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Tree risk assessment in the urban environment of Thessaloniki using the U.S. Forest Service 10-point numeric system

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ABSTRACT: *While trees are vital to urban settings, cities often fail to provide them with optimal living conditions. A tree on a city sidewalk develops differently from one growing in a forest. Consequently, trees in urban environments have a shorter life expectancy than those in natural habitats. Many urban trees exhibit structural weaknesses or deformities (defects). However, defective trees are not considered hazardous unless a nearby target is present. This study aims to visually evaluate tree risk in the Municipality of Thessaloniki using the U.S. Forest Service 10-point numeric system. A total of 71 elm trees (Ulmus sp.) located on the sidewalks of Stratou Avenue were assessed. This evaluation form can serve as a valuable tool for urban green officers, aiding both in tree risk assessment and in making informed management decisions.*
KEYWORDS: *Urban trees, tree defects, tree risk assessment*

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I. INTRODUCTION

Although trees are an important part of the urban environment (Vassios, 2026), cities often fail to provide them with optimal living conditions (Barcelona, 2017). A tree on a city sidewalk develops differently from one growing, e.g., in a meadow or in aforest ecosystem. Urban trees tend to have a shorter lifespan compared to their counterparts in natural environments. During different stages of their life cycle, they are exposed to multiple stress factors that further weaken them and reduce their life expectancy (Barcelona, 2011). Factors such as sunlight, soil, the width and orientation of the street, the type of surfacing, the height of buildings, the use of the surrounding buildings, traffic density etc., all have a notable impact on the ability of each species to survive. The limiting factors not only affect the well-being of the visible aerial part of the tree, but also the root system, which is of vital importance for its growth (Figure 1) (Barcelona, 2017).

Figure 1: Tree development in a natural environment (left) and in an urban environment (right)

There are as many ways for trees to fail as there are trees. An ice storm can overload all the branches on a tree, a blustery wind can blow down a tree if its roots are restricted, or a cracked tree can fail under its own weight. A *sound tree* becomes potentially dangerous whenits woody structure is weakened by one or more defects. *Defects* are structural weaknesses or deformities in the tree's branches, stem or root system and they are visible signs that a tree has the potential to fail. Tree failure can be predicted to some extent because defects indicate where the tree is likely to fail. The main categories of defects are: Decayed wood, cracks, root problems, weak branch unions, cankers, poor tree architecture and dead trees, tops or branches (Figure 2) (Pokorny, 2003).

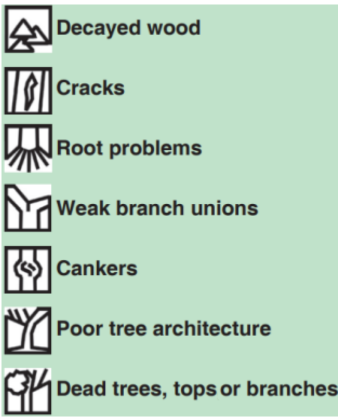

Figure 2: Defect categories

A *defective tree* is a tree with one or more defects (Pokorny, 2003). However, it is not considered hazardous unless a target is present within a potential-failure zone (Albers & Hayes, 1993; USDA Forest Service, 2014). A target could be a person, vehicle, building, park bench, picnic table etc. (Albers & Hayes, 1993), while the potential-failure zone is a circle around the tree with a radius that is the same as the total tree height or the same as the length of a dislodged top, branch, slab or chunk (Figure 3) (USDA Forest Service, 2014). For enhanced safety, this radius may be defined as1.5times the height of the tree or the length of the defective tree section(Pokorny, 2003;Guyon et al., 2017). By definition, *a hazard tree = a defective tree + a target*(Albers & Hayes, 1993).

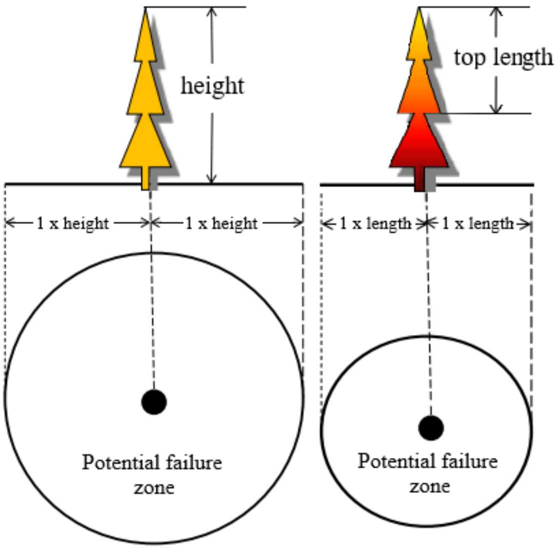

Figure 3: Potential failure zone

In addition to structural defects, important factors influencing tree stability include tree height and the slenderness index (H:D ratio), along with crown-related characteristics such as crown asymmetry, crown length etc., all considered together with the impacts of wind and precipitation (Kontogianni et al., 2011).

Although most defects and symptoms can readily be recognized, there are root problems and some internal defects that are not easily observable and may require in-depth inspections. Even though not all defective/unsound trees and problematic tree species can be detected, the aim of urban green managers is to find at least 80% of them with each inspection. The overall goal of a community tree risk management program is to reduce the risk for injury and damage to people and property to levels that are considered acceptable in compliance with city policies and practices. By doing inspections and acting on urban trees, the risk of tree failure can successfully be managed (Pokorny, 2003). If a hazardous situation exists, there are three basic options for corrective actions: 1. move the target, 2. remove the hazardous part of the tree by pruning, 3. remove the tree (Albers & Hayes, 1993).

The objective of this paper is to visually assess tree risk within the Municipality of Thessaloniki, utilizing the U.S. Forest Service 10-point numeric evaluation tool. A total of 71 elm trees (*Ulmus* sp.) situated along the sidewalks of Stratou Avenue were evaluated.

II. METHODOLOGY

The tree risk evaluation form used is the U.S. Forest Service 10-point numeric system(Pokorny, 2003). The form incorporates four variables:

VAR1. Probability of failure (1-4 points):
1. Low: Some minor defects
2. Moderate: Several moderate defects
3. High: Multiple or significant defects
4. Extremely high: Multiple and significant defects

VAR2. Size of defective part(s) (1-3 points):
1. Parts less than 4 inches in diameter
2. Parts from 4 to 20 inches in diameter
3. Parts greater than 20 inches in diameter

VAR3. Probability of target impact (1-3 points):
1. Occasional use
2. Intermediate use
3. Frequent use

VAR4. Other risk factors (0-2 points): This optional variable is to be used if professional judgment suggests the need to increase the risk rating and invoke immediate corrective actions. For instance, an evaluator may wish to increase a tree's risk rating from 8 to 9 as a means of ensuring the tree will receive immediate corrective treatment.

The total **Risk Rating** (**RR**) [3-10 (12) points] (total score) is equal to the numeric sum of variables VAR1, VAR2, VAR3 and VAR4: **RR = VAR1 + VAR2 + VAR3 + VAR4**. The maximum rating that can be recorded, due to the fourth variable, is 12. However, even if in some extreme case a score equal to 11 or 12 occurs, it will be recorded as 10. Trees with lower ratings have lower risk compared to those with higher ratings. Those witha numeric risk rating of 9 or 10 would be identified as high priority trees to receive corrective treatments first.

The recommended **Corrective Actions** (**CA**) for the trees include: 1) no action required, 2) light pruning, 3) moderate pruning (crown thinning/crown reduction), 4) hard pruning, 5) remove the tree, 6) move the target/exclude visitors from the target area, 7) cabling/bracing/propping and 8) convert to a wildlife tree (Pokorny, 2003).

A total of 71 elm trees (*Ulmus* sp.) located on the sidewalks of Stratou Avenue were assessed. Stratou Avenue is a central road in the Municipality of Thessaloniki, where most of the trees show major defects, mainly due to chronic infestation by the *Galerucellaluteola* insect. The evaluations were conducted in August 2025.

Data handling and statistical analyses were conducted using IBM SPSS Statistics (Version 21). More specifically, the statistical analyses included:

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

Kruskal-Wallis test: The non-parametric Kruskal-Wallis test is used when the groups being tested are more than two, independent of one another and do not follow a normal distribution (Dawson & Trapp, 2004).

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

III. FINDINGS

Descriptive statistics:

Figure 4 illustrates the distribution of VAR1, VAR2, VAR3 and VAR4.

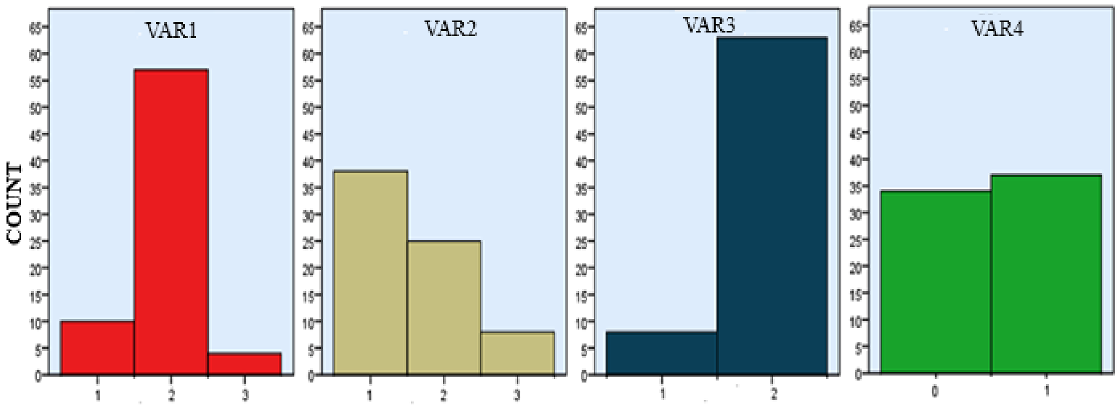

Figure 4: Distribution ofVAR1, VAR2, VAR3 and VAR4

The histogram and box plot of Risk Rating (RR) are depicted in Figure 5.

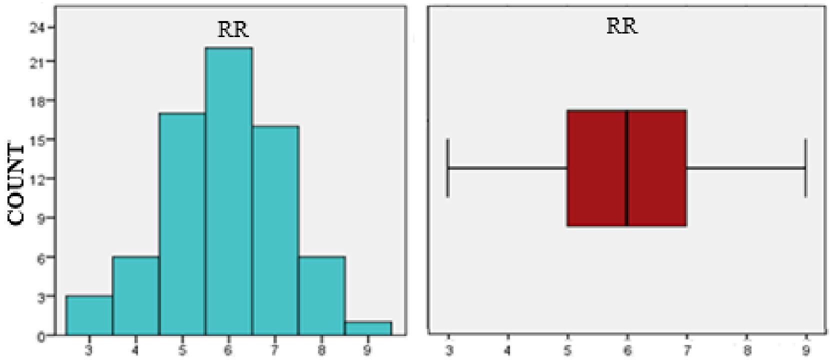

Figure 5: Histogram and box plot of RR

The recommended corrective actions (CA) are illustrated in Figure 6 (left), while the graph on the right presents a comparison of these proposed corrective actions based on the total Risk Rating (RR) score.

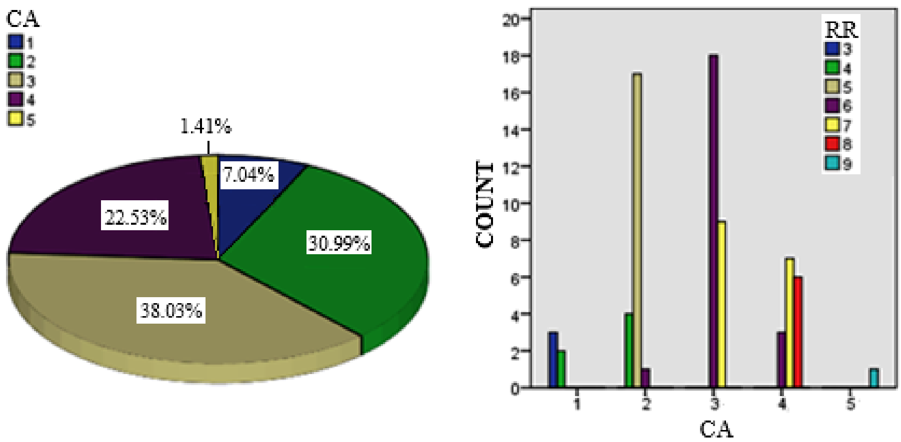

Figure 6: Graphs of CA

Kruskal-Wallis test:

The Kruskal-Wallis test was used to investigate whether there was a statistically significant difference based on the values ofvariable CA in relation tovariable RR. Statistically significant differences were observed between the proposed corrective actions (Chi-Square=57.886, df=4, sig<0.001) (Table 1).

CA	N	Mean Rank
1	5	3.80
2	22	16.80
3	27	43.83

4	16	57.06
5	1	71.00

Table 1: Kruskal-Wallis test (RR and CA)

Correlation analysis:

The correlation between the variables RR and CA was investigated using the Spearman correlation coefficient. RR showed a very strong, positive and statistically significant correlation with CA($r=0.899$, $p<0.01$) (Table 2).

	RR	**CA**
RR	1.000	0.899
CA	0.899	1.000

Table 2: Correlation between RR and CA

IV. DISCUSSION

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

Regarding RR, the data appear to follow a normal distribution with no outliers or extreme observations. The range is from 3 to 9, while 50% of the trees have a score from 5 to 7, indicating minor to moderate risk levels. The value 6 is both the median and the mode. One tree (1.41%) received a score of 9.

About 60% of the trees require moderate to severe pruning. Only the tree with a score of 9 was assessed as too hazardous and required removal. All trees with a score of 8 should be heavily pruned. Moreover,trees with a score of 6 and 7 should be pruned at least moderately. Therefore, the threshold at which a tree must be considered for heavy pruning is 7 and potentially 6 for problematic tree species. Currently, the guidelines state that trees with a numeric risk rating of 9 or 10 are identified as high-priority trees to receive corrective treatments first, without specifying actions for those with lower scores. Consequently, the guidelines should be revised accordinglyregarding the proposed corrective actions per score. The Kruskal-Wallis test also supports this, as statistically significant differences emerged among the proposed corrective actions. The variables RR and CA show a very strong positive correlation with each other, demonstrating that the higher the score, the more intensive the corrective action.

The evaluation form is appropriate for a quick and easy visual assessment of tree risk. Furthermore, due to the fourth variable, the assessor can slightly increase the score if this is deemed necessary, which makes the form more sensitive and accurate. The variables include the very basic characteristics that make up the risk of urban trees. However, another variable could be added to the form related to the severity of the consequences of a tree fall (or parts of it), combined with a redefinition of the range of the measurement scale for individual variables, so that the total score still maintains a maximum value of 10. In this way, the form will be more complete, while maintaining the advantage of a quick and easy evaluation. In addition to the paper-based form, it would be beneficial to develop a digital application that also includes a photo of the tree. Once such a database is established, the evaluation process could be enhanced through the use of artificial intelligence.

It is fully understood that this form serves as a valuable tool for urban green officers, aiding not only in tree risk assessment but also in implementing the appropriate management policy. However, further evaluations should be conducted on representative samples across all tree-lined streets and avenues of the Municipality of Thessaloniki, so that the results can be reliably generalizedto the entire population. Naturally, appropriate staff training must precede this implementation.

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