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AHP–GROUP DECISION-MAKING IN SELECTING TREE SPECIES FOR URBAN WET SITES*

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SUMMARY: This paper deals with the problem of tree species selection for urban wet sites. The Analytic Hierarchy Process (AHP) is used in its standard version and the aggregation of individual decision makers' preferences in mixing selected tree species is performed by geometric averaging method. For the hierarchy of the problem with four criteria and seven tree species, optimal tree species composition is obtained. The proposed approach aims at encouraging landscape planners to adopt contemporary decision-making methodologies in performing related engineering tasks. The numerical example is illustrative.

Key words: *urban wet sites, tree species selection, Analytic Hierarchy Process, group decision making*

INTRODUCTION

The selection of tree species is essential for successful urban greening. In cities, trees are endangered by severe environment conditions and the most common problems are air pollution, drought, insufficient space for the development of root system and crown and a lack of sunshine. It is widely accepted that plants have to be very tolerant and adaptive to survive in urban areas, and therefore landscape planners have to carefully select plants species; otherwise, plants might become unhealthy or even die. Multi-criteria analysis and optimization in selecting and mixing tree species can be helpful in fulfilling real-life urban planning requirements and reaching best interests of a society.

This paper considers the problem of landscaping urban wet zones influenced by both surface and underground waters, which make tree survival (and selection) even harder. The problem solution is finding the optimal (in multi-criteria sense) mixture of seven tree species (*Chamaecyparis lawsoniana, Thuja occidentalis, Acer saccharinum, Platanus x acerifolia, Quercus robur, Salix babylonica* and *Taxodium distichum*), all recognized as compatible in greening urban wet sites (Gerhold and Porter, 2007). The problem is stated as a group decision-making problem and solved by the Analytic hier-

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archy method, a well known decision support tool. Four landscape architects evaluated the tree species against mutually agreed four selection criteria (adaptability to the environment site conditions, resistance to damaging agents – pests and diseases, ornamental value and costs of establishment and management). Individual decisions (mixtures of tree species) are aggregated geometrically.

MATERIALS AND METHODS

Hierarchy of the decision-making problem is shown in Fig.1.

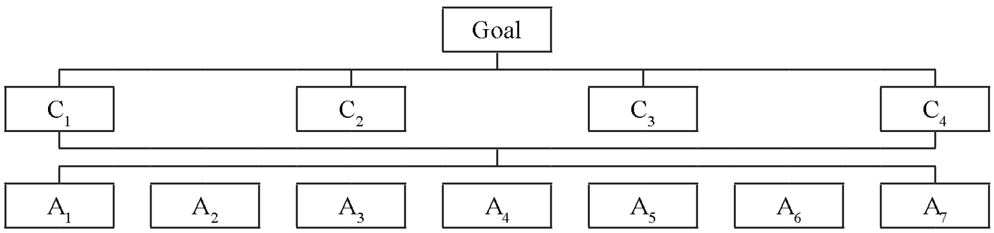

Fig.1. Hierarchy of the problem (Lakićević et al, 2011)

The overall goal is stated as determining the best mixture of seven tree species. A set of four evaluation criteria is stated as:

(C_1) Adaptability to the environment site conditions
(C_2) Resistance to damaging agents – pests and diseases
(C_3) Ornamental value
(C_4) Cost of establishment and management.

The tree species are considered as alternatives, namely:

(A_1) *Chamaecyparis lawsoniana* (Murr.) Parl. is an evergreen tree growing to 40 m at medium rate, with a symmetrical, pyramidal and dense crown. Lawson's Cypress is native to North America. This is the most commonly cultivated plant from this genus in Serbia. It is a shade and wind tolerant and long-lived tree distributed over wet areas. It is well adapted to the environment conditions in cities (Vukićević, 1996).

(A_2) *Thuja occidentalis* L. is an evergreen medium-sized tree, up to 20 m tall. Although originally cultivated in North America, nowadays it is a common plant in Middle and Southern Europe. It is most often associated with cool, moist, nutrient-rich sites, particularly organic soils near streams or other drainageways, or calcareous mineral soils. Northern white cedar grows best in full sun, but will tolerate some shade (Jovanović, 2000).

(A_3) *Acer saccharinum* L. is a deciduous large-sized tree common in North America. It is also called silver, river, swamp, water and white maple. It is ideal for wet lowland sites, and will easily recover from periods of extended flooding. Due to its high ornamental values, this species often occurs in urban parks. Frequently it is planted as a shade tree on account of its rapid growth. It is a soft wood tree, hence susceptible to wind and storm damages (Vukićević, 1996).

(A_4) *Platanus x acerifolia* (Ait.) Willd. is a deciduous tree growing to 35 m with a widely spreading, high domed crown. London plane is usually considered to be an interspecies hybrid between *Platanus orientalis* and *Platanus occidentalis.* This species prefers deep, sufficiently moist, well-drained soil. It is generally very adaptable in city environments and also a smoke and frost tolerant tree (Knežević and Šijačić-Nikolić, 2005).

(A_5) *Quercus robur* L. is a deciduous tree up to 50 m tall. Pedunculate Oak is native to Europe and western Asia. This species is not that flexible when it comes to soil, requiring deep and fertile soils which are influenced by underground waters and occasionally flooded. The largest areas covered by Pedunculate Oak forests in Serbia are in the valleys of the Sava (Srem is the area with the best quality Pedunculate Oak forests), the Danube and the Morava Rivers (Batos et al, 2010).

(A_6) *Salix babylonica* L. is a deciduous tree growing to 18 m at a fast rate with an open crown and pendulous branches. Weeping willow is of Asiatic origin and it was introduced to Europe centuries ago. It is a short-lived and rapidly growing tree that can exist even on wetlands. This is a light-demanding species, susceptible to windthrow (Vukićević, 1996).

(A_7) *Taxodium distichum* Rich. is a deciduous large-sized conifer native to swamps of the United States. Bald Cypress is reputed to be a slow growing and very long-lived tree. When near water, its root form "knees" which stick up above the water level (Phillips and Grant, 1983). It is a light-demanding species, successfully adapted and cultivated in Serbia.

The decision makers were four landscape architects, identified herein as DM1-DM4, all academic professionals.

Analytic hierarchy process in individual and group decision making

The Analytic hierarchy process (AHP) (Saaty, 1980) is the most commonly used multi-criteria based tool for supporting decision-making processes in both individual and group frameworks. It requires a well-structured problem represented as a hierarchy with the goal at the top and, at following levels downward, criteria (and sub criteria, if they are specified) and the alternatives at the bottom level.

The AHP determines preferences among the set of decision elements at the given level of a hierarchy against each element at the upper level. The decision maker performs pair-wise comparisons by using the Saaty's importance scale given in Table 1 and creates a comparison matrix. An upper triangle of the matrix contains assigned values to semantic comparisons (Cf. Table 1) made by the decision maker. The main diagonal entries are 1s, and the lower triangle contains reciprocal values from the upper triangle (symmetrically).

Table 1. Saaty's Importance Scale

Semantic definition	Assigned value
Equally important	1
Weak importance	3
Strong importance	5
Demonstrated importance	7
Absolute importance	9
Intermediate values	2,4,6,8

The given comparison matrix, a priority vector which contains weights of compared elements, can be computed as a principal (right) eigenvector as suggested by Saaty (1980). Although there are other methods to identify priority vector from the given comparison matrix, the eigenvector method (EV) is the most commonly used (Srdjevic, 2005).

The AHP synthesis is performed once all priority vectors are computed within a hierarchy. Simple additive weighting procedure provides the final utilities (weights) of alternatives at the bottom level versus the overall goal at the top of a hierarchy.

Standard AHP evaluates consistency at all levels of the hierarchy and computes consistency ratio (CR) for the whole hierarchy, unlike other multi-criteria decision-making methods (Lakićević and Srđević, 2011). If CR is smaller than prescribed value 0.10, originally proposed by Saaty (1980), then the decision maker is considered consistent within tolerant limit. If not, the inconsistent decision maker should re-evaluate her/his judgments; in practice, inconsistent matrices are sometimes accepted if CR tolerant value of 0.10 is not significantly violated (Jandrić and Srđević, 2000).

In AHP-group decision-making it is necessary to aggregate information obtained by decision makers (Srđević, 2006). There are different ways to do this (e.g., Forman and Peniwati, 1998). A trustful method is to geometrically average the final individual priority vectors, i.e. the weights of alternatives versus goal, by applying formula (1):

$$w_i^G = \prod_{k=1}^{K} [w_i(k)]^{\alpha_k} \quad (1)$$

where K is the number of decision-makers, $w_i(k)$ is the weight of alternative i computed for the decision-maker k, α_k is the weight of the decision-maker, and w_i^G is the the final (group) weight.

RESULTS AND DISCUSSION

AHP method is applied for the hierarchy in Fig. 1 by all four decision makers (DM1-D4) and results are presented in Tables 2 and 3.

Table 2. Weights of criteria with respect to goal

Criteria	Weights of criteria			
	DM1	DM2	DM3	DM4
C_1	0.527	0.168	0.240	0.063
C_2	0.291	0.464	0.160	0.080
C_3	0.115	0.329	0.372	0.421
C_4	0.067	0.039	0.228	0.436

Table 3. Weights of alternatives (tree species) with respect to criteria

Alt.	DM1				DM2			
	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
A_1	0.074	0.252	0.040	0.043	0.087	0.285	0.030	0.037
A_2	0.058	0.201	0.028	0.056	0.068	0.161	0.024	0.044
A_3	0.056	0.158	0.278	0.225	0.103	0.085	0.283	0.233
A_4	0.105	0.105	0.268	0.132	0.073	0.121	0.072	0.127
A_5	0.380	0.057	0.083	0.231	0.367	0.055	0.136	0.251
A_6	0.196	0.033	0.207	0.231	0.212	0.050	0.274	0.251
A_7	0.130	0.195	0.096	0.081	0.090	0.243	0.181	0.056
Alt.	DM3				DM4			
	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
A_1	0.292	0.152	0.258	0.044	0.321	0.037	0.307	0.048
A_2	0.177	0.026	0.024	0.047	0.180	0.245	0.126	0.043
A_3	0.356	0.457	0.160	0.223	0.321	0.183	0.091	0.225
A_4	0.058	0.185	0.050	0.116	0.059	0.031	0.029	0.116
A_5	0.052	0.109	0.085	0.219	0.053	0.058	0.095	0.237
A_6	0.023	0.045	0.260	0.287	0.023	0.161	0.299	0.246
A_7	0.042	0.025	0.163	0.064	0.042	0.285	0.052	0.086

The weights of alternatives versus goal, individually obtained by standard AHP synthesis, are presented in Table 4. These values represent preferences of the decision makers if they would individually define an optimal (in multi-criteria sense) mixture of tree species in a given wet urban area.

For equally 'weighted' decision makers ($\alpha_1=\alpha_2=\alpha_3=\alpha_4=0.25$), the geometrically averaged weights are presented in the last column of the Table 4. These values represent the final 'participation' of assessed tree species in the mixture as the joint group decision.

Table 4. The final AHP results – individual and group

Alt.	Tree species	Weights				
		DM1	DM2	DM3	DM4	Group
$_{A}1$	Chamaecyparis lawsoniana	0.120	0.158	0.200	0.173	0.165
A_2	Thuja occidentalis	0.096	0.096	0.067	0.103	0.092
A_3	Acer saccharinum	0.123	0.159	0.269	0.171	0.179
A_4	Platanus x acerifolia	0.125	0.097	0.089	0.069	0.096
A_5	Quercus robur	0.242	0.142	0.112	0.151	0.160
A_6	Salix babylonica	0.152	0.159	0.175	0.247	0.185
A_7	Taxodium distichum	0.142	0.190	0.089	0.085	0.123

Worthy of note is that the overall consistencies (CR) of decision makers were within tolerant limit of 0.10, except the decision maker 3 (Table 5). This situation can be considered as a usual one.

Table 5. Consistency Ratio (CR)

DM	CR
DM1	0.067
DM2	0.066
DM3	0.151
DM4	0.049

CONCLUSION

The survival of trees in any urban environment is a demanding task. The selection of the most appropriate trees to create mixtures for specific urban sites, especially wet ones, is a task to be performed by landscape planners in attempt to maintain healthy and graceful green areas. To define the best tree mixture, it is important to take into account certain criteria and sometimes sub-criteria. Multi-criteria analysis and the Analytic hierarchy process, as recognized methods in the subject area, may help to compute the exact mixture share (percentage) of tree species.

An illustrative scientific experiment described in this paper demonstrates how the group decision making process can be performed in landscape planning, namely in mixing seven selected tree species in greening urban wet area. The result of this particular AHP-group application indicates that the approach we used could also be efficient if more different adaptable tree species were evaluated in order to preserve endangered biodiversity in cities.

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AHP – GRUPNO ODLUČIVANJE O IZBORU VRSTA DRVEĆA ZA VLAŽNA STANIŠTA U GRADOVIMA

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Izvod

Razmatra se problem izbora vrsta drveća za vlažna staništa u gradovima. Kao naučni metod korišćen je analitički hijerahijski proces (AHP) u standardnoj verziji, a objedinjavanje preferenci donosilaca odluka vršeno je geometrijskim osrednjavanjem težina razmatranih alternativa pri individualnim primenama AHP. Za problem odlučivanja struktuiran kao hijerarhija sa četiri kriterijuma vrednovanja za sedam vrsta drveća, dobijen je, u višekriterijumskom smislu optimalan sastav drveća. Cilj rada je da ukaže na pristup koji bi pejzažne planere mogao da podstakne na savremeno rešavanje pripadajućih inženjerskih zadataka. Numerički primer ima ilustrativni karakter.

Ključne reči: vlažna gradska staništa, izbor vrsta drveća, analitički hijerarhijski proces, grupno odlučivanje.

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