Combination of Artificial Intelligence Techniques for prediction the Behavior of Urban Vehicular traffic in the city of São Paulo

Abstract— **In recent years the behavior of the parcel delivery market has undergone significant changes influenced by increased competitiveness, concern with the environment, electronic commerce, increasing the number of customers, reducing the order size, increase the flow of urban vehicles; increase the fleet; complexity of the operations of pickup and delivery; increased restrictions on movement of vehicles, increased restrictions on size and capacity of vehicles. Thus the routing and scheduling of vehicles tend to receive a prominent focus, observing the requirements of the consumer market and end customer within the urban distribution logistics. The aim of this paper is to apply a neuro fuzzy network to forecast the behavior of the urban traffic of the city of São Paulo supported by a hierarchy of three levels of routing: strategic represented by forecasting the behavior of traffic, tactical represented by dynamic vehicle routing and operational routing by routing algorithms. The methodology of the paper consists in the capture of relevant events that affect the flow of traffic of the city of São Paulo and the application of a fuzzy neuro network trained with these notable occurrences to predict the behavior of traffic. This paper presents the results of using neuro fuzzy network (NFN) in predicting the behavior of the traffic of the city of São Paulo for a week.**

Keywords — Dynamic Vehicle Routing; Hierarchy of Routing; Neuro Fuzzy Network.

I. INTRODUCTION

The new consumption habits of Brazilians have brought to market products with shorter life cycle thus increasing volumes of items collected and distributed every day [1].

An important aspect for maximum efficiency in transportation is the definition of the routes of the pickup and deliveries. This setting determines the path that a vehicle will travel to complete the requirements of transport services [2].

The vehicle routing problem is to define routes of vehicles that minimize the total cost of attendance, each of which starting and ending at the depot or base of vehicles, ensuring that each point is visited exactly once and the demand on any route does not exceed the ability of the vehicle that meets. When the definition of the routes involves not only spatial or geographical aspects, but also temporal, such as restrictions on hours of service points to be visited, the problems are so called vehicle routing and scheduling [3].

In urban areas it is possible to give up some advantage regarding the minimum distance to obtain a shorter shift [4]. The proposed dynamic vehicle routing deviations from regions with lower traffic flow in time offering other alternative routes that minimize the waiting time (unproductive).

The traffic chaos witnessed in the city of São Paulo is formed by several notable events recorded during the day and directly interferes with the flow of traffic, congestion hamper the efficiency of urban transport and cause considerable damage. Notable occurrences are instances highlighted by the Operations Center of the Traffic Engineering Company, which affect or may affect conditions of traffic flow and safety of the city [5].

A vehicle stops on a busy road immediately causes a decrease in vehicle speed that way. The consequence is the variation in traffic flow on streets perpendicular or parallel, there was momentary chaos. In cities without adequate urban planning as São Paulo, chaos may to become by permanent [6].

A fuzzy neural network was developed using an artificial neural network architecture of multilayer perceptrons (MLP) with backpropagation algorithm. Data were collected notable occurrences of traffic in the metropolitan region of São Paulo in the period from 14 to 18 December 2009.

Fig. 1 shows the distribution of notable occurrences reported by the CET applied in neuro fuzzy network in order to obtain the impact of such occurrences in the flow of traffic through relevant events on the behavior of traffic, these parameters were converted by the function of fuzzy sets. This paper will present the results of forecasting the behavior of urban traffic in São Paulo in the period from 14 to 18 December 2009.

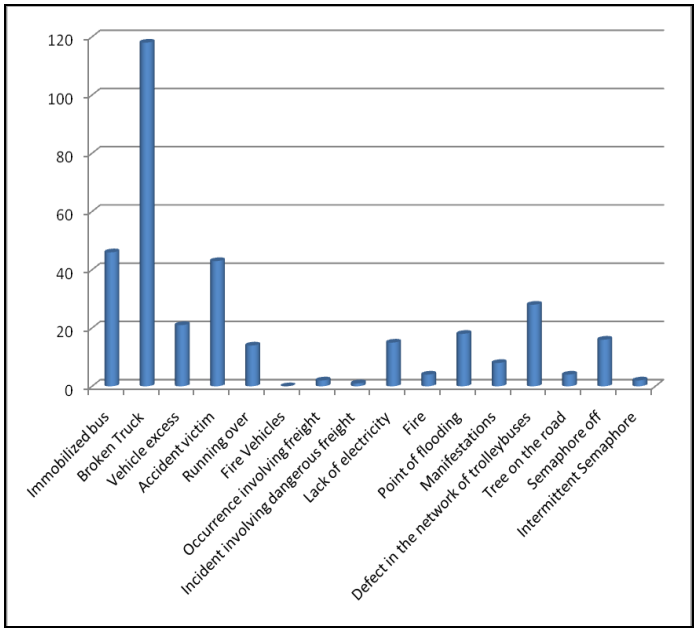

Figure 1. Distribution of the notable occurrences in the period from 14 to 18 December 2009.

II. THE HIERARCHY OF ROUTING

Across the three hierarchical levels of routing is possible to consider not only the basic underlying routing (routing algorithms) as well as external factors, relevant events, which directly affect service levels in large cities (dynamic vehicle routing) that represents the tactical level the routing. The prediction of traffic behavior represents the strategic level of routing. Fig. 2 illustrates the proposed hierarchy for routing supported by three levels [7].

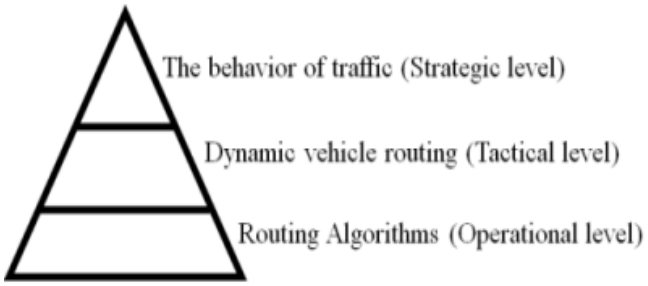

Figure 2. The Hierarchy of Routing [15].

III. DYNAMIC VEHICLE ROUTING

The static routes do not allow to optimize the entire path of the vehicle and urban areas are fertile in events that directly influence the travel distance and time so the time lost in traffic jams, and increase the cost of travel, provides greater fuel burning [8]. With dynamic vehicle routing, deliveries continue to be performed and, after interruption, the before congested region can be serviced normally without prejudice to all delivery points.

Figures 3, 4 and 5 illustrate an example step by step in changing the route during a break in the road on which would be held up deliveries of supplies and other items already in the initial route changed without affecting other customers , so just stopping the vehicle resumes deliveries to the semi-arc missed in the initial route.

Fig. 3 (A) shows the path to the barren region of distribution (blue line) and points to be served (green dot) and the initial planned route (red line). Fig. 3 (B) shows the interruption of part of the path within the range of distribution schedule.

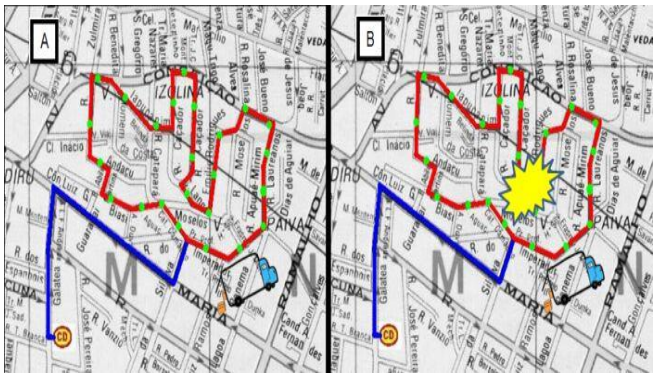

Figure 3. Region of distribution (A and B) [15].

Fig. 4 (C) shows the alternative route (yellow line) that enables the delivery of the same region of distribution continue to be made. Fig. 4 (D) shows the end of the interruption and the customers that have not been met.

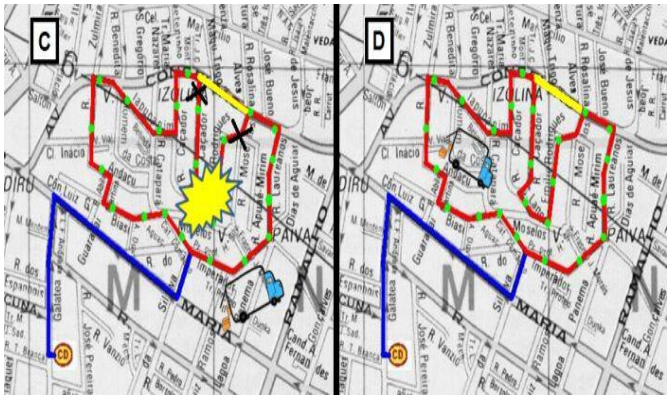

Figure 4. Region of distribution (C e D) [15]

Fig. 5 (E) shows the new alternative route (yellow line) that will serve customers in the semi-arc missed in the initial routing.

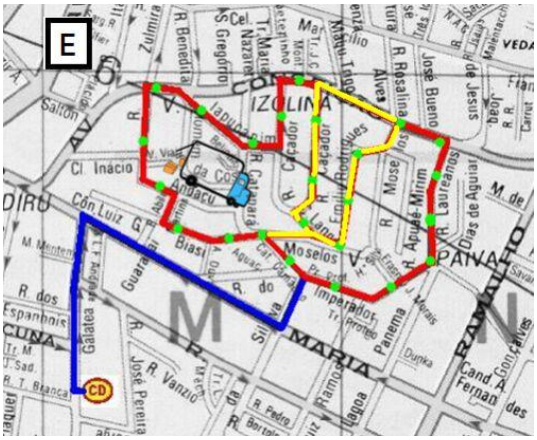

Figure 5. Region of distribution (E) [15].

The dynamic vehicle routing in this paper represents the tactical level of routing, as seen in section II.

IV. COMBINATION OF ARTIFICIAL INTELLIGENCE TECHNIQUES

The concepts of fuzzy logic can be used to translate in mathematical terms the inaccurate information expressed by a set of linguistic variables [9].

Will be used the nomenclature of fuzzy sets by defining them as a class of objects of continuous variables. These sets are characterized by membership functions which indicate for each element a membership degree 0 to 1 [10,11, 14].

The neural networks are models inspired by brain structure aiming to simulate human behavior such as learning, association, generalization and abstraction [12].

The fuzzy neural networks have emerged as a promising tool, because they gather the benefits of Neural Networks and Fuzzy Logic, where the learning and computational power of neural networks, and capacity for representation and reasoning of fuzzy logic are combined [13].

As a programming language was used Scilab 5.1, according to the advantages pointed out in (http://www.scilab.org) There are also available in this language computer packages (toolboxes) specially designed for Fuzzy logic and Neural Networks. The average error was defined as metric to verify the validity of the network, it was established as the difference between the value returned by the network and the output of the database. The Fig. 6 shows the flow of information and neuro fuzzy network used.

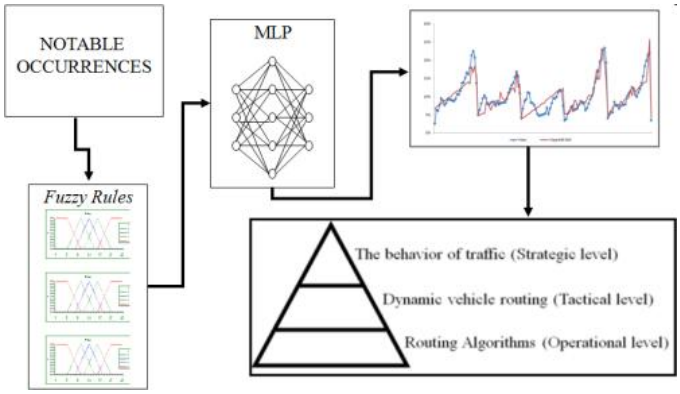

Figure 6. Flow of information and Neuro Fuzzy Network [15].

Data were collected notable occurrences of traffic in metropolitan São Paulo with the objective of obtaining the impact of such occurrences in the flow of traffic through relevant events on the behavior of traffic, these parameters were converted through the fuzzy sets. Table I shows the types of notable occurrences recorded that were used in neuro fuzzy network (inputs).

TABLE I

Notable Occurrences
1. Accident victim
2. Point of flooding
3. Running over
4. Broken Truck
5. Defect in the network of trolleybuses
6. Lack of electricity
7. Fire
8. Fire Vehicles
9. Manifestations
10. Occurrence involving freight
11. Incident involving dangerous freight
12. Immobilized bus
13. Tree on the road
14. Semaphore off
15. Intermittent Semaphore
16. Vehicle excess

Source: Adapted from CET, 2009

To model the membership functions corresponding to the notable occurrences were used Gaussian functions, as shown in equation (1) below:

$$\mu^{\alpha}(x) = e^{-\frac{1}{\sigma}(x-c_{\alpha})^2} \quad (1)$$

Where:

c_{α}: Center of Gaussian function
σ_{α}: Dispersions of the function
α: Linguistic label (high, medium, low)

The training algorithm used in the MLP is the error backpropagation [12] which works as follows: presents a pattern to the input layer of neural network, this pattern is processed layer by layer, until the output processed to provide the answer, f_{MLP}, calculated as shown below in equation (2).

$$f_{MLP}(x) = \varphi\left(\sum_{1}^{Non} v_l \cdot \varphi\left(\sum w_{lj} x_l + b_{l0}\right) + b_0\right) \quad (2)$$

Where v_l and w_{lj} are synaptic weights; b_{l0} and b_0 are the biases; and φ the activation function, usually specified as the sigmoid function as shown in Fig. 7.

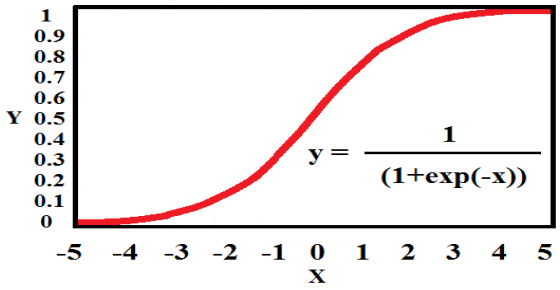

Figure 7. Sigmoid Function [16].

Fig. 8 illustrates the results obtained by neuro fuzzy network compared with those obtained by the CET during the week studied.

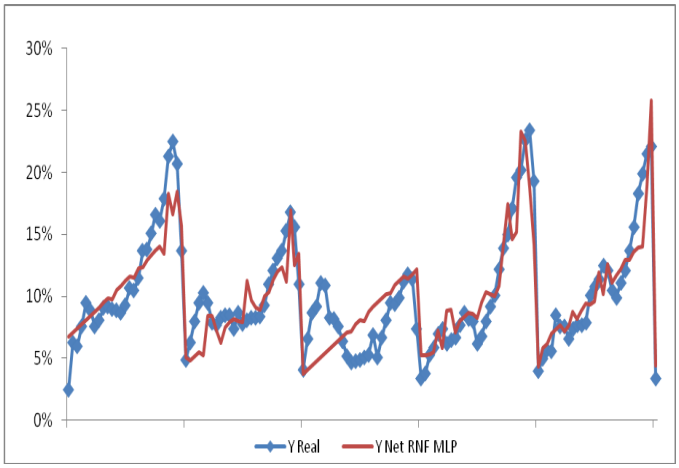

Figura 8. Behavior calculated by the neuro fuzzy network.

With the initial results it appears that the neuro fuzzy network got a reasonable result of the proposed problem to assist in decision making regarding the time frames that must be avoided and that exhibit the behavior above the norm.

V. CONCLUSION

The prediction of traffic behavior can contribute to decision making prior to routing to support the stages of physical distribution with greater effectiveness and productivity. With the possibility to predict the fluctuations of traffic flow, it is possible choose the best windows service in order to avoid times when traffic forecasting point to levels that compromise the slow attendance. The combined dynamic vehicle routing traffic forecasting can significantly increase the efficiency of routing in large cities. The static routes do not allow perfect the whole route of the vehicle so that all customers are met within the time frame estimated. The deviations intelligent aimed at reducing time in transit, even if distance is a little bigger, and there is a savings in time and fuel, it is concluded that the prediction of the behavior of traffic routing and dynamic vehicle routing are promising alternatives.

Aim is to continue with research using other data samples collected on different days of the week, in different months and days with atypical of São Paulo to get new results by applying the neuro fuzzy network. The dynamic vehicle routing will also be studied in conjunction with a view to possible integration of the three levels of routing as proposed in the paper. The aim is also replace the multilayer perceptrons (MLP) with another type of artificial neural network Radial Basis Function (RBF) in association with Fuzzy Logic, called MLP RBF contrasting results with the MLP NFN developed in this paper.

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