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THE INFLUENCE OF THE INTRODUCTION OF AN ARTIFICIAL NEURAL NETWORK FOR TRAFFIC SIGNAL CONTROL

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Rezumat

Dezvoltările urbanistice si economice din ultimi ani au generat modificări in desfășurarea traficului rutier, determinate de creșterea continua a parcului de autovehicule, creșterea indicelui de mobilitate a parcului auto existent si a sporirii numărului de autovehicule ce tranzitează principalele orașe ale tarii, acest lucru având drept consecințe scăderea capacitaților de circulație a străzilor. Prin aplicarea unor tehnologii inovative, care permit anticiparea si dirijarea traficului rutier se evita apariția ambuteiajelor, acest lucru conducând la creșterea calității vieții. In cadrul acestui articol a fost analizat un studiu de caz, in care s-a implementat o rețea neuronala artificiala in cadrul unui model de trafic, cu ajutorul căreia s-au efectuat predicții asupra timpilor de semaforizare. Rezultatele obținute sunt satisfăcătoare, iar acest lucru este pus in evidenta de către parametrii de performanta exportații din modelele de trafic.

Cuvinte cheie: rețele neuronale artificiale, trafic, nivel de serviciu, cozi de vehicule

Abstract

The urban and economic developments of recent years have generated changes in the development of road traffic, determined by the continuous growth of the vehicle fleet, the increase in the mobility index of the existing vehicle fleet and the increase in the number of vehicles transiting the main cities of the country, this having as consequences the decrease in the traffic capacity of the streets. Through the application of innovative technologies, which allow the anticipation and control of road traffic, traffic jams are avoided, this leads to an increase in the quality of life. In this article, a case study was analyzed, in which an artificial neural network was implemented within a traffic model, with the help of which predictions were made on traffic light times. The results obtained are satisfactory, and are highlighted by the performance parameters exported from the traffic models.

Keywords: artificial neural networks, traffic, service level, vehicle queues

1. INTRODUCTION

1.1. General context

In recent years, most of the congested cities in the world are facing huge ? due to traffic conditions. Therefore, public authorities focused on solving congestion, accidents and pollution. One of the solutions for problems related to traffic congestion consists in building new transport infrastructures. This solution can reach a level with a limited duration of time until the new autonomous vehicles will spread widely. One of the important ways to increase transport efficiency, reduce traffic congestion and ensure traffic safety is the implementation of new traffic control technologies and the efficient use of road resources [1,2,3,4]. It should be mentioned that in Eastern European countries where resources are limited and public authorities have made less investments due to political and economic constraints, in recent years in the transport sector, the problem of traffic congestion is becoming a big challenge. Most of the big cities in Romania face traffic problems characterized by different levels of congestion, noise and air pollution followed by traffic events.

Current practice in traffic management and control strategies is dominated by the use of intelligent transportation systems (ITS), the rapid development of computers with high processing powers, and flexible mathematical methods. The overall objective of such systems is to increase the operational efficiency and capabilities of the transportation system, through the extensive and multifunctional use of advanced technological and telecommunication systems [5]. The concept of creating an efficient ITS environment is based on providing a continuous flow of information about how traffic parameters (such as traffic flow, occupancy and speed) evolve over time [6,7]. The main goal in traffic management is to predict some critical (traffic) variables, such as volume, speed, density, travel time, saturation flows. Various methods for predicting traffic parameters are reported in the specialized literature, among which we can list temporal data analysis, statistical methods, and machine learning, etc. Hence it becomes essential to understand the mechanism behind each of these methods to know the associated limitations and advantages.

1.2. Existing situation

In order to reduce congestion in urban areas, the traffic light control systems play an important role. Neural networks represent one of the computing approaches used more and more often, within the scientific research for the field of traffic engineering.

A definition given by Simon Haykin [8] consists in comparing neural networks with a processor, which allows laborious calculations to be performed in parallel and which offers the possibility of accumulating knowledge that can be made available to users [7]. One of the peculiarities of artificial neural networks (ANN) consists in the fact that they have the possibility to adapt to the following [11,12]:

- can operate large data sets;
- allow the establishment of non-linear relationships between dependent and independent variables;
- allow the detection of possible interactions between predictive variables

The current research carried out by Srinivasan and others [13] proposes the use of some ANNs that do not require a model of the system, but they need a large number of data and information processing times due to the large number of variables specific to urban areas. Another more flexible approach is that of Hamilton [14], which is structured on the use of a linear model that does not take into account the order of the traffic light phases or the traffic light cycle. This method would have the possibility to change the traffic light times at any time, but it does not allow the correlation of several intersections in a network.

The architecture of a neural network can differ, depending on the user's requirements, through the type of neuron, the number of levels, the existence or lack of feedback loops, etc. In order to ensure certain performances imposed in the real context, it is necessary to train it.

The case study presented below describes the use of a feed-forward artificial neural network equipped with a back propagation algorithm. Essentially, the back-propagation algorithm consists of comparing the output set to a reference set and back-propagating the error from one level to the next, adjusting the input weights so that the error is minimized. It is actually a step-by-step gradient modification algorithm of the error function [9].

1.3. Traffic model

In this article, a microscopic analysis of a signal control T-intersection (shown in figure 1) in the city of Hateg between Titulescu Street (DN 66) and Tudor Vladimirescu Street was carried out. The traffic model presented schematically in figure no. 2 was developed with the help of the VISSIM program, which uses behavioral algorithms of car drivers to predict the movement of traffic through the network. This type of program calculates the movements of each vehicle and pedestrian in the network over a very short period of time (usually between 0.1 and 0.5 seconds) and takes into account how they will interact. At the same time, controls like "give way" and traffic lights are modeled at a high level of detail. Being a traffic simulation system based on a general-purpose computer, junction networks are modeled very precise. With the help of this kind of software, it is possible to introduce several modes of transport, such as pedestrians, cyclists, cars, buses and trams, into the same traffic model. [7].

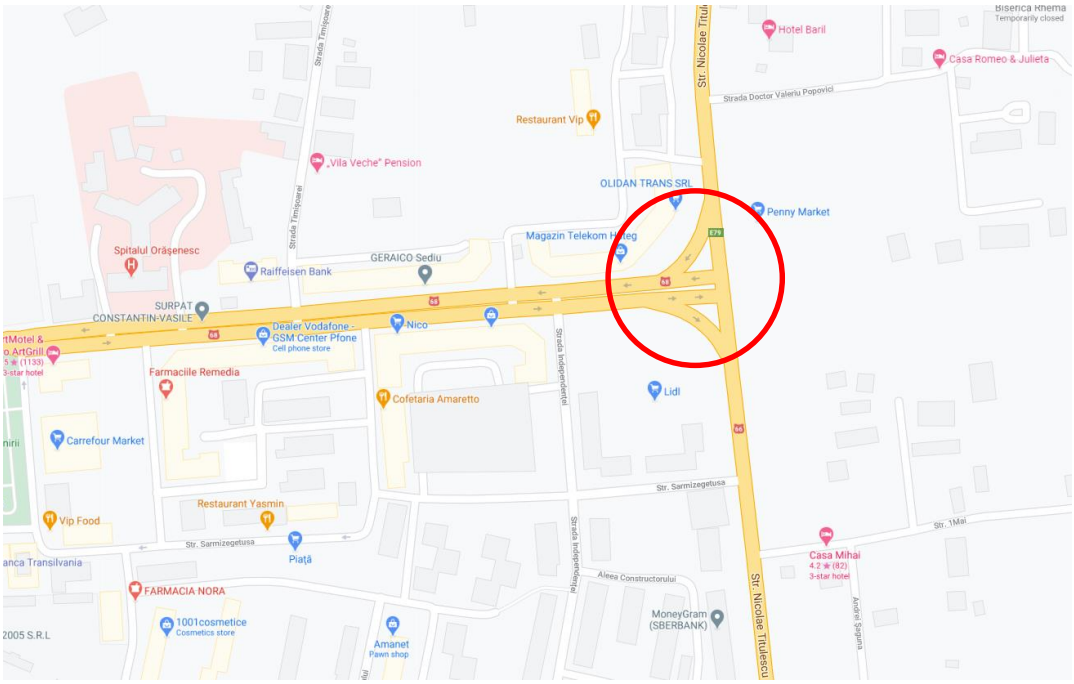

Figure 1. The junction analyzed in this article (Google maps)

For the calibration of the traffic model, it was necessary to collect the following information from the study area:

• the topographic survey of the intersection mentioned above in order to establish the geometric elements;

• identification of existing markings and indicators;

• measurements of saturation flow at all arms of the traffic lighted intersection;

• establishing points of conflict between vehicles or between vehicles and pedestrians;

• traffic flows from peak hours resulting from a census carried out between February 23-24, 2021.

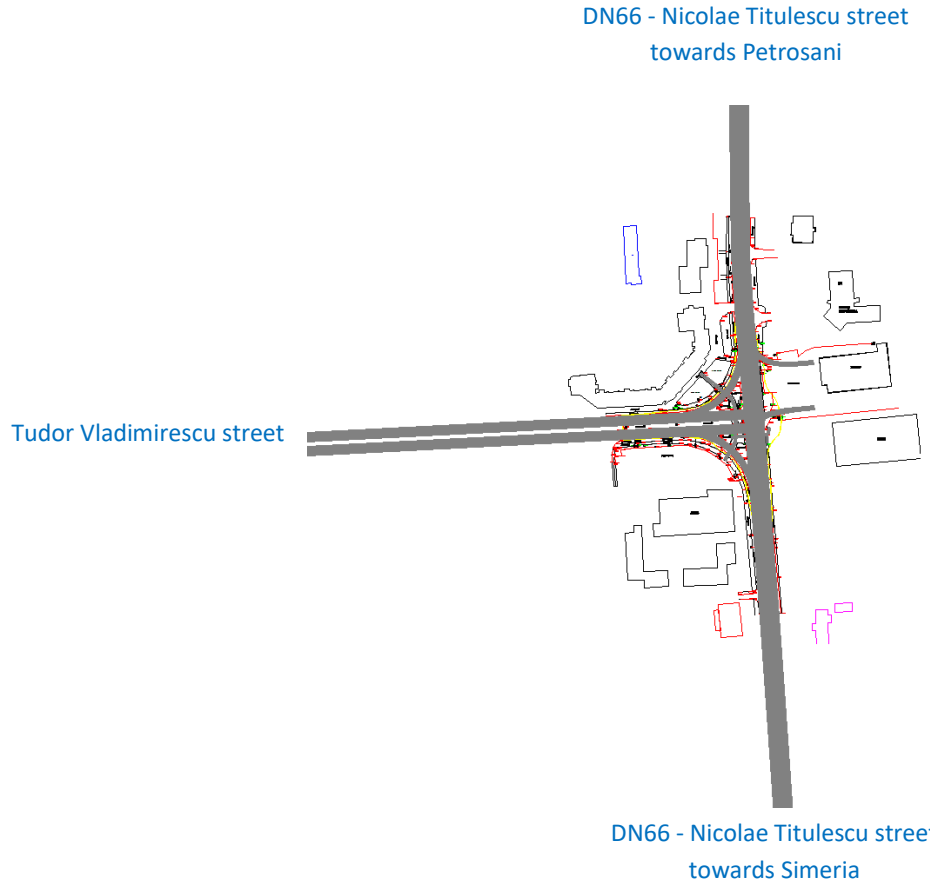

Figure 2. Extract from the traffic model for the existing situation related to the analysis area

The stages of creating this traffic model are described in figure no. 3 below. In order to verify that the data entry has been carried out properly and the calibration parameters have been correctly set, a traffic flow check needs to be done. It consists in comparing traffic flow values from traffic censuses with those from peak hour traffic models using the GHG statistical parameter.

The GEH statistical parameter has the following calculation formula:

$$GEH = \sqrt{\frac{(M-C)^2}{(M+C)/2}}$$

where:

M – represents the values from the traffic model, and C – the measured values.

It is considered that for values of GEH lower than 5 in at least 85% of the cases, the model is validated.

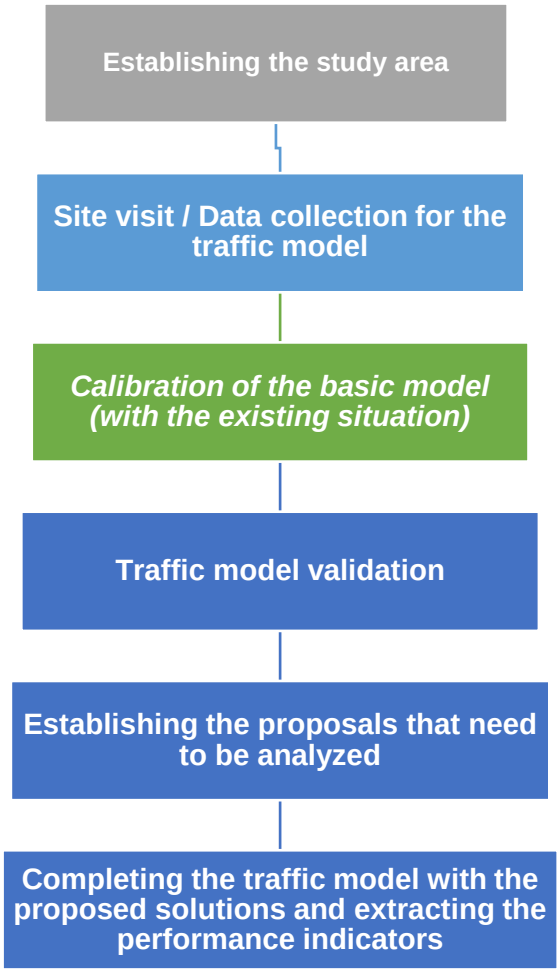

Figure 3. The stages of calibration and validation of the traffic model

In order to validate the traffic model, an independent parameter was chosen by making comparisons between the measured saturation flows and those extracted from the traffic model. Following this analysis, the results extracted from the model are within a tolerance of ± 10%, compared to those observed on the ground.

2. PROPOSED SOLUTION

2.1 Establishing the effect of implementing an artificial neural network

After the validation of the traffic model, the next step was carried out, which consisted in the creation of an artificial neural network to obtain higher traffic capacities at the signal control junction. From all the input data, which the traffic model has available, the parameters that have the highest degree of independence were selected. The following factors were taken over:

- traffic flows for each arm of the intersection;
- the saturation flows for each arm of the intersection;

The output data that is desired to be forecasted are the green times that should offer superior performance in the traffic signal control of the intersection. To create ANN, the Visual Gene Developer software developed by the University of California-Davis was used, which is based on a standard learning algorithm with back propagation.

The proposed work algorithm is described in the diagram in figure no. 4 below. To train the neural networks, traffic light times optimized only for the existing situation were used. Taking into account the developments proposed in the Sustainable Urban Mobility Plan of the city of Hateg, to make a data prediction, the traffic flows have been modified, and the trained neural network will be loaded with the new values.

In order to obtain the most efficient results, the traffic light times were extracted from the ANN for 15-minute intervals, in the framework of simulations related to each rush hour. The microsimulation program in which the traffic model was developed has the possibility to modify a traffic light diagram both automatically, within the VisVap programmable interface, or manually in the signal control module.[10]

Since the program in which the neural networks were created works with series of numbers contained in the interval [-1, 1], they must be demultiplied to obtain subunit series.

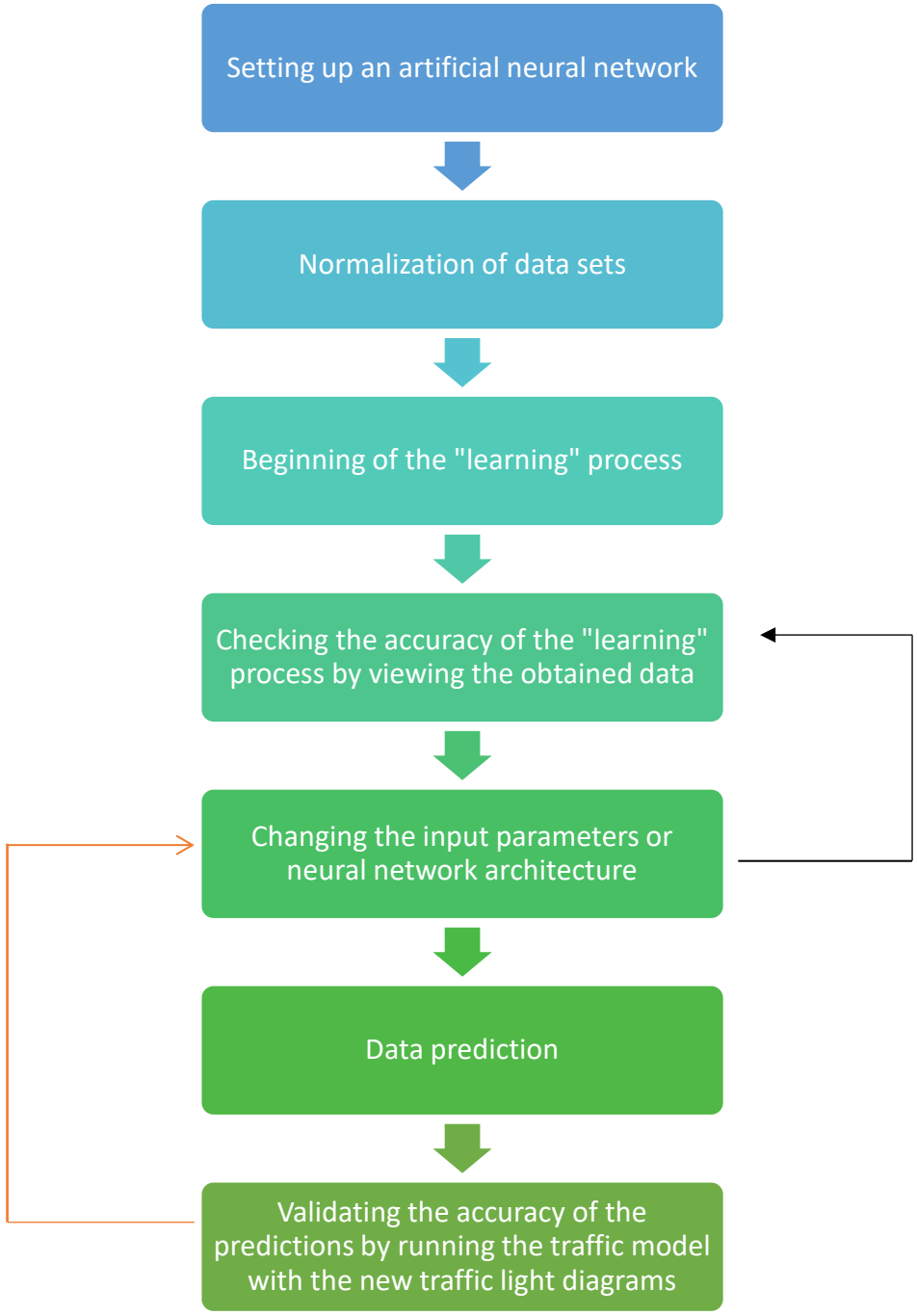

Figure 4. The stages for implementing a neural network [10]

In this case study, several configurations of a neural network were taken into consideration:

- Number of input nodes –6
- Number of output nodes – 3
- Number of hidden statuses – 1 and 2

- Number of nodes per hidden layer – between 5 and 10
- Learning rate – 0.01
- Transfer function – hyperbolic tangent
- Target error – 0.00001

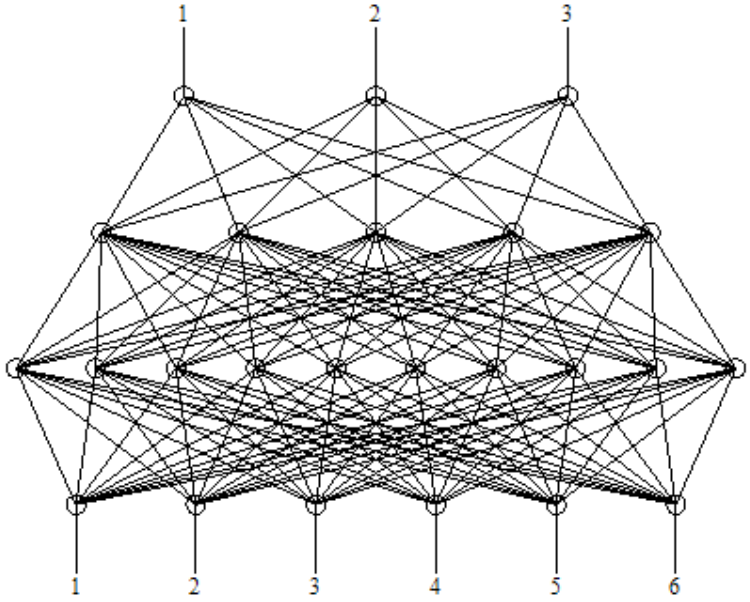

Figure 5. – Neural network architecture

For the neural network consisting of 2 hidden layers, the lowest total error of 0.06% is obtained with a number of iterations of 32000.

Based on the new traffic flows, the trained artificial neural network was able to predict a new set of optimized traffic times. In order to analyze these data, the signal control times predicted by the ANN for 15-minute intervals were introduced into the traffic model, in microsimulations of 2 hours each, related to each rush hour.

Comparative results of the simulation in the situation of an intersection equipped with ANN and without ANN are presented comparatively in figures 6, 7 and 8 below:

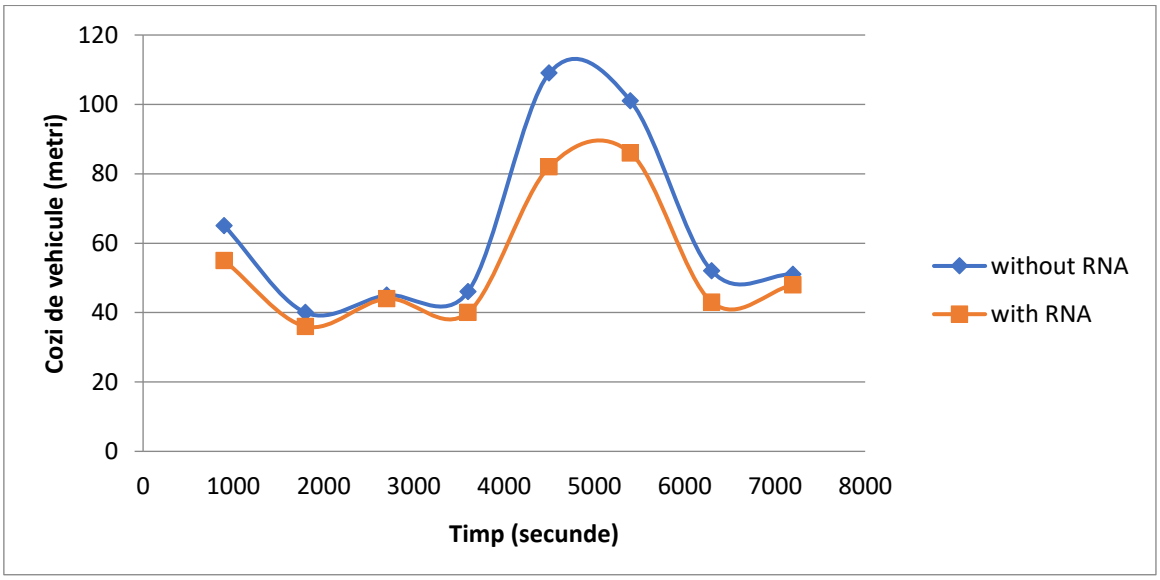

Figure 6. – Queues of vehicles for the Titulescu road arm towards Simeria in the scenario of using an ANN and without ANN for the morning peak hour

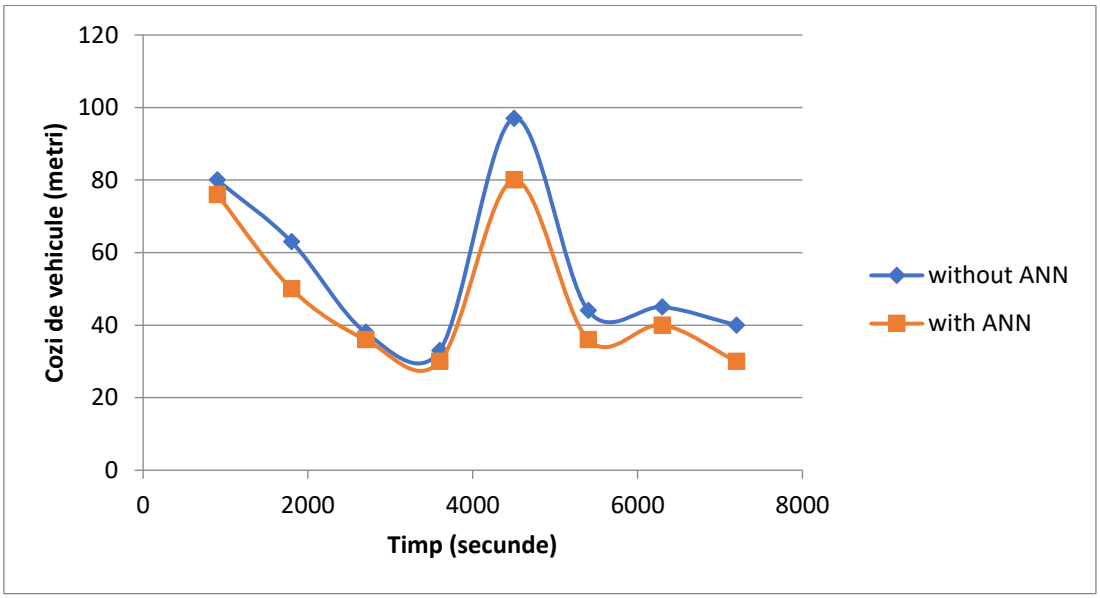

Figure 7. – Queues of vehicles for the Titulescu road arm towards Petrosani in the scenario of using an ANN and without an ANN for the morning peak hour

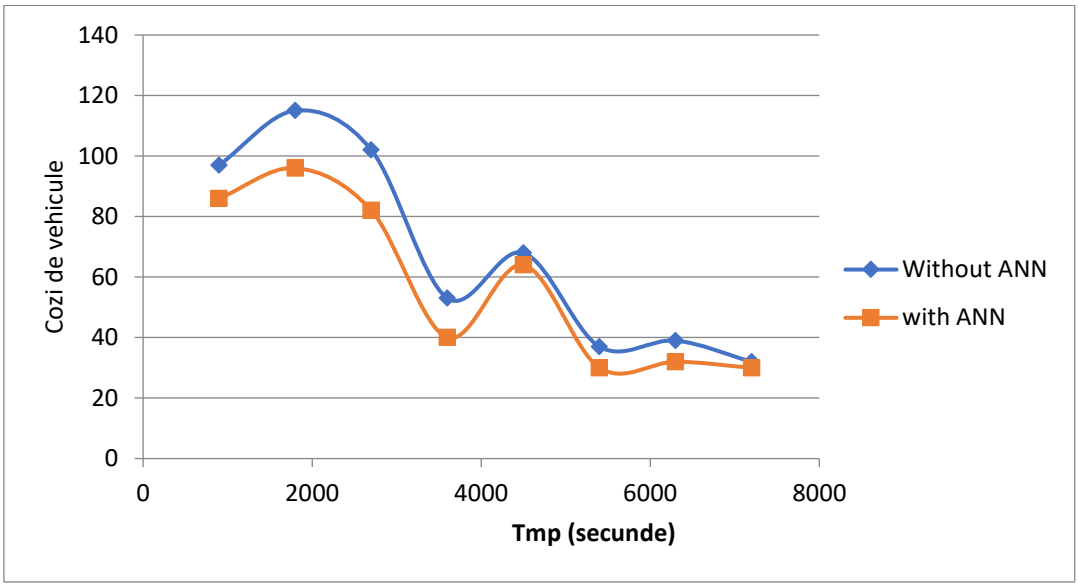

Figure 8. – Queues of vehicles for the Tudor Vladimirescu arm towards Simeria in the scenario of using an ANN and without an ANN for the afternoon rush hour

From the analysis of the results above, it can be seen that by equipping a signal control junction with artificial intelligence elements, the queues of vehicles and implicitly the travel times are reduced. By incorporating artificial neural networks into traffic control machines, it is possible to predict traffic light times, which approximate real traffic conditions as accurately as possible.

3. CONCLUSIONS

In this article, a summary of the traffic conditions affecting urban agglomerations was presented. In order to reduce traffic congestion, the authors of the article propose the use of artificial intelligence elements, which would offer flexibility in the control of traffic light intersections. Therefore, the traffic model of an intersection (with traffic lights) was presented, which took from a trained artificial neural network the optimized traffic light time. The results presented in the form of graphs demonstrate the fact that by introducing some ANNs in the signal controller machines, travel times and vehicle queues improve significantly.

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