Cost Action C15
Working Group B (Vegetation & transport infrastructure – Roads, Railroads and vegetation))

Management of urban trees: Identification of key issues and solutions for preventing conflicts and future needs.

By Jitze Kopinga

IDENTIFICATION

Introduction & backgrounds

During the action working group B (WG-B) focused on problems related to the interaction between vegetation and urban traffic infrastructure. During the course of the successive meetings it was decided to set up some kind of overview by:

- identifying the various problems, or categories of similar problems,
- investigating the existing knowledge on the backgrounds of these problems and experiences with solutions and collate key references
- discussing these matters in the WG's meetings in order to formulate "best practices"
- investigating the white spots within the existing knowledge and identifying future needs

Besides this the WG also discussed about "best practices" on the most adequate dessimination of this information. Below the key issues, based on events or keywords as suggested by the group, are listed together with a short comment on each issue about the state of the art and the main results of the discussions.

Restricted rooting space – enlarging restricted rooting space
This item is regarded as a general and most common threat to maintaining durable and sustainable tree plantings in the urban environment. The backgrounds of these limitations however are not restricted to only the interaction with the claims on space for traffic facilities. Also the underground utilities play an important role within this kind of problems.

It can be stated that during the past decades numerous articles and a number of book shave been published on this matter providing a huge amount of useful information for the town planners and arborists (see further reading appendix 4 to this article). It also must be concluded that obviously this informations has not yet adequately reached the right vocational level or persons. See a more detailed description of this key issue in appendix 1 to this article.

Draining and irrigation of root spaces
The presence of paved area nearby or on top of the root projection of trees usually has influence on the quantity of water that infiltrates to the rooted zone of the soil and may result in either a shortage or an excess of water with the risk that a tree may either be dying from drought or water logging.

By recognizing situations in which these threats are likely to occur a number of existing technical provisions can be applied, or planning adjustments can be made to minimize the risks associated to a changed water regime of the soil.

Preventing soil compaction

Frequent or heavy traffic loads usually result in soil compaction to levels on which root penetration into the soil is not possible anymore. Besides that, soil compaction also may have an adverse effect on a number of soil physical properties such as soil aeration and capillary suction. As a final result, the rootable soil volume is decreased and the possibilities for a healthy development of the tree are diminished. During the past decades various solutions to prevent soil compaction by traffic have been developed and also extensively tested in practice, varying form using so called structural soil as planting pit material to planting trees in rigid load bearing constructions or large insulated underground containers.

Protection against de-icing salt

Salt damage, as a result of the use of thawing salts (sodium chloride) on road surfaces nearby trees is a well known phenomenon. Damage may occur when excess of salt is present in the soil water and taken up by tree roots or when above parts of the tree are exposed to aerial spray of the melted salt water blown into the air by the traffic. Indirect damage may occur when physical and chemical soil properties are adversely affected by the salt (e.g. structure and air diffusion of clay containing soils, potassium deficiency). Adjusting quantities and techniques of salt application (e.g. using wet salt, or a mixture of sodium chloride and calcium chloride) may effectively reduce the frequency and number of cases of salt damage. Besides that adjustments of the construction planting site and applying protective barriers for salt spray may also contribute to minimizing salt damage. Finally when designing a tree planting the planner also may take advantage of the existing difference of salt tolerance among the various tree species.

Protection against mechanical damage

The presence of trees nearby or alongside transport infrastructures seems to be unavoidably associated with collision damage of variable intensity and character. Minimizing these risk usually is a matter of spatial planning of both the traffic way and the planting site. According to the situation, mechanical protective measures can be installed (e.g. crash barriers, raised planting pits on parking lots, et cetera).

Weed control aspects

The use of herbicide for removing inconvenient vegetation from paved surfaces formerly was a well known cause of herbicide damage to trees. At the moment in many countries the frequency of herbicide damage has been drastically decreased because of changed governmental regulations on the use of pesticides in the urban green. Nowadays many green services are using alternative methods for weed control such as deploying small vehicles with rotating brushes or using heat pulse devices, et cetera. It also has been shown that adjusting the paved area to its actual use and thus avoiding excess of paved area in which weed can freely develop, is a simple and effective control measure.

Preventing damage to pavements

Damage to pavements is a very common and well known phenomenon and there are several ways in which tree roots may damage pavements or paving elements varying form direct action as a result of diameter growth of stem base, root flares and main roots to indirect action such as the swelling and shrinking of clay containing soil underneath the pavement influenced by the quantity of water extracted form these soils by tree roots.

During the last three decades several studies have been made on effectiveness and limitations of various strategies and methods to prevent or minimize damage. As a matter of fact there are lots of useful technical situations available at the moment which have been proved to be more or les effective in controlling the problems. However, the spatial design of the planting site and the traffic way, together with the choice of the right tree species still plays an important, if not determining role.
See a more detailed description of this key issue in appendix 2 to this article.

Preventing damage to underground utilities

This key issue has not been discussed intensively in WG-B as it was the main issue of WG-A. Discussions were limited to overlapping approaches such as the use and effectiveness of so called anti root barriers or other root growth directing methods.

Traffic safety – Tree safety

Traffic safety can be endangered when the mechanical structure of a roadside tree is weakened for some reason and when this results in an increased risk of breaking of branches or even falling over of the whole tree. Sometimes the occurrence of such problems (e.g. branch breaking) is inherent to certain tree species or cultivars, and can be avoided by choosing the right species, but in many cases this is not the case and is the mechanical weakening of the tree a direct or indirect result of an "unfortunate" interaction between above and below ground urban infrastructure. At the moment there are several publications containing practical information for the arborist and urban forester on principles of tree hazard assessment and management.

Traffic safety – tree litter aspects

Nuisance from tree litter (inflorescence, seeds, leaves) is a "traditional" phenomenon that have been regarded for centuries and normally the urban green and cleansing departments are organized and equipped to deal with this annual returning nuisance. But in situations when leaf litter adversely affects the use and reliability of railway transport systems, specific measures has to be taken to solve certain problems. However, derangement of railway transport due to leaf litter only seems to be of serious significance in a minor part of the European countries. See a more detailed description of this key issue in appendix 3 to this article.

Scope and limitations of tree selection

It is evident that many problems can be avoided by using the right tree species for the right place. However, for some species and cultivars, especially the ones that are only recently introduced, the knowledge about specific characteristic is limited. Testing of new cultivars on "hardiness" for urban situations may give earlier information and thus bridge some of the gaps in the existing knowledge, but nowadays this approach still is no common practice in the selection and production of promising trees. To avoid long periods of testing, another strategy for selection could be aimed to a survey on potential parent trees that already have proved over years to be able to perform well under suboptimal urban conditions. If desired, selection can be limited to only native tree species.

Renovation / rejuvenation aspects - redesigning street profiles
Little information is available on studies that deal with strategies that can be followed when plantings of old and worn out trees re to be replaced with young trees. In many situations the presence of valuable old trees is blocking large scale rejuvenation of a tree planting, but occasions in which a street profile completely has to be designed e.g. because of infrastructure of utility services, chances may arise for redesigning the desired balance between green and "grey" infrastructure.

How to "marry" pavement and root space quality (water infiltration, oxygen supply, compaction)
This issue deals especially with transforming the existing scientific information into ready-to-eat directives for the vocational experts that are involved in the planning and establishment of various kinds of urban infrastructure. In brief, nowadays there may be much more need for examples of good practice than the need for only fundamental knowledge.

Using rainwater
In some European countries the control of rain and storm water demands for special facilities within the urban infrastructure. Thus far little attention has been paid to use these systems partly to meet the water requirements of urban trees. Several approaches for this are realistic and could be further developed and worked out.

NEEDS AND FUTURE NEEDS

Handbook
During the course of the discussions in the successive meetings there was a general feeling that the need for practical information could be met most effectively by producing some kind of practical handbook. The format of such a book was discussed, but finally it was conclude that a handbook may be too ambitious as a deliverable, given the limitations on time of the working group members. It was decided that in the final report at least a couple of good practices could be presented as illustration of the ideas of the working group and could serve as an example for further additions and elaboration in a later stage. It was suggested and concluded decision makers, designers and engineers, but also vocational arborists and urban foresters were the primary target groups. It was also concluded that the work should not be a comprehensive overview of all developments and achievements over the year within this field of interest, or otherwise duplicate already available information, but should be aimed to complement this information.

It was also decided that the information should not be focused on bad practices but should focus on short and richly illustrated descriptions of case studies of good practices which may give more specific direction to general standards of practice. The way in which such a handbook should eb available in future (printed or digital version, access to a central website, et cetera, should be part of further study when more is know about the possibilities (time, money) of such an initiative.

CONCLUDING AND SUMMING UP

During the discussion in WG-B it gradually became clear that, as a matter of fact there's already a bulk of technical knowledge available nowadays to provide custom made solutions for problems encountered between vegetation and transport infrastructure. Therefore an intriguing question is not primarily how to gather such information but how to make this information available, understandable and usable for the final users, which are the decision makers, town planners, civil engineers and urban forester and arborist.
There are several possible explanations for this type of backlog. Some of these may be tracked down to so called cultural differences. However it cannot be emphasised enough that a sound interaction on the right times between the green and "grey" professionals that are involved in the town planning is a basic condition for a durable solutions of the various conflicts between the green and the "grey" infrastructure.

ENLARGING RESTRICTED ROOTING SPACE FOR URBAN TREES
By Jitze Kopinga

Background and key problems

Urban trees often have limited rooting space that often is restricted to only the dimensions of the original planting hole. As a result of this, the supply of water and nutrients to the tree in shorter or longer term is insufficient to have the tree grown out in a healthy state to its normal size. For this reason, the green structures that city planners intend to create are realized only on a very long term and if so, often at the expense of considerable efforts.

In the past, i.e. from the seventies on, the have been several publication in the vocational literature on the minimal rooting space urban trees require. Most of the calculations in these papers were based on the needs for water and a few were also based on the nutrient supply, especially nitrogen.

As a rule of thumb, it is assumed nowadays that an “average” tree needs approximately ¾ m3 rootable soil for each m2 of its crown projection. This applies for circumstances in which the tree is totally depending on the annual precipitation of water that falls during the growing season together with the quantity of water that has been stored into the soil during the winter period. In circumstances where the trees water demand also can be (partly) covered by ground water a rootable soil volume of ½ m3 per m2 crown projection is considered to be sufficient. With regard to the nitrogen balance this also is an adequate volume. This means that generally trees of the third height class (small trees) will do well, at least for the first two or three decennia, with about 9 m3, trees of the second hight class with 16 m3 and trees of the first height calss with 25 m3 of rootable soil.

Subject to specific properties of the tree species, such as total leaf surface (usually expressed as Leaf Area Index), leaf nitrogen content, leaf evaporation c.q. drought sensitivity, the afore mentioned dimensions may be adjusted downwards to some extent, depending on various environmental conditions as nitrogen deposition from the air or from the excrements of pets together with growing site construction that facilitates the tree to get precipitation from a larger area than merely the surface of the crown projection.

Suggested (and meanwhile no more suggested) actions to be taken

A traditional approach to enlarge and also improve the volume of rootable soil, is to drill a large number of holes into the soil underneath the crown projection which are backfilled with a soil mix or substrate with usually a high content of organic matter. If there is a risk for damage to underground obstacles the holes can be made by means of air (under pressure or vacuum) or water.
A draw back of this approach is that the total volume of soil that is ameliorated this way is relatively small and usually only a fraction of the standards presented above.
Moreover, the new root development mainly will be restricted to only these points of loosened soil. All in al this will make the tree more liable to drought when the water in these small pits is rapidly extracted by the root that has developed in there. Of coarse this disadvantage is of less influence when by making the holes compacted soil layers that prevent root penetration

are disturbed and as a result roots are able to explore more of the total soil volume of the root projection or escape to better surroundings.

A variant of how to get tree roots out of a planting hole in an otherwise compacted soil out to near by verges or gardens is the installation of so called root tunnels already during the construction of the growing site. Various materials and methods can be applied for this purpose such as spacious (diamater ca. 30 cm) PVC pipes or the vertically placed so called aeration sheets. The advantage of these methods is that the “conflict” between bearing capacity of the soil (for the sake of traffic) and its rooting possibilities (for the sake of the tree) is avoided to some extent.

The above mentioned example applies to the many existing situations in which there are restricted possibilities to created enough rootable soil volume directly around the planting hole. However, with regard to avoid damage to vital tree roots, for instance during excavation activities, it is more advantageous to have most of the roots at not too far away from the tree. For that matter a variety of methods are eligible.

When it is possible, for instance by shifting some utilities a couple of meters, the positive effect of a trench of 1 x 1 (w x d) meter along one or more sides of the planting hole already will be considerable. This soil from this trench must be exchanged, or mixed with high quality substrate with sufficient organic matter. When using large quantities of such enriched mixtures it may be necessary to also install a couple of soil aeration pipes as these mixtures tend to have an increased rate of oxygen conversion during the first period of at least several months after it has been processed.

Sometimes a shallow ground water table may be limiting for the depth to which a planting hole can be enlarged. But also there may be other circumstances that restrict diffusion of oxygen to a required depth. For so far the latter can not be improved by a lasting aeration system raising the level of the total planting hole may be a solution. This also may have the advantage of protecting trees this way against damage by traffic or the influence of deicing salt (in situations when a salt/snow mixture should be shifted away from the road onto the planting site) and if desired it can be combined with architectural accommodations such as seats or benches.

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<u>Directives with regard to the planting hole mixture</u>

An important question is to what extent the top layer of the planting hole will be used for activities that give rise to soil compaction and to what extent eventual paving over the planting hole will be affecting the diffusion of oxygen and rainwater into the subsoil (te latter is especially important when ground water cannot be utilized.
When none of these activities will happen a usual high-grade soil mixture can be applied without objection, for instance a sandy soil containing a small quantity of clay (up to ca. 10%) and with an organic matter content of up to 8 % (w/w) or even more.
On the other hand, in situations where the load baring capacity of the soil is also important, for instance when cars will be parked above the root zone, soil mixtures that warrant sufficient bearing of these loads have to be applied.
Already from some decennia ago research has been carried out into the development of so called structural soils. These can be sand mixtures of a texture that after some slight artificial compaction gives enough structure for load bearing and also still allows to penetrate and develop (the so called Tree sand). It also can be a high-grad substrate to which coarse material

(such as rubble, lava stone or expanded slate) is added to such a content that after filling of the planting hole, the element of the coarse material will provide some kind of skeleton structure that is very hard to compact.
A drawback of such a skeleton soil is that the coarse elements contribute relatively little to the nutrient and water storing and delivering capacity of the soil mixture in its entirety. An advantage, on the other hand, is that the soil mixture in between the hollows of the coars elements may be richer in organic matter than the maximum that applies for tree sand. For that matter, a kind of underground skeleton also can be created by the using load distributing plastic constructions such as beer crate shaped boxes (city of Apeldoorn) or concrete constructions or pilers. The latter however are relatively expensive.

An aditional advantage of both the structural soils as the self bearing constructions is that intentional and unintentional excavation within the rooting zone of the trees is discouraged and people are invited this way to look for more tree friendly solutions. Besides that, when the rootable soil volume within this construction is of sufficient dimension, eventual rot damage outside it will hardly affect the further growth and development of the tree.

There may be situations where merely the application of load dividing slabs will be sufficient to prevent soil compaction and its use can be considered when entrance of water and oxygen into the rooted zone is not too much adversely affected. For this purpose, the slabs must be rigid enough to divide the pressure of the loads. The foil material that is frequently used in civil engineering is too weak for this purpose and therefore not suitable unless it is combined with a sturdy construction. This accounts also for plates that are build of two layers of non woven foils kept apart by a mat of coarse plastic wire (for instance “Enkadrain 112”). The additional value of this material is that it may facilitate the entrance of oxygen in the subsoil. Also it might be expected that it will reduce condensation of moisture just underneath the pavement too some extent. This could be of importance with regard to eventual development of root damage to pavement during the coarse of time but the merits of the material with regard to this specific purpose are not sufficiently known yet.

APPENDIX 2

PREVENTING DAMAGE TO PAVEMENTS BY TREE ROOTS

By Jitze Kopinga

Background and key problems

Damage to road pavements by tree roots is a well known phenomenon where trees are standing alongside roads. Because of road safety aspects the road manager is obliged to control this damage and repair the pavements which may give rise to considerable annual expenses.

Tree roots develop underneath pavements because they are attracted by the relatively high moisture content of the soil directly underneath the pavement as a result of condensation of water vapour. Because the quantity of water however is low and likewise the amount of nutrients in the road sand, roots branching is not abundant and usually roots bridge the width of the road within one growing season. Once the opposite verge is reached, rooting will be more intensive and this enables the few roots underneath the pavement that are connected to the tree to increase in thickness. As these roots mainly are located in te boundary layer between the sand and the pavement, it only takes a while (from only a few years on) when they start to lift up the pavement, tipping off tiles from stone pavements or causing more or less transverse cracks in asphalt pavements that gradually grow deeper and wider.

Suggested (and no longer suggested) actions to be taken

There are roughly three strategies to solve the problem of root damage: Tree based strategies, Infrastructure based strategies and root zone based strategies. Within tree based strategies, the first is to see what can be achieved with the choice of tree species. It is know that root damage especially occurs where so called pioneer species are planted such as Willow (*Salix spp*.), Poplar (*Populus spp*.) Blach locust (*Robinia pseudoacacia*) and Birch (*Betula spp*.). On the contrary Pendunculate oak (*Quercus robur*), Beach (*Fagus sylvatica*) and Lime tree (*Tillia spp*.) will give substantially less damage in comparable circumstances and conditions.

Apart form this pioneer "behaviour" of the species there appears to be a trend that the shallow rooting species more often cause damage than the species that naturally develop a deeper root system. It will be evident that smaller trees as a rule will cause less damage than bigger trees, however there are a few exceptions such as Sea buckthorn (*Hippophae rhamnoides*). Otherwise also the so called non aggressive trees will cause damage when the rootable soil volume is so small that tree roots simply are forced to escape from the planting hole underneath the pavement to look for better surroundings. This means that choosing the right species will only meet the problems of root damage to some extent if the tree's growing conditions are sufficiently met.

Formerly it was assumed that damage could be prevented when tree roots were kept away from the pavement by enticing them to location within the root zone where the soil was of good quality (e.g. by soil amelioration). However, it appears that tree roots, obviously because of their opportunistic behaviour, also develop root underneath pavements under circumstances where the quality and volume of the growing site are quite generous and the tree's demands are abundantly met. Although there are not sufficient research data to support the theory, there is some evidence that the occurence of damage will be less, or in a later stage, when trees are properly planted in a large enough planting hole. On its turn this also has the advantage that when for some reason too far out growing root has to be removed, the damage to the tree roots will be comparatively low and will have only negligible effect on the further growth and development of the tree.

Probably the most effective civil engineering solution is an underpinned pavement, free from the soil and also the tree roots (the so called floating construction). No doubt this is a rather expensive solution, but it may be considered in situations where root development underneath the pavement is necessary for reasons of sufficient rooting space.

Another, considerably cheaper solution refers to the choice of the material for the road bedding. Root damage mainly, if not solely, emerges at light constructed pavements that are laid down directly on top of a bedding of compacted sand. Research has pointed out that when coarse gravel is used instead of sand, there will not be, or hardly not be, any root development directly underneath the pavement even not after a period of several (say 10) years. Probably this can be explained from a combination of mechanical restraints created by the gravel elements and so called air pruning because of the large hollows in between the coarse elements. It has been shown that the effectiveness will decrease substantially when these hollows are filled with sand.

A method that has found only little utilization in the past is the use of a root cutter by which roots that have developed or were going to develop, underneath the pavement were cut off just alongside the pavement to a depth of about half a meter or even more. Especially the frequency in which he method has to applied to give effective and lasting results (and therefore the involved costs) and also the risk to damage underground obstacles such as utilities appeared to be limiting its application in practice. It also appeared that when thicker roots already had developed underneath the pavement and were cut off, new roots or even shoots would develop from the cut off parts and on their turn would damage the pavement after some time. However this may be inhibited or reduced by using herbicides on the cut off edges, but apart from the effectiveness of these agents, and the difficulty to apply them under these specific circumstances, the use of herbicides in urban green nowadays is not allowed anymore in many European countries because of changed legislation.

This implies that when repairing root damage, either the roots have to be dug out and removed, or the pavement has to be repaired in such a way that the existing roots are bridged over and kept free from the new pavement. The latter of course is far less harmful for the tree. When sidewalks or bicycle roads are concerned, also application of flexible paving material may be considered. In this case, over some length (usually those of the root projection of the tree), a pavement of asphalt or tiles is replaced by a rubber mat on top of a layer of sand and/or recycled plastic. On one hand this will spare the tree roots and on the other eventually arising unevenness generally will be of acceptable proportion with respect to the passableness and safety of the pathway.

A increasing widely used method is the application of mechanical barriers such as plastic foils or screens, the so called anti root screens. As a rule these screens are placed vertically in the soil to a certain depth. Various materials and systems have been developed and tested for this purpose. Water impermeable plastic foils appear to fence off root penetration effectively provided that they are mechanically strong enough i.c. will not be damaged when they are installed. Water permeable foils of the types that are frequently used in civil engineering (so

called geotextiles) and made of non woven plastic fiber may have positive effect but this will depend also on their thickness. Root penetration may occurs through the thinner materials although the number of roots that grows trough the foil in first instance will be lower than the number of roots that will bend away from the screen in alongside directions.
Trough the thicker materials in first instance some fine root may penetrate, but it is questionable if they will develop too thick roots as they are pinched of at the point of entrance after a while. The more rigid, thicker plastic screens are applied either circular (around the root system of a tree) or linear (alongside the pavement of the road). A drawback of the circular screens is that initially the tree will grow in a so called flowerpot situation with its subsequent negative effects (drought sensitiveness and nutrient deficiency).

Depending on the possibilities for root development, there also may be a risk for instability of the tree on longer term. The biggest drawback however is that some roots of the tree still will tend to grow up to the surface again on the other side once they have passed underneath the screen. It does need no further explanation that, although the screens may have a marked effect, this “imperfection” also will decrease its application on a large scale.

Apart from that, irrespective of the type of material tree roots growing underneath the screens always can be expected when vertical mechanical barriers are not placed deep enough into the soil i.c. reaching into the permanent anaerobic zone of the soil (or down the lowest level of the ground water table).

Root also may grow along the top of the screen when it has insufficient connection with the pavement or when the screen in its entirety has been installed too deep or when the top of the screen has been weathered by sunlight or frost or damaged by e.g. grass mowing equipment. Anyway, these aspects have to be considered when choosing the materials and applying the methods.

Table 1. Indicative list of some common street trees of first size (h > 12 m) and the frequency in which damage to pavements is observed in The Netherlands. (Indications between brackets are based on a statistically low level of observations and must be regarded as provisional)

Species	Frequently	Occasionally	Rarely
Acer platanoides			x
Acer pseudoplatanus		x	
Acer saccharinum	x		
Aesculus hippocastanum			x
Ailanthus altissima		(x)	
Betula spp.	x		
Carpinus betulus			x
Catalpa spp.		(x)	
Celtis spp.		(x)	
Corylus colurna			x
Fagus sylvatica			x
Fraxinus excelsior		x	
Gledisia triacanthos		x	
Juglans nigra			x
Pauwlonia tomentosa		(x)	
Pinus sylvestris	x		
Platanus acerifolia		x	
Populus alba	x		
Populus nigra	x		
Populus simonii		(x)	
Populus spp.	x		
Quercus robur			x
Quercus rubra		x	
Quercus palustris		x	
Robinia pseudoacacia	x		
Salix alba	x		
Sophora japonica		(x)	
Sorbus spp.			x
Tilia spp.			x
Ulmus spp.		x *	
*: also depending on type of rootstock			

LEAF LITTER AND TRAFFIC SAFETY

By Jitze Kopinga

Background and key problems

Leaves from trees, but also the inflorescence and seeds may be a nuisance for people or may give rise to unsafe of the road for traffic. Although there is not known so much about the quantitative contribution of leaf litter to the safety of the road and with that the number of accidents, it hardly needs an argument that a blanket of fallen leaves will decrease the "grip" for the tyres of vehicles.

Most tree species loose their leaves during autumn, usually during a short period of time, and many municipal cleansing departments or urban green departments are logistically prepared for the annual job of getting rid of the fallen leaves before they bring about an unacceptable mess. If, when and to what extent such a mess will develop will depend on local weather conditions and other specific local situations such as the towns green structure. During thunderstorms large amounts of leaves may come down during a rather short period. When wet, this may adhere to the road surface from which it is not easily removed with the usual blowing equipment, once it is flattened out by vehicles riding over it. A relative advantage is that usually on busy traffic road the leaves and also the smeared out leaves on the road surface will be blown aside whining a relative short time because of the traffic action itself. It also must be noted that in many cases trees along this type of roads are planted on a larger distance form the driveway so that proportionally less amount of leaves will fall directly on the road surface. However it is reported sometimes by road maintenance services that it may endanger the safety of the side strips when the slurry of leaves is pressed into the space between the stony particles of the asphalt pavement from where it is difficult to remove (there no cleaning action from the wheel of vehicles) and may serve as some kind of growing substrate for weeds that develop which on its turn will have an advere effect on the traffic safety of the side strips.

On smaller streets, where trees have hanging their branches also hanging above the driveway, this will be different also because the traffic generally is driving slower and there is less influence of its action itself. It has been suggested that especially on this locations accidents may occur in which a relative high number of bicycles, scooters and motorbikes are involved.

A case on its own are the railroads and tramways. Fallen leaves that adhere to the rail surface causes that wheels slip when the vehicle is braking or speeding up. This results in unevenness in the wheels rounding and extra (expensive) repair costs.
Besides that, some metro trains are equipped with an automatic speed control system that comes into action when the electric contact of the wheels with the metal rails is interrupted. As a consequence the speed of the train is limited to walking speed.
The latter occurs frequently during autumn and can be ascribed to tree leaves that are pressed to some kind of dry film of organic material and iron rust on top of the rail. The link up of these events at times may disturb daily passenger to a great extent.

Actions and results

Actions to be taken are mainly, if not exclusively tree based strategies. Which are selection of tree species and designing aspects of the urban green. The nature of litter, i.e. seeds and inflorescence often can be controlled by a conscious choice of tree. If fruiting is a problem for traffic safety (e.g. the acorns of certain oaks -*Quercus spp* -) it is better to choose for trees that for example have catkins (e.g. White willow -*Salix alba* -, Poplar - *Populus spp*.-). If blossoming is desired, but fruits not, a (restricted) number of cultivars can be used that have sterile flowers, such as the cv. Baumannii of the Horse chestnut (*Aesculus hippocastanum*). For that mater litter from petioles will have generally not so much influence on traffic safety as, apart form a few exceptions, the abundant flowering trees usually are small or medium sized trees and with that the amount of litter is proportionally low and also its horizontal dispersion.

Falling of leaves (or needles) however is more difficult to manipulate as the presence and regular fall of leaves on trees is an established fact for all deciduous trees (and even for evergreens although the period of shedding of part of their foliage may not correspond with those of deciduous trees). The amount of leaf litter that "hits" the road can be controlled by taking into account the tree size including its total leaf mass when designing the road profile in its entirety and coherence.

Initially one may think of the distance to the road with respect to final tree height, from the point of view that the higher the tree will grow the more leaves will fall and the larger will be the dispersion area thereof. But it also my be considered to reduce the number of trees by enlarging planting distance or even planting trees as clusters so that the source of "pollution" is concentrated to a relatively small area and removing the litter will assumingly take less time.

Along circular roads or entrance roads that have sufficient space in the verges a planting structure may be established in which the higher trees are standing at the greatest distance from the road and the smaller trees inclusive the shrubs at shorter distance. This design has the additional advantage that much of the leaves are "caught" by the plantation itself and that relatively less will be blown elsewhere. Besides it also may stay within the planting to further contribute to the natural mineral recycle which brings down the need to clear it away.

If the width of the road profile allows a structure of hedges this may reduce the amount of leaves that are blown away from the trees over a large distance once they have fallen to the ground. It even may be possible to construct some kind of natural collection points by doing so, but there is not yet much practical experience with the application of hedges for this specific purpose to give any directives for the design.

When regarding the total leaf mass account, it may be interesting for the urban green planner to know that there are substantial differences between tree species of the same crown volume. Commonly the amount of foliage is expressed as Leaf Area Index (LAI) which is the total ratio between total leaf area and the crown projection of the tree As a rule of thumb, an "average' solitary, non columnar or fastigiate tree will have a LAI of about 4 to 5 and a fresh weight of the leaves of about 150 to 200 g/m2 leaf surface. For a tree with a crown projection of 100 m2, the total weight of the freshly fallen foliage will be somewhere between 60 and 100 kg per tree.
But taking the differences between trees into account, there are both substantial differences in both the LAI and (sometimes) also weight of leaf mass. For instance, an adult Common maple (*Acer pseudoplatanus*) and Norway maple (*Acer platanoides*) at the age of about 70 years both have a comparable crown volume (ca. 1200 - 1400 m3), but a total leaf surface of respectively 400 and 1100 m2. Corrected for leaf weigth of resp. 160 and 150 g/m2 (this is

not so much different in this case), this results in total leaf weights of respectively 64 and 165 kg per single tree. These are “attractive’ differences to be considered when setting up planting designs in locations where presence of abundant leaf litter is less desired or someway has to be limited.

As far as railway traffic is concerned, besides tree based strategies there are also some technical solutions to prevent or overcome nuisance. Often most of the trouble occurs after nights when the first trains ride out. During the day most of the freshly fallen leaves usually are blown away from by the passing trains and the rails will stay rather clean. In this case the first trains sometimes are preceded by a heavy locomotive that crushes and pushes away any leaf debris including films of iron rust that has formed overnight from the top of the rails. When this method has too little effect, special wagons can be put in operation with broom like devices in front of the wheels sometime in combination with a device that sprays a roughening agent (e.g. Sandite) on top of the rails. So, from a technical point of view the problem can be controlled to some extent, and its impact on traffic safety can be brought down to an acceptable level although it needs no further elucidation that also extra maintenance costs are involved, although it must be emphasized that also without the presence of leaf litter rails may become slippery because of rust formation and therefor have to be maintained anyhow.

Preventing of weed development on side strips of motroways, promoted by leaf litter, is still a subject to be studied further as the possibilities for using chemicals (apart form deicing salt, of which summer application may be effective) are restricted nowadays in many European countries.

<u>Influence of some biotic and abiotic factors on leaf fall</u>
Mostly leaf fall is regarded, and also accepted as a common and natural phenomenon, provide that it will be restricted to the autumn period, as cleansing departments take this into account in their organization of usual annual activities.
It may happen however that substantial leaf fall already occurs during (early) summer and thus may give rise to unsafe traffic situation at unusual (and unexpected) times.
The reasons for premature leaf fall can be a prolonged period of drought, but also attacks by some pests and diseases. Examples are: Leaf blotch of Plane tree (Platanus x acerifolia) caused by the fungus *Apiognomonia errabunda*; Leaf blotch of Horse chestnut (*Aesculus hippocastanum),* caused by the fungus *Guignardia aesculi*; Rust or Leaf spickle disease of Poplar (*Populus spp*.), caused by respectively the fungi *Melampsora spp*. and *Marssonina spp.*, but also insects like the Horse chestnut leaf miner (*Cameraria ohridella*). This may be a reason tot take also the sensitiveness of the tree to these type of ‘persistent’ diseases into account when defining and choosing tree species on locations where premature leaf fall might be a problem or a nuisance.

Apart from premature leaf fall some pests can give rise to nuisance by for instance excretion of honey dew by leaf aphids. This is a sticky substance that under specific conditions also may adversely affect the roughness of the road surface. Although this only might happen in extreme occasions it may be a type of nuisance that could be taken into account when selecting the right tree for the right place. In this way for example, most Lime species (*Tilia spp*.) are not to be preferred to use as a shade tree on parking lots because of their annual infestation by the leaf aphid *Eucallipterus tiliae*. But fortunately there are enough other tree species with comparable characteristics and markedly less honeydew that can be used instead.

Conclusion

Unsafe traffic situations because of leaf litter will be mainly restricted to locations where masses of fallen leaves can concentrate (e.g. by wind turbulence) or where fallen leaves are converted to a kind of slippery porridge before it is cleared away by road maintenance services. If and to what extent these situations will occur will depend on the duration of leaf fall: when all leaves come down within a very short period of time the nuisance will be more, but the duration of the time that traffic unsafe situations might occur will be shorter.

Of coarse the way the road cleansing department is accustomed and equipped to handle these situations will play an important role. By taking the above mentioned aspects into account when planning the spatial structure of the urban green, a number of potential problems with leaf litter may be prevented or overcome.

Table 1: Indicative fresh weight of total foliage of some urban trees at crown volumes of 1000 m3. (Source: Vreštiak, 1991)

Tree species	**Total fresh weight (kg)**
A campestre	45
A. negundo	65
A. platanoides	150
A. pseudoplatanus	90
A. saccharinum	115
Aesculus hippocastanum	325
Ailanthus altissima	65
Betula verrucosa	140
Carpinus betulus	50
Celtis occidentalis	60
Fagus sylvatica	55
Fagus s. 'Atropurpurea'	70
Fraxinus excelsior	90
Gleditsia triacanthos	85
Juglans nigra	125
Pauwlownis tomentosa	200
Platanus x acerifolia	115
Populus nigra	60
Populus simonii	80
Quercus robur	80
Quercus rubra	120
Robinia pseudoacacia	90
Salix alba 'Tristis'	75
Sophora japonica	100
Tilia platanoides	75
Ulmus glabra	80

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Cost Action C15
Working Group B (Vegetation & transport infrastructure – Roads, Railroads and vegetation))

Management of urban trees: Identification of key issues and solutions for preventing conflicts and future needs.

By Jitze Kopinga

IDENTIFICATION

Introduction & backgrounds

During the action working group B (WG-B) focused on problems related to the interaction between vegetation and urban traffic infrastructure. During the course of the successive meetings it was decided to set up some kind of overview by:

- identifying the various problems, or categories of similar problems,
- investigating the existing knowledge on the backgrounds of these problems and experiences with solutions and collate key references
- discussing these matters in the WG's meetings in order to formulate "best practices"
- investigating the white spots within the existing knowledge and identifying future needs

Besides this the WG also discussed about "best practices" on the most adequate dessimination of this information. Below the key issues, based on events or keywords as suggested by the group, are listed together with a short comment on each issue about the state of the art and the main results of the discussions.

Restricted rooting space – enlarging restricted rooting space
This item is regarded as a general and most common threat to maintaining durable and sustainable tree plantings in the urban environment. The backgrounds of these limitations however are not restricted to only the interaction with the claims on space for traffic facilities. Also the underground utilities play an important role within this kind of problems.

It can be stated that during the past decades numerous articles and a number of book shave been published on this matter providing a huge amount of useful information for the town planners and arborists (see further reading appendix 4 to this article). It also must be concluded that obviously this informations has not yet adequately reached the right vocational level or persons. See a more detailed description of this key issue in appendix 1 to this article.

Draining and irrigation of root spaces
The presence of paved area nearby or on top of the root projection of trees usually has influence on the quantity of water that infiltrates to the rooted zone of the soil and may result in either a shortage or an excess of water with the risk that a tree may either be dying from drought or water logging.

By recognizing situations in which these threats are likely to occur a number of existing technical provisions can be applied, or planning adjustments can be made to minimize the risks associated to a changed water regime of the soil.

Preventing soil compaction

Frequent or heavy traffic loads usually result in soil compaction to levels on which root penetration into the soil is not possible anymore. Besides that, soil compaction also may have an adverse effect on a number of soil physical properties such as soil aeration and capillary suction. As a final result, the rootable soil volume is decreased and the possibilities for a healthy development of the tree are diminished. During the past decades various solutions to prevent soil compaction by traffic have been developed and also extensively tested in practice, varying form using so called structural soil as planting pit material to planting trees in rigid load bearing constructions or large insulated underground containers.

Protection against de-icing salt

Salt damage, as a result of the use of thawing salts (sodium chloride) on road surfaces nearby trees is a well known phenomenon. Damage may occur when excess of salt is present in the soil water and taken up by tree roots or when above parts of the tree are exposed to aerial spray of the melted salt water blown into the air by the traffic. Indirect damage may occur when physical and chemical soil properties are adversely affected by the salt (e.g. structure and air diffusion of clay containing soils, potassium deficiency). Adjusting quantities and techniques of salt application (e.g. using wet salt, or a mixture of sodium chloride and calcium chloride) may effectively reduce the frequency and number of cases of salt damage. Besides that adjustments of the construction planting site and applying protective barriers for salt spray may also contribute to minimizing salt damage. Finally when designing a tree planting the planner also may take advantage of the existing difference of salt tolerance among the various tree species.

Protection against mechanical damage

The presence of trees nearby or alongside transport infrastructures seems to be unavoidably associated with collision damage of variable intensity and character. Minimizing these risk usually is a matter of spatial planning of both the traffic way and the planting site. According to the situation, mechanical protective measures can be installed (e.g. crash barriers, raised planting pits on parking lots, et cetera).

Weed control aspects

The use of herbicide for removing inconvenient vegetation from paved surfaces formerly was a well known cause of herbicide damage to trees. At the moment in many countries the frequency of herbicide damage has been drastically decreased because of changed governmental regulations on the use of pesticides in the urban green. Nowadays many green services are using alternative methods for weed control such as deploying small vehicles with rotating brushes or using heat pulse devices, et cetera. It also has been shown that adjusting the paved area to its actual use and thus avoiding excess of paved area in which weed can freely develop, is a simple and effective control measure.

Preventing damage to pavements

Damage to pavements is a very common and well known phenomenon and there are several ways in which tree roots may damage pavements or paving elements varying form direct action as a result of diameter growth of stem base, root flares and main roots to indirect action such as the swelling and shrinking of clay containing soil underneath the pavement influenced by the quantity of water extracted form these soils by tree roots.

During the last three decades several studies have been made on effectiveness and limitations of various strategies and methods to prevent or minimize damage. As a matter of fact there are lots of useful technical situations available at the moment which have been proved to be more or les effective in controlling the problems. However, the spatial design of the planting site and the traffic way, together with the choice of the right tree species still plays an important, if not determining role.
See a more detailed description of this key issue in appendix 2 to this article.

Preventing damage to underground utilities

This key issue has not been discussed intensively in WG-B as it was the main issue of WG-A. Discussions were limited to overlapping approaches such as the use and effectiveness of so called anti root barriers or other root growth directing methods.

Traffic safety – Tree safety

Traffic safety can be endangered when the mechanical structure of a roadside tree is weakened for some reason and when this results in an increased risk of breaking of branches or even falling over of the whole tree. Sometimes the occurrence of such problems (e.g. branch breaking) is inherent to certain tree species or cultivars, and can be avoided by choosing the right species, but in many cases this is not the case and is the mechanical weakening of the tree a direct or indirect result of an "unfortunate" interaction between above and below ground urban infrastructure. At the moment there are several publications containing practical information for the arborist and urban forester on principles of tree hazard assessment and management.

Traffic safety – tree litter aspects

Nuisance from tree litter (inflorescence, seeds, leaves) is a "traditional" phenomenon that have been regarded for centuries and normally the urban green and cleansing departments are organized and equipped to deal with this annual returning nuisance. But in situations when leaf litter adversely affects the use and reliability of railway transport systems, specific measures has to be taken to solve certain problems. However, derangement of railway transport due to leaf litter only seems to be of serious significance in a minor part of the European countries. See a more detailed description of this key issue in appendix 3 to this article.

Scope and limitations of tree selection

It is evident that many problems can be avoided by using the right tree species for the right place. However, for some species and cultivars, especially the ones that are only recently introduced, the knowledge about specific characteristic is limited. Testing of new cultivars on "hardiness" for urban situations may give earlier information and thus bridge some of the gaps in the existing knowledge, but nowadays this approach still is no common practice in the selection and production of promising trees. To avoid long periods of testing, another strategy for selection could be aimed to a survey on potential parent trees that already have proved over years to be able to perform well under suboptimal urban conditions. If desired, selection can be limited to only native tree species.

<u>Renovation / rejuvenation aspects - redesigning street profiles</u>
Little information is available on studies that deal with strategies that can be followed when plantings of old and worn out trees re to be replaced with young trees. In many situations the presence of valuable old trees is blocking large scale rejuvenation of a tree planting, but occasions in which a street profile completely has to be designed e.g. because of infrastructure of utility services, chances may arise for redesigning the desired balance between green and "grey" infrastructure.

<u>How to "marry" pavement and root space quality (water infiltration, oxygen supply, compaction)</u>
This issue deals especially with transforming the existing scientific information into ready-to-eat directives for the vocational experts that are involved in the planning and establishment of various kinds of urban infrastructure. In brief, nowadays there may be much more need for examples of good practice than the need for only fundamental knowledge.

<u>Using rainwater</u>
In some European countries the control of rain and storm water demands for special facilities within the urban infrastructure. Thus far little attention has been paid to use these systems partly to meet the water requirements of urban trees. Several approaches for this are realistic and could be further developed and worked out.

NEEDS AND FUTURE NEEDS

<u>Handbook</u>
During the course of the discussions in the successive meetings there was a general feeling that the need for practical information could be met most effectively by producing some kind of practical handbook. The format of such a book was discussed, but finally it was conclude that a handbook may be too ambitious as a deliverable, given the limitations on time of the working group members. It was decided that in the final report at least a couple of good practices could be presented as illustration of the ideas of the working group and could serve as an example for further additions and elaboration in a later stage. It was suggested and concluded decision makers, designers and engineers, but also vocational arborists and urban foresters were the primary target groups. It was also concluded that the work should not be a comprehensive overview of all developments and achievements over the year within this field of interest, or otherwise duplicate already available information, but should be aimed to complement this information.

It was also decided that the information should not be focused on bad practices but should focus on short and richly illustrated descriptions of case studies of good practices which may give more specific direction to general standards of practice. The way in which such a handbook should eb available in future (printed or digital version, access to a central website, et cetera, should be part of further study when more is know about the possibilities (time, money) of such an initiative.

CONCLUDING AND SUMMING UP

During the discussion in WG-B it gradually became clear that, as a matter of fact there's already a bulk of technical knowledge available nowadays to provide custom made solutions for problems encountered between vegetation and transport infrastructure. Therefore an intriguing question is not primarily how to gather such information but how to make this information available, understandable and usable for the final users, which are the decision makers, town planners, civil engineers and urban forester and arborist.
There are several possible explanations for this type of backlog. Some of these may be tracked down to so called cultural differences. However it cannot be emphasised enough that a sound interaction on the right times between the green and "grey" professionals that are involved in the town planning is a basic condition for a durable solutions of the various conflicts between the green and the "grey" infrastructure.