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# Artificial neural network prediction of citizens' climate mitigation perception related to urban green infrastructure: The Case of Drama City in Greece

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**Abstract.** Social perceptions and attitudes are important dimensions for the successful implementation of Green Infrastructure (GI) projects, as these are typically designed to improve environmental conditions and promote a green economy. This paper attempts to investigate social behavioral patterns of climate mitigation perceptions related to a complex and long-ongoing urban GI project in the city of Drama, which is located in northeastern Greece. A multilayer perceptron Artificial Neural Network (ANN) was developed and validated to identify the climate mitigation perception of Drama citizens with emphasis on Human Thermal Comfort improvement aimed through the GI project implementation. The study population consisted of 200 respondents of which 70% formed the training set and 30% the test set. The input variables included the level of information about the GI project, the education level, the residence location, the awareness about the importance of the GI expected effect on the aesthetics and the functional improvement of the area, job opportunities, and the quality of life improvement. The ANN had good accuracy (92.9%), precision (94.8%), and area under the curve (85.2%). Therefore, it can be a useful tool for communicating more efficiently the expected benefits of the urban GI project and increasing its social acceptability.

**Keywords:** Human Thermal Comfort, neural networks, urban green infrastructure, public perception, climate mitigation

## 1. Introduction

Interest on Green Infrastructure (GI) in urban environments is increasing globally as a means of addressing challenges related to climate mitigation and adaptation, health and quality of life, aesthetic and functional improvement, energy use efficiency, water purification and clean air, as well as promoting a green economy (Tzoulas et al. 2007, Chen and Jim 2008, Barnhill and Smardon 2012). However, implementation of urban GI often faces multiple barriers, among which as important have been recognized various city policies, governance means, resources and social perception (Matthews et al. 2015, O'Donnell et al. 2017, Kazana et al. 2021, Chrysanthidou et al. 2021, Adib et al. 2023). Social factors in particular may be critical barriers when they reflect people's negative mindset and attitudes towards GI and lack of knowledge about the GI benefits and challenges.

The scope of this study concerns a diverse GI ongoing project, which was set out three years ago in the downtown area of the city of Drama in northeastern Greece. The GI project included several eco-facilities, among which a new water supply and sewage network, underground power supply cables, energy saving street lighting, pavement and road reconstruction with cool paving materials, tree planting and special urban bioclimatic constructions aiming overall at climate mitigation through improvement of the bioclimatic conditions of the city center, as well as improvement of economic conditions. However, the long implementation period of this GI project, the functional role of the intervention area in the citizens' everyday activities and the top-down planning approach at the earlier stages of the GI project created a social upset and had a negative attitude impact on several groups of citizens. In order to improve community engagement and increase the GI project social acceptability, the city Authorities financed the setup and function of a governance network. The authors of the paper were involved in the set up and activities of this governance network.

There is scant published research on the identification of public behavioral patterns to reflect climate mitigation perception in relation to the role of urban GI. In this context, the current article presents the attempt made to develop and test an Artificial Neural Network (ANN) model based on data from one of a series of surveys conducted through the governance network activities, targeted to the citizens' of Drama city. ANNs are relatively

complex mathematical methods which are used in prediction and classification research in a range of scientific disciplines. The basic premise of ANNs is that a precise relationship between the dependent and the independent variables can be estimated with nonlinear mathematical functions. An ANN involves interconnected units, called "neurons" capable of performing pattern recognition, including classification and prediction. ANNs store the knowledge they obtain through pattern recognition in data in weights, which are analogous to regression coefficients (Barbour et al. 2007). They can be in the form of radial basis function networks or multilayer perceptrons (MLP). ANNs recognize patterns in data by using activation functions to estimate weights. An MLP consists of input layers, which include the independent variables, hidden layers, which operate as a "black box" and the output layer, which includes the dependent variable. The estimated weights joining the input and output layers show the relative importance of the inputs into and out of the hidden layer.

The MLP ANN model presented in the current article aims at predicting the citizens' of Drama city behavioral patterns that reflect their climate mitigation perception with focus on the Human Thermal Comfort improvement pursued through the implementation of the GI project.

## 2. Methods

Data information for the current study were collected with individual face-to-face interviews on surveying sites in the city of Drama by using a structured questionnaire. The respondents were selected in each surveying site in a random systematic manner until a representative sample of the city population was completed. The questionnaire was piloted during May 2021 to 25 respondents and it indicated that it required no modification. The main survey was conducted in July and August 2021, while the GI project was still ongoing having completed almost two years since its initiation. The questionnaire contained 33 questions. General demographic items included residence location, sex, age, marital status, occupation and education level. Other questions aimed to collect information on the level of knowledge information about the GI project, perceptions on the relative importance of the different GI project items and perceptions regarding the effects of the GI project on climate mitigation and in particular the Human Thermal Comfort (HTC) improvement, the functional improvement of the intervention area, job opportunities, aesthetic improvement of the area and improvement of the quality of life. Also, questions were included to record the problems the GI project implementation created in the citizens' everyday activities.

Data were at first checked, scaled and normalized. Correlation statistics was performed and scatter plots of each variable were produced. Variable selection was conducted by eliminating the ones which showed a very small correlation. The ones retained were used to develop the MLP ANN model. The data set was randomly split into a training set (70%) and test set (30%). The network was trained using the batch training method, which can provide optimal results with few input variables (Tang et al. 2007).

The sigmoid function was used as the activation function, which is mathematically expressed as

$$f(x) = \frac{R}{1 + e^{-k(x-x_0)}}$$

where

R= the maximum value of the curve,

$x_0$= the initial value of the function

k= the slope of the curve

e= the natural logarithm ( a constant equal to 2.718)

## 3. Results

### *3.1 Participants characteristics*

A total of 200 citizens of Drama city participated in the survey of which 47.2% males and 52.8% females. About 55.5% of the respondents stated that they were city center dwellers, 31% stayed in the suburbs and the remaining 27% in nearby towns and villages.

### *3.2 ANN variables, accuracy, prediction and sensitivity*

The binary classification model which can identify whether a citizen exhibits acceptability (positive perception) on the expected effect of the GI project on the HTC improvement for climate mitigation is based on the input variables presented in Table 1. The model has 2 hidden layers with 6 units in hidden layer 1 and 5 units in hidden layer 2.

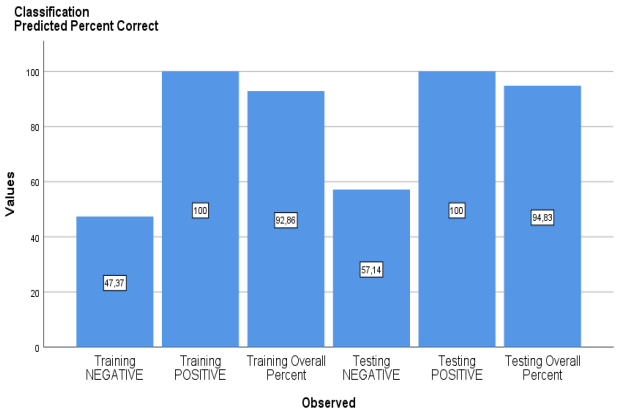


**Figure 1.** Accuracy of classification

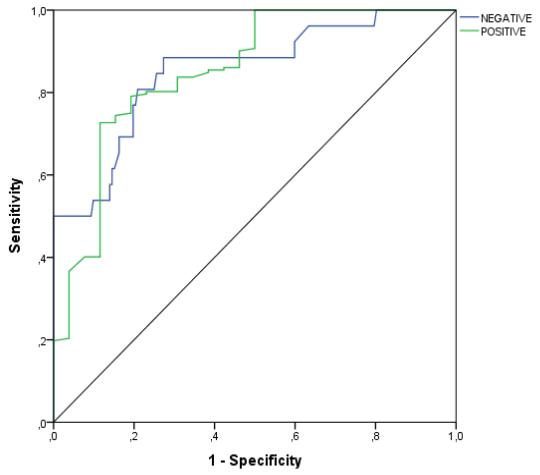


**Figure 2.** Receiver Operating Characteristic curves of the dependent variable: Heat Thermal Comfort improvement perception (Negative/Positive)
Area under the curve = 85.2%

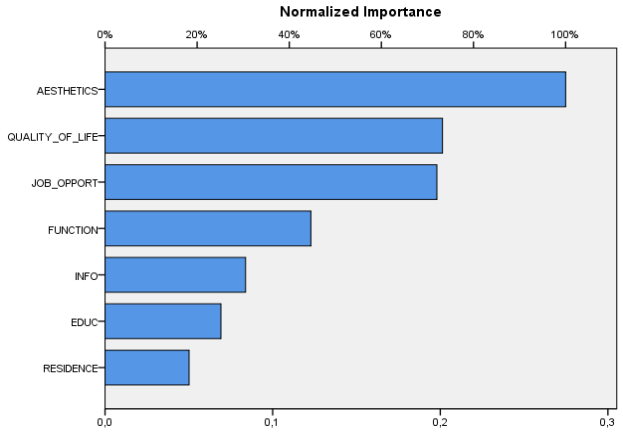


**Figure 3.** Independent variable importance

The estimated weights showed nonlinear patterns across the 17 units indicating that a multiple regression model would not be capable of capturing the data complexity. Figure 1 depicts the classification accuracy of the ANN model for training and testing processes, which is 92.86% and 94.83%, respectively. Overall, the citizens exhibiting negative perception in terms of the GI effect on HTC improvement of the area constitute 6.4% and 6.9% of the training and testing sets respectively and the citizens with positive HTC perception constitute 93.6% and 93.1% of the training and testing sets respectively.

Classification accuracy for both negative and positive HTC perception citizens exceeded 90% in both data sets. Sensitivity for the citizens with negative HTC perception was calculated equal to 47.4% and 57.1% of the training and testing sets respectively, that is, 52.6% and 42.9% were misclassified respectively. On the other hand for the citizens with positive HTC perception sensitivity was 100% that is, all the citizens both of the training and testing sets were perfectly accurately classified.

**Table 1.** Input and Output nodes

| No. | Output node(Y) | Input nodes (X) |
|---|---|---|
| 1. | Heat Thermal Comfort improvement (positive/negative) | The GI project will improve the area aesthetics (positive/negative attitude) |
| 2. | | The GI project will improve the quality of life (positive/negative attitude) |
| 3. | | The GI project will improve the area function (paving, square, green spaces) (positive/negative attitude) |
| 4. | | The GI project will promote job opportunities (positive/negative attitude) |
| 5. | | Informed about the GI project (No or little/ moderately/ highly) |
| 6. | | Residence location (city center/ suburbs/ out of town) |
| 7. | | Education level (primary, secondary, tertiary) |

Figure 2 presents the ROC curves for both categories of the dependent variable. All points fall on the two curves above the diagonal, indicating good classification. The area under the curves on both training and testing sets was 0.852, which is considered as a high classification accuracy rate.

Finally, figure 3 depicts the variable normalized importance values of the independent variables. All independent variables contribute to classifying negative and positive HTC improvement perceptions of Drama citizens with respect to implementation of the GI project.

## 4. Discussion

The ANN analysis showed that correct prediction of Drama citizens as either positively or negatively accepting the effect of the GI project implemented in the city regarding the HTC improvement of the intervention area for climate mitigation depends on the importance awareness of the GI project effect on i) the improvement of the area aesthetics, ii) the improvement of quality of life, iii) the improvement of job opportunities and iv) the improvement of the function of the area through facilities involving the paving of roads, creation of a square and green spaces. Moreover, to a lesser degree, it depends also on i) whether the citizens were little, moderately or highly informed about the GI project, ii) whether they were dwellers of the city center, the suburbs or nearby towns or

villages and iii) their education level, that is whether they were primary, secondary or tertiary education graduates.

From the technical point of view the ANN model is adaptive, as it does not require assumptions regarding the relationships between input and output variables, it is not limited to linear functions and the work performance of the model is very good. Therefore, the current research can contribute to the knowledge gap related to the accurate identification of citizens' behavioral patterns, so as to reflect their perception on HTC improvement for climate mitigation with respect to urban GI facilities. Extension of similar research in the future with even larger data sets in other areas will gradually generate the level of up scaled knowledge required by city planners, resource managers and policy decision makers to improve community engagement, increase social acceptability of GI facilities and successfully implement and maintain GI projects.

## 5. Conclusions

In the current paper a multilayer perceptron Artifical Neural Network (ANN) case model was presented with respect to a diverse urban GI ongoing project in Drama city located in northeastern Greece. ANN was developed and validated so as to identify accurately behavioral patterns of Drama citizens' perceptions (positive or negative) on Human Thermal Comfort improvement for climate mitigation aimed through the implementation GI project in the intervention area.
The ANN had good accuracy (92.9%), precision (94.8%), and area under the curve (85.2%). Therefore, it can be a useful tool for planners, managers and decision makers to increase social acceptability of GI facilities by communicating more efficiently the expected benefits of relevant projects.

## 6. Acknowledgments

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