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USE OF ARTIFICIAL INTELLIGENCE (AI) FOR OPTIMAL DELIVERY IN URBAN LOGISTICS

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ABSTRACT

Performance In an urban area, the delivery of products in a short delay represents a vital requirement for the customer, but a permanent challenge for the providers, because this parameter "delay" is affected by several factors, which makes its prediction a delicate matter.

This paper presents an approach to predict the delivery time in urban areas through a decision-making model based on the fuzzy logic method. This model relies on three input factors namely: traffic density, mileage and road infrastructure quality to determine the delivery time which is the output parameter.

The importance of this model lies in its ability to accurately delineate the impact of each input parameter and adjust them in order to reduce the delivery time and therefore satisfy the customer.

Keywords: - *Fuzzy Logic, Delivery Of Products, Industrial Performance, Decision Making Model, Traffic Density, Mileage And Road Infrastructure Quality.*

1. INTRODUCTION

Traffic at rush hour, races between cars, buses, scooters and other modes of transport, lost deliveries, absent customers, forbidden parking: last-mile delivery in urban areas is certainly the most delicate link to manage. In addition to this, new challenges have arisen, making the problem even more complex and imposing agility and responsiveness on an entire sector [1]. According to a Capgemini study, 48% of clients would refuse to call on the distributor again in the event of a delivery problem. On the contrary, 55% of clients would appreciate a fast delivery in less than 2 hours. Finally, 82% of customers satisfied with their delivery would not hesitate to recommend the distributor to their friends and family. [2].

« Nowadays, the last mile is considered the most important element in the logistics and supply chain. The main objective is to deliver the package as quickly as possible. This is the key to customer satisfaction» [3]. This is the longest and most expensive step in the entire supply chain process. Thus, if done well, it can save time and money, which can make a company efficient, profitable and well reputed, and this a challenge is not easy to meet, it requires careful planning and thorough study of factors influencing the delivery time.

In our research a delivery time forecasting model will be established through modeling these factors and adopting the fuzzy logic approach, these factors will play the role of input parameters.

The originality of this designed system is its flexibility thanks to the exploitation of previous delivery cases in order to increase its prediction performance. Indeed, to train the fuzzy logic system, data were collected via 100 delivery cases under different conditions. In addition to the 100 delivery cases used to train the fuzzy logic engine, 16 data from them were used to verify and test the system and 16 delivery cases were evaluated by the created fuzzy logic engine.

2. RESEARCH METHODOLOGY

The objective of this research is to develop a decision support tool that allows experts to predict the delivery time of products in urban areas in order to meet the customer's need within a defined time and avoid delay, therefore, satisfy his need, through the use of one of the artificial intelligence techniques: "Fuzzy Logic".

In our research work, a brief description of the logistic spaces will be used. Thus, to emphasize the importance of the estimation of the delivery time. Then, to present meticulously the concept of the

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fuzzy logic used Then, to model the input parameters impacting the delay which constitutes the output parameter, using membership functions and the subsets associated with each. Finally, a discussion of the results obtained, to end with a concentrated conclusion

2.1. Hierarchical Framework

- The Urban logistics area.

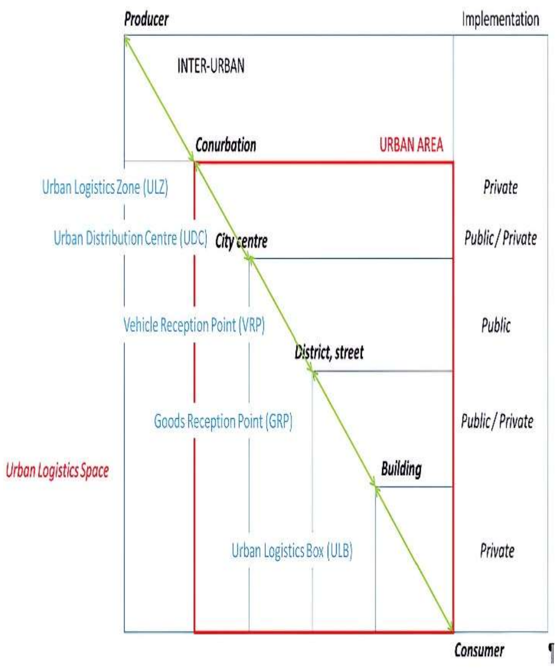

Figure 1: La Typologie Des Espaces Logistiques Urbains [4].

«It is a platform for receiving and redistributing products, pooling flows and rationalizing resources, located in an urban environment inside or outside fixed or temporary buildings. The local reorganization of exchanges and flows aims at optimizing the circulation of products in the city» [5].

We will detail the spaces in the City Center, in the surrounding area, on the building. and even at the bus stop. The different logistic spaces do not have the same function, nor the same range of action, the Urban Logistic Area (ULA) gather several transport companies, they have for roles to bring closer the actors of the logistics of their customers.

Urban Distribution Centers (UDCs) are grouping and deconsolidation platforms. Their main role is to manage flows to dense areas. In this sense, they are generally located a few kilometers from the city center.

Vehicle Reception Points (VRP) are infrastructures dedicated to the allocation of a part of the roadway to the parking of vehicles for the transport of products.

The Goods Reception Points (GRP) must make it possible to concentrate the shipments to or from an area without the recipient or the shipper having to cross the carrier.

Urban Logistics Boxes (UBLs) act as an interface between the deliverer and the recipient, without the two parties having to meet.

They can be mobile or fixed boxes that are located at street level or in a building.

2.2 Parameters Presentation.

The delivery time depends mainly on many parameters and factors which are interconnected and have different levels of impact. In this section, a detailed presentation of the major input factors is given:

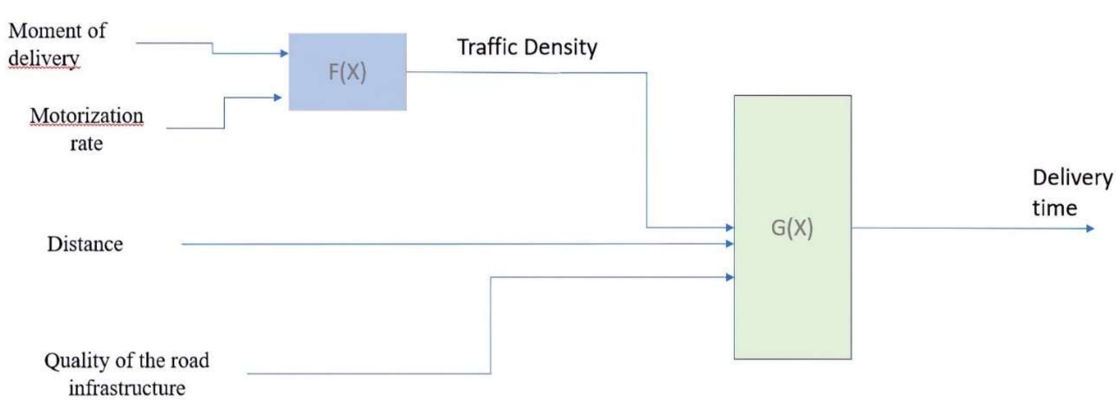

Figure 2: The Principal Contributors To Urban Logistics.

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Traffic is dense, it is when a high concentration of motorized vehicles circulates with difficulty on a road in the same direction. This situation generally leads to traffic congestion, which hinders the progress of users who have difficulty reaching their destinations via that section of road.

Traffic Density is one of the different forms of slowdowns that can occur on the road and cause traffic jams.

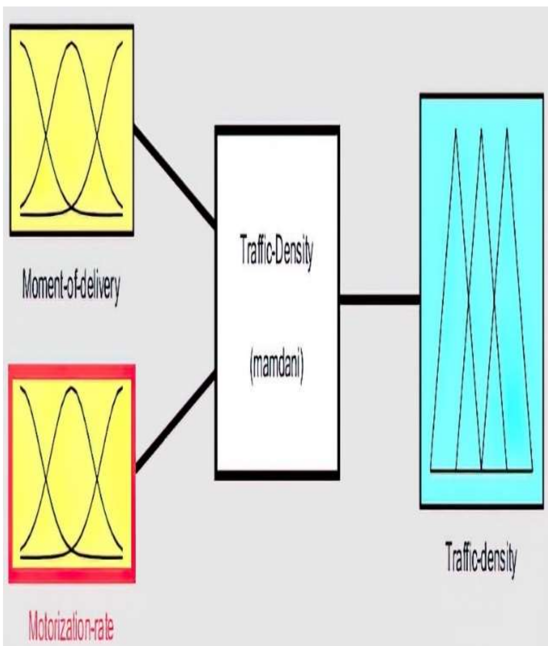

Figure 3. Traffic Density.

the Distance is the Mileage between the delivery point and the customer. The greater the distance, the longer it takes to get to the customer, which is why vendors are always creating new delivery points in town.

The quality of the infrastructure or the road infra structures are all the fixed installations that it is necessary to arrange to allow the circulation of the vehicles and more generally the functioning of the systems of transport. It is obvious that the better the quality of the infrastructure, the less traffic congestion there is.

2.3. Delivery time estimation

It refers to the time between the time the product is picked up by the carrier and the time it is delivered to the final recipient. Internal factors such as production, and external factors such as shipping. These measures include

To estimate the average transit time, all shipments on the selected routes are considered. Even though the calculations are made with the highest possible accuracy, the transit time may vary from case to case and is therefore not guaranteed. In this case, it will be necessary to ensure that there are no works in the intended roadway, checking the weather conditions in order to predict the route to be followed, consequently, logistics is in charge of managing the means that allow to reach the objective of satisfying demands that concern the management of materials (transport, storage ...) and the associated information flows (traceability).

3. SUGGESTED APPROACH (FUZZY LOGIC).

The method proposed is based on the fuzzy logic theory. It is an extension of classical logic which allows the modeling of data imperfections and gets closer to some extent to the flexibility of human reasoning.

In fuzzy logic is a form of many valued logic in which the truth value of variables may be any real number between 0 and 1 both inclusive. It is employed to handle the partial truth value many ranges between completely true and completely false. Fuzzy logic is based on the observation that people make decisions based on imprecise and non-numerical information. « Fuzzy models or sets are mathematical means of representing vagueness and imprecise information» [6].

This system is based on four fundamental steps: fuzzification, rule base, inference engine and defuzzification. This system is illustrated in the following diagram

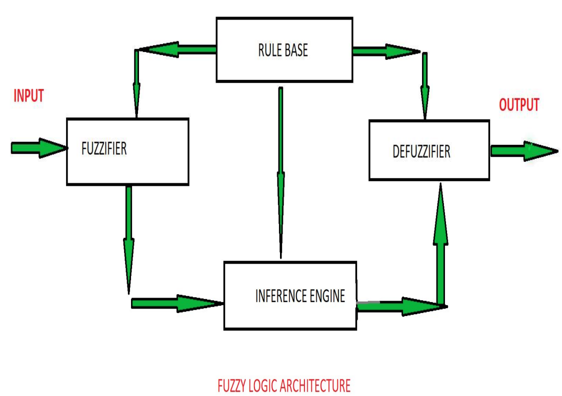

Figure 4. The Fuzzy Logic Architecture [7].

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3.1 Fuzzification

This step consists in converting the defined input sets into a fuzzy set by using fuzzy linguistic variables. All this with the help of membership functions by choosing different shapes associated with each function namely: (triangular, rectangular ...), the curves are present in a universe of discourse in the form of an interval and an ordered y whose values vary from 0 to 1, shows the degree of membership, by allocating to each interval a subset.

In our case, we choose the triangular form to express the membership function of our output, delivery time with three subsets (small, medium and large), illustrated in Figure: Delivery time

The other parameters are modeled in the same way. Traffic density, road infrastructure quality and Distance have appropriate linguistic values. These are represented in the diagrams below

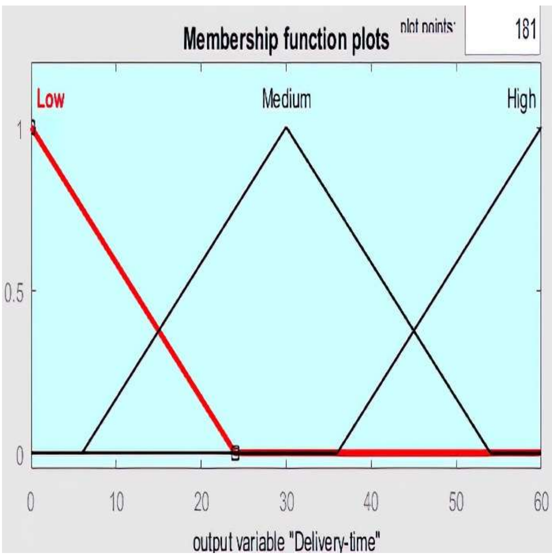

Figure 5. Delivery Time Membership Function.

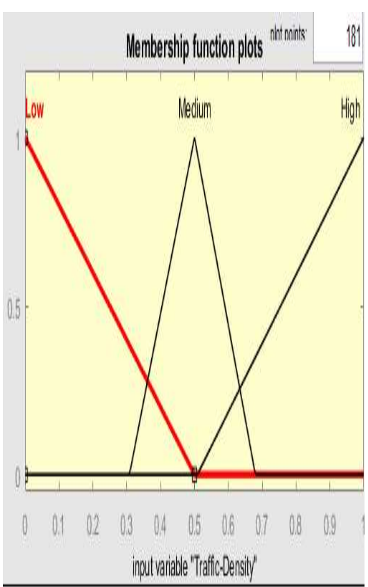

Figure 6. Delivery Time Membership Function.

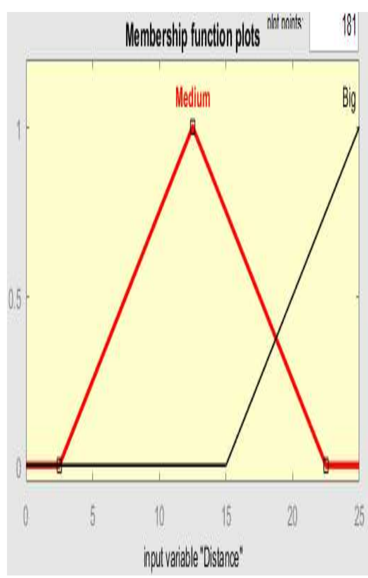

Figure 7. Distance Membership Function.

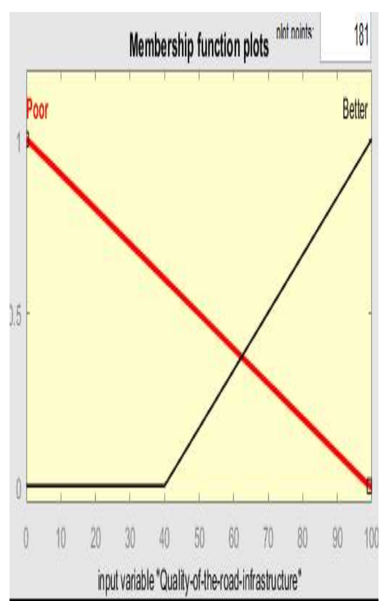

Figure 8. Quality Of The Road Infrastructure Membership Function.

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For example, the traffic density can be minimum, average or maximum as in the figure.
In this study, the membership functions chosen are developed by experts. For example, on the figure "density" three subsets: maximum, average, maximum is displayed
For each value along the "x-axis" universe of discourse, we obtain the corresponding degree of membership in the y-axis. Specifically, as we see a value of the x-axis can take several sets. In the figure "density", the value 0.4 of traffic density can take both as "minimum and average" at the same time, with degrees of membership, at 0.24 and 0.41 respectively.

3.2 Rules base

It gathers the set of IF-THEN rules and conditions established by the experts to manage the decision system, based on linguistic information. Modern developments in fuzzy theory have allowed the development of several efficient methods for designing and tuning fuzzy controllers. Most of these developments minimize the number of fuzzy rules.
So, a delivery time estimation model requires a set of rules, these rules in the form of a condition and an "if...then" conclusion
Example: if traffic density is minimal, mileage is small, and the quality of road infrastructure is poor, then delivery time is small.
If (premise) conjunction (premise) implication (conclusion).
These rules are developed by domain experts in the same way.

3.3. Fuzzy inference.

It determines how well the current fuzzy input matches each rule and decides which rules to trigger based on the input field. Then the triggered rules are combined to form the control actions. [7]. «There are two main types of fuzzy inference systems that can be implemented: the Mamdani type (1977) and the Sugeno-tupe type (1985). These two types of inference systems vary somewhat in the way the outputs are determined. » [8].

3.4 Defuzzification.

The procedure on which the fuzzy values are minimized into numerical values. There are several forms of defuzzification, including the center of gravity, means of maximum (MOM), and mean of centers.

3.5. Estimated delivery time modeling.

The delivery time in the urban area is calculated after the study of the parameters and the implementation of the suggestions regarding the entrance parameters, construction of the infrastructure, traffic regulation with the installation of cameras. To know more precisely the primary factors to be studied again. On the other hand, the knowledge of the urban area in all sides (population, vehicle, road condition ...), will help us to classify the most important to the simplest to regulate.
In this research, we will present a method for estimating the delivery time at the urban level based on fuzzy logic. We will use the linguistic variables Maximum and Average to describe the traffic density that can be acted as an output that is characterized by criteria to be studied namely the motorization rate and the period of the vehicle movement, moreover, all these criteria can influence the delivery time with a different degree.
In this case, the estimation of the duration has an intense impact for the entrepreneurs in terms of time and cost.

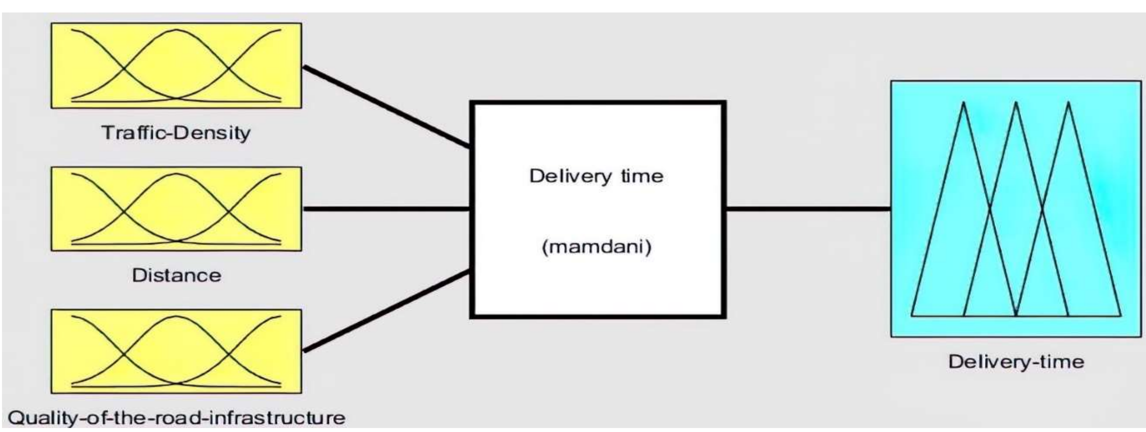

Figure 9. Fuzzy Relation For Delivery Time Output.

3.7. Overview of our system.

Previously, we have modeled the input parameters, by allocating to each input a membership function characterized by linguistic variables, fuzzy rules are represented in the figure 10.

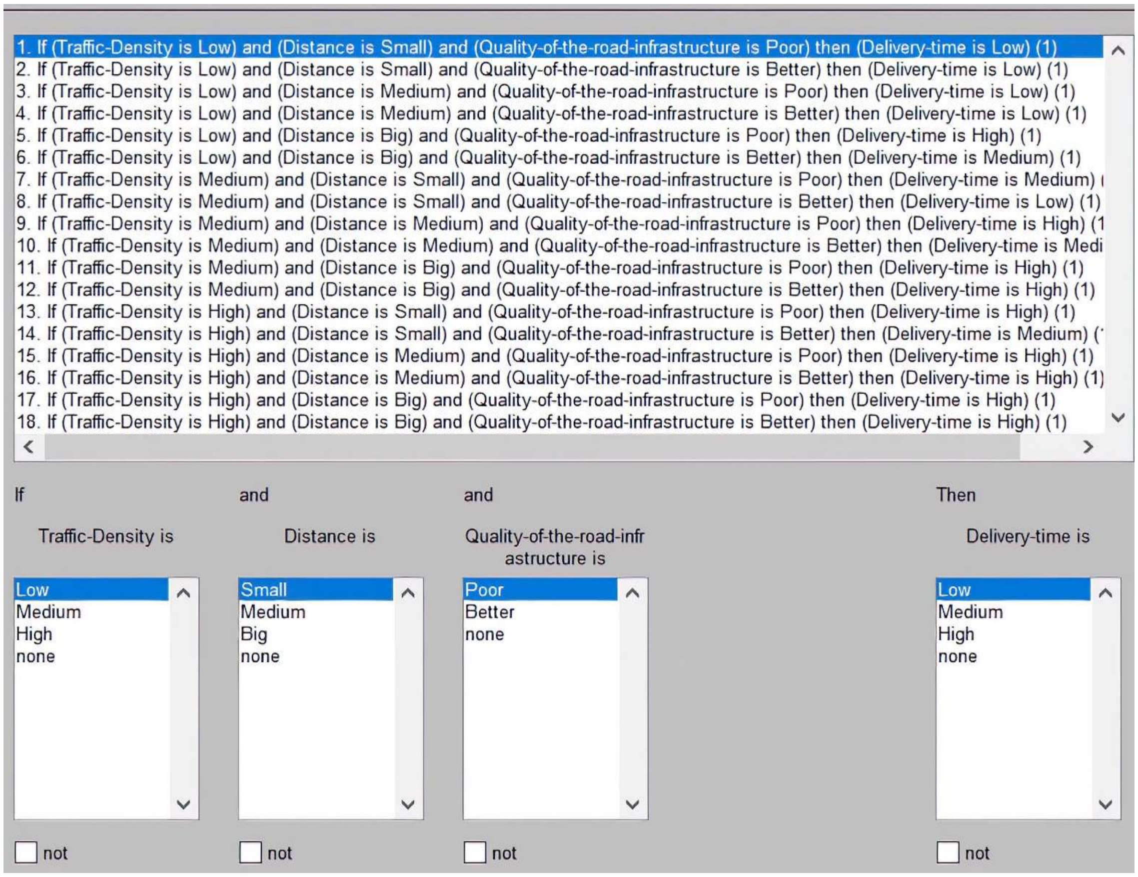

Figure 10: Rules View.

4. . DISCUSSION.

4.1. Result and interpretation.

After establishing our system, we can interpret and analyze the results.
The analysis of the graphs will help to understand the coherence between the three parameters that we have modeled. To do this, we will analyze the surfaces, working only with two inputs, we set the third on a constant value, and o, visualize the result of the output on the axis of order.

Case N 1 :(x, y, Medium)
In this case Quality of the road infrastructure is fixed on medium which means 0.5
X: Traffic density.
Y: Distance.

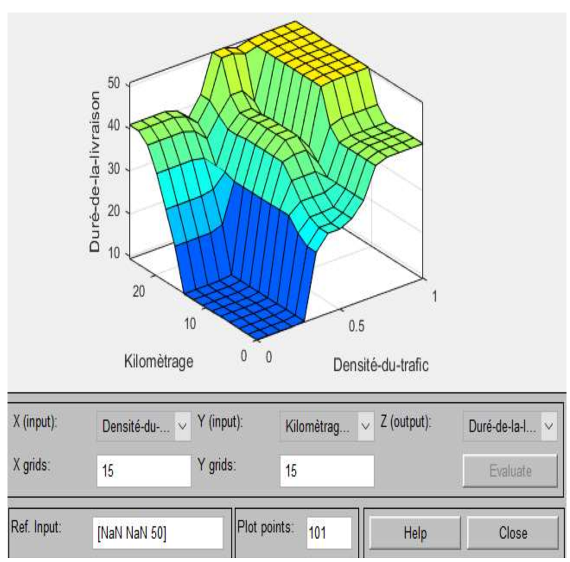

Figure11: Surface For Case N° 1.

The surface shows that the delivery time is small when the traffic density is low and the mileage is high or medium. It is medium when the density is medium regardless of the mileage or when the density is low and the mileage is high. Similarly, the duration will be high when the traffic density is high and the Distance is medium or high.

Cas N 2 :(x, Medium, z)

In this case the distance is fixed on medium which means 0.5

X: Traffic density

Z: Quality of the road infrastructure indicator

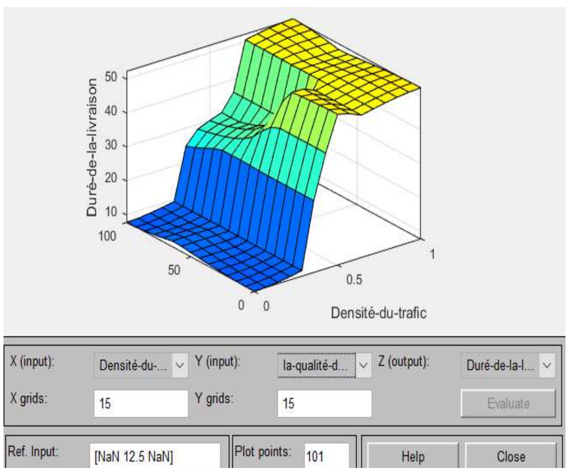

Figure 12: Surface For Case N°2.

The displayed area shows that the delivery time is small when the traffic density is low regardless of the road infrastructure quality index. It is medium when the density is medium and the infrastructure quality is better. It is large when the density is high or medium and the quality of the infrastructure is poor. The result obtained are not found in the binary logic, where the delivery time will be small if and only if all the input parameters are in good condition hence the advantage of fuzzy logic.

This simulation is a direct projection to the decision rules set up by the experts, hence the usefulness of modifying these rules when necessary via rule recovery and the allocation of appropriate membership functions to each input variable.

4.2. Results simulation

The figure below, shows a simulation model of the duration of the delivery by the software of "MATLAB SIMULINK", the originality in this Simulink, it is that it is enough to type the values of entry and the software itself gives you the duration of the estimated delivery. By associating two inputs to the traffic density, namely the motorization rate and the traffic period. For example, for the case of the motorization rate is 0.5 and the time is 12:00, the distance is 12.5km and the quality of the infrastructure is 50% then the delivery time will be 19.6min.

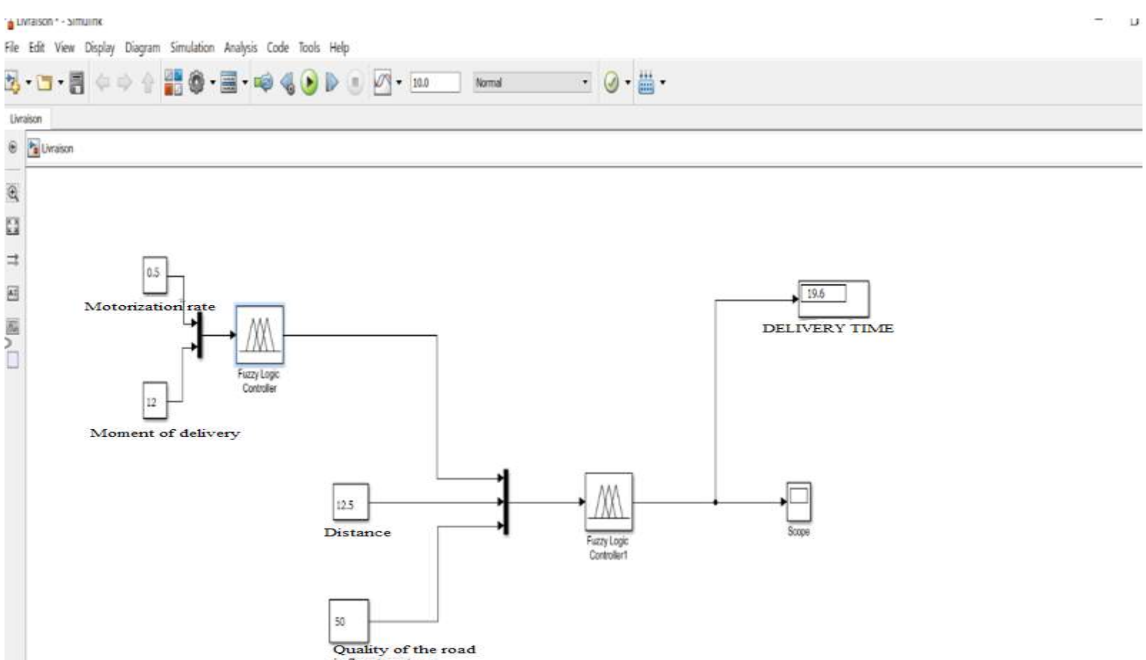

Figure 13: Simulink.

4 .3. Evaluation of the presented model.

To evaluate our model, we took 10 real examples for a company in the delivery shown in the table. We compared the duration estimated by our model with that in reality. The results obtained are closer. Indeed, for the customer n7, the departure time of the delivery man was at 21h00, the motorization rate of the region was 0,331, the separating distance between the departure and the arrival point was 6 km and the quality of the road infrastructure associated with the delivery route was 79%. So, the time obtained by our model was 21 min and the real time was 9 min. This gives a relative error value of 6.25, which is acceptable and reflects the degree of accuracy of our decision support model. By updating and correcting the decision rules established by the experts. We can decrease the error for more accuracy.

Table 1: Historical Data Input For 10 Urban Delivery Example

Customer N.	**Period**	**Motorization rate**	**Distance**	**Quality of the Road infrastructure**
1	14h30	0,459	15	65 %
2	11h15	0,501	10,3	79 %
3	16h10	0,389	20	71 %
4	10h03	0,450	25	69 %
5	15h10	0,553	9,8	70 %
6	07h00	0,302	8,4	71 %
7	21h00	0,331	6	79 %
8	13h35	0,583	9,2	65 %
9	07h10	0,457	10	80 %
10	02h45	0,7	13	81 %

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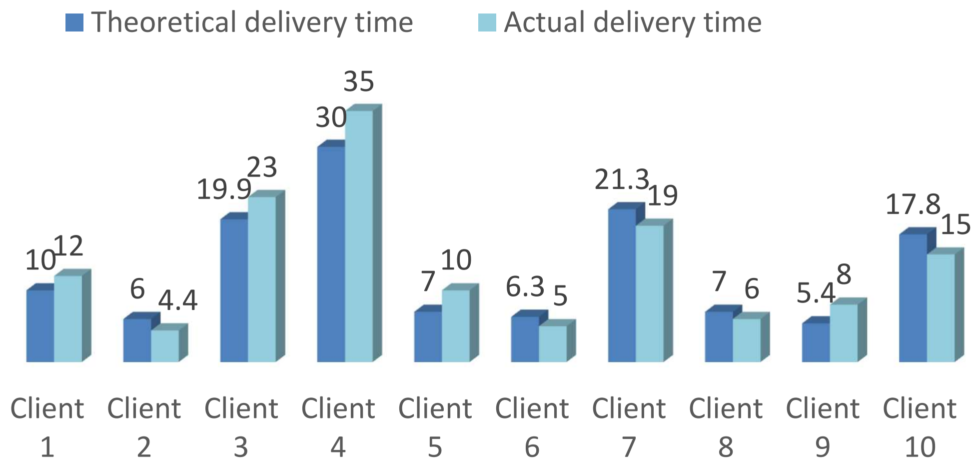

Figure 14: Theorical And Actual Delivery Time In Minutes.

The figure above compares the actual delivery times with those obtained with our proposed approach.
In order to evaluate the quality of the forecast it is essential to introduce the calculation of the relative error which represents a tool to evaluate our forecasting model. Its formula is the following:

$$\textbf{relative error} = \left| \frac{\textbf{experimental value} - \textbf{theoretical value}}{\textbf{theoretical value}} \right|$$

deed, the closer the error index is to 0, the more accurate our model is.
So, for the case N°4, the relative error= | (30-35)/35|= 0.14
This difference in values between the results obtained reflects the impact of the non-returned parameters in our model because there are other unpredictable parameters that are not considered, related to the different scenarios, such as the behavior of the delivery drivers in an aggregated way for each delivery zone.

5. CONCLUSION

The results obtained represent approximate values with respect to reality, since there are other unpredictable parameters that are not considered, related to the different scenarios, such as the behavior of delivery drivers in an aggregated way for each delivery area, for example the radius of influence of a delivery area. But further modeling of the behavior of the actors (double parking, police enforcement, driver attitudes, etc.) would be a significant contribution to the representation of reality.

To conclude, understanding the transportation of goods in the city is a difficult task, hence the importance of implementing a scientific artificial intelligence model based on fuzzy logic theory that allows the company to model and automatically predict the delivery time in the urban area. The originality of this model is that the company will develop its own unique model according to the influence criterion. Thus, the establishment of rules adapted according to the experience of experts. All this to optimize the delivery time. In future work, we propose to determine other major factors and to choose membership functions for the studied criterion.

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