International Journal of Business and Management Invention (IJBMI)
ISSN (Online): 2319 – 8028, ISSN (Print): 2319 – 801X
www.ijbmi.org || Volume 12 Issue 12 || December 2023 || PP: 33-38

Development of a tool for tree risk assessment in the urban environment: Relationships and dependencies between measurable variables

Vassios Dimitrios
Electrical Engineer Forester M.Sc. Ph.D., Municipality of Thessaloniki, Greece

ABSTRACT: *As an important part of the urban environment, trees have certain risks while living in harmony with humans. The risks are mainly due to structural defects and deviations from their typical shape. The objective of the study is to develop a tool for tree risk assessment in the urban environment, as well as to investigate the relationships and dependencies between measurement variables. The tool includes 7 variables related to structural defects, deviations from standard shape, age, robustness, crown and also, slenderness index. The specific tool can be a useful "weapon" in the hands of geotechnical municipal officers regarding the risk assessment of trees that growing in the cities, as well as for making the appropriate management decisions.*
KEY WORD*: Urban greenery, tree risk assessment, Thessaloniki*

Date of Submission: 08-12-2023 Date of Acceptance: 22-12-2023

I. INTRODUCTION

Urban greenery leads to the sustainable development of cities through the interaction of a number of factors, namely the social context, the management objectives, the means, the management's results and the various information (Dwyer et al, 2003). As an important part of the urban environment, trees have certain risks while living in harmony with humans. The failure of trees in extreme weather may cause casualties and damage to public and private (Haibin et al, 2022). So, in many cases, trees show various structural defects and deviations from their typical shape, a fact that made them dangerous (Vassios, 2023). Many studies have been carried out about tree risk assessment (Kolarik, 2003; James et al., 2006; Coder, 2007; Kontogianni et al., 2011) which however, require specialized knowledge and instruments, while generally being time-consuming. Also, there are some sophisticated forms like ISA Basic Tree Risk Assessment Form (https://wwv.isa-arbor.com/education/resources/BasicTreeRiskAssessmentForm_Print_2017.pdf).

II. RESEARCH OBJECTIVES

The objective of the study is to develop a tool for tree risk assessment in the urban environment, mostly on sidewalks, as well as to investigate the relationships and dependencies between measurement variables. 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 7 relatively easily assessable and measurable variables related to structural defects, deviations from standard shape, age, robustness, crown and also, slenderness index (H/D). 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 very high risk. Further information and instructions are given for the convenience of the evaluator for slope, age and height to diameter ratio. The sum of the score of each variable constitutes the total risk score of each tree (VAR8). From a score of 15 and above, interventions on the tree are considered, from mild pruning to cutting, always depending on the individual score and in combination with the overall macroscopic image of the tree, the species, the total growth space and the general conditions as well.

In addition, in the questionnaire form (tool) there is the variable "Characterization of risk" (VAR9) with which the evaluator assesses the risk in general based on the overall macroscopic image of the tree, combined with the type of the tree, the total growing space, the general conditions of the space, 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 (VAR10). 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 101 trees (elms/*Ulmus* sp.) growing on Stratou Avenue were evaluated. Stratou Avenue is a central road of the Municipality of Thessaloniki and most of the trees show strong defects and deviations mainly due to the chronic infestation by the *Galerucella luteola* insect. The evaluations of the trees were carried out in August 2023.

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

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

Reliability. The reliability of a questionnaire/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 questionnaire measures what it is intended to measure and how well it measures (Babbie, 2011).

Correlations. Correlation estimates the degree or the relationship between two or more 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).

Categorical regression. Categorical regression quantifies categorical variable data by assigning numerical values to the categories for the purpose of the best linear regression of the transformed variables (Van der Kooij and Meulman, 1997). With categorical regression it is possible to predict values of a dependent variable for any combination of independent variables (Androulidakis and Siardos, 1999).

IV. FINDINGS

Descriptive statistics:

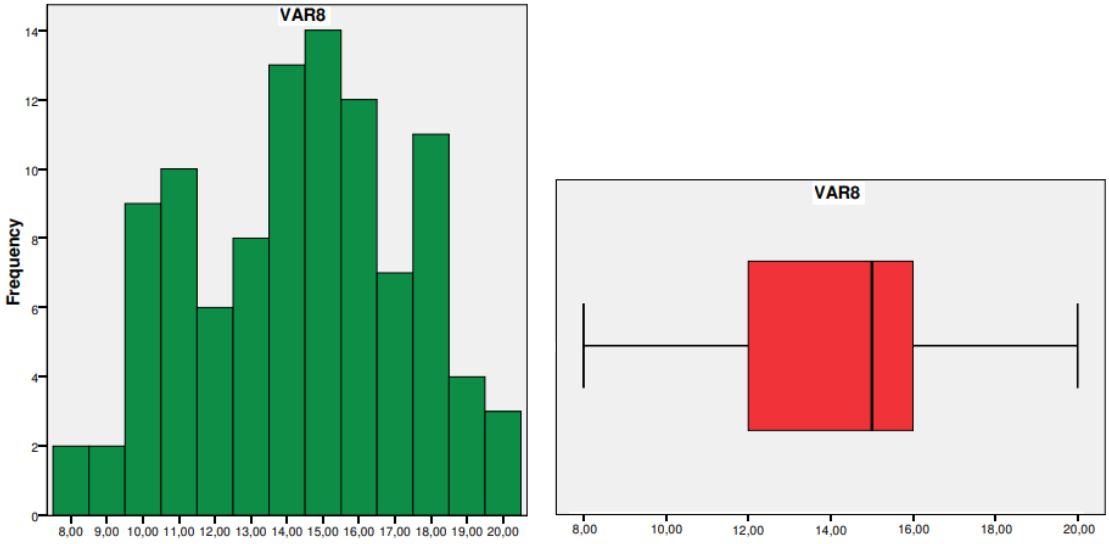
The ratings of 101 trees are presented in total in Table 1.

Table 1: Trees' ratings

Variable	1	2	3	4	5
	Percentage (%)				
Cavities (VAR1)	68.3	6.9	22.8	2.0	0.0
Crown asymmetry/crown size (VAR2)	27.8	45.5	25.7	1.0	0.0
Other defects (bend/warp, forks, twists, base swelling etc.) (VAR3)	9.9	67.3	22.8	0.0	0.0
Vitality/robustness (VAR4)	4.0	56.4	34.6	5.0	0.0
Deviation from the vertical axis (VAR5)	69.3	27.7	3.0	0.0	0.0
Age (VAR6)	1.0	36.6	62.4	0.0	0.0
Slenderness index (H/D) (VAR7)	13.9	44.5	41.6	0.0	0.0

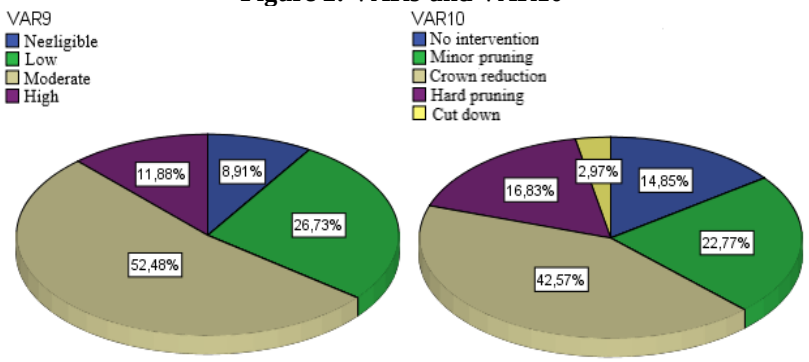
The total score's (VAR8) histogram and box plot are depicted in Figure 1.

Figure 1: Histogram and box plot (VAR8)



VAR9 and VAR10 are depicted in Figure 2.

Figure 2: VAR9 and VAR10



Reliability analysis/Construct validity:

The tool was tested for its reliability and validity. Concerning the reliability, the entire tool has a Cronbach's alpha coefficient of 0.759 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 2.125, 2.010 and 1.359 respectively, which state that 30.36% of the explained variance is explained by the first factor, 28.72% by the second and 19.41% by the third, accounting for 78.49% of the total explained variance. The first factor can be called "Dimensions & asymmetries" and shows high loadings from the variables VAR2, VAR6 and VAR7. The second factor can be called "Robustness/health" and shows high loadings from the variables VAR1 and VAR4. The third factor can be called "Deviations & structural defects" and shows high loadings from the variables VAR3 and VAR5. In more detail, the results of reliability and validity were presented in a previous study (Vassios, 2023).

Correlations:

The correlation between the variables VAR8, VAR9 and VAR10, was investigated through the Spearman correlation coefficient (Table 2). VAR8 shows very high positive correlation (0.893) and statistically significant differences at the significance level of 0.01 with VAR9 and very high positive correlation (0.929) and statistically significant differences at the significance level of 0.01 with VAR10. VAR9 shows very high positive correlation (0.928) and statistically significant differences at the significance level of 0.01 with VAR10.

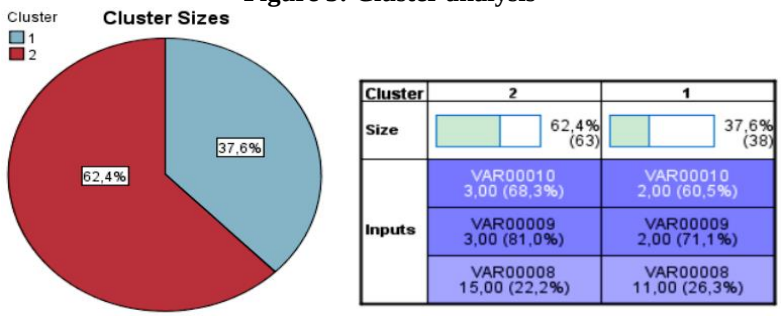
Table 2: Correlations

	VAR8	VAR9	VAR10
VAR8	1.000	0.893	0.929
VAR9	0.893	1.000	0.928
VAR10	0.929	0.928	1.000

Cluster analysis:

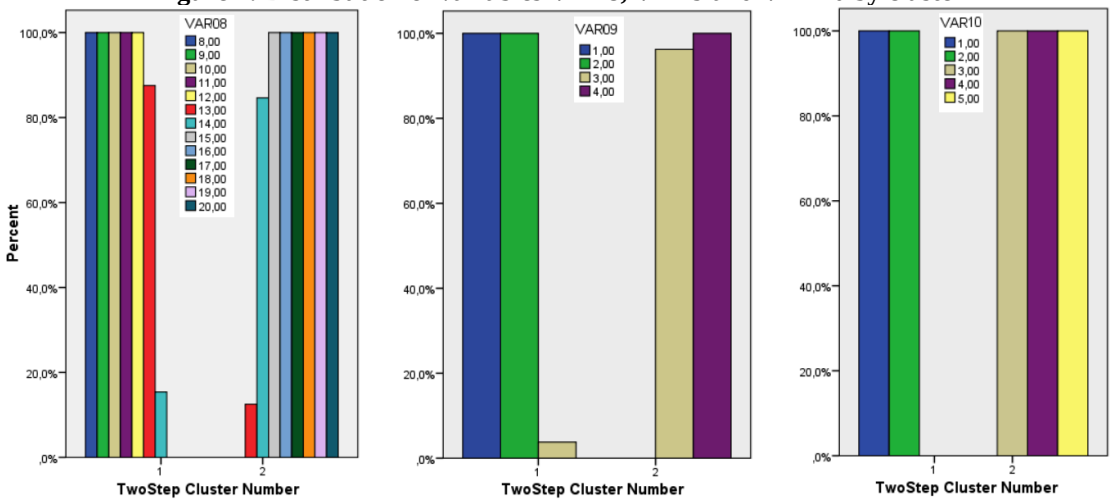
The variables chosen to perform the cluster analysis are VAR8, VAR9 and VAR10. Two clusters emerged. Cluster 2 includes 62.4% of the trees. The variable with the highest predictive significance is VAR 10, followed by VAR9 and VAR8 (Figure 3).

Figure 3: Cluster analysis



Cluster 2 includes trees with a higher degree of risk concerning VAR8, VAR9 and VAR10, compared to cluster 1 (Figure 4).

Figure 4: Distribution of variables VAR8, VAR9 and VAR10 by cluster



Categorical regression:

In this analysis, VAR1, VAR2, VAR3, VAR4, VAR5, VAR6 and VAR7 are the independent variables while the Cluster number is the dependent variable. Categorical regression yielded a multiple correlation coefficient R value of 0.981 and a multiple determination coefficient R^2 of 0.779 indicating that 77.9% of the variance in the transformed values of the dependent variable is explained by the transformed values of the independent variables. The analysis of variance for a significance level α equal to 0.05 gave an F value equal to 19.965 which corresponds to a zero significance level, showing the very good fit of the model to the data.

At a significance level 0.05, the absence from the equation of variables VAR1, VAR4 and VAR5, with the presence of the others, do not reduce the exploratory capacity of the equation. The rest variables are statistically significant (sig<0.05). The standardized regression coefficients are all positive. VAR6 has the bigger coefficient. VAR1, VAR4 and VAR5 have the smaller coefficients. Table 3 presents the standardized coefficients along with the F values.

Table 3: Standardized coefficients and F values

	Standardized Coefficients	df	F	Sig.
	Beta			
VAR1	0.092	1	0.739	0.392
VAR2	0.224	4	6.284	0.000
VAR3	0.148	3	4.443	0.006
VAR4	0.115	2	1.510	0.227
VAR5	0.054	1	0.850	0.359
VAR6	0.436	1	11.860	0.001
VAR7	0.173	3	2.990	0.035

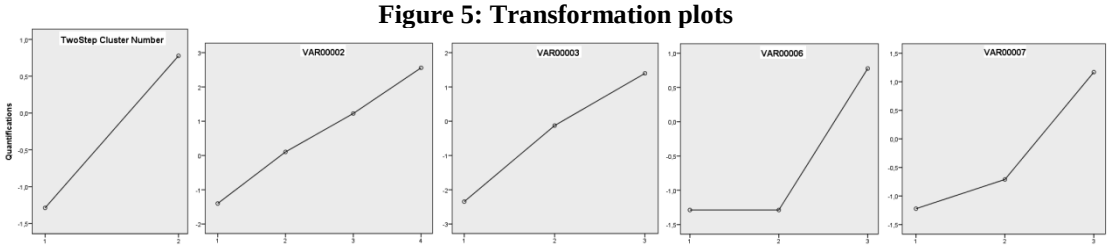
Concerning the correlation coefficients, all of them are positive. VAR6 has the higher correlation coefficients. Regarding importance, VAR6 has the higher value. Table 4 presents the zero-order correlation coefficients, partial correlation coefficients, part correlation coefficients, importance and tolerance values of the independent variables.

Table 4: Correlations, importance and tolerance

	Correlations			Importance	Tolerance
	Zero-Order	Partial	Part		
VAR1	0.529	0.117	0.055	0.062	0.363
VAR2	0.611	0.335	0.167	0.176	0.558
VAR3	0.490	0.256	0.124	0.093	0.709
VAR4	0.450	0.166	0.079	0.067	0.472
VAR5	0.207	0.105	0.050	0.014	0.838
VAR6	0.789	0.512	0.281	0.442	0.414
VAR7	0.660	0.230	0.111	0.147	0.413

The transformation plots of Cluster number, VAR2, VAR3, VAR6 and VAR7 are depicted in Figure 5.

Figure 5: Transformation plots



V. DISCUSSION

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

- The specific form (tool) can be a useful "weapon" in the hands of foresters and agronomists who deal with urban greenery regarding the risk assessment of trees that growing in the cities, as well as for making the suitable management decisions. Of course, the appropriate information and training of the staff should be preceded. It can also be used to educate students of geotechnical and environmental schools on structural defects and deviations from the standard shape of trees.

- Apart from the 10 variables included in the form, there could possibly be an extra variable for the likelihood of failure, which will be measured on an ordinal scale with potential values Improbable, Possible, Probable and Imminent.

- Most trees have a score of 15, which is also the median. The data show some asymmetry towards the highest scores, while there are no outliers or extremes. The range is from 8 to 20. Only 3% have the highest score. On average, these trees show moderate risk findings in general. Half of them have a score of 15 and above, which means that some operations will have to be done on them, from mild to severe pruning mainly, while those with a high score should be scrutinized.

- The results are highly encouraging regarding the reliability and validity of the tool. More specifically, the tool shows satisfactory reliability, as well as 3 very 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. Furthermore, the 3 factors explain a very large percentage of the total variance. Nevertheless, it would be useful to carry out other such recordings and evaluations in a representative sample of an appropriate size in all tree lined avenues and streets of the Municipality of Thessaloniki in order to recheck the tool and make possible improvements and also to be able to generalize the results.

- The variables VAR8, VAR9 and VAR10 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.

- According to the cluster analysis, all the trees with a score of 15 and above are characterized by high to very high risk and are required as actions, mostly pruning and in 3% of cases cutting. In many cases, the same applies to trees with a score of 14. This was roughly the initial estimate of the score above which interventions on trees are required.

- Concerning the categorical regression, the variables VAR2, VAR6 and VAR7 are the ones that influence the model to a great extent and VAR3 secondarily. VAR2, VAR6 and VAR7 are also the ones that constitute the first and most important factor that emerged from the factor analysis and which is named "Dimensions & asymmetries". So, the trees belonging to the second cluster show a high score in the specific three variables as well as in the first factor.

- Stratou Avenue provides very good conditions for the growth of trees as the width of the sidewalk is large, while cars are not parked under the trees. Also, there are no houses at all. Therefore, the risk rating is more lenient than if the trees were growing in a spot with more limited growth space.

BIBLIOGRAPHY

[1]. Anderson, T, & Finn, J. (1996). The new statistical analysis of data. New York: Springer.
[2]. Androulidakis, S., & Siardos, G. (1999). Leadership ability dimensions as related to rural women's characteristics: A methodological approach for further consideration. In J. Kania and M. Dygar (Eds.), Proceedings of the 14th European Seminar on Extension and Education. Volume 1, August 30-September 4 (pp. 163-175). Poland: The Agricultural University of Cragow.
[3]. Babbie, E. (2011). Introduction to social research. Wadsworth: Cengage Learning.
[4]. Bland, J., & Altman, D. (2002). Validating scales and indexes. BMJ 2002, 324(7337), 606-607.
[5]. Coder, K. (2007). Storm wind loads on trees. University of Georgia and Warnell: Outreach Publication SFNR07-3.
[6]. Dwyer, J., Nowak, D., & Noble, M. (2003). Urban forests. Journal of Arboriculture, 29(1), 49-55.
[7]. Foster, J., Barkus, E., & Yavorsky, C. (2006). Understanding and using advanced statistics. London: SAGE Publications.
[8]. Haibin, L., Xiaowei, Z., Zeqing, L., Jian, W., & Xu, T. (2022). A review of research on tree risk assessment methods. Forests, 13(10), 1-20.
[9]. Healey, J. (2015). Statistics: A tool for social research. USA: Cengage Learning.
[10]. James, R., Haritos, N., & Ades, P. (2006). Mechanical stability of trees under dynamic loads. Am. J. Bot., 93(10), 1522–1530.
[11]. Kolarik, J. (2003). The application of the static integrated approach for arboricultural practice. In: Proc. Workshop, Westonbirt, UK, July.
[12]. Kontogianni, A., Tsitsoni, T., & Goudelis, G. (2011). An index based on silvicultural knowledge for tree stability assessment and improved ecological function in urban ecosystems. Ecological Engineering, 37, 914-919.
[13]. Manly, B. (1994). Multivariate statistical methods. A primer. London, New York: Chapman & Hall.
[14]. Van der Kooij, A., & Meulman, J. (1997). MURALS: Multiple regression and optimal scaling using alternating least squares. In E. Faulbaum & W. Bandilla (Eds.), Softstat '97. Stuttgart: Lucius & Lucius.
[15]. Vassios, D. (2023). Development and validation of a tool for tree risk assessment in the urban environment: Statistical tests of reliability and validity. International Journal of Humanities and Social Science Invention, 12(9), 5-8.

Vassios Dimitrios. "Development of a tool for tree risk assessment in the urban environment: Relationships and dependencies between measurable variables." *International Journal of Business and Management Invention (IJBMI)*, vol. 112(12), 2023, pp. 33-38. Journal DOI-10.35629/8028