting fine root lifespan from plant functional traits in temperate trees,* s.l.: New Phytologist.

Pryor, M. & Watson, G., 2016. *Mature tree transplanting: Science supports best management practice,* s.l.: Arboriculture Journal.

Smiley, D. E. T., 2001. *Air Excavation to Improve Tree Health.* s.l.:Tree Care Industry.

Steuart, H., 1828. *The planter's guide (2nd ed.).* London: John Murray.

Sweet, R., 2016. *Ease Excavating Dangers with Compressed Air Tools.* s.l.:Damage Prevention Professional.

Watson, G., 1992. Root development after transplanting. *The landscape below ground I: Proceedings of an international conference on tree root development in urban soils,* pp. 55-68.

Watson, G., 2009. *Desiccation tolerance of green ash and sugar maple fine roots,* s.l.: Journal of Environmental Horticulture.

Watson, G. & Hewitt, A., 2020. *Large trees establish more rapidly when transplanted bare root,* s.l.: Arboriculture Journal - The International Journal of Forestry.

Watson, G. & Himelick, E., 2013. *The practical science of planting trees (pp. 250),* Champaign, IL: International Society of Arboriculture.

Watson, G. W., Himelick, E. B. & Smiley, E. T., 1986. *Twig growth of eight species of shade trees following transplanting,* s.l.: Journal of Arboriculture.

Webb, R., 1991. *Tree planting and maintenance in Hong Kong,* s.l.: Hong Kong Government, Standing Interdepartmental Landscape Technical Group.

Wells, C., Kelby, F. L. & Smiley, D. E. T., 2009. *Soil decompaction and amendment for urban trees..* s.l.:Tree Care Industry.