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RESEARCH REPORT NO. 3
Presentation of a microsimulation with real traffic data incorporating information resulting from the development of an artificial neural network

related to the doctoral thesis

"Contributions on the use of neural networks in traffic engineering"

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Contents:

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Chapter 1. Introduction

Once the architecture of a neural network is established, it is necessary to train it through a learning process in order to ensure results as close to reality as possible. We distinguish in this case the following learning typologies that can be applied to neural networks:

- unsupervised learning method;
- partially supervised learning method;
- supervised learning method;
- reinforcement learning method.

In the unsupervised learning method, the main objective is to detect simulation objects in a group and to separate those that are completely different, in the absence of an external "guide" that offers possibilities for supervision. This method is used mainly in situations where the desired results are not known or in the absence of a method for their approximation. The main uses of this method are as follows:

- clustering: allows grouping objects or simulation data;
- anomaly detection offering the possibility to establish from a large data set some parameters that stand out. The applicability of this feature is used in the case of fraudulent financial transactions, the establishment of anomalies in some hardware components or the discovery of human mistakes in manual data entry.
- setting associated data. It is used in the case of marketing analyzes to highlight some categories of goods, which are most often purchased in a period of time.

In the case of supervised learning the user has at his disposal a set of data consisting of known inputs and outputs, through which a neural network can be trained in a certain period of time. The algorithms used in this case are based on a response function, adjusting errors until they are minimized [1]. This way after training the artificial neural network (ANN) will be able to analyze another new data set and provide correct results.

There are currently a multitude of neural networks, which may differ from each other depending on the structure or method of entrainment. Thus, in case study Number 2, a feed - forward ANN equipped with back-propagation algorithm was trained. From the perspective of the definition offered by researcher Leon Florin, backpropagation algorithm is the most known and used supervised learning algorithm. Also called the generalized delta algorithm because it extends the way of entraining the Adaline network (delta rule), it is based on minimizing the difference between the desired output and the actual output, also by the downward gradient Method [2].

For such a neural network information propagation is described by the equation below:

$b_j = f(\sum_{i=1}^{n}(w_{ij}a_i) - T_j)$, where

a_i represents the input vector.

b_j represents the output vector,

w_{ij} represent synaptic weights,

T_j represents the threshold value

f is the activation function

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After calculating the errors, a correction of the synaptic weights and threshold values is made based on the following equations:

$$w_{ij}^{actual} = w_{ij}^{initial} + \eta * \sum_{p} \delta_{pj} O_{pi} + \alpha * \Delta w_{ij}^{inital} \quad ,$$

$$T_j^{actual} = T_j^{initial} + \eta * \sum_p \delta_{pj} O_{pi} + \alpha * \Delta T_j^{inital}$$, where

η represents the rate of learning,
Δw represents the change in synaptic weights,
ΔT represents the change in threshold values,
It represents the exits,
δ represents the correction brought by the downward gradient

Unlike other methods, reinforcement learning is used instead of static information, dynamic data generated by the work environment.

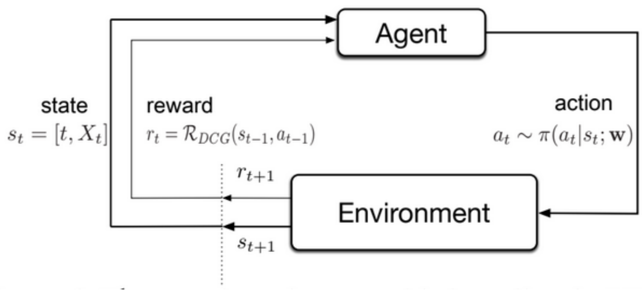

Figure 1. Logical scheme of the reinforcement learning method [3,4]

The purpose of this process is to train a virtual agent, which can be an autonomous entity, to complete a certain task, through actions (A), in an unknown environment. The virtual agent receives observations and rewards from the environment, in turn transmitting actions to the environment. The reward (r) received is depending on the degree of success of his actions for completing tasks [3]. The environment also presents various situations called States (s).

The virtual agent comprises two components:

- policy or tactics: it consists of the strategy you will use to determine the next action, taking into account the current state. In practice this is an approximation function with a multitude of adjustable parameters.

- learning algorithm: consists of constantly updating tactics to follow based on actions, observations or rewards. The learning algorithm seeks an optimized strategy that maximizes cumulative rewards [3].

Additionally, utility (V) is defined as the sum of rewards for a sequence of states, representing the total long-term gain, as opposed to the reward that is the short-term gain [5]. In addition, it describes the utility of a state s (Q (a.s)), similar to the notion of utility (V), but which adds an additional parameter to the current action (a).

In conclusion this method stimulates the agent to explore and exploit the various state - action pairs, so as to obtain the most rewards with the passage of time. [6].

With this method, the following steps are taken:

1. in a first phase the agent observes a certain state of the environment st and performs an action at;

2. in the second stage the agent notices a new state and receives a reward or penalty (cost) immediately r_{t+1}, updating state utilities;

3. calculate the value of an Excel policy as the expected value of the sum of all observed updated rewards after all possible sequences of states [5]

Thus, the cumulative value of future rewards Following an action for a state s is defined by the equation below [7]:

$$Q^{\pi}\text{(s, a)}=E(r_t+\gamma r_{t+1}+\gamma^2 r_{t+1}+\cdots|s_t=s,a_t=a,\pi)=E\left[\sum_{k=1}^{\infty}\gamma^k r_{t+k|} \quad |s_t=s,a_t=a,\pi\right],$$

in which the value of the discount factor is in the range of [0,1]. This interval was chosen so that immediate rewards are more important than longer-term ones, in order to avoid delayed gratification.

Therefore, if the agent knows the Q values of the following states, he will choose based on the actions, which offer the highest cumulative rewards. In this case, the optimal utility π^* of a state is the immediate reward for that state to which the maximum expected utility of the next state is added [5]. This can be expressed by Bellman's equation, as follows [7]:

$$Q^{\pi^*}(s,a)=E_{s'}[r_t+\gamma maxQ(s_{t+1},a|s,a])$$

If the estimated optimal future reward is obtained, the cumulative reward can be calculated. This equation can be solved by dynamic programming, but requires that the number of states be finite to make the computational complexity controllable [7].

The use of neural networks as approximation functions becomes useful in the case of reinforcement learning method because the state or action is too complex to be correctly perceived. Therefore, a neural network can be useful in approximating the utility of a state or policy [8].

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Chapter 2. Traffic patterns

1.1 Methodology of work

In order to carry out the case studies, the Vissim microsimulation program was used, which has the possibility of individual discretization of each vehicle. With the help of this program, you can model the traffic behavior of drivers, as well as traffic dynamics. Although this computing program has a good graphical interface, in the case of complex projects or research work, a series of pre - or post-processing calculations are required, which require running on other software platforms. Therefore, Vissim has the possibility to be used together other applications as a platform for running traffic planning algorithms.

Through the COM interface with which the VISSIM program is equipped, the components of a traffic model can be exported. Since the com interface supports Microsoft automation, a number of programming languages such as Visual Basic or programming environments such as Visual C++ or Visual J++can be used. In the case of this work, we opted to use the MATLAB programming language which includes a module related to neural networks.

The working algorithm used to make informational links between the two computing programs consists of the following steps:

1. realization of the traffic model in the VISSIM microsimulation program. During this stage, the calibration and validation of the traffic model will be carried out according to the requirements presented in the previous chapters.
2. Creating the possibility of exporting information from the microsimulation program by activating the COM option.
3. Creating a neural network in the Matlab / Visual Gene Development program. This will analyze traffic flows, how to move from the traffic light phase to another, vehicle queues, delays, travel times, etc.
4. With the help of program developed in Matlab will intervene within the traffic model. For example, neural networks can modify the parameters of drivers ' behavior, contributing to a faster validation of the traffic pattern. Or by training neural networks, better performance indicators of the traffic pattern will be obtained, such as smaller vehicle queues, less travel times, more efficient coordination of traffic intersections networks, etc.
5. Running the traffic model using optimized parameters through neural networks developed in the program Matlab / Visual Gene Development.

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1.2 Case study no. 3 - Use of artificial neural networks with deep reinforcement learning

In continuation of Case Study no. 1, presented in detail in research report no. 2, switched to signal control intersections. Aurel Vlaicu avenue -access Vivo Mall and. Aurel Vlaicu avenue-Stefanita Voda street. In this case, a simulation was made of the effects of equipping the controller of the junctions with neural networks with deep learning through reinforcement type "deep reinforcement learning".

The computational approach whose logical schema is presented at the beginning of Chapter 4 is based on the creation of a traffic model in the Vissim microsimulation program. This model is loaded with traffic values, junction control method and real geometric elements. Then data from the virtual detection network is exported via the COM interface to the Matlab program that runs the data in an RNA.

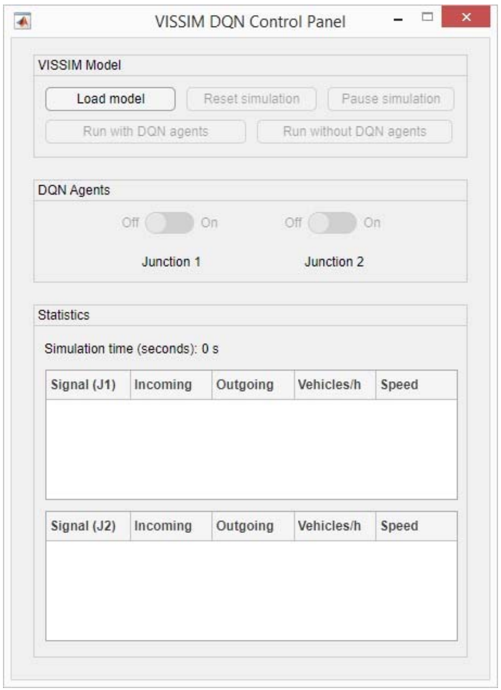


Figure 2- Control panel of the calculation program

The general framework of this working methodology consists of a group of two traffic light junctions which together with the traffic light equipment are considered the working environment. The agent represents the analytical thinking of the neural network that, by exploring and exploiting the various state - action pairs, seeks to obtain the most rewards. The control policy is obtained by associating various states such as waiting time, vehicle queues, delays with optimal control actions from which we list the modification of the sequence of traffic light phases, increase / decrease of the green period at a certain phase, modification of the traffic light cycle, etc. [6, 9]

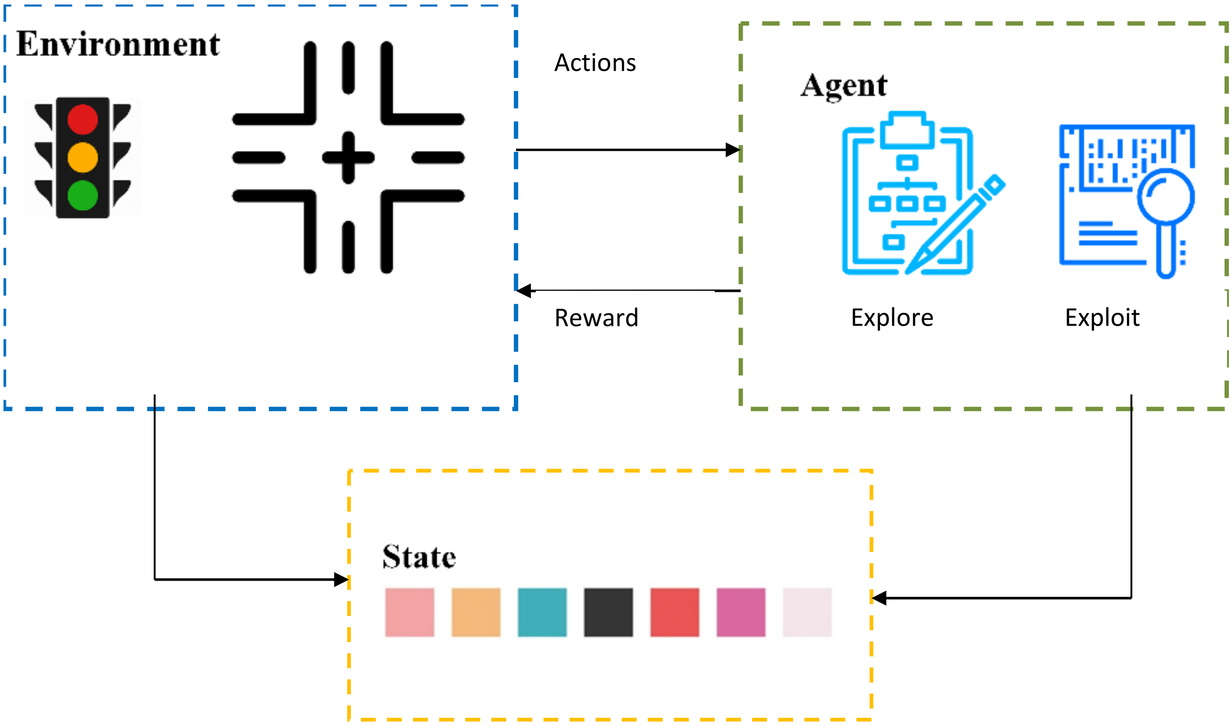


Figure 3- General framework of calculation methodology [9]

Using this calculation algorithm requires solving two important problems:

1. establishing the correct sequence of traffic light phases;

2. duration of a traffic light phase. In this case, for setting the traffic light parameters, the maximum and minimum values for a phase can be set. This avoids too long waiting times for antagonistic phases by setting a maximum of green. In addition, by configuring the minimum Times of a phase it ensures that a minimum number of vehicles can evacuate the intersection after the green color appears at the traffic lights.

To begin with, the following operations were performed:

-the points of conflict between vehicles or between vehicles and pedestrians have been determined depending on the geometric elements of the above-mentioned intersections and the transverse stop markings for vehicles and pedestrian crossings.

-In the second stage, the evacuation lengths of the intersection by vehicles and pedestrians were determined, respectively the evacuation times, and the obtained results were introduced into the intergreen matrix.

In figures no. 4 and 5 below are presented the intergreen matrices for signal control junction.

Figure 4- Intregreen matrix at Aurel Vlaicu Avenue-Vivo Mall access junction

	1	2	3	4	5	6
1: V1			5	5		6
2: V2				5		6
3: V3	5			5		
4: V4	5	5	5		5	
5: P1				5		
6: P2	5	5				

where V1- Aurel Vlaicu avenue to Tomis avenue, V2- Aurel Vlaicu avenue to I. C. Bratianu avenue, V3- Aurel Vlaicu to access Mall, V4-access Vivo Mall, P1, P2-pedestrian crossings

Figure 5- Intregreen matrix at Intersection Matrix. Aurel Vlaicu avenue -Stefanita Voda street junction

	1	2	3	4	5	6
1: V1			5	5	5	
2: V2				5	6	
3: V3	5			5		
4: V4	5	5	5			5
5: P1	5	5				
6: P2				5		

where V1- Aurel Vlaicu avenue to Tomis avenue, V2- Aurel Vlaicu avenue to. I. C. Bratianu avenue, V3-. Aurel Vlaicu avenue to Stefanita Voda street, V4-Stefanita Voda street, P1, P2-pedestrian crossings

The calculation methodology continued with the establishment of the sequence of traffic light phases, presented in Figures 6 and 7 below.

Figure 6- The proposed sequence of the signal control phases at the junction of Aurel Vlaicu Avenue-Vivo Mall access

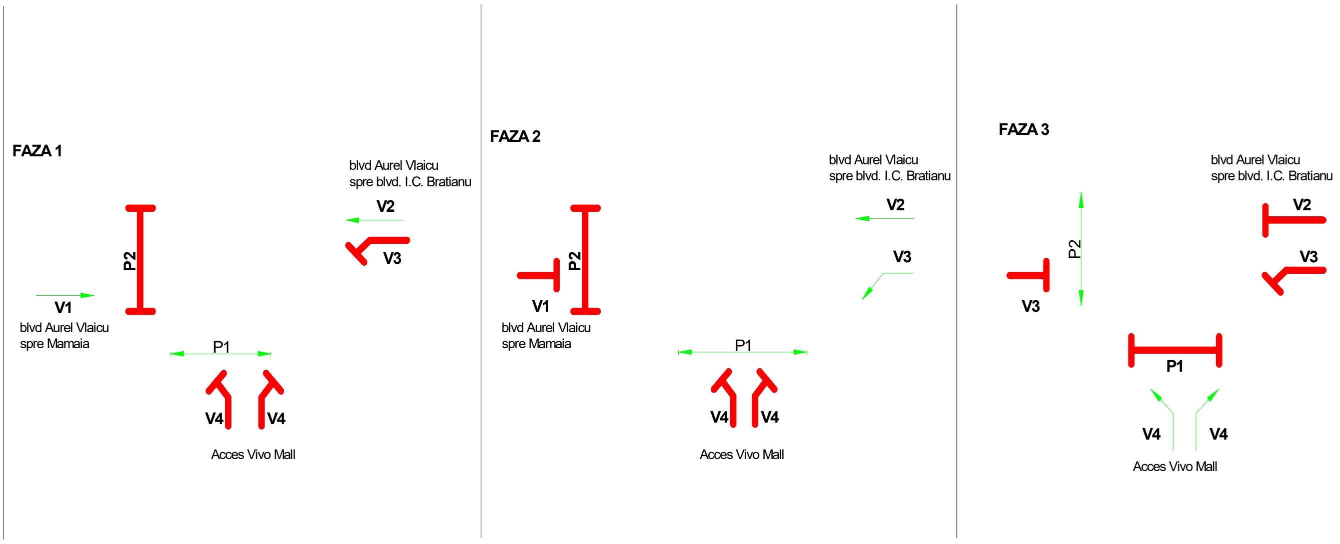
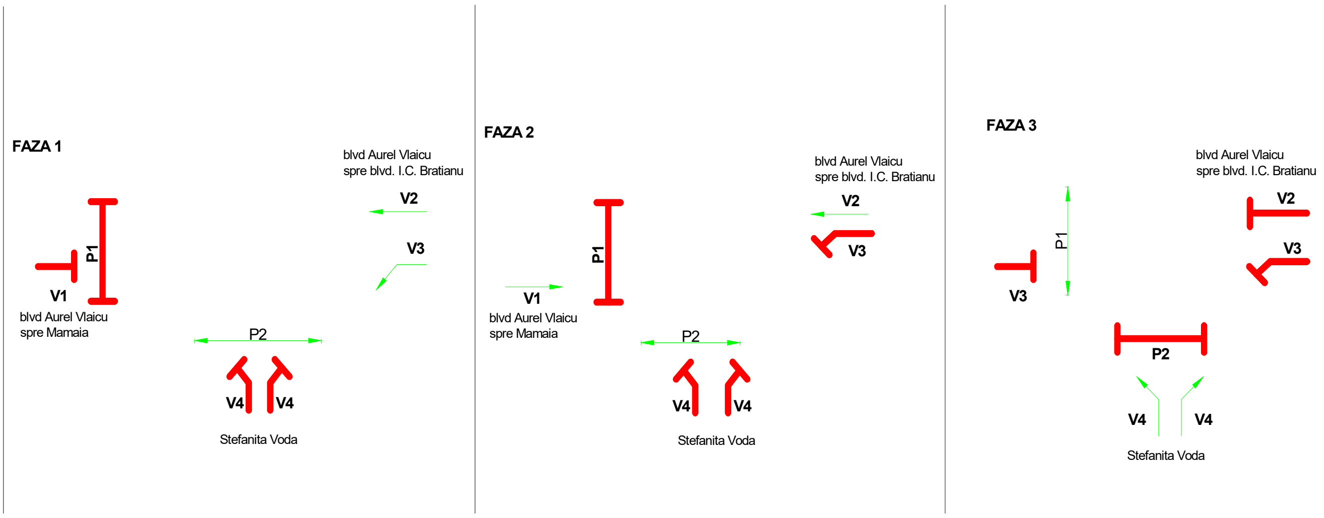


Figure 7- The proposed sequence of the signal control at the intersection of blvd. Aurel Vlaicu-str. Stefanita Voda



The neural network used in this analysis is of the Deep Q-Network type, whose architecture is characterized by two main features: the resumption of experience and the "target" Network [10, 11]. The virtual agent is represented by the traffic light control automaton, which receives data from the external environment. The working process consists in the use by the virtual agent of the stored data (from previous experiences) D_t= (e_1, e_2,...e_n) as they have accumulated from the interaction of the agent with the environment as time passes (t=1, 2...n). Then this stored

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information is randomly selected so as to optimize the learning process. By using "target" networks, a virtual agent creates a duplicate of the main network and uses the weights of the "target" network$_k$ to calculate the target values Q, which contain the states and actions for each step. During the learning process, Target Q values are used to assess the losses/costs of an action and to stabilize the learning process. Basically by using the weight θ_k the main network, approximates Q values of type Q(s, a, θ_k), where *s* represents a state and an action at a given iteration k [12].

In the work algorithm the main network is used to select an action of$_t$ at a certain state s_t observed after analyzing the environment, by the virtual agent in order to obtain the best reward/penalty at the next state s_{t+1}. The "target" network representing a duplicate of the main network is intended to approximate the Q values of the type Q (s, A, θ_k), after a number of K iterations. By using the "target" network the values Q (s, A, θ_k) of the main network are updated at each K iteration. Weighting θ_j of the target network are updated by copying the weights$^-$, of the "target" network in the main network, so as to provide updated values of Q (s, θ_k), along the way to advancing the algorithm. Such weightings θj they are used to minimize error approximation between the Q values of the main network and the "target"network. [6, 12]

The objective (error minimization) function that will be used in the learning process will have the following form:

$L_j\left(\theta_j\right) = E_{sj,aj\sim p}\left[(y_j - Q_j\,(sj, aj; \theta_j)^2\right]$, where p (s,a) represents the probability distribution of the state/action pairs (s,a) and y_j, represents the target value of the share$_{j-1}^-$, in the previous iteration j-1 [67, 79].

Therefore, the gradient objective function is given by the expression below [6, 13]:

$\Delta_\theta L_j\left(\theta_j\right) = E_{sj,aj\sim p}\left[(y_j - Q_j\,(sj, aj; \theta_j)\Delta_\theta Q_j\,(sj, aj; \theta_j)\right]$

In the figure below no.8 the architecture of a Q Network neural network used in the simulation process is presented.

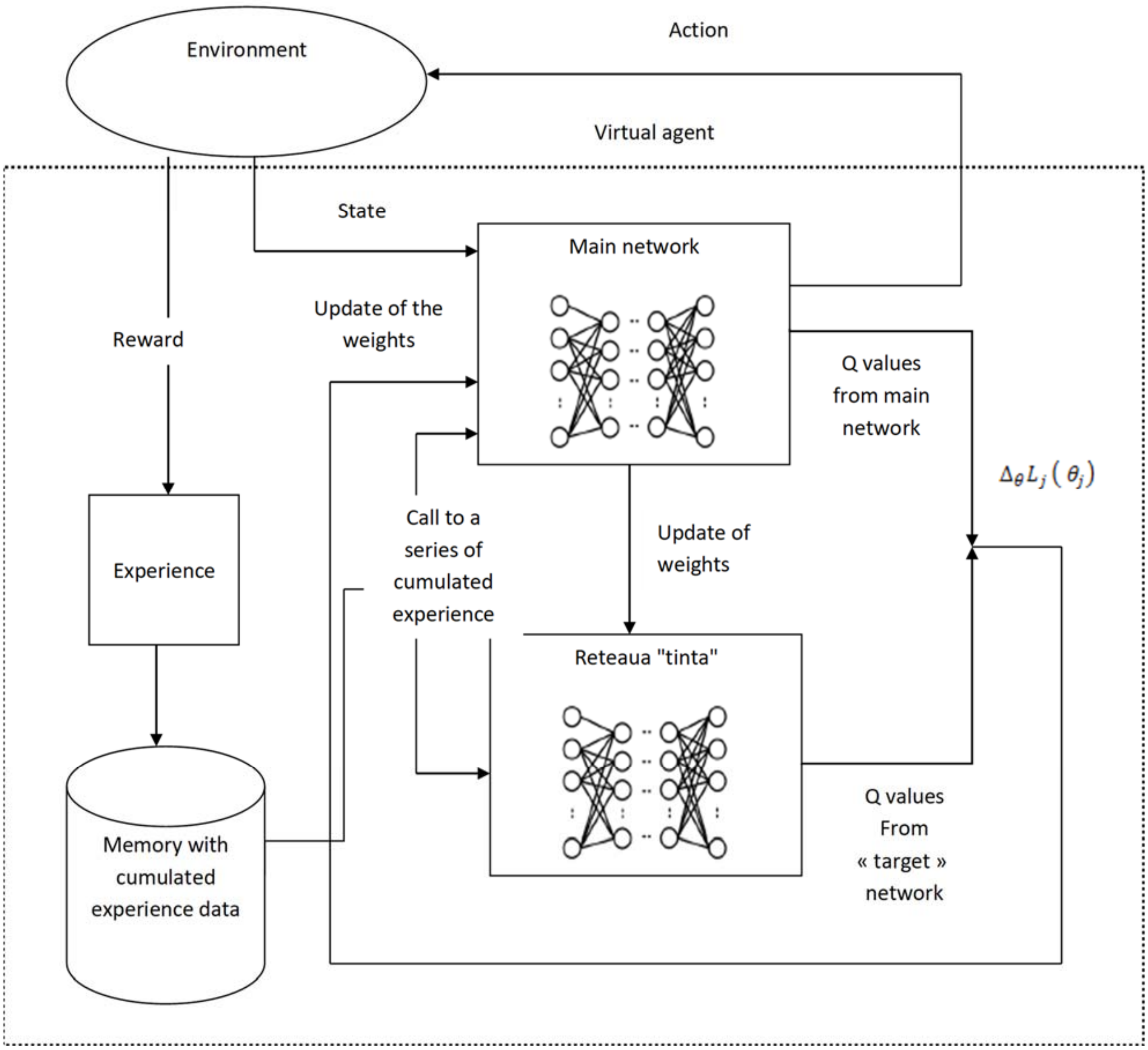

Figure 8- Architecture of a deep Q network [6]

With the help of Matlab program was created a neural network of the type described above in which the following elements are implemented:

1. neural network states

The environment in which the virtual agent operates is characterized by a state of traffic, which can be made up of several components, called substations. In the case of a traffic light intersection, the following substations are defined that can characterize the parameters of the working environment. They are as follows:

- queues of vehicles waiting at traffic lights in a lane or arm of an intersection. A state s_t^i represents the maximum number of vehicles that the traffic detector records;

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- the red time corresponding to a phase is represented by a state $s_t^{i.l} = 1$, and when the color at the traffic light changes to yellow or green by the state $s_t^{i.l} = 0$.
- green time;
- current phase in operation. Within the neural network a certain state s_t^i from junction I, it may contain several substations of possible traffic light phases. For example, at Time t, we can have a state $s_t^i = \left(s_t^{i.1}, s_t^{i.2}, s_t^{i.3}, s_t^{i.4}\right) = (0,1,0,0)$, in which the activated phase is the second, according to predefined succession.
- vehicle position;
- vehicle speed.

2. actions of the virtual agent

The possible actions of the virtual agent are as follows:

- applying a green duration for a certain traffic light phase. For example, an action $a_i^t = \{a_1^i, a_2^i \dots\}$, represents the way in which the virtual agent maintains the current phase a_1^i or move on to the next phase a_2^i, if the current phase does not receive the best reward [6];
- sequence of signal control phases. These can be in the order predefined by the user or in case of absence where traffic requests, in a random sequence.

3. rewards / penalties awarded

Possible actions of the agent lead to a response from the working environment in the form of rewards or penalties/costs. Usually, a reward has a fixed value while a penalty is represented by a null value. Within the calculation methodology approached, the following types of rewards/penalties were considered:

- relative vehicle queue. For this parameter the virtual agent receives from the working environment a reward or a penalty depending on the length of the queues. The number of rewards or penalties are obtained from the calculation of the difference between the vehicles evacuating the intersection and the resulting tail at the end of the red period. If vehicle queues start to increase, penalties are received, and if they decrease, rewards are received;
- waiting time at traffic lights for a vehicle to evacuate the intersection. It is calculated in the form of differences between the average waiting time of vehicles in a lane or arm of the intersection at a time t relative to that of time t+1.
- transition between traffic light phases. This is evaluated according to the time lost for switching from one phase to another, according to the minimum values imposed by the integreen matrix.

In this case study, a comparative analysis was performed between intersections equipped with the proposed calculation algorithm and those with fixed traffic light Times, extracting the main performance indicators.

After "running" the traffic model with the data received from the program elaborate in Matlab calculation program in which the RNAs were developed, the following results were obtained:

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Table 1. Resulted values of vehicle queues between the two signal control methods at the Aurel Vlaicu Avenue-Vivo Mall access intersection

Time Interval (seconds)	**Control method with fixed traffic light Times**			**Control method with the proposed algorithm**		
	Intersection arm			**Intersection arm**		
	Aurel Vlaicu to Mamaia	Vivo Mall Access	Aurel Vlaicu to I. C. Bratianu	Aurel Vlaicu to Mamaia	Vivo Mall Access	Aurel Vlaicu to I. C. Bratianu
0-300	90	20	19	78	18	17
300-600	64	13	46	54	11	40
600-900	107	13	33	92	12	29
900-1200	93	14	40	78	12	35
1200-1500	116	7	47	99	6	40
1500-1800	66	13	40	57	11	35
1800-2100	89	14	18	77	12	16
2400-2700	105	19	38	91	17	33
2700-3000	114	19	33	96	17	27
3000-3300	74	7	34	62	6	30
3300-3600	83	13	46	72	12	40
3600-3900	52	19	39	45	16	34
3900-4200	77	19	33	66	11	29
4200-4500	40	19	53	34	17	41
4500-4800	52	13	38	45	12	33
4800-5100	67	12	26	58	11	20
5100-5400	58	6	65	50	5	57
5400-5700	80	13	54	62	11	43
5700-6000	46	13	26	38	11	23
6000-6300	60	19	32	52	15	28
6300-6600	91	13	46	72	12	37
6600-6900	57	13	38	49	12	33
6900-7200	57	18	38	49	15	33
Average	***76***	***14***	***38***	***64***	***12***	***33***

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Figure 9. Graphical comparison of how vehicle queues accumulate between the two signal control methods at the Aurel Vlaicu avenue -Vivo Mall access intersection

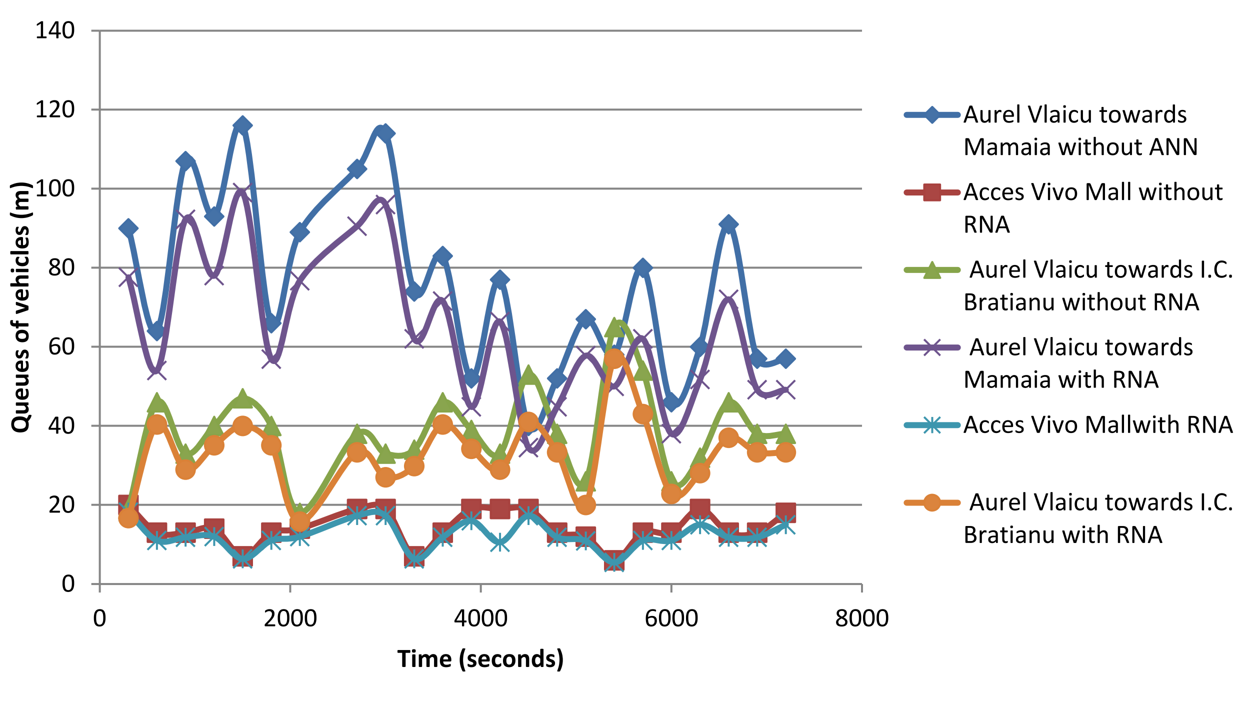

Table 2. Resulted values of vehicle queues between the two control methods at the Aurel Vlaicu avenue-str. Stefanita Voda junction

Time Interval (seconds)	**Control method with fixed traffic light Times**			**Control method with the proposed algorithm**		
	Intersection arm			**Intersection arm**		
	Aurel Vlaicu to Mamaia	Stefanita Voda	Aurel Vlaicu to I. C. Bratianu	Aurel Vlaicu to Mamaia	Stefanita Voda	Aurel Vlaicu to I. C. Bratianu
0-300	178	59	44	153	54	39
300-600	81	46	41	68	42	34
600-900	59	106	50	51	90	44
900-1200	93	54	59	77	49	35
1200-1500	54	72	31	47	65	27
1500-1800	60	84	67	53	74	54
1800-2100	88	66	79	70	60	64
2400-2700	79	53	31	68	43	27
2700-3000	240	90	60	204	81	50
3000-3300	188	53	74	159	75	65
3300-3600	79	85	32	62	77	27
3600-3900	32	69	73	28	63	64
3900-4200	51	45	94	40	40	81

Time Interval (seconds)	**Control method with fixed traffic light Times**			**Control method with the proposed algorithm**		
	Intersection arm			**Intersection arm**		
	Aurel Vlaicu to Mamaia	Stefanita Voda	Aurel Vlaicu to I. C. Bratianu	Aurel Vlaicu to Mamaia	Stefanita Voda	Aurel Vlaicu to I. C. Bratianu
4200-4500	32	59	38	28	54	31
4500-4800	20	58	54	17	52	45
4800-5100	20	68	52	17	60	44
5100-5400	27	57	76	23	52	67
5400-5700	47	37	68	39	33	60
5700-6000	26	35	81	22	32	68
6000-6300	27	77	52	23	68	46
6300-6600	68	56	59	59	49	53
6600-6900	54	55	81	47	46	68
6900-7200	35	117	65	30	104	55
Average	***71***	***65***	***59***	***60***	***59***	***50***

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Figure 10. Graphical representation of how vehicle queues accumulate between the two control methods at the Aurel Vlaicu avenue-str. Stefanita Voda junction

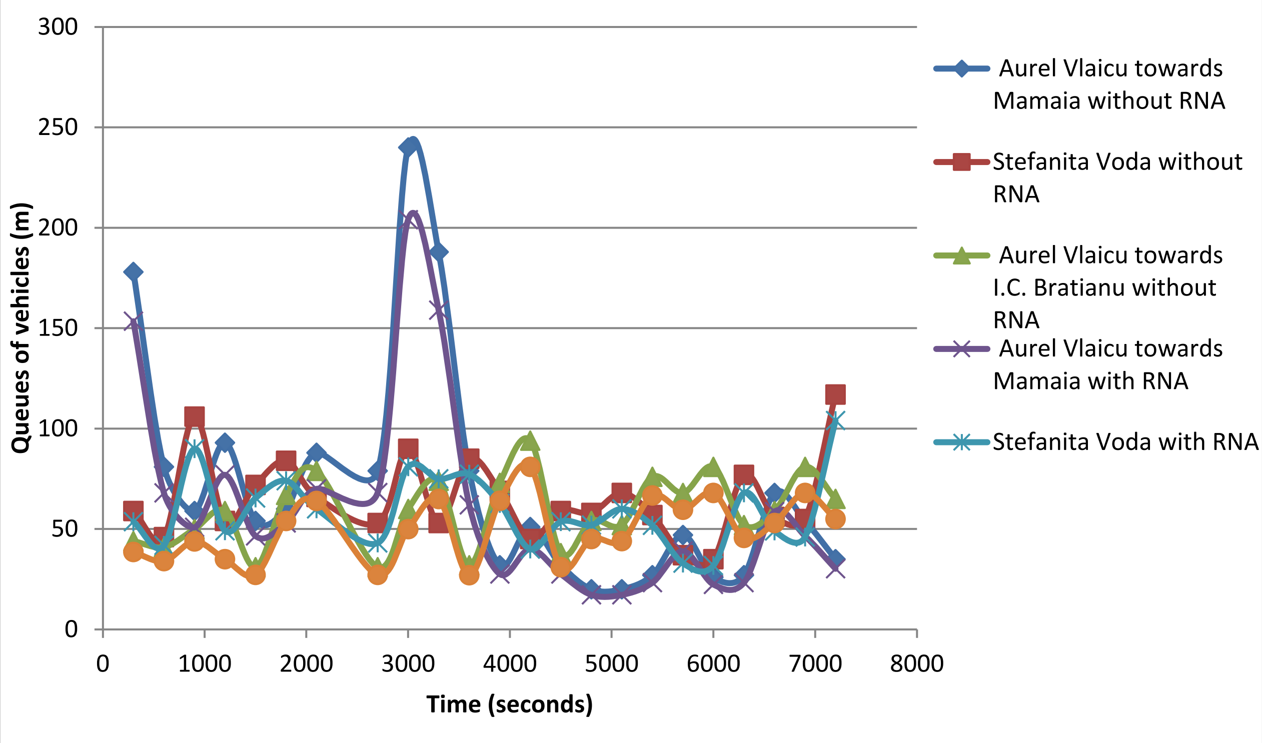

Table 3. Values of average vehicle delays between the two control methods at the Aurel Vlaicu Avenue-Vivo Mall access intersection

Time Interval (seconds)	Control method with fixed traffic light Times			Control method with the proposed algorithm		
	Intersection arm			Intersection arm		
	Aurel Vlaicu to Mamaia	Vivo Mall Access	. Aurel Vlaicu to I. C. Bratianu	Aurel Vlaicu to Mamaia	Vivo Mall Access	Aurel Vlaicu to I. C. Bratianu
0-300	23.75	22	22.5	20.47	20.00	19.74
300-600	16.34	54	43.1	14.09	46.96	36.22
600-900	18.62	29.3	23.9	16.05	26.64	20.08
900-1200	19.19	25.7	31.2	16.26	22.95	26.22
1200-1500	21.09	24.6	27.1	18.18	21.96	23.77
1500-1800	19.95	25.1	29.5	17.20	22.41	25.21
1800-2100	21.28	17.8	28.4	17.88	15.34	24.27
2400-2700	26.03	22	26.9	22.44	18.97	22.99
2700-3000	17.67	10.2	32.8	15.23	8.79	28.77
3000-3300	19.57	11.6	33.5	16.31	10.00	29.39
3300-3600	18.81	15.9	25.3	15.42	13.47	21.44
3600-3900	18.05	24.7	38.8	15.56	21.48	32.88
3900-4200	21.66	14.7	33.2	18.67	12.46	28.14

4200-4500	16.53	40.8	37	13.89	34.58	31.36
4500-4800	16.72	24.8	32.2	14.41	21.02	28.25
4800-5100	25.65	57.8	33.3	14.25	48.57	28.96
5100-5400	14.25	15.4	33.3	7.92	12.94	28.22
5400-5700	22.04	32.9	31.7	12.24	27.65	27.57
5700-6000	22.42	21.5	39.5	19.33	19.55	34.65
6000-6300	19.95	37.8	24	16.76	32.31	21.05
6300-6600	24.89	28.4	32.8	20.74	24.27	28.77
6600-6900	17.67	26.8	37	15.23	22.91	32.46
6900-7200	18.81	24.4	27.5	16.22	22.18	24.12
Average	***20.0***	***26.4***	***31.5***	***16.3***	***22.9***	***27.2***

Figure 11. Graphical representation of average vehicle delays between the two control methods at the Aurel Vlaicu Avenue-Vivo Mall access intersection

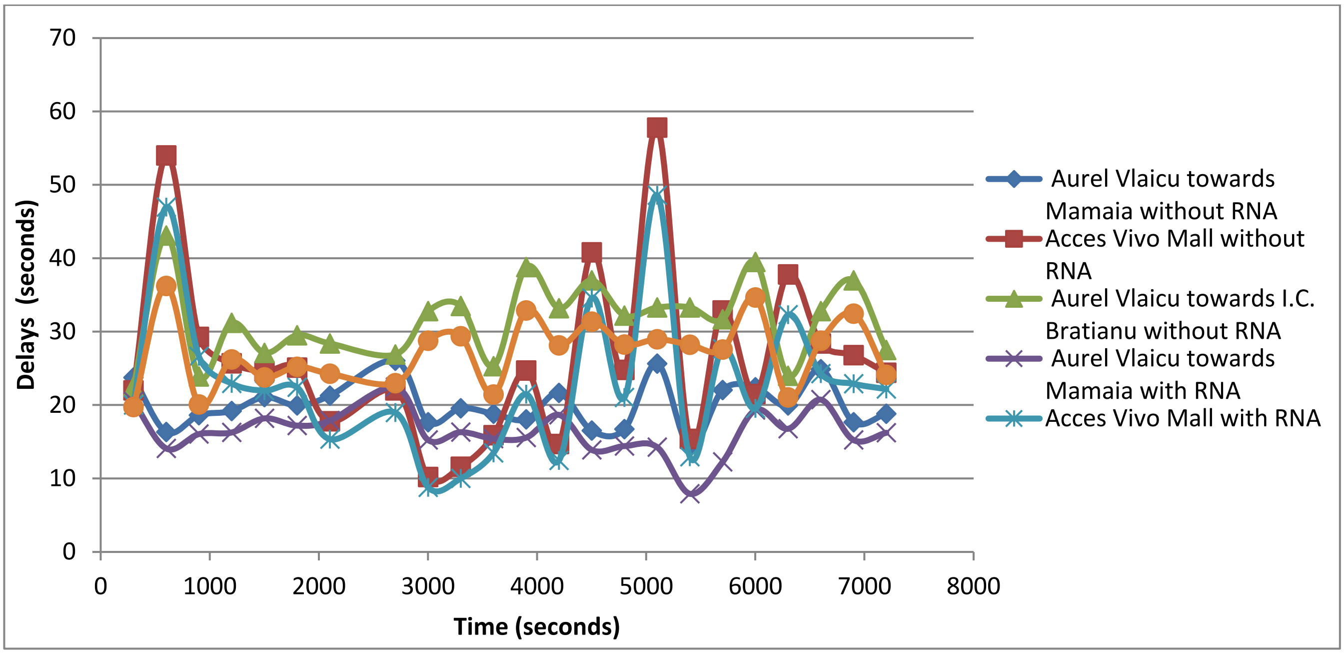

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Table 4. Values of average vehicle delays between the two control methods at the Aurel Vlaicu avenue-str. Stefanita Voda junction

Time Interval (seconds)	**Control method with fixed traffic light Times**			**Control method with the proposed algorithm**		
	Intersection arm			**Intersection arm**		
	Aurel Vlaicu to Mamaia	Stefanita Voda	Aurel Vlaicu to I. C. Bratianu	Aurel Vlaicu to Mamaia	Stefanita Voda	Aurel Vlaicu to I. C. Bratianu
0-300	26.7	23.5	23.7	23.02	21.36	20.79
300-600	17.8	34.5	40.1	15.34	30.00	33.70
600-900	21	46.5	17.8	17.80	42.27	14.96
900-1200	20.9	33.3	20.8	17.71	29.73	17.48
1200-1500	20.7	26.4	22.1	17.84	23.16	19.39
1500-1800	20	39.1	24	16.95	34.91	20.51
1800-2100	25.6	33.7	25.7	21.51	29.05	21.97
2400-2700	22	36.5	26.9	18.97	31.47	22.80
2700-3000	32	35.4	23.1	27.59	30.52	20.26
3000-3300	30.3	27.4	28	25.25	23.62	24.56
3300-3600	19.6	41	22.3	16.07	34.75	18.90
3600-3900	16.2	28.5	36.4	13.97	24.78	30.59
3900-4200	20.7	27.4	33	17.69	23.22	27.97
4200-4500	18.1	40.2	28.5	15.21	34.07	23.95
4500-4800	15.8	33.7	30.4	13.62	28.56	26.67
4800-5100	21.7	38.8	26.4	12.06	32.61	22.96
5100-5400	12.8	31.1	34.1	7.11	27.77	28.90
5400-5700	18.6	27.1	26.5	10.33	22.77	23.04
5700-6000	20.1	27.9	35.1	17.33	25.36	30.79
6000-6300	17.5	32.7	20.5	14.71	27.95	17.98
6300-6600	24.3	31.5	28.1	20.25	26.92	24.65
6600-6900	19.1	38.1	29.5	16.19	32.56	25.88
6900-7200	16.6	44.8	20.1	14.31	40.73	17.63
Average	***20.8***	***33.9***	***27.1***	***17.0***	***29.5***	***23.3***

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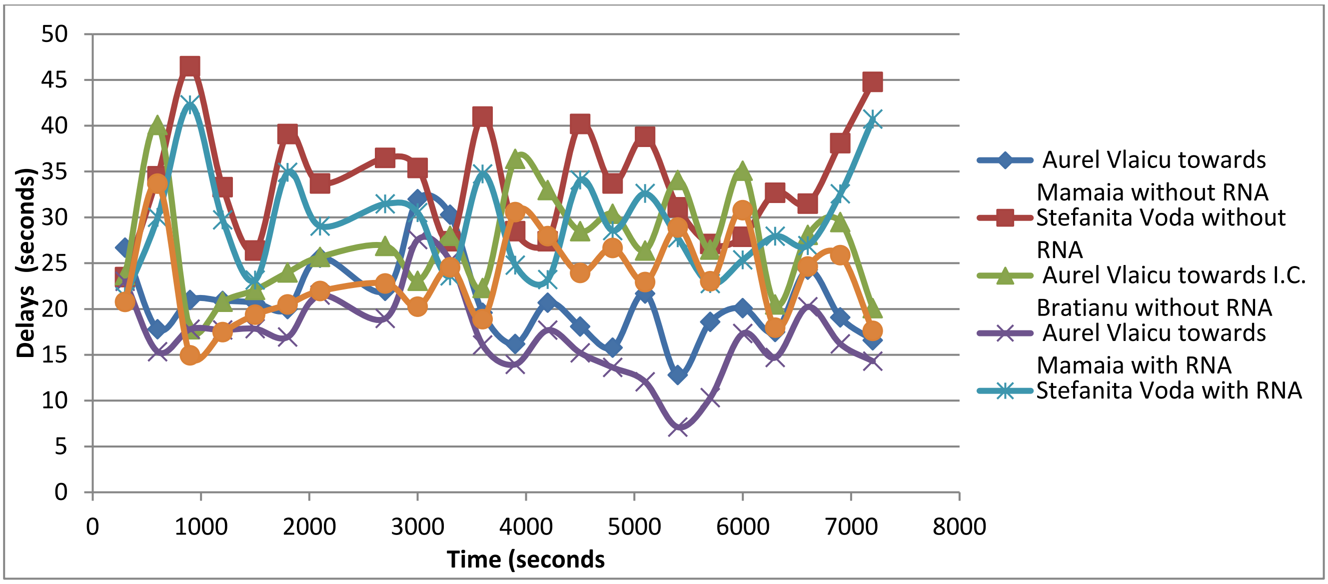
Figure 12. Graphical representation of average vehicle delays between the two control methods at the Aurel Vlaicu avenue-str. Stefanita Voda junction



From the analysis of the results obtained, the following conclusions can be drawn:

- by implementing traffic controllers with elements of artificial intelligence, we obtain a reduction of vehicle queues for the above-mentioned intersections by 12% to 16% depending on the arm of an intersection;
- the decrease in average vehicle delays by using the proposed algorithm is between 14% - 20% depending on the arm of an intersection;
- in the case of an analysis that includes several intersections with complex geometric shapes and with a higher degree of saturation, the use of the proposed algorithm will lead to greater benefits.

In these cases, superior computing powers will be required to decrease the training times of neural networks.

1.3 Development of a methodology for calculating the multimodal service level

Cities' development policies have relied for decades on increased road infrastructure combined with increased motorization. The results of such transport strategies have led to the extension of the street tram, often having negative urban consequences and ultimately leading to the amplification of traffic jams. In order to try to quantify traffic conditions, in 1965, a group of researchers created one of the first traffic manuals (Highway Capacity Manual), in which the theoretical foundations of a new parameter were laid: the level of service.

By its definition the service level presents a classification of traffic conditions in an intersection/street segment [14] using according to the calculation methodology as evaluation parameters delays, speed, flow / capacity ratio for a vehicle, a lane or several arms of junctions. The use of the service level provides information only from the driver's perspective and cannot lead to a differentiated assessment of the types of multimodal travel.

Although a theoretical element had been invented, which should have evaluated traffic congestion, it indirectly led to the enhancement of road infrastructure projects that were accompanied by the increase in the level of segregation of communities, the increase for a limited period of speed of traffic, the increase in road accidents and the decrease in the quality of life. The criticism that is brought to the level of service is that it places too much emphasis on the automobile in relation to other means of transport.

Modern road traffic planning methods prioritize the reduction of pollution in major cities, the decrease of congestion generated by cars, the improvement of mobility between neighborhoods/centers of interest, the decrease of fuel consumption and travel times, the increase of life expectancy, etc. This made the attention of the public authorities shift to trips made by public transport, by bicycle or on foot..

In order to assess the quality of transport alternatives in the literature, the idea of improving the concept mentioned above was approached by using a ***multimodal service level***. It tried to cover the experience of using alternative modes of transport taking into account the user's perception.

From the specialized studies consulted by the author of the doctoral thesis we can list the analysis made in the transportation Manual of the city of Charlotte, in the state of North Carolina, USA [15] on the service levels of pedestrians and cyclists. The level of Service is calculated according to the score obtained by a set of variables regarding the facilities for crossing intersections by cyclists and pedestrians. A disadvantage of this method is the fact that it cannot be applied to street segments, and the selection mode of some factors used in the evaluation (e.g., the connection radius between streets, the presence of intermittent green at traffic lights) are questionable.

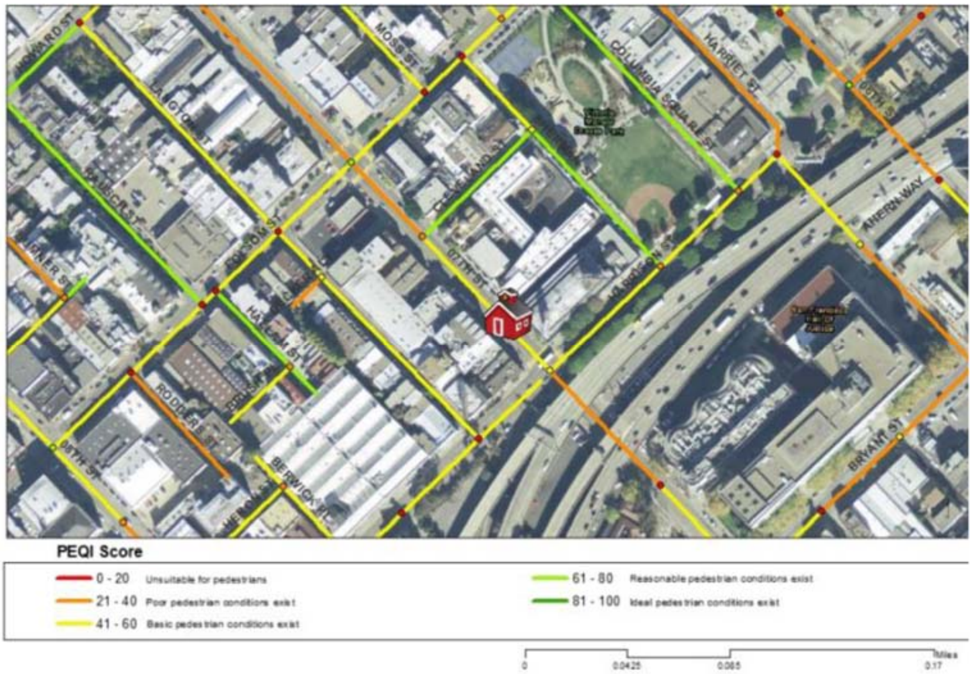


Figure 13- Excerpt from the electronic map made in the city of San Francisco [16]

Another view of this problem was conducted by the Department of public health of the city of San Francisco, USA. In this case, a system based on indices from 0 to 100 was used, which measures how a section of street or intersection satisfies the need for pedestrian mobility or bicycle use. This method allowed the creation of GIS-type maps in which indices were weighted and representatives with a certain colour according to the conditions made available to users. For example, the red colour represents a more "hostile" environment for pedestrians and cyclists, while the green colour offers conditions close to ideal. Figure number 93 shows an example of such a map.[16].

In the manual on Multimodal Transport developed by the city of Fort Collins, Colorado, USA [74], the assessment of the level of service of cyclists depends on the degree of compliance with local design standards for existing facilities, being one of the limiting elements of this method. For pedestrians, the methodology takes into account factors such as the continuity of the paths, the safety of the traffic and the facilities offered for this mode of transport. In relation to other calculation methodologies there is also an approach to the level of service for public transport. Its influencing factors are the characteristics of the operating routes and the geographical area covered.

In order to achieve a unitary concept that highlights a multimodal service level as close as possible to reality, in the doctoral thesis is proposed a calculation methodology that provides a result as close as possible to reality. Thus, in assessing the level of service for public transport, the presence or lack of running paths dedicated only to this means of transport should not be the factor with the highest weight. The evaluation of a transport service must take into account the following elements:

- accessibility of the service by pedestrians;
- regularity of the line of public transport;
- travel time of a public transport.

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In order to quantify a global service level of public transport, we shall allocate the weight of each factor mentioned above. Regarding the accessibility of the service by pedestrians is considered a score based on a distance from the point of origin of the journey to the public transport station as well as the existing pedestrian facilities according to the table below:

Table 5. Number of points related to the distance from the point of origin of the journey to the transport station

Distance from point of origin to public transport station (m)	Number of points
100	10
200	8
300	6
400	4
500	2

Table 6. Number of points allocated according to crossings of streets

Number of pedestrian crossings	Number of points
1	10
2	8
3	6
4	4
5	2

In the case of traffic light pedestrian crossings although pedestrian safety increases, travel times will increase, therefore the score decreases by half.

In order to establish the score regarding the regularity, it is proposed to use the frequency between the vehicles of the public transport line accessed by the passengers

It is recommended that the use of this factor be used only for public transport services that include at least two to three stops in public transport stations, the express lines being removed from this category.

Table 7. Number of points allocated by frequency between vehicles of the public transport line

Time distance between vehicles (minutes)	Frequency of means of transport (Vehicles / time)	Number of points
60	1	1
45	1.33	4
30	2	6
15	4	8
10	6	10
5	20	12

When determining the travel time per kilometre travelled on a public transport route, the actual travel time and the waiting time at the station will be included.

Table 8. Number of points allocated according to travel times

Vehicle travel times (minutes / km)	Number of points
2	12
2.5	10
3	8
5	6
10	4
15	2
20	1

Additionally, it is advisable to score the comfort conditions in public transport such as the facilities at bus stops, the density of the passengers in the public transport vehicle or the presence of air conditioning. The degree of crowding in the public transport vehicle is expressed by the ratio between the number of people and the number of seats available

It is therefore proposed to add the following according to the tables below.

Table 9. Number of points allocated according to the degree of crowding in public transport

The ratio of the total number of people to the number of seats	Number of points
0.8	18
1	16
1.4	14
1.8	12
2	10
2.2	8
2.4	6
2.6	4
2.8	2
3	1

Table 10. Number of points allocated to travel comfort facilities

The presence of canopies in public transport stations	Number of points
Yes	10
No	1
Presence of air conditioning in the public transport vehicle	**Number of points**
Yes	20
No	1

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In conclusion the proposed calculation formula for assessing the multimodal service level of public transport is as follows:

Score Public Transport (TP) = accessibility of the service TP x 0.15 + number of pedestrian crossings x 0.12 + line frequency x 0.2 + journey time x 0.25 + ratio of the total number of people and the number of seats x 0.1 + presence of canopies in public transport stations x 0.05+ presence of air conditioning in the public transport vehicle x 0.13

The transformation of the score obtained after applying the above formula in the size classes of service levels denoted by letters A to F will be performed according to the table below.

Table 11. The level of service of public transport in relation to the calculated score

Public transport score	Service level
Over 11 points	A
Between 9.5 and 11 points	B
Between 7.5 and 9.5 points	C
Between 5.5 and 7.5 points	D
Between 2.5 points and 5.5 points	E
Below 2.5 points	F

In the calculation example below is presented how to apply the proposed calculation methodology. A section of two tram lines 55 and 41 will be compared. For line 55, the service level between Granitul station and Piata Iancului will be calculated, on which 6 stations are located. The length of this section is 4.5 km. The journey time from the first to the last station under assessment is 25 minutes, resulting in an average of 5.5 minutes/km. The trams operated by STB on this route do not have air conditioning, and in the stations are equipped with awnings. At rush hour the total number of trips is on average 40% higher in relation to the number of seats. Distances between residential buildings and tram stops are between 150 - 200m.

Based on the above algorithm results in a total of 7.3 points, framing line 55 at service level D.

For line 41, the route between Grant Bridge and Drumul Taberei will be taken into account. The length of the route is 4.8 km, covered in 12 minutes, resulting in a time of 2.5 min/km. The other travel conditions are similar to line 55.

Based on the above algorithm results in a total of 9.6 points, framing line 41 at service level B.

From the comparative analysis of travel conditions and service levels on the two tram lines, the following conclusions can be drawn:
- even if both public transport lines have a dedicated taxiway, the frequency of line 41 is better due to the system of prioritization of public transport means;
- line 41 can get lower travel times because waiting times at signal control junctions are lower;
- the comfort of the trip can lead to a change in the level of Service;

- the existence of overpases is intended to improve travel conditions. An eloquent example of this is the tram line (supertram) in the British city of Sheffield, which benefits from its own taxiway and a multitude of bumpy intersections;
- in order for a public transport line to be preferred by the travellers to the detriment of the automobile, the travel times by public transport means must be lower. In addition, the choice of public transport routes must be based on the mobility directions resulting from a macroscopic model of a city together with the adjacent metropolitan area;
- the operation of modern means of transport leads to an improvement in the level of Service;
- the level of Service D for line 55 leads to a decrease in the attractiveness of intermodal parking at Granitul, which should decrease the passenger car trips for trips from Ilfov County to / from Bucharest;
- the methodology used above can be applied both on various sections of transmission lines, offering the possibility to establish measures to prioritize or improve travel conditions.

1.4 **Development of a detailed methodology for conducting traffic studies**

Conducting traffic studies is an important stage in establishing the solutions and geometric elements of roads and streets. In order to achieve this goal, it is necessary to correctly quantify the benefits and impact that a project has on existing or proposed road infrastructure. At present it is noted that the legislation in our country does not describe in a laborious manner the entire methodological procedure for the elaboration of traffic studies, which would allow the successful implementation of the objectives of some projects and solve the possible adverse effects. The normative AND 600/2010 or the standards of the series 10144/4-5 describe only the mathematical formulas advisable for carrying out some calculations of the circulation capacities.

Within this doctoral thesis are laid the foundations of a methodology through which traffic specialists can identify definitely the necessary steps in carrying out traffic analyses, which provide forecasts with high accuracy of the main critical variables (traffic). The main steps in achieving a traffic model that provides relevant information consist of the following:

- Preparatory phase before the start of the development of the traffic model;
- Initial modelling;
- Calibration and validation of the traffic model;
- Analysis of proposed alternatives;
- Technical report with presentation of results and completion of drawn parts.

Stage no. 1. During this phase, the design theme and the objectives of the project will be finalized, which must be presented for the approval of the deciding factors. At the same time, an analytical analysis will be carried out on the area of influence of the project, taking into account the distribution of road traffic generated and attracted by the project. In the case of a private development, the following factors will be considered:

- what is the geographical position of the main accesses to a development, in relation to the current street network, as well as to the proposed one;

- what are the critical temporal periods. In this case it is checked whether the peak periods of transit flows coincide with those of developments during a day or there is a certain seasonality of traffic flows. An eloquent example of this is the city of Constanta, in which the traffic peaks attracted / generated by seaside tourism are predominantly at the end of the week, and the local traffic peaks are during the week.

- it will be determined according to the requirements of the client requirments and the complexity of the project which are the necessary simulation calculation programs. In this respect we can mention that in European capitals are imposed certain software packages that local authorities. For example, in London, the Transport for London (TfL) approval authority requires the use of macromodelling programs (TRANSYT, LINSIG, ARCADY) for projects with unsaturated intersections or containing less complex geometric elements and mandatory use of microsimulation software (VISSIM) for more congested arteries.

As a suggestive comparison, for the city of Bucharest, in the case of any project that brings traffic flows on the north - south, east - west axes and the central ring of the capital should include the realization of microsimulations of high precision.

Stage no. 2.

This stage consists in collecting the data necessary for the realization of traffic models. Given that the results of a traffic analysis depend on the quality and quantity of the data used, it is necessary that the minimum collected times comply with the recommendations of the normative AND 600/2010. Highlighting peak hours can be done either by an automatic measurement over several days or by consulting digital databases of maps on the internet (e.g., Google Maps). For traffic measurements on driving directions, it is necessary to choose a "normal" day, which is not influenced by weather conditions, road events, festivals/concerts or works on the carriageway.

Depending on the calculation program used, the traffic specialist may request a smaller or larger variety of information. They can be grouped into the following categories:

- information on the geometric elements of the analysed street/road or junctions;
- information on how to control intersections;
- information on transport demand expressed by traffic intensities or origin-destination values;
- data needed in the process of validating traffic patterns;

Depending on the calculation program used geometric elements will include information on the number length, width of traffic lanes and storage pockets for turns (if any), as well as curvature radii. Advanced microsimulation programs may also require data on longitudinal declivities, technical condition of the carriageway, position of public transport stations or adjacent parking lots. This type of information can be collected using orthophoto planes, GIS databases or topographic elevations.

Depending on the type of control of an intersection, the following data will be identified: access routes with and without priority, and in the case of this traffic light, the number and sequence of traffic light phases, the length of the traffic light cycle, traffic light diagrams, the matrix of intergreen, the allowed movements related to each traffic light phase, etc. It is recommended as much as possible that this information comes from the manager of the road/streets, but it is preferable to make some checks for each location.

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In order to establish the road traffic component, traffic measurements on driving directions will be made at peak hours on time intervals between 5 - 15 minutes. Also, the length of the queues will be collected, expressed in number vehicles per vehicle category, and then these data will be converted into meters.

Depending on the complexity of the calculation program, measurements of travel times, saturation flows or drivers ' behaviour will be required according to the detailed descriptions presented in Chapter no. 2 of the doctoral thesis. At this stage it is important to check whether the general tendency of drivers is to respect the traffic rules as much as possible or whether the current car behaviour also contains elements of "courtesy" regarding assisting other vehicles in order to join the flow as easily as possible.

An important element that can affect traffic measurements is the presence of traffic jams. In this case, it is preferable that the measurements begin before the congestion occurs and be completed after their completion so that the transport demand can be assessed as accurately as possible. On the other hand, during the critical periods of peak hours it is necessary to establish as accurately as possible the capacity of movement for certain directions. The rule of maximum saturation degree will be considered. This consists in introducing in the traffic model a traffic flow that through the traffic queues generated by the traffic model does not exceed the length between two analysed intersections.

Stage no. 3. In this phase, the traffic model will be built based on the data collected in the steps described above. In general, most computer programs require the definition of nodes that are assimilated to intersections (signal control or not) and the links between them (links). The plane definition of nodes is usually done in an orthogonal reference system, Type x-y, and in some more complex calculation programs will be introduced and quotas (z). In the case of microsimulation models, it will be possible to import orthophoto planes or topographic elevations made in DXF. or dwg files.

In high-complexity traffic models, the behaviour of the driver can be defined using predetermined parameters. Based on field observations, the traffic specialist can modify the traffic aggressiveness of the drivers. This can be replicated in traffic patterns by the average distance between vehicles, the number of seconds between vehicles to give way or the response time to the appearance of the yellow colour at the traffic light.

Although modern traffic models have many options to simulate traffic conditions, in some situations, data collected from the field may be insufficient or require long periods of observation to achieve driver behaviour close to that in reality. Such cases somewhat more difficult to model occur in the following situations:

- when changing lanes in areas with traffic congestion;
- intersections controlled by priority rules with low levels of traffic capacity. An example of this is the level intersections on the Bucharest Ring Road, where although vehicles entering the Ring Road have priority, due to courtesy some drivers allow access to vehicles without priority;
- maximum variation in acceleration and deceleration;
- the use of a traffic lane for multiple stops or stationaries due to cargo deliveries, entrances or exits between - a parking lot arranged. In this case if the traffic model does not allow partial" closure " on a certain length of the traffic lane, so as to simulate a decrease in traffic capacity, it is preferable that this lane be removed locally from the traffic model;

After completing the traffic pattern, a run of it with preset values will be performed. The following will be considered mainly:

- simulation time period. Its choice will depend on the interval of rush hour. If the morning rush hour is between 8 AM and 9 AM it will simulate at least half an hour before rush hour to allow vehicles to be loaded into the traffic pattern and the formation of queues observed when collecting data on the ground and at least half an hour after rush hour to highlight the simulation of traffic dissipation;

- resolution of simulations results on time intervals (5 minutes, 15 minutes, 30 minutes, 1 hour, etc). Normally the data is entered in 15 minutes/60 minutes intervals and the results are exported in the same way. At some intersections we list the mini - roundabout at the. I. C. Bratianu avenue with the Pasajului Street junction in Constanta municipality or the intersection of the A312 Uxbridge Road / Harlington Road East in London, UK, vehicle queues quickly increase to a maximum value and last only a few minutes, followed by a lull. In these particular cases it is advisable that the collected data be entered into the traffic model on smaller time intervals, respectively the performance indicators to be exported in a similar way;

- setting the types of result reports or video renderings obtained.

Stage no. 4. In this phase of the traffic study the focus will be on checking possible modelling errors and correcting them. Depending on the complexity of the calculation program, the checks are divided into two categories:

- analytical checks by comparing the measured traffic data with those extracted from the traffic model. It is necessary that the data extracted from the program be as possible other than those used to make the traffic model.

- visual checks of the animation of the calculation program.

From the point of view of the necessary checks presented in the case studies in the previous research report, the following are recommended:

- comparison of the measured traffic flows with those in the model on the arms of the main connecting arteries with intersections according to the table below. The GEH statistical parameter described in the research report no. 1.

Vehicle type	Intersection arm	Measured values	Metrics from the traffic model	GEH	Percentage difference

- making critical parameter envelope for traffic model validation. It is recommended to check travel times and saturation flows. In the case of simpler calculation programs in the absence of the above parameters, traffic queues will be compared.

Upon completion of the verifications mentioned above, it may be concluded that minor changes in the intrinsic parameters of the traffic pattern are necessary or that the traffic pattern may be considered valid. After the validation of the traffic model, the main performance indicators will be presented in the study area for the current situation, from which we list: vehicle queues, degree of saturation, delays, level of service, reserve of traffic capacity, etc.

Stage no. 5. After completing the validation of the traffic model, it is necessary to forecast the traffic for the perspective period. The time horizon of the perspective period will be considered according to the class of the analysed intersections and the recommended time periods in the normative and 600/2010.

In the case of proposed developments in the area of influence of the traffic study, one of the two methods presented below can be used:

- method of generating trips;
- occupancy method.

Trip Generation (Trip Generation)
This calculation methodology is based on the manuals developed by the Institute of Transport Engineering (ITE) versions 8 and 9 [17].

In order to estimate the number of trips generated by a development, the following equations are used:
* Linear equation - $t = aX + b$
* Logarithmic equation-$T = a \, Ln (X) + b$
where T = number of trips forecast
X = independent variable
A and b = constants resulting from raw data processing

In essence this method is based on the estimation of the Travelers attracted and generated by a development, depending on the deployed areas built. The total number of trips consists of the following:
- travellers who have as their destination the proposed development. These will generate additional traffic flows on the network of streets in the analysis area;
- travellers who have intermediate stopping point in development between an origin and a final destination (pas by trips). This category of trips does not produce additional traffic flows on the street networks in the area of influence of the project;
- travels between various locations of the same developments. This type of travel does not apply to this project and is specific to investments with large areas and varied functions. An example could be Baneasa Shopping Centre in the north of Bucharest;
- trips attracted by the network of communication pathways resulting from the implementation of the investment.

It should also be mentioned that in order to establish the number of vehicles attracted/generated by a development it is necessary to establish the degree of load of a vehicle. As an example, the figure below shows the occupancy rate of vehicles measured over several years in the European Union and the USA. Compared to the data mentioned below in the Bucharest mobility survey from 2007-2008, there was an occupancy rate of vehicles in the passenger car category of only 1.21 persons/vehicle.

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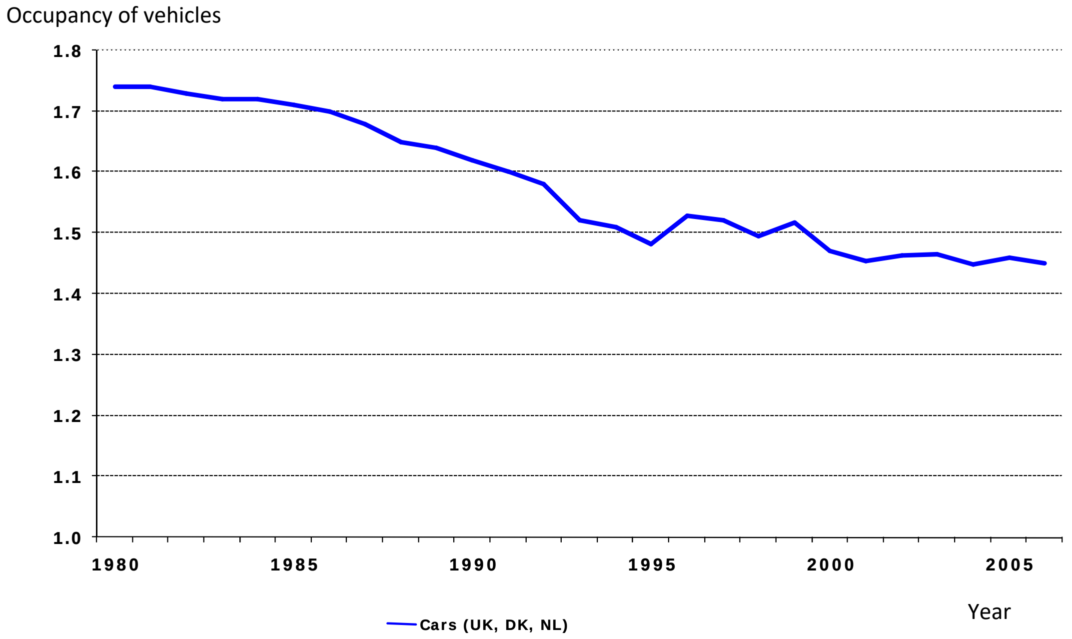

Figure 14- Occupancy of vehicles [18]

In Figure no. 17 below shows the distribution of trips according to its type.

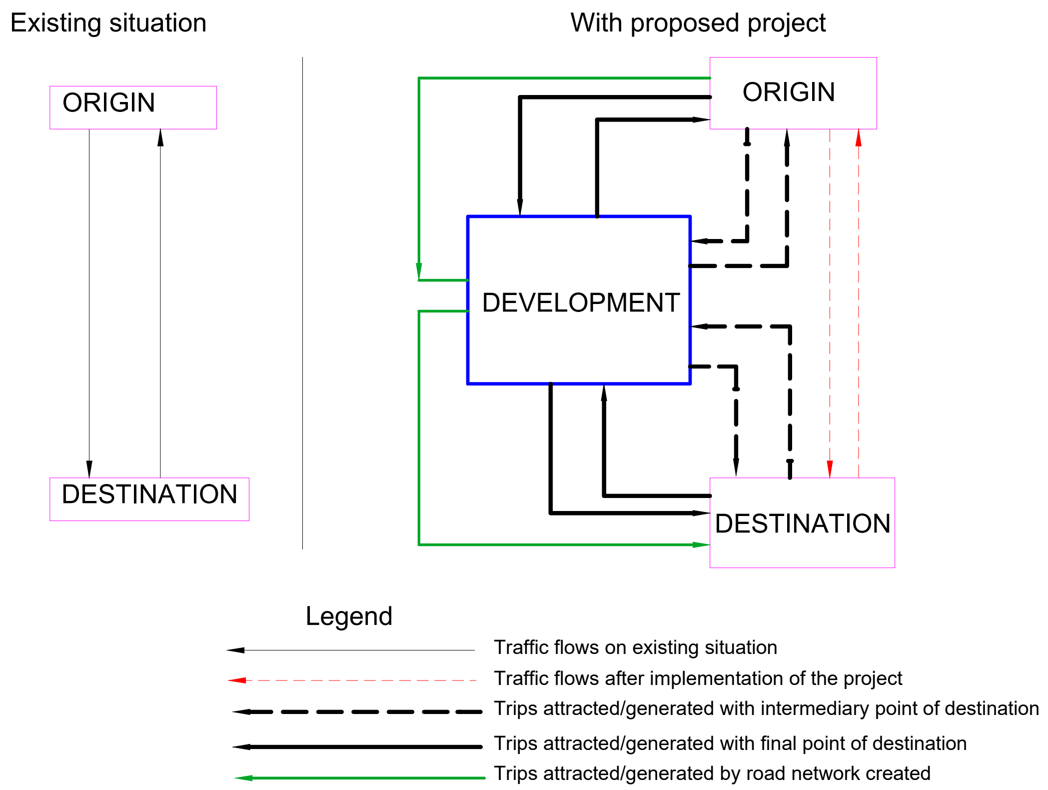

Figure 15- Graph on how to generate trips by travel method

Occupancy method

This calculation methodology is based on statistical analysis of the following information:
- Number of parking spaces;
- information from the marketing study on the annual daily average of visitors;
- statistical data from other developments currently open regarding parking occupancy;
- provisions of the normative P132 / 93-normative for the design of urban parking in localities.

An element of this method is the approximation of the degree of use of parking at the rush hour of a development, taking into account the information mentioned above. In addition, it will take into account the time period, which a visitor a party in commercial development, depending on its characteristics. For example, from the author's experience at shopping malls or commercial stores with showroom surfaces, the average waiting time is around 1.5 hours, while in DIY stores the average time is up to one hour. At the opposite end are smaller supermarket-type food commercial developments, where customers spend around 45 minutes.

In this calculation method the traffic generated by the development is based on a degree of rotation between 10 - 25% of the total parking spaces.

Stage no. 6. In the last phase will be calculated the performance indicators for each intersection (existing or proposed), highlighting the effects of the influence of traffic flows attracted and generated in relation to the existing situation. The technical memo will contain a summary of all the steps described above. Extensive results of running the traffic model should be entered in an annex of the technical memo so that another traffic specialist can analyse or use them accordingly.

Chapter 3. Conclusions

Research in both neural networks is booming and concerns a significant number of scientists in various fields. This is due to their great potential and their applicability in a particularly wide spectrum of activity (as can be deduced from the titles mentioned in the paper and the very diverse areas in which neural networks have been used). In the process of designing a neural network with supervised learning, the main problem is to minimize the training time.

In this regard when choosing the architecture must be made a compromise between the performance of the network and the amount of memory and the calculation time required. However, despite some difficulties encountered in the implementation of neural networks, the advantages they offer recommend them as viable solutions, with outstanding performance in identifying, modelling and conducting systems

Within the elaboration of the doctoral thesis will be introduced a chapter called "Final conclusions, original contributions, dissemination of information and future research directions". It will contain the following:

- a presentation of the main objective of the doctoral thesis;
- the role of predictions in traffic engineering by using modern computational algorithms;
- conclusions on the use of RNAs to improve intersection control methods;
- detailed theoretical and applied contributions for the application of artificial intelligence and the development of the calculation methodology;
- possibility of post-doctoral research;
- compatibility of doctoral research with objectives aligned with European policies.

Chapter 4. Bibliography

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