International Journal of Humanities and Social Science Invention (IJHSSI)
ISSN (Online): 2319 – 7722, ISSN (Print): 2319 – 7714
www.ijhssi.org ||Volume 15 Issue 2 || February 2026 || PP. 07-13

Tree risk assessment in the urban environment of the Municipality of Thessaloniki: Comparison of results between two evaluation forms

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ABSTRACT: *Trees are an important part of the urban environment. However, trees are living organisms subject to constant pressure, particularly in urban fabric. During the different stages of their life cycles, they deal with numerous attacks. The intensity and duration of these attacks inevitably affect the health of the trees. All trees have a varying level of risk for failure. Trees with defects is not considered hazardous unless there is a nearby target that it could hit. Whereas all defective trees cannot be detected, the aim is to find 80% or more of them. The objective of the study is to visually assess the risk of some trees in the Municipality of Thessaloniki with two different evaluationforms(tools) and to compare the results, in order to determine which of the two is more reliable and valid. These tools can be useful "weapons" 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.*
KEYWORDS: *Urban trees, tree risk assessment, Municipality of Thessaloniki*

Date of Submission: 01-02-2026 Date of acceptance: 10-02-2026

I. INTRODUCTION

Trees arean important part of the urban environment (Haibin et al., 2022· Vassios, 2025). However, 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 mostly by the weather, nutritional deficiencies and physical injuries, or may be attacked directly by pests and diseases (Barcelona City Council, 2011).

Defective tree is a tree with one or more defects. *Defects* are structural weaknesses or deformities in the tree's branches, stem or root system. Tree defects can be of two kinds: Injury or disease that seriously weakens the stems, roots,branches or trees, predisposing them to fail, or structural problems arising from poor tree architecture, including V-shaped crotches in stems and branches, shallow rooting habits etc. (Figure 1)(Pokorny, 2003).

Figure 1: Seven basic categories of defects

Defective trees fail sooner than *sound* trees. Defects are visible signs that a tree has the potential to fail and the location of a defect signals where failure is most likely to occur (Pokorny, 2003).A defective tree is not considered hazardous unless there is a nearby target that it could hit. A target could be a person, vehicle, building, park bench, picnic table etc. By definition, *a hazard tree = a defective tree + a target*(Figure 2) (Albers & Hayes, 1993).

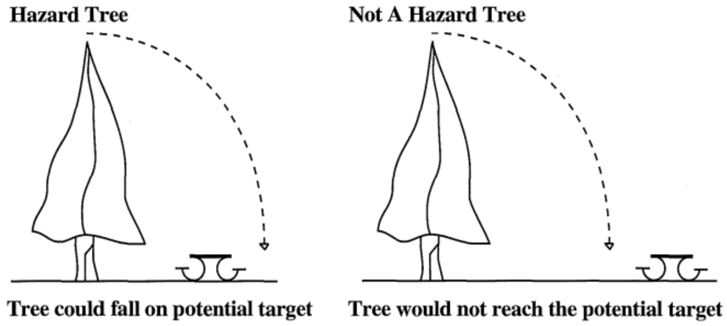

Figure 2: Evaluating a tree as hazard or not due to proximity to a target

All defective trees cannot be detected, corrected or eliminated. Although most defects and symptomssuch as excessive leaning, punky wood, cracks, cankers, weak unions etc. can readily be recognized, there are root problems and some internal defects that are not easily discernable and may require in-depth inspections and the use of specialized diagnostic tools. Also, trees can survive for many years with internal defects. Defect severity can and does change with time. Whereas all defective trees cannot be detected, the aim of municipal geotechnical officers is to find 80% or more of defective trees with each inspection(Pokorny, 2003).

All trees have a varying level of *risk* for failure. On the extremes, trees rated as low in their risk for failure can fail during extreme windstorms, while highly defective trees and tree parts can fail during calm days.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 accordance to city policies and practices. Initiating a tree risk management program is an important step in developing effective tree management programs and community tree populations that maximize public benefits and minimize community liability. By doing inspections and acting on them, the risk of tree failurecan 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 the study is to visually assess the risk of some trees in the Municipality of Thessaloniki with two different evaluation forms(tools) and to compare the results, in order to determine which of the two is more reliable and valid. The evaluations were carried out simultaneously by the same assessor.

II. METHODOLOGY

The first tree risk evaluation form is a 10-point numeric system of U.S. Forest Service. Trees with the highest numeric risk ratings receive corrective treatment first. The form incorporatesfour 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 example, trees with a numeric risk rating of 9 or 10 would be identified as high priority trees to receive corrective treatments first. An inspector 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 ofvariables VAR1, VAR2, VAR3 and VAR4: RR= VAR1 + VAR2 + VAR3 +VAR4. The maximum rating that can be recorded, due to the fourth variable, is 12. The maximum score 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 to make comparisons between tree scores easy. 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 (Pokorny, 2003).

The second tree risk evaluation form is a 10-point numeric system of U.S.D.A. Forest Service. Trees with the highest numeric risk ratings receive corrective treatment first. The formincorporates three variables:
V1: Failure potential(1-4 points). The potential that a tree or tree part may fail.
1. Very low: Live trees without visible defects
2. Low: Live trees with minor defects that do not impair tree structure
3. Medium: Live trees with moderate defects
4. High: Dead trees; live trees with major defects

V2: Target value(1-3 points). The value given to a tree based on its proximity to people and property.
1. Low: Tree's potential impact zone includes, at most, features with limited use and short use
2. Moderate: Tree's potential impact zone includes, at most, features with moderate use and short use length
3. High: Tree's potential impact zone often has people or valuable property present for long periods

V3: Damage potential(1-3 points). The potential that property damage, injury or death may result from a tree or a tree part failure.
1. Minor: Tree or tree part's small size (<3 inch diameter) and short falling distance to target indicate its force or impact could cause minor injury or light damage to property
2. Medium: Tree or tree part's size and falling distance indicate its force or impact could cause at least moderate injury or moderate but not major structural damage
3. Extensive: Tree or tree part's size and falling distance indicate its force or impact could cause serious injury or death or severe damage to property

The total **Hazard Tree Rating**(**HTR**) (3-10 points)(total score) is equal to the numeric sum of variables V1, V2 and V3: HTR= V1 + V2 + V3. Trees with lower ratings have lower risk compared to those with higher ratings. A Hazard Tree Rating matrixindicates four treatment priority classes [low (green background), moderate (yellow), high (red) and severe (purple)], for trees in forest areas.In this matrix, variables V2 (Target value) and V3 (Damage potential) are added and their sum (Target value + Damage potential) constitutes one of the two input variables. Through this simplified 2-waymatrix, the evaluator can easily and quickly quantify the risk(Figure 3) (Guyon etal., 2017).

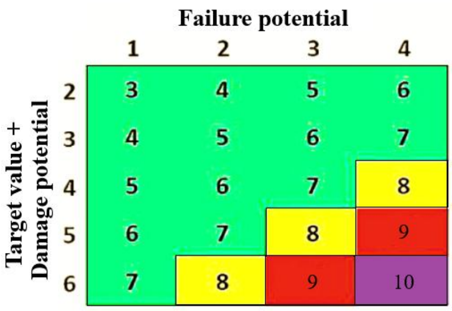

Figure 3: Hazard Tree Rating matrix

In both evaluation forms, the recommended **corrective actions**(**CA**) on the trees are: 1. no action required, 2. light pruning, 3. moderate pruning (crown thinning/crownreduction), 4. hard pruning, 5. remove the tree, 6. move the target/exclude visitors from target area, 7. cabling/bracing/propping, 8. convert to wildlife tree.Also, in both guides from which the evaluationforms were derived, detailed instructions for completing them are given.

A total of 40 trees (elms/*Ulmus* sp.) growing on Stratou Avenue were evaluated simultaneously with both forms. Stratou Avenue is a central road of the Municipality of Thessaloniki and most of the trees show major defects mainly due to the chronic infestation by the *Galerucella luteola* insect. The evaluations of the trees were carried out in September 2025.

Data handling and analyses were conducted using IBM SPSS Statistics 21 and Microsoft Office Excel 2007. More specifically, statistical analyses include:
Descriptive statistics. Descriptive statistics deal with methods of organizing and presenting data (Anderson & Finn, 1996).
Kruskal-Wallis. The non-parametric Kruskal-Wallis test is used when the groups being tested are more than two and independent of one another and do not follow the normal distribution (Dawson and Trapp, 2004).
Correlation analysis. Correlation estimates the degree or the relationshipbetween 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).

III. FINDINGS

Descriptive statistics:

First evaluation form:

Figure 4 shows VAR1, VAR2, VAR3 and VAR4.

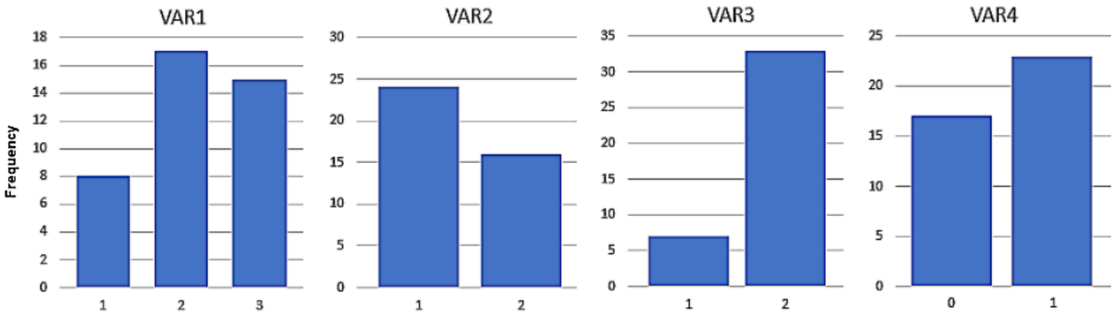

Figure 4: VAR1, VAR2, VAR3 and VAR4

Risk Rating's(first form's total score) histogram and box plot are depicted in Figure 5.

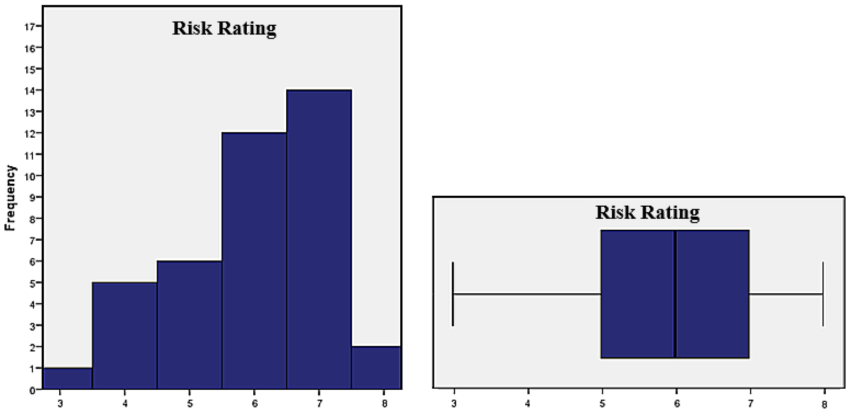

Figure 5: Histogram and box plot (Risk Rating)

Second evaluation form:

Figure 6 shows V1and (V2 + V3).

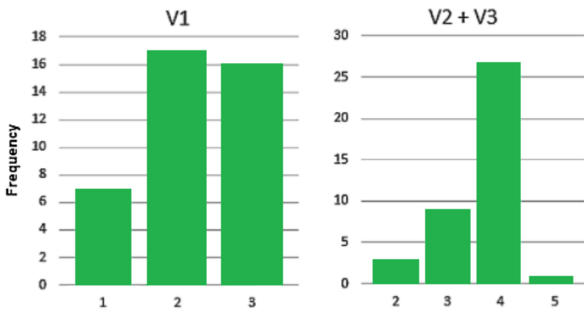

Figure 6: V1 and (V2 + V3)

Hazard Tree Rating's(second form's total score) histogram and box plot are depicted in Figure 7.

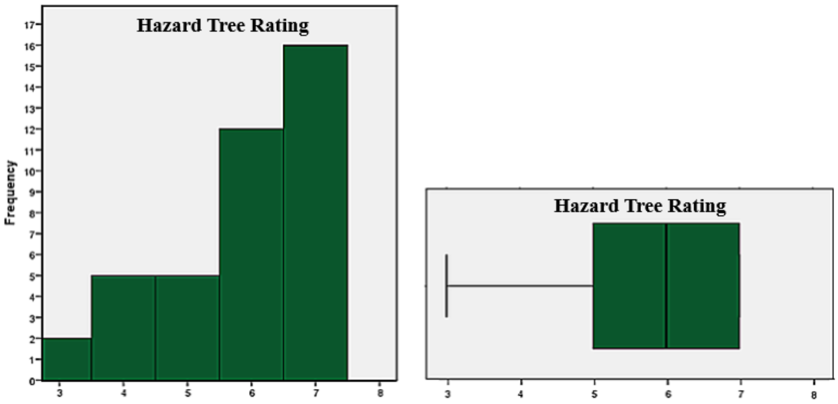

Figure 7: Histogram and box plot (Hazard Tree Rating)

The recommendedcorrective actions are depicted in Figure 8.

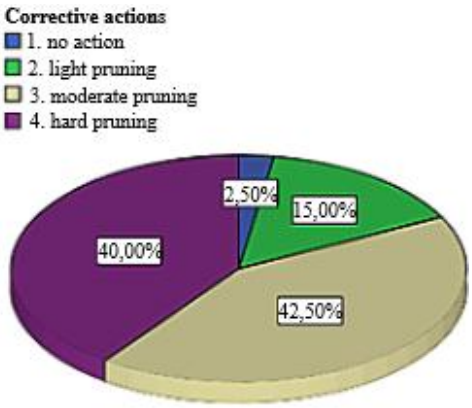

Figure 8: Corrective actions

Figure 9 shows a comparative illustration of the proposed corrective actions combined with the total score of each tree according to the two evaluation forms (RR and HTR respectively).

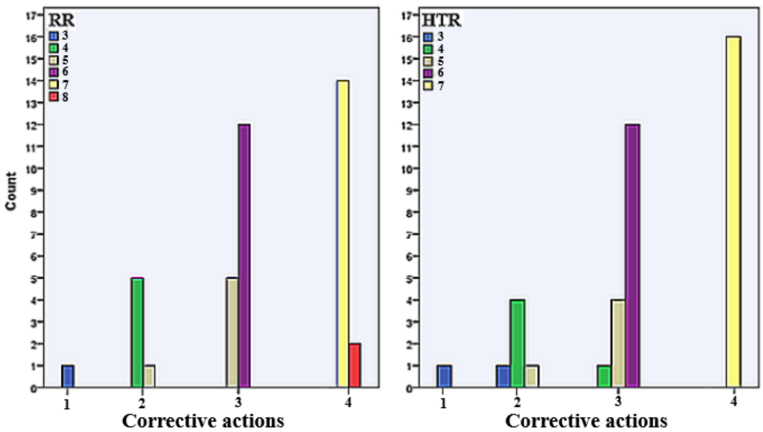

Figure 9: Comparative corrective actions according to the total scores (RR and HTR)

Kruskal-Wallis:

With Kruskal-Wallis test, it was investigated whether there is a statistically significant difference among the values of the variable CA (corrective actions)(i) regarding variable RR and (ii) regarding variable HTR.

RR: Statistically significant differences emerged among the proposed corrective actions(Chi-Square=35.654, df =3, sig<0.001)(Table 1).

CA	N	Mean Rank
1	1	1.50
2	6	5.25
3	17	15.71
4	16	32.50

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

HTR: Statistically significant differences emerged among the proposed corrective actions(Chi-Square=35.967, df =3, sig<0.001)(Table 2).

CA	N	Mean Rank
1	1	1.00
2	6	4.92
3	17	15.85
4	16	32.50

Table 2: Kruskal-Wallis test (HTR and CA)

Correlation analysis:

Correlationsamong variables RR, HTR and CA, were investigated through the Spearman correlation coefficient (Table 3). RR shows very strongpositive correlation (0.985) and statistically significant differences at the0.01 level with HTR and very strong positive correlation (0.956) and statistically significant differences at the0.01 level with CA. HTR shows very strong positive correlation (0.960) and statistically significant differences at the0.01 level with CA.

	RR	HTR	CA
RR	1.000	0.985	0.956
HTR	0.985	1.000	0.960
CA	0.956	0.960	1.000

Table 3: Correlations

IV. DISCUSSION

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

- As far asRR (first evaluation form) is concerned, the datashow negative skewness, while there are no outliers or extreme observations. The range is from 3 to 8, while 50% of trees have score from 5 to 7 that is, they appear minor to moderate findings.2 (two) trees (5%) received a score of 8.

- ConcerningHTR (second evaluation form), the datashow negative skewness, while there are no outliers or extreme observations. The range is from 3 to 7, while 50% of trees have score from 5 to 7 that is, they appear minor to moderate findings. The trees that received a score of 8 in the first form, received a score of 7 in this form.

- About 80% of the trees require moderate to hard pruning. None of the 40 trees were assessed as being too dangerous to be removed.With both forms, it is found that all trees with a score of 6 should be pruned moderately and all trees with a score of 7 should be pruned hardly, as well as the 2 trees that in the first form were scored with an 8, that is, 1 point more than in the second form. Therefore, the threshold at which a tree must be checked for hard pruning is 7, while trees with a score of 8 need re-evaluation.Of course, the instructions of the first form are that trees witha numeric risk rating of 9 or 10 would be identified as high priority trees to receive corrective treatments first, without mentioning actions on trees with lower score (rating). Furthermore, the instructions of the second formare that trees witha numeric risk rating of 7 would be identified as low priority trees to receive corrective treatments. Indeed, the aforementioned instructions for the second form refer to trees that grow in forest areas and not on pavements in the urban fabric. Therefore, the instructions should be appropriately adapted regarding the proposed corrective actions per score.Kruskal-Wallistest also supports this, as almost the same statistically significant differences emerged,in both scores (RR and HTR), among the proposed corrective actions.

- The variables RR, HTR and CAshowvery strong positive correlations with each other which demonstrates that the higher the score, the more drastic the corrective action will be.Moreover, the very strong positive correlation between RR and HTR, indicates that the two forms givesimilar results.

- Both tools (evaluation forms) are appropriate for a quick and easy visual assessment of tree risk. The main advantage of the first tool is that the assessment is done very simply through a 2-waymatrix. On the other hand, the second tool, due to the fourth variable, allows the assessor to slightly increase the score if this is deemednecessary, which makes it more sensitive and accurate. The variables of the two forms include the very basic characteristics that make up the risk of urban trees. Of course, another variable could be added to the first form related to the severity of the consequences of the fall of the tree or its part/parts, in combination with a redefinition of the range of the measurement scale of the individual variables, so that the total score still has a maximum value of 10. In this way, the form will be more complete, and at the same time the advantage of easy and quickevaluation will be maintained.

- It is fully understood that theseevaluation forms could be useful "weapons" in the hands of geotechnical municipal officers who deal with urban greenery, not only for tree risk assessment butalso for making the suitable management decisions. 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 results can be safelygeneralizedto the entire population.Of course, it cannot be denied that the appropriate training of the staff should be preceded.

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