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Reliability and validity of a tool for tree risk assessment in the urban environment of Thessaloniki

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ABSTRACT: *Urban greenery leads to the sustainable development of cities through the interaction of a number of factors. However, in many cases trees show various structural defects and deviations from their typical shape, a fact that made them dangerous. The objective of the study is to develop and validate, through reliability and validity testing, a tool for tree risk assessment in the urban environment. The form includes 9 variables related to structural defects, deviations from standard shape, age, vitality, crown, root space, position of the tree 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. The results are highly encouraging, but the procedures must be repeated on suitable samples of urban trees, in order to revalidate the tool and make possible improvements.*
KEY WORD*: Urban greenery, tree risk assessment, Municipality of Thessaloniki*

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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). However, in many cases trees show various structural defects and deviations from their typical shape, a fact that made them dangerous e.g. in adverse weather conditions (Tsoumis, 1991; Kane, 2008; Kontogianni et al., 2011). In order to assess the risk of trees, many studies have been carried out (Kolarik, 2003; James et al., 2006; Coder, 2007; Kontogianni et al., 2011) which however, require specialized knowledge and instruments, while generally being time-consuming. 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 (Pokorny, 2003). The failure of trees may cause casualties and damage to public and private (Haibin et al, 2022). 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. The main ways to reduce or eliminate tree risk focus on (i) 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 validate, through reliability and validity testing, a tool for tree risk assessment in the urban environment, mostly on tree-lined streets and avenues. 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, deviation from straightness and the vertical axis, age, vitality, crown, root space, 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 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 (VAR10).

In addition, in the form (tool) 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, combined with the type of the tree, the tree pit and 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 (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. Stratou is a central avenue 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. 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 analysis included:

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

Reliability. The reliability of a questionnaire relates to the consistency with which it measures the concept that it claims to measure (Bland & Altman, 2002). The assessment of reliability is performed by test-retest, split-half, internal consistency, inter-observer and inter-rater reliability testing (Ouzouni & Nakakis, 2011). 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).

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:

Figure 1 shows the tree species.

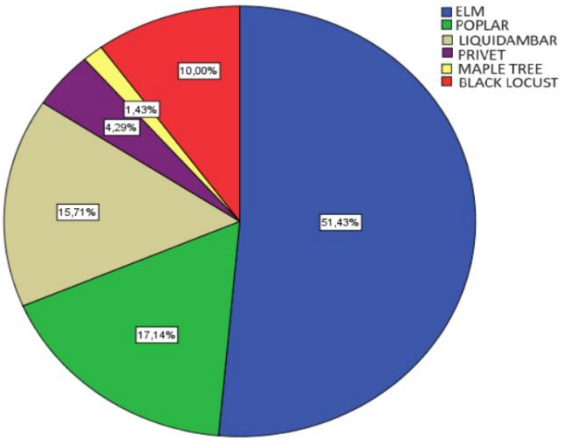

Figure 1: Tree species

The ratings of 70 trees are presented in total 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: Trees' ratings

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

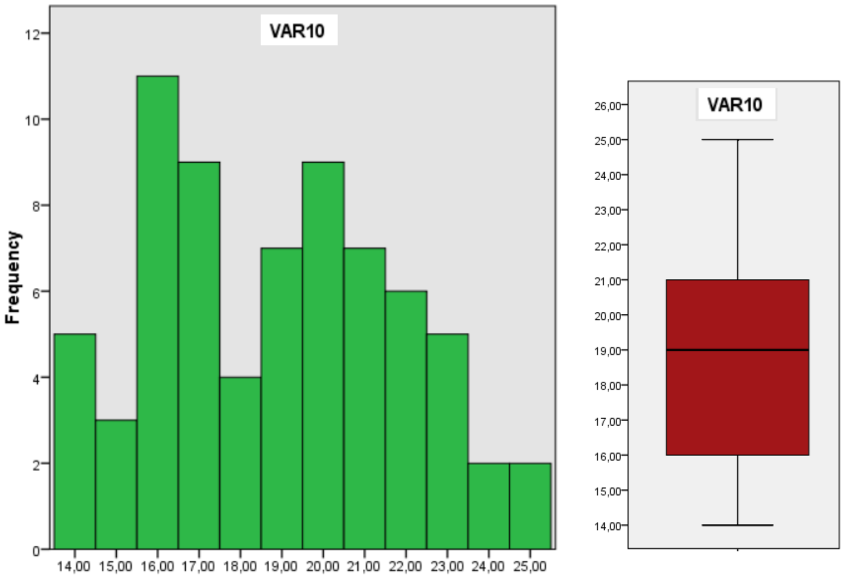

Figure 2: Histogram and box plot

VAR11 and VAR12 are depicted in Figure 3.

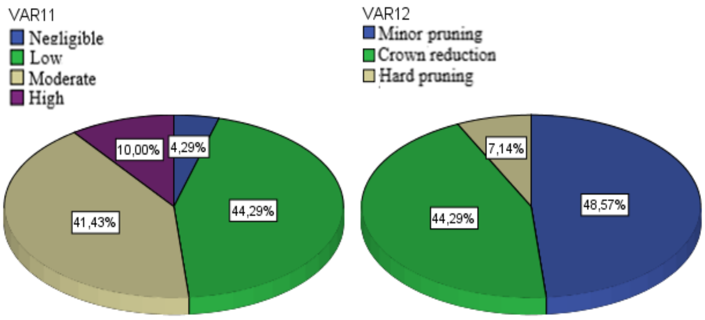

Figure 3: VAR11 and VAR12

Reliability analysis:

The entire tool has a Cronbach's alpha coefficient of 0.657 which is acceptable.

Construct validity:

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 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 loads of the factors are presented in Table 2. The first factor can be called "Dimensions & asymmetries", the second "Robustness/growth" and the third "Stem and root defects". For the sake of brevity and ease of processing, the 3 factors were given the abbreviations F1, F2 and F3 respectively and will henceforth be used in the text. The variables VAR2, VAR4, VAR6 and VAR7 appear with high positive loads on F1. The variables VAR1, VAR5 and VAR9 appear with high positive loads on F2. The variables VAR3 and VAR8 appear with high positive loads on F3.

Variable	Factor		
	1	2	3
VAR1		0.663	

VAR2	0.741		
VAR3			0.760
VAR4	0.869		
VAR5		0,749	
VAR6	0.726		
VAR7	0.535		
VAR8			0.564
VAR9		0.621	

Table 2: Factors' loads

Categorical regression:

Model 1-Dependent variable: VAR10. In this model, the 3 factors are the independent variables while VAR10 is the dependent variable. Categorical regression yielded a multiple correlation coefficient R value of 0.971 and a multiple determination coefficient R^2 of 0.943 indicating that 94.3% 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 0.001 gave an F value equal to 362.282 which corresponds to a zero significance level, showing the very good fit of the model to the data.

At a significance level 0.001, the absence from the equation of each variable separately, with the presence of the others, reduces the exploratory capacity of the equation as all variables are statistically significant (sig<0.001). The standardized regression coefficients are all positive. The third factor has a slightly smaller coefficient. Table 3 presents the standardized coefficients along with the F values.

	Standardized Coefficients	**df**	**F**	**Sig.**
	Beta			
F1	0.757	1	146.737	0.000
F2	0.578	1	147.640	0.000
F3	0.249	1	46.893	0.000

Table 3: Standardized coefficients and F values (VAR10)

Of the correlation coefficients, all are positive while somewhat smaller than the others is the one corresponding to the third factor (zero-order and part). Regarding importance, the third factor has a low value. Regarding tolerance, high values are observed in all three factors. Table 4 presents the zero-order correlation coefficients, partial correlation coefficients, part correlation coefficients, importance and tolerance values of the independent variables.

	Correlations			**Importance**	**Tolerance**
	Zero-Order	**Partial**	**Part**		
F1	0.729	0.953	0.756	0.586	0.997
F2	0.568	0.924	0.577	0.349	0.996
F3	0.249	0.720	0.248	0.066	0.995

Table 4: Correlations, importance and tolerance (VAR10)

The transformation plots of VAR10, F1, F2 and F3, are depicted in Figure 4.

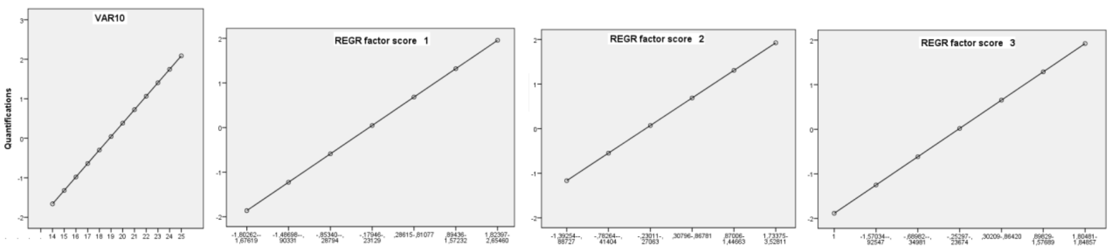

Figure 4: Transformation plots (VAR10)

Model 2-Dependent variable: VAR11. In this model, the 3 factors are the independent variables while VAR11 is the dependent variable. Categorical regression yielded a multiple correlation coefficient R value of 0.903 and a multiple determination coefficient R^2 of 0.816 indicating that 81.6% 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 0.001 gave an F value equal to 97.346 which corresponds to a zero significance level, showing the very good fit of the model to the data.

At a significance level 0.01, the absence from the equation of each variable separately, with the presence of the others, reduces the exploratory capacity of the equation as all variables are statistically significant (sig<0.01). The standardized regression coefficients are all positive. The third factor has a smaller coefficient. Table 5 presents the standardized coefficients along with the F values.

	Standardized Coefficients	df	F	Sig.
	Beta			
F1	0.787	1	195.800	0.000
F2	0.432	1	55.597	0.000
F3	0.184	1	9.853	0.003

Table 5: Standardized coefficients and F values (VAR11)

Of the correlation coefficients, all are positive while somewhat smaller than the others is the one corresponding to the third factor. Regarding importance, the third factor has a low value. Regarding tolerance, high values are observed in all three factors. Table 6 presents the zero-order correlation coefficients, partial correlation coefficients, part correlation coefficients, importance and tolerance values of the independent variables.

	Correlations			Importance	Tolerance
	Zero-Order	Partial	Part		
F1	0.766	0.878	0.786	0.739	0.997
F2	0.418	0.709	0.431	0.221	0.996
F3	0.175	0.392	0.183	0.039	0.995

Table 6: Correlations, importance and tolerance (VAR11)

The transformation plots of VAR11, F1, F2 and F3, are depicted in Figure 5.

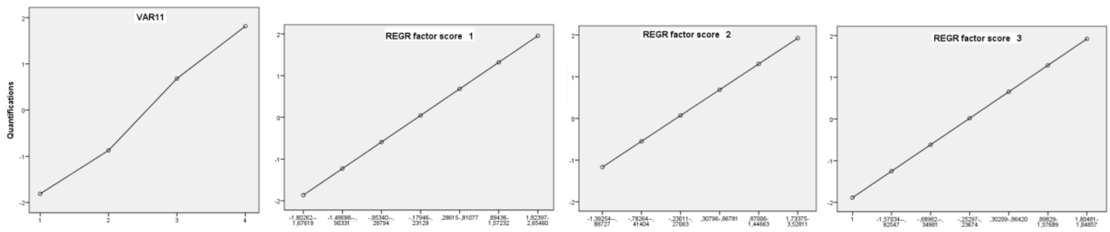

Figure 5: Transformation plots (VAR11)

Model 3-Dependent variable: VAR12. In this model, the 3 factors are the independent variables while VAR12 is the dependent variable. Categorical regression yielded a multiple correlation coefficient R value of 0.898 and a multiple determination coefficient R^2 of 0.806 indicating that 80.6% 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 0.001 gave an F value equal to 91.663 which corresponds to a zero significance level, showing the very good fit of the model to the data.

At a significance level 0.001, the absence from the equation of each variable separately, with the presence of the others, reduces the exploratory capacity of the equation as all variables are statistically significant (sig<0.001). The standardized regression coefficients are all positive. The second and the third factor have slightly smaller coefficients. Table 7 presents the standardized coefficients along with the F values.

	Standardized Coefficients	df	F	Sig.
	Beta			
F1	0.796	1	203.005	0.000
F2	0.357	1	39.134	0.000
F3	0.264	1	19.885	0.000

Table 7: Standardized coefficients and F values (VAR12)

Of the correlation coefficients, all are positive while somewhat smaller than the others is the one corresponding to the second and the third factor (zero-order and part). Regarding importance, the second and the third factor have lower values. Regarding tolerance, high values are observed in all three factors. Table 8 presents the zero-order correlation coefficients, partial correlation coefficients, part correlation coefficients, importance and tolerance values of the independent variables.

	Correlations			Importance	Tolerance
	Zero-Order	**Partial**	**Part**		
F1	0.774	0.875	0.795	0.765	0.997
F2	0.347	0.629	0.356	0.153	0.996
F3	0.250	0.513	0.263	0.082	0.995

Table 8: Correlations, importance and tolerance (VAR12)

The transformation plots of VAR12, F1, F2 and F3, are depicted in Figure 6.

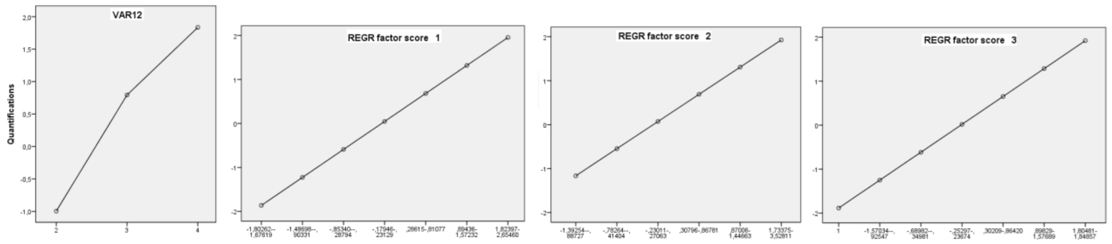

Figure 6: Transformation plots (VAR12)

As the factors increase, so do variables VAR10, VAR11 and VAR12 in the corresponding models.

V. DISCUSSION

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

- Concerning VAR10, 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 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 hard pruning (7.14%). Only 10% of the trees were classified as "high risk" to the variable VAR11. No trees need to be cut down.

- 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. Furthermore, the 3 factors explain a satisfactory 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 streets and avenues of the Municipality of Thessaloniki in order to recheck the tool and make possible improvements and also to be able to generalize the results. Also, the sample must be selected with appropriate representative stratified sampling including all tree species that grow on the streets of the Municipality of Thessaloniki, in order to investigate the relationship between tree species and risk. The assessment of reliability could additionally be done through inter-observer and inter-rater reliability testing.

- Concerning the categorical regression, all 3 factors contribute greatly to the predictive ability of the 3 models. As the factors increase, so do variables VAR10, VAR11 and VAR12. The third factor shows less importance. So, due to the very high R^2, combined with the total explained variance, the Beta coefficients, the correlations and the importance, the third factor could possibly be omitted from the models, without reducing their predictive ability. In the first regression model, F1 and F2 contribute a lot to the predictive ability.

- The specific 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.

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