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Tree risk assessment in the urban environment of Thessaloniki: Introducing a new tool

Vassios Dimitrios
Electrical Engineer Forester M.Sc. Ph.D., Municipality of Thessaloniki, Greece
Corresponding Author: Vassios Dimitrios vassiosd@for.auth.gr

ABSTRACT: *Urban trees are living organisms subject to constant pressure. During the different stages of their life cycles they have to deal with numerous attacks. Their intensity and duration inevitably affects the health of the tree. Trees are sometimes affected by physiological changes or may be attacked directly by pests and diseases. Tree risk management involves the process of inspecting and assessing trees for their potential to injure people or damage property. The objective of the study is to develop a tool for tree risk assessment in the urban environment, as well as to present and analyze the results through appropriate statistical methods. The specific tool includes variables related to structural defects, deviations from typical shape, age, vitality, crown, root, position of the tree and slenderness index, and can be a useful "weapon" in the hands of geotechnical municipal officers regarding the risk assessment of trees that growing in the cities, but also for making the appropriate management decisions. However, further evaluations should be carried out on representative samples of urban trees, so that the tool could be re-validated and improved.*
KEY WORD*: Urban trees, tree risk assessment, Thessaloniki*

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I. INTRODUCTION

Undoubtedly, trees are an important part of the urban environment (Haibin et al., 2022). However, in many cases, trees show various structural defects and deviations from their typical shape, a fact that make them dangerous (Vassios, 2023). Trees are living organisms subject to constant pressure, particularly in urban areas. During the different stages of their life cycles they have to deal with numerous attacks, some more serious than others. Their intensity and duration inevitably affects the health of the tree. Trees are sometimes affected by physiological changes (caused by the weather, nutritional deficiencies, poisoning, burns, physical injuries) or may be attacked directly by pests and diseases (viruses, bacteria, fungi, nematodes, insects, mites etc.) (Barcelona City Council, 2011). Furthermore, important variables that affect the stability of trees are the height, the slenderness index, as well as variables related to the tree crown (Kontogianni et al., 2011). Many studies have been carried out about tree risk assessment (Kolarik, 2003; James et al., 2006; Coder, 2007; Kontogianni et al., 2011). However, according to these studies, recordings and evaluations are time-consuming, not to mention that specialized knowledge and instruments are required. The methods of assessing the risk of trees vary. Basic methods are (a) Visual Tree Assessment, (b) Systematic Tree Risk Assessment and (c) Risk Assessment Based on Tree Mechanics (Haibin et al., 2022).

Risk management is a well-established concept in the management of public spaces. Tree risk management involves the process of inspecting and assessing trees for their potential to injure people or damage property. The tree risk management plan should be fully integrated with tree planting and tree pruning programs, and share a common goal of promoting healthy and structurally sound trees. The main ways to reduce or eliminate tree risk focus on (i) moving/removing the "target", (ii) pruning and (iii) cutting down the tree (Pokorny, 2003).

II. RESEARCH OBJECTIVES

The objective of the study is to develop and introduce a tool (form) for tree risk assessment in the urban environment, as well as to present and analyze the results through appropriate multivariate, mostly, statistical methods. With this tool, the assessment can be done quickly and easily without the use of specialized and complex instruments, but macroscopically and visually.

III. RESEARCH METHODOLOGY AND DATA ANALYSIS

The tool includes 9 relatively easily assessable and measurable variables related to structural defects, deviations from typical shape, age, vitality, crown, root collar, position of the tree and also slenderness index (height/diameter at breast height). The final form is based on a previous 7-variable tool with satisfactory reliability and validity (Vassios, 2023). Variables are measured on an ordinal scale of 1 to 5. 1 corresponds to findings of zero/negligible risk, 2 to findings of mild risk, 3 to findings of moderate risk, 4 to findings of high risk, while 5 to findings of extreme risk. The sum of the score of each variable constitutes the total risk score of each tree (VAR10).

In addition, in the form there is the variable "Characterization of risk" (VAR11) with which the evaluator assesses the risk in general based on the overall macroscopic image of the tree ("body language" of the tree), combined with the type of the tree, the pit and the total growing space, the general conditions of the place, as well as the stability of the tree. The values of the variable are 1: Negligible, 2: Low, 3: Moderate, 4: High and 5: Very high. Also, there is the "Recommended interventions" variable (VAR12). The values of the variable are 1: No intervention, 2: Minor pruning, 3: Crown reduction, 4: Hard pruning and 5: Cut down.

A total of 70 trees growing on Stratou Avenue were evaluated. As for Stratou Avenue, is a central road of the Municipality of Thessaloniki. A specific section of the Stratou Avenue was chosen where there are houses and stores close to the tree line, while various species of trees grow there. The evaluations of the trees were carried out in August 2024.

Data handling and analyses were conducted using the IBM SPSS Statistics 21. More specifically, statistical analyses include:

Descriptive statistics. Descriptive statistics deal with methods of organizing and presenting data (Anderson & Finn, 1996).

Reliability. The reliability of a measuring tool relates to the consistency with which it measures the concept that it claims to measure. One of the most common reliability coefficients is Cronbach's alpha (Bland & Altman, 2002).

Validity. The term validity refers to whether a measuring tool measures what it is intended to measure and how well it measures (Babbie, 2011).

Correlation analysis. Correlation estimates the degree or the relationship between variables (Healey, 2015). When one or all of the variables are measured on an ordinal scale, Spearman correlation coefficient is used instead of Pearson correlation coefficient (Foster et al., 2006).

Cluster analysis. Cluster analysis is about identifying groups with similar characteristics (Manly, 1994).

Mann-Whitney U. The non-parametric Mann-Whitney U test is used when the groups being tested are 2 and independent of one another and do not follow the normal distribution (Dawson and Trapp, 2004).

IV. FINDINGS

Descriptive statistics:

Figure 1 shows the tree species.

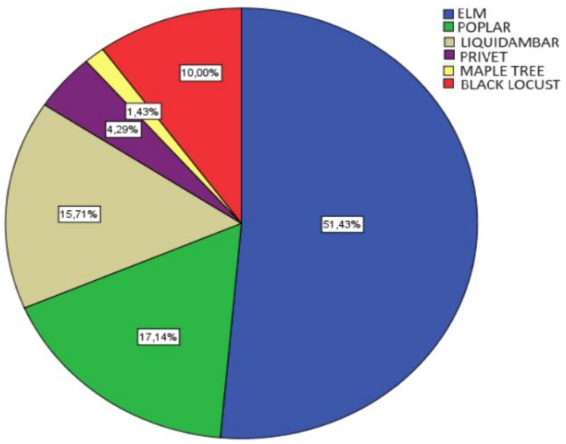

Figure 1: Tree species

The recording and evaluation of the 70 trees according to the measuring variables are presented in Table 1.

Variable	1	2	3	4	5
	Percentage (%)				
Deviation from straightness (VAR1)	38.6	45.7	14.3	1.4	0.0
Deviation from the vertical axis (VAR2)	61.4	24.3	14.3	1.0	0.0
Other defects (forks, twists etc.) (VAR3)	37.1	57.1	5.7	0.0	0.0
Crown size/crown asymmetry (VAR4)	21.4	51.4	25.7	1.4	0.0

Vitality (VAR5)	5.7	61.4	30.0	2.9	0.0
Age (VAR6)	0.0	38.6	57.1	4.3	0.0
Slenderness index (VAR7)	17.1	70.0	12.9	0.0	0.0
Root space/base of the tree (VAR8)	0.0	60.0	32.9	7.1	0.0
Position of the tree (VAR9)	0.0	58.6	40.0	1.4	0.0

Table 1: Recording and evaluation of trees

The total score's (VAR10) histogram and box plot are depicted in Figure 2.

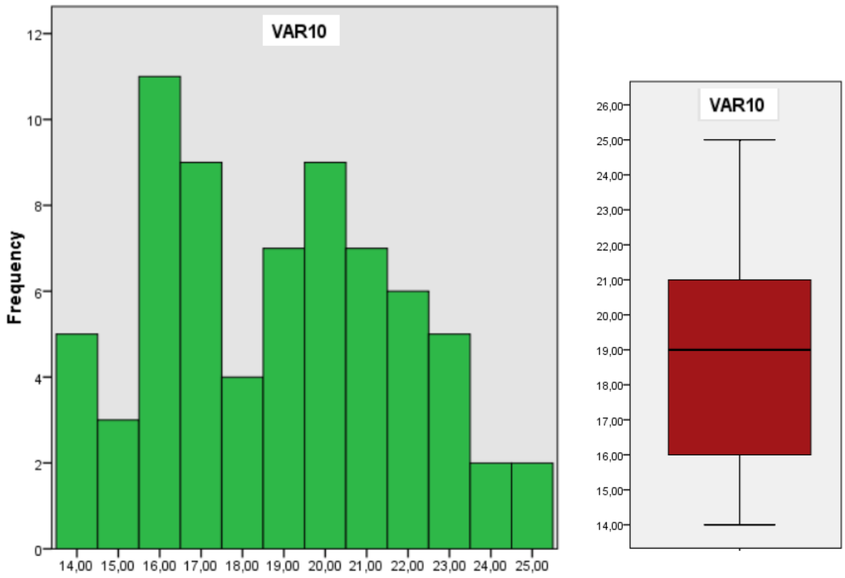

Figure 2: Histogram and box plot

VAR11 and VAR12 are depicted in Figure 3.

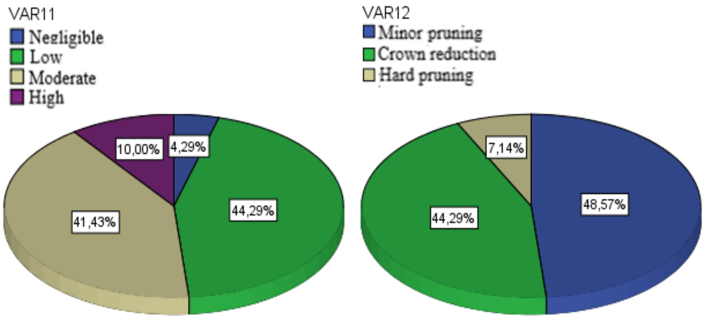

Figure 3: VAR11 and VAR12

Reliability analysis/Construct validity:

The tool was tested for its reliability and validity. As far as reliability is concerned, the entire tool has a Cronbach's alpha coefficient of 0.657 which is acceptable. The construct validity check was performed by using the Factor Analysis. The extraction of factors was done by Principal Component Analysis and the rotation of the axes by Varimax Method. The analysis met the appropriate factorization criteria (KMO, Bartlett's Test of Sphericity, Communalities). A 3-dimensional solution (3 factors), gave characteristic values of 2.561, 1.621 and 1.180 respectively, which state that 28.46% of the explained variance is explained by the first factor, 18.01% by the second and 13.11% by the third, accounting for 59.58% of the total explained variance. The variables VAR2, VAR4, VAR6 and VAR7 appear with high positive loads on first factor. The variables VAR1, VAR5 and VAR9 appear with high positive loads on second factor. The variables VAR3 and VAR8 appear with high positive loads on third factor. The first factor can be called "Dimensions & asymmetries", the second "Robustness/growth" and the third "Stem and root defects". The 3 factors explain a large percentage of the total variance, while each variable loads highly on only one factor. In more detail, the results of reliability and validity were presented in a previous study (Vassios, 2024).

Correlation analysis:

Correlations among the variables VAR10, VAR11 and VAR12, were investigated through the Spearman correlation coefficient (Table 2). VAR10 shows very high positive correlation (0.903) and statistically significant differences at the significance level of 0.01 with VAR11 and very high positive correlation (0.881) and statistically significant differences at the significance level of 0.01 with VAR12. VAR11 shows very high positive correlation (0.929) and statistically significant differences at the significance level of 0.01 with VAR12.

	VAR10	VAR11	VAR12
VAR10	1.000	0.903	0.881
VAR11	0.903	1.000	0.929
VAR12	0.881	0.929	1.000

Table 2: Correlations

The total score corresponds to the evaluator's characterization and the proposed interventions.

Cluster analysis:

The variables that were chosen for the cluster analysis are VAR1, VAR2, VAR3, VAR4, VAR5, VAR6, VAR7, VAR8 and VAR9. Two clusters emerged. Cluster 1 includes 70.0% of the trees and cluster 2 includes 30.0% of the trees, while VAR2, VAR4, VAR1, VAR8 and VAR6 have the greatest predictor importance concerning the classification of trees into clusters (Figure 4). Cluster 2 includes trees with more notable findings concerning VAR1, VAR2, VAR4, VAR6 and VAR8, compared to cluster 1.

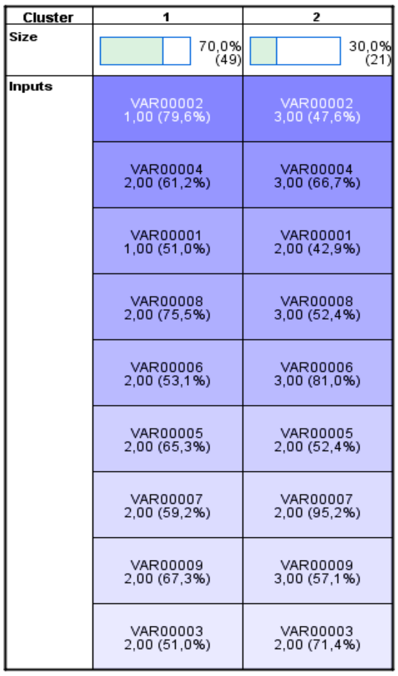

Figure 4: Cluster analysis

Furthermore, cluster 2 includes trees with a higher degree of risk compared to cluster 1, which require more stringent pruning interventions (Figure 5).

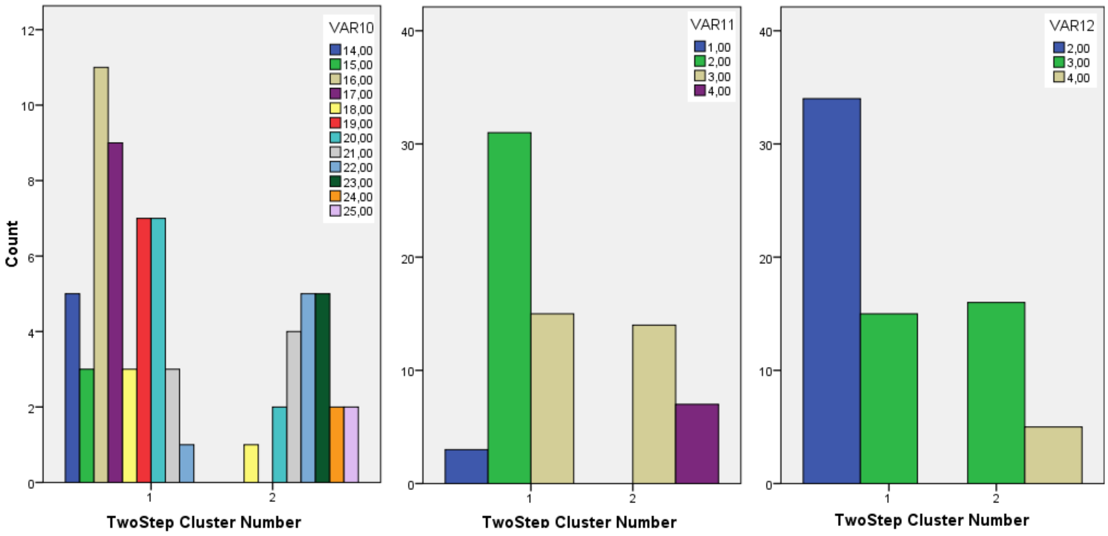

***Figure 5: Distribution of variables VAR10, VAR11 and VAR12 by* cluster**

Mann-Whitney U:

With Mann-Whitney U test, it was investigated whether there is a statistically significant difference (at significance level 0.05) between the values of the variables VAR10, VAR11 and VAR12 and the variable "Two step cluster" according the cluster analysis.

VAR10: Statistically significant differences emerged between the two clusters (sig<0.001, Mann-Whitney U=47.000, Z=-6.027). The mean rank of the first cluster is equal to 25.96, while the mean rank of the second cluster is equal to 57.76.

VAR11: Statistically significant differences emerged between the two clusters (sig<0.001, Mann-Whitney U=105.000, Z=-5.722). The mean rank of the first cluster is equal to 27.14, while the mean rank of the second cluster is equal to 55.00.

VAR12: Statistically significant differences emerged between the two clusters (sig<0.001, Mann-Whitney U=120.000, Z=-5.659). The mean rank of the first cluster is equal to 27.45, while the mean rank of the second cluster is equal to 54.29.

V. DISCUSSION

According to the results of the study, it appears that:

- As far as variable VAR10 is concerned, the data show negative skewness, while there are no outliers or extremes observations. The range of total score is from 14 to 25, while 50% of trees have score from 16 to 21 that is, they appear mild to moderate findings. Several trees show moderate findings in the variables VAR4, VAR5, VAR8 and VAR9. Furthermore, more than half of the trees (57.1%) are at least in the middle of their life cycle. About half of them (54.3%) have a score of 19 (median) to 25, which means that some operations will have to be done on them, mostly crown reduction (44.29%) and in some cases (7.14%) hard pruning. As for variable VAR11, only 10% of the trees were classified as “high risk”.

- The results are highly encouraging regarding the reliability and validity of the tool. More specifically, the tool shows satisfactory reliability, as well as 3 distinct factors which strengthen its construct validity. The loadings of the original variables on each of the factors are high and positive, while each variable loads highly on only one factor. In addition, the 3 factors explain a satisfactory percentage of the total variance. However, further evaluations should be carried out on representative samples in all tree-lined streets and avenues of the Municipality of Thessaloniki, so that the tool could be re-validated and improved and also the results can be safely generalized to the entire population. Of course, samples must be selected with appropriate representative stratified sampling, including all tree species that grow in the Municipality of Thessaloniki, in order to investigate not only the relationship between tree species and risk but also the relationships among all the measuring variables. The assessment of reliability can additionally be done through inter-observer and inter-rater reliability testing.

- The variables VAR10, VAR11 and VAR12 show a very high positive correlation with each other which demonstrates that the more dangerous a tree is assessed, the more drastic intervention must be done on it to remove the hazard. Also, the total score corresponds to a large extend to the evaluator's characterization.

- According to the cluster analysis and combined with Mann-Whitney U test, all the trees with a score of 23 and above belong to the second cluster and they are characterized by high risk, while pruning is mostly required as corrective action. Trees of the second cluster, with a score of 20 to 22, are characterized by moderate to high risk. Trees with a score of 19 are on the borderline regarding pruning intensity. The second cluster mainly includes relatively old trees with a large and unbalanced crown, which they grow in small pits and show moderate findings concerning deviation from the vertical axis and structural defects at the base of them. The 7 trees that were evaluated with a score of 4 in the variable VAR11 may need to be re-evaluated, in combination with the other measurable variables and the type of the tree, so that some of these trees ultimately will be cut down.

- It is fully understood that the specific tool could be a useful "weapon" in the hands of foresters and agronomists who deal with urban greenery, not only for tree risk assessment but for making the suitable management decisions as well. Of course, it cannot be denied that the appropriate training of the staff should be preceded. The tool also can be used to educate students of geotechnical and environmental universities and schools on structural defects and deviations from the standard shape of trees.

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