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APPLICATION OF FUZZY LOGIC IN ESTIMATION OF CARBON MONOXIDE OF URBAN TRANSPORT IN THE CITY OF KENITRA, MOROCCO

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ABSTRACT

Decreasing carbon monoxide (CO) emissions has become an overarching concern for transportation policy and planning throughout the world. This article presents a fuzzy logic based approach for urban transport sustainability. We address the issue of reducing CO emissions by varying other factors related to urban transport. Fuzzy logic modeling is developed using three input variables including speed, fuel consumption, and number of bus stops for the case of the city of Kenitra. The fuzzy controllers Mamdani and Sugeno were used to develop this model. The results of this study provide a decision-support model for help local authorities to reduce CO emissions by varying the other factors related to urban transport.
Keywords: *Fuzzy Logic, CO Emission, Urban Transport, Speed, Fuel Consumption, Number Of Bus Stops, Kenitra*

1. INTRODUCTION

Without a doubt, it is necessary to tackle the problems of urban air quality in cities to improve health and improve the well-being of people. The air is the first of the elements necessary for life and the man breathes daily 14000 liters. Air is composed of gases (78% nitrogen, 21% oxygen and 1% other gases) and particles. Clean air is very important and is considered by the United Nations as one of the goals of sustainable development [2]. Air pollution is a dangerous environmental problem that requires attention and action. The World Health Organization's cancer control agency, in its project "Health Risks Associated with Air Pollution in Europe," officially classified air pollution as a carcinogen for man [3]. This air pollution is caused by atmospheric pollutants namely ozone (O3), particulates, carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2) and volatile organic compounds. They are emitted into the atmosphere as gases or particles (PM) from different sources. The main activities that create pollutants are:

- ✓ industrial emissions [4]
- ✓ emissions from shipping
- ✓ Domestic heating
- ✓ thermal power stations
- ✓ road traffic

Road traffic is the champion of the causes of air pollution especially in the cities. Around the world the cities have experienced a sustained population, resulting in increasing urbanization. Urbanization is the gradual increase in the proportion of people living in urban areas and how societies adapt to change. This is the process by which cities and agglomerations are formed. Cities are growing because more and more people are starting to live and work there. As a result, urbanization leads to high levels of air pollutants in urban areas as the demand for mobility is very high.

The city of Kenitra has tremendously mushroomed in recent years, from 292,457 in 1994 to almost 450,000, today. Therefore, the city has considerably expanded. It is now facing major urban problems while the rate of motorization continues to increase (80 cars per capital in 2016 versus only 70 cars in 2014), which causes serious ecological problems, and hence it severely affects our eco-system. In contrast to industrial discharges from stationary sources, road pollution is the accumulation of millions of mobile sources, which makes it difficult to study, let alone to analyze. In fact, the problems of pollution and congestion urge the need to make change within the management of the city and why not come up with new workable and long-lived solutions in order to reduce gaseous emissions to the threshold in agreement with the regulations in force, as well as to meet the global requirements for the protection of the environment [5]. Hence, the use of efficient and reliable estimation methods is crucial.

In this article, we will explore a new way and to build an expert system that is primarily based on fuzzy logic. Such system is a robust tool, capable of working with uncertain or inaccurate data and allowing the aggregation of disparate input disparate in a uniform way. The expert system, we describe here, is the reflection of an expert perception of the emission estimates of atmospheric pollutants. In this study, we will thoroughly treat a single atmospheric pollutant, namely carbon monoxide (CO). The objective of the current study is to investigate and figure out how fuzzy regulation can estimate CO emissions by taking into account several factors; including speed, fuel consumption and number of bus stops in the city of Kenitra. The following questions will help establish a thorough understanding among the following factors: What is the influence of each of these factors on the reduction of CO emissions? And how can local authorities use the results obtained by the simulations so as to meet the requirements of the standards in force?

2. METHODOLOGIE

The purpose of this work is to give an answer to originals questions (see introduction). We adopted the IMRAD methodology, especially in the "Outcome" section. This study begins with the presentation of the main methods used to estimate gaseous fumes of urban transport while highlighting their weak points. Furthermore, the main concepts of fuzzy logic are presented. Subsequently, a collection of data on the input and output variables is gathered. The variables are therefore determined according to the purpose of the study, and calls for engineering expertise and know-how [6]. The input variables are: the speed, the number of bus stops and the fuel consumption of urban transport vehicles. The output variable is the CO emission. These data are modeled with the membership functions. The linguistic values of each variable are low, medium and high. Decisions are made by fuzzy inference using decision rules. The result is a graphical profile of CO emissions. The resulting curves and graphs change characteristics by changing input elements. Simulation examples are presented to show how easy to use this methodology and how interesting it is to model the knowledge and make the decision process automatic. The local authorities of the city of Kenitra can, then, and according to the objectives of the study, define an optimal solution to minimize CO emissions. The objective is to provide a fuzzy logic based technique for estimating CO emissions in the urban environment. This model emanates from the collection of data on input and output variables. The input variables are: the speed, the number of bus stops and the fuel consumption of public urban transport vehicles. Finally, in the "Discussion" section, the merits and demerits of the proposed solution are presented. As for the "Conclusion" section the new perspective will be dealt with in depth in the subsequent article.

3. RESULTS

3.1 Notion and sources of air pollutants

3.1.1 Notion of air pollutants

Air pollution is caused by air pollutants. The origin of these pollutants is either of anthropogenic origin (produced by human activities) or of natural origin (emissions by vegetation, soil erosion, volcanoes, oceans, etc.). All sectors of human activity are likely to emit atmospheric pollutants: industrial activities, transport (road and non-road), domestic activities (heating in particular), agriculture, and forestry. They are emitted into the atmosphere as gases or particulates (PM) from different sources, then transported and / or processed in this compartment and then removed by means of dry or wet deposition (aerosols) (incorporated in the rain or the clouds). Air pollution manifests itself in the form of a thick suffocating fog called smoke [7]. Smoke is a mixture of air pollutants composed of ozone, particulates, carbon monoxide, nitrogen oxides and volatile organic compounds. It is a yellow-brown fog that is present in large cities, but there are also high concentrations of smoke in the periphery and in the countryside, mainly because of the wind. Smoke irritates the eyes, the respiratory and cardiovascular routes aggravates heart and lung diseases, as asthma damages the mucous membranes of the lungs increases the risk of lung cancer and premature death. Seniors, children, asthmatics, people with lung diseases and heart problems, smokers, and people who exercise outdoors are even more sensitive to toxic gases forming the smoke [8].

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3.1.2 Sources of air pollutants

Sources of air pollutants can be anthropogenic (heating with wood, fuel oil, vehicular or industrial emissions, burning of green waste, cooking activities ...) or natural (plants, crustal dust). Pollutants observed in the atmosphere are not all emitted directly from these sources. They also result from physico-chemical reactions between chemical components (primary pollutants and other constituents of the atmosphere) governed by weather conditions. Table X shows the emission sources of the main air pollutants.

Table 1: Sources of air polluants [9]

Pollutants	Emission Sources
Nitrogen dioxide (NO_2)	NO_2 comes mainly from the combustion of fuels and as well as from incineration plants.
Ozone (O_3)	There are no sources of emission: ozone (O_3) is a secondary pollutant that is formed at low altitude by chemical reactions produced under the effect of sunlight, from atmospheric pollutants - said precursors - such as nitrogen oxides (NO_X) and volatile organic compounds (VOCs).
Sulphur dioxide (SO_2)	SO_2 comes mainly from the combustion of fuels and fuels containing sulfur (fuel oil, diesel, coal, etc.). Sulfur impurities in fossil fuels are oxidized by oxygen in the air (O_2) to sulfur dioxide (SO_2).
Carbon monoxide (CO)	CO is formed during the incomplete combustion of fuels. Traffic is responsible for most of the carbon monoxide emissions followed by industrial and domestic heating.
Primary Particles (PM)	The largest anthropogenic sources of particulate emissions are road transport, energy production, agriculture, industrial combustion, non-road transportation, residential heating and industrial processes.

3.2 Literature Review

To carry out our study, we first present the different methods, listed below, used by other authors to estimate CO emissions. In recent years, a number of research studies on CO emission estimation have been conducted.

3.2.1 Spot measurement of emissions (Estimates of air pollutants using point stations)

Measuring stations can be stationary. They are located in 2m x 3m x 4m cabins, or in rooms (schools and hospitals) where equipment monitoring is possible. They can also be mounted on a truck and be mobile. They allow pollution level to be monitored at the local level, and cannot directly provide a map of the concentration of pollutants. Each measuring station has multiple sensors based on various physical principles and for measuring the concentration of a particular pollutant [10]. The measurement principles used involve a sample of air, its introduction into an analysis chamber, frequent and careful recalibrations. The costs of installation, maintenance and management [11] of this device are significant and limit the number of measuring stations installed.

3.2.2 Mobile source emission inventory model

The originality of the Mobile source emission inventory model [12] ~~is~~ emanates from its ability to handle road-scale measurements, as well as to provide more global information on transport flows that are usually extracted from statistical data on road transport population representative of larger areas. The model uses specific exhaust emission factors based on actual driving patterns and a representative fleet of vehicles. Such a model offers a refined and can be applied to perform sensitivity tests and vehicle evolution impact studies.

3.2.3 Multisensors method

A sensor is a device that transforms the state of an observed physical or chemical quantity

[13] (measurand m) into a usable quantity (signal s, most often electrical), such that s = F (m). The transformation F is done by means of a test body sensitive to the measurand, also called sensitive element, and which ensures a first translation into another nonelectric physical quantity (secondary measurand). Thanks to a transducer, the secondary measurand is, then, transformed into an electrical quantity [14]. We speak of a gas sensor [15] when at least one of its physical properties changes when it is subjected a change of gaseous environment. There are several families of gas sensors that are distinguished by the type of sensitive layer and the principle of transduction.

3.2.4 The Infrared Atmospheric Sounding Interferometer (IASI)

The Infrared Atmospheric Sounding Interferometer (IASI) [16] is a cutting-edge Michelson spectrometer developed by the "Centre National d'Etudes Spatiales (CNES)" in cooperation with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The first flight model was launched in 2006 in orbit on the METOP-A satellite (2006) and the Fourier TANSO transform spectrometer on the GOSAT satellite (2009). Therefore, the IASI was designed to improve meteorological forecasting (reconstruction of high-precision temperature and water vapor profiles) and to estimate and monitor global trace gases, such as ozone, methane or carbon monoxide. The measurement technique is based on passive infrared remote sensing using a Fourier transform spectrometer calibrated accurately and working in the spectral range from 3.7 to 15.5 µm [17].

3.2.5 Discussion of methods

Although the estimates of CO emissions using point measuring stations are reliable and accurate, they suffer from some pitfalls. They lack mobility because measurements are always made at the same geographical point. This makes dynamic measurements and / or meshing of a site difficult. On the other hand, the cost of installation and operation is very high. The mobile source emission inventory model also requires a lot of data on traffic density and speed for accurate emissions calculations. However, we cannot rely on the methods mentioned above for the following reasons:

- ✓ Lack of data-specific to our case where previous data collection is not possible. As well as the latter may include uncertainties [18]
- ✓ Available [19]

Therefore, fuzzy logic makes it possible to reason not on numerical variables, but on linguistic ones, that is to say, on qualitative variables (large, small, medium, far, close, strong, etc.). Reasoning on these linguistic variables will make it possible to use the knowledge in a natural language setting. Hence, the choice of the application of fuzzy logic is used.

3.2 Fuzzy logic

The blurred global term first appeared in 1965 when Professor Lotfi A. Zadeh of the University of Berkeley in the United States published an article entitled "Fuzzy Sets". He made many major theoretical advances in the field and was quickly accompanied by many researchers developing theoretical work. At the same time, some researchers have focused on the fuzzy resolution of problems considered difficult. The application of fuzzy logic in several fields first appeared in Japan, where the research is not only theoretical but also highly applicative. The fuzzy logic then knows its true growth. In the late 1980s, it's a real boom. From 1990, it is in Germany that applications appear in large numbers and to a lesser extent in the United States. Finally around the world, fuzzy logic is becoming a reality today.

3.2.1 Fuzzy logic concepts

Fuzzification is intended to transform a digital datum into a linguistic variable. Fuzzy logic systems use approximate data and "language rules" to arrive at human-like decisions [20]. With these linguistic rules, expert opinions can be integrated into the fuzzy logic system [21]. The fuzzifier, fuzzy inference engine, fuzzy rules, and defuzzifier make up the fuzzy logic inference system [22].

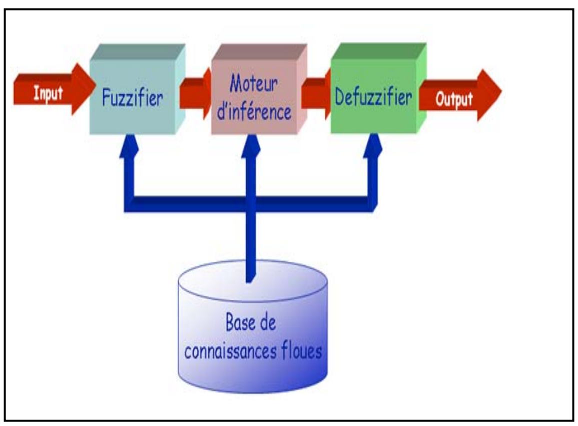

Figure 1: Main parts of a fuzzy system [23]

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3.2.2 Fuzzification

Numeric input values are converted from the fuzzifier into linguistic variables. Linguistic variables, therefore, take values of words or sentences in relation to numerical values [24]. For each variable, several language sets can be defined. Input variables may belong in part to more than one linguistic group. The membership of any input variable to a certain linguistic set is defined as the degree of membership of that set and can take any value in the range [0,1] [25].

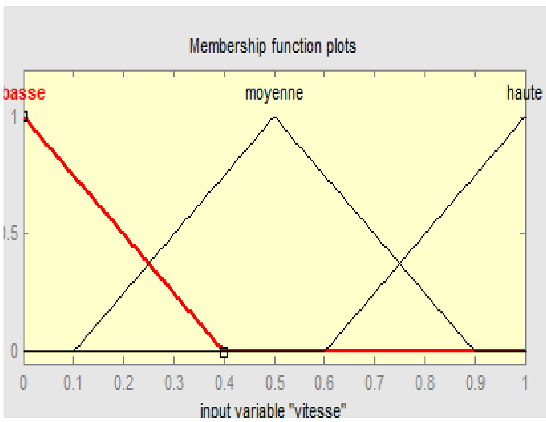
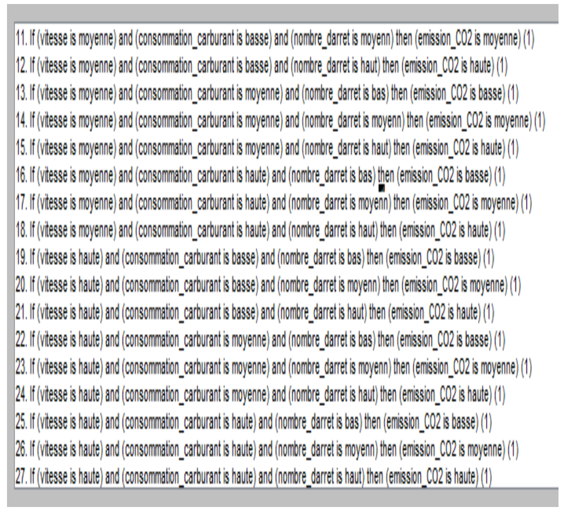


Figure 2: Example of Membership function

3.2.3 Inference engine

In this part, the first thing to do is to list all the rules that we know to apply to the system. These rules must be in the form If condition, then a conclusion [26]. For example, IF the speed is high AND the fuel consumption is low, AND the number of stops is medium while the CO emission is medium, then it is a valid inference rule. The choice of the operators is entirely up to the designer of the fuzzy system, which can even decide to create its own operators that will replace the logical operators by respecting certain algebraic properties (see figure 3). Once we have drawn up a list of rules of inference that we have chosen and the logical operators that we wanted to use, it is sufficient to apply each rule to the linguistic variables calculated in the fuzzification stage. The results of these rules can go directly to the final stage of defuzzification. The set of rules of a fuzzy system is called the decision matrix.



11. If (vitesse is moyenne) and (consommation_carburant is basse) and (nombre_darret is moyenn) then (emission_CO2 is moyenne) (1)
12. If (vitesse is moyenne) and (consommation_carburant is basse) and (nombre_darret is haut) then (emission_CO2 is haute) (1)
13. If (vitesse is moyenne) and (consommation_carburant is moyenne) and (nombre_darret is bas) then (emission_CO2 is basse) (1)
14. If (vitesse is moyenne) and (consommation_carburant is moyenne) and (nombre_darret is moyenn) then (emission_CO2 is moyenne) (1)
15. If (vitesse is moyenne) and (consommation_carburant is moyenne) and (nombre_darret is haut) then (emission_CO2 is haute) (1)
16. If (vitesse is moyenne) and (consommation_carburant is haute) and (nombre_darret is bas) then (emission_CO2 is basse) (1)
17. If (vitesse is moyenne) and (consommation_carburant is haute) and (nombre_darret is moyenn) then (emission_CO2 is moyenne) (1)
18. If (vitesse is moyenne) and (consommation_carburant is haute) and (nombre_darret is haut) then (emission_CO2 is haute) (1)
19. If (vitesse is haute) and (consommation_carburant is basse) and (nombre_darret is bas) then (emission_CO2 is basse) (1)
20. If (vitesse is haute) and (consommation_carburant is basse) and (nombre_darret is moyenn) then (emission_CO2 is moyenne) (1)
21. If (vitesse is haute) and (consommation_carburant is basse) and (nombre_darret is haut) then (emission_CO2 is haute) (1)
22. If (vitesse is haute) and (consommation_carburant is moyenne) and (nombre_darret is bas) then (emission_CO2 is basse) (1)
23. If (vitesse is haute) and (consommation_carburant is moyenne) and (nombre_darret is moyenn) then (emission_CO2 is moyenne) (1)
24. If (vitesse is haute) and (consommation_carburant is moyenne) and (nombre_darret is haut) then (emission_CO2 is haute) (1)
25. If (vitesse is haute) and (consommation_carburant is haute) and (nombre_darret is bas) then (emission_CO2 is basse) (1)
26. If (vitesse is haute) and (consommation_carburant is haute) and (nombre_darret is moyenn) then (emission_CO2 is moyenne) (1)
27. If (vitesse is haute) and (consommation_carburant is haute) and (nombre_darret is haut) then (emission_CO2 is haute) (1)

Figure 3: List of rules

3.2.4 Defuzzification

Defuzzification is the last step [27]. It allows having a fuzzy operational system. In this model, we generated a set of commands in the form of linguistic variables (one command per rule). The purpose of defuzzification is to merge these commands and transform the resulting parameters into numerical data. The defuzzification stage takes place in two stages: First, it is necessary to merge the common linguistic variables using a fuzzy logic operator chosen by the system designer. If we have several inference rules that generate several values of the same linguistic variable, we can choose an operator to combine the values of the variable. In the next step, we can begin the delicate part of defuzzification. Therefore, we have developed a series of linguistic variables that characterize the same data. For example, we can have three linguistic variables: high speed at 35%, medium speed at 80% and low speed at 10%, which qualifies the speed. These linguistic variables each have a membership function. Defuzzifying the speed data, therefore, amounts to finding the best quantitative value according to the membership functions of the linguistic variables. There are several methods to defuzzify. Among the most used, we can mention the method of the center of gravity. It consists of taking the abscissa corresponding to the center of gravity of the membership function [28]. This approach has its origin in the idea to select a value u' [29] that, on average, would lead to the smallest error in the sense of a criterion. If u' is chosen, and the best value is u, then the error is u'-u. Thus, to determine u' the least squares method can be used. As weights for each square (u'-u), one can take the grade of

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membership uB'(u) with which u is a reasonable value. As a result one has to find

$$\upsilon' = \arg\min_{\upsilon'} \int_U \upsilon B'(\upsilon)(\upsilon' - \upsilon)^2 d\upsilon \quad (1)$$

Differentiating with respect to the unknown and equating the derivative to zero, the formula

$$\upsilon' = \frac{\mu B' \int_U \upsilon \mu B'(\upsilon) d\upsilon}{\int_U \mu B'(\upsilon) d\upsilon} \quad (2)$$

is obtained, which determines the value of the abscissa of the centre of gravity of the area below the membership function υB'(υ).

3.4 Case study

The city of Kenitra is considered one of the important cities in northwestern Morocco. It is located on the left bank of Oued Sebou, 12 km from its mouth on the Atlantic Ocean. It is a recent city whose creation dates back only 120 years. It occupies a privileged and strategic geographical position at the crossroads of the most important roads, Tangier-Tetouan in the North, Fez-Meknes in the East and Rabat-Casablanca in the South.

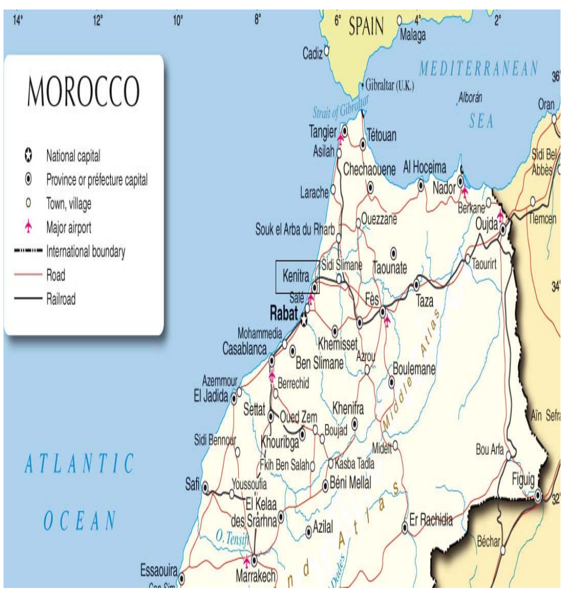

Figure 4: The geograhic location of Kénitra [30]

The city of Kenitra has known sustained population and urban growth with a population of 431.282 [31] (2014 RGPU General Population and Planning Census). Increasing urbanization places high demands on infrastructure, such as transportation. This causes the increase of different pollutants (CO, NO, NO2, O3 and PM10) in the atmosphere [32]. The city of Kenitra increasingly demands smart solutions in sustainable urban transportation planning. The purpose of this study is to use artificial intelligence techniques [32] in estimating CO emissions. Vehicle CO emissions generally depend on speed, fuel consumption and number of stops. The traditional methods of estimating these emissions have significant limitations because the input variables need to be accurately measured, which requires a lot of time and resources. Fuzzy logic provides the opportunity to exploit human knowledge that is often guided by approximations by accepting input values and using linguistic terms.

3.4.1 Data collection

Fuzzy logic modeling is developed using three input variables including speed, fuel consumption, and numbers of stops of urban transport in the city of Kenitra. The only output variable of the fuzzy model is the CO emission. All input and output variables are divided into three fuzzy subsets. The forms and ranges of the membership functions of the variables are illustrated in Figure 3.

3.4.1.1 Subset Speed

The speed in the urban environment in Morocco does not exceed 60 km / h. We choose for the subsets:

- ✓ Low speed: 20 km /h
- ✓ Medium speed: 30 km /h
- ✓ High speed: 60 km/h

3.4.1.2 Subset fuel consumption

The fuel consumption of an urban bus (70 passengers) depends on several factors that will vary the fuel consumption in a fairly wide range (+/- single to double). These (most important) factors are [33]:

- ✓ PTC of the vehicle which varies from 13.000 to 19.000 kg;
- ✓ Power / displacement / engine technology / manufacturer (brand);
- ✓ Effectiveness of general maintenance; Equipped with air conditioning or not;
- ✓ Terrain relief on which the bus is traveling;
- ✓ Number of stops; - desired average speed;
- ✓ Driver training (very important);
- ✓ Type of tires installed;
- ✓ Operating mode of the cooling fan of the heat engine.

Consumption and according to the factors above can vary in an order of magnitude from 30 to 60 liters per 100 km. As an example, of fuel consumption for buses in Morocco, and given the state of buses observed in cities. The values quoted above must be exceeded:

- ✓ Low consumption: 40 l/100km
- ✓ Medium consumption: 55 l/100km
- ✓ High consumption: 70 l/100km

3.4.1.3 Subset number of bus stops

Kenitra is a medium-sized city with an area of 76 km^2.

Figure 5: Satellite map of Kenitra [34]

According to the scheme of the urban transport network of the contracting company of the market and the number of stop resulting from the light signal system, we chose:

- ✓ low bus stop number: 15
- ✓ medium bus stop number: 20
- ✓ High bus stop number: 30

3.4.4 Subset CO emission

To define the values of the subset of fuel consumption, European emission standards are considered as a barometer.

European emission standards are regulations of the European Union (EU), also known as EURO standards, Euro 0 to Euro 6 (Euro 0: the most polluting, Euro 6: the least polluting). This is a set of standards that apply to new vehicles; the aim is to reduce air pollution caused by road transport. CO2 emissions are not taken into account. Since 1970 these European regulations impose maximum emission limits for nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC) and particulates. Heavy goods vehicles are concerned, as are passenger cars, light commercial vehicles or 2 and 3-wheelers, but are given a specific timetable. Tables (X) show the demanding standards for emissions from HGVs, buses and coaches.

Table 2: Limit value in grams per kilowatt hour (g / kWh) of carbon monoxide (CO) [35]

Norm	Date of implementation	CO (g/kWh)
Euro 0	01-10-1990	11,2
Euro I	01-10-1993	4,9
Euro II	01-101996	4,0
Euro III	01-10-2001	2,1
Euro IV	01-10-2006	1,5
Euro V	01-10-2009	1,5
Euro VI	31-12-2013	1,5

In Morocco, the CO emissions are not regulated by law, hence we limit the choice of values of the subset of CO emissions between Euro 1 and Euro 3 [36].

- ✓ Low CO emission: 500 mg/km
- ✓ Medium CO emission: 800 mg/km
- ✓ High CO emission: 1000 mg/km

3.4.1.4 Membership function

The membership functions of the fuzzy subsets have the following linguistic terms: {Low, medium and High}.

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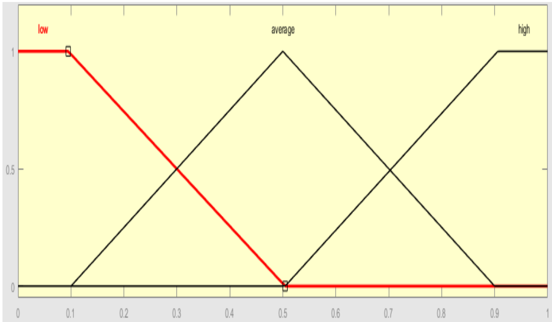

Figure 6: number of stops membership function

The other parameters are presented by the same method, using the same membership functions characterizing. The abscise axis represents speed, fuel consumption, number of stops and CO emission. The coordinates axis represent the degree of adhesion.

3.5 Discussions

The study of the graphs obtained after defuzzification generated important special cases that can be treated, given the estimate of the emission of CO according to input variables.

3.5.1 One indicator is fixed and tow are changed

The modeling of the various functions and parameters according to the principles of the fuzzy logic makes it possible to establish the graphs of the correlation of the variables studied, as well as their impact on the resulting parameter, namely: The CO EMISSION. The graphs that highlight this dependence and interaction between the variables chosen at the beginning of this study are shown in Figures (5, 6, and 7).

Example N°1

The indicator of fuel consumption is fixed in advance: Medium

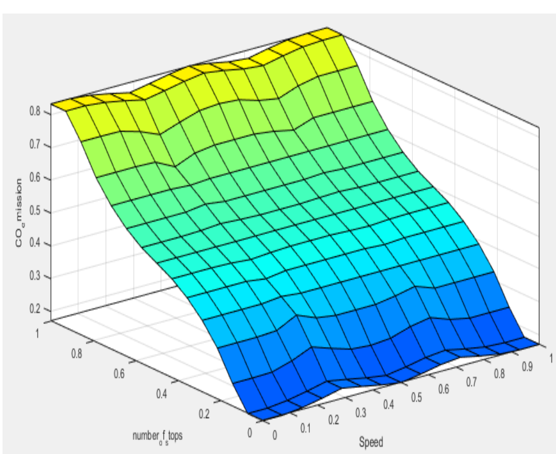

Figure 7: Surface viewers of example N°1

Discuss curve of the example N°1

The curve above shows that the emission of CO is zero when the two parameters (speed and number of stops) are zero. However, it is medium when both are average. This is important when both indicators are important. On this point, the CO emits the significant value possible.

Example N°2

The indicator of speed is fixed in advance: Medium

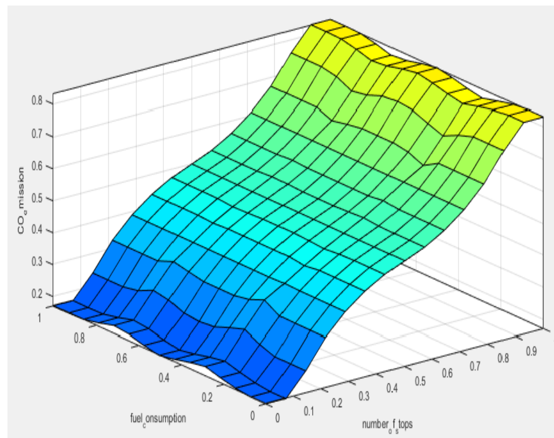
Figure 8: Surface viewers of example N°2

Discuss curve of the example N ° 2

The curve above shows that the emission of CO is zero when the two parameters (fuel consumption and number of stops) are zero. However, it is medium when both are medium. This is important when both indicators are important. On this point, the CO emits the significant value possible.

Example N°3

The indicator of number of stops is fixed in advance: Medium

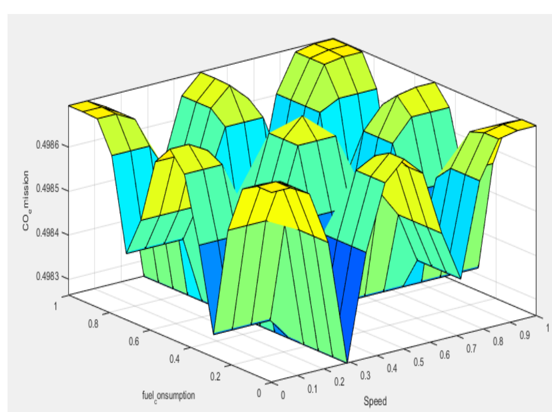

Figure 9: Surface viewers of example N°3

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The study of the curve above shows that the combination of the speed and the fuel consumption does not affect the rate of CO emissions.

3.5.2 Tow indicator are fixed and one is changed

In order to evaluate the relative importance of each input parameter on the output variable of the fuzzy model, a sensitivity analysis can be performed separately for each input variable so that an input parameter is varied; two other input variables are held constant and optional. The graph that highlights this dependence is shown in Figure 7. It is assumed that the value of CO emission depends only on an input variable that has been varied from 0 to 100%. This analysis reflects the operation of the system and gives, particularly an indication to the relative weight of the input variables vis-à-vis the value of CO emissions. However, the effect on the CO emission of the fluctuation of a variable over the range of its transition interval is highly dependent on the values of the other variables and the results presented here are only illustrations of the operation of the system.

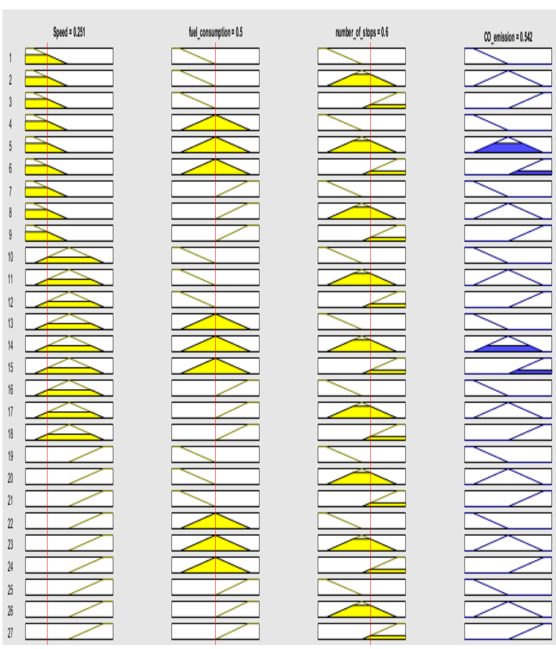

Figure 10: Rules viewers

In this study, several important special cases can be treated, given the possibility of contributing to the reduction of CO emissions by varying the influence factors mentioned above.

Example N°4: (Figure 11)

- ➢ The indicator of speed is fixed in advance can be described high.
- ➢ The indicator of fuel consumption is fixed in advance can be described low.

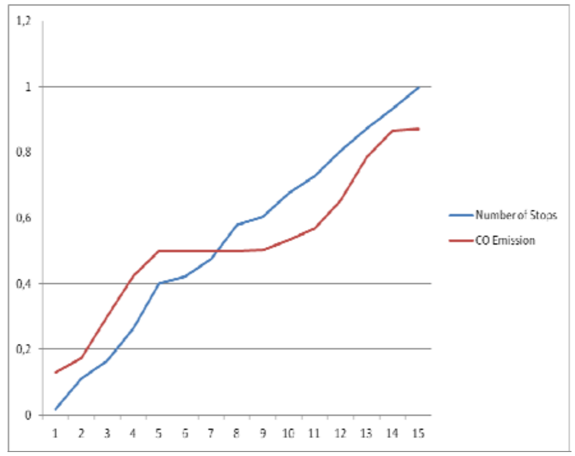

Figure 11: The curve of example N°3

CO emissions increase linearly with the number of stops.

Example N°5

- ✓ The indicator of speed is fixed in advance can be described high
- ✓ The indicator of fuel consumption is fixed in advance can be described low

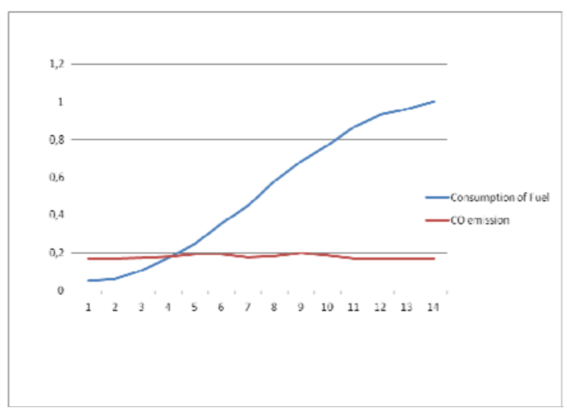

Figure 12: The curve of example N°4

One can see from the graph that the increase in the vehicle fuel consumption does not affect the rate of CO emissions.

The calculations in Examples 4 and 5 can be used to make decisions based on the values taken by one or more variables. It will be recalled that these results purely stem from the choices made at the different stages of the system's development:

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choice of input variables, definition of their transition intervals, and values given to the conclusions of the decision rules.

3.5.3 A different modeling of diagram in figure 7

The diagram in figure 7 has a different modeling. In this regard we can estimate the CO emission at less than 54% (Figure 7), if all the input functions are as follows:

- ✓ Speed: 25%
- ✓ Fuel consumption: 50%
- ✓ Number of stops: 60%

3.6 The difference from prior work

The construction of a system for estimating carbon monoxide (CO) emissions requires answering the following questions: what are the input variables to be taken into account and how to aggregate these variables? In this article, we have answered both, but its originality comes from the answer of the second question. If we compare our work methods with other methods, it brings about two new elements: on the one hand, the use of fuzzy sets, and on the other hand, that of decision rules. Fuzzy sets offer an elegant solution to the choice of limit values for input variables .For example, between high speed and average speed. With decision rules, we have an "intelligent" aggregation of input variables.

The estimation of carbon monoxide emissions, using fuzzy logic, has another advantage over the methods mentioned in 3.2, it makes it possible to reason not only on numerical variables, but also on linguistic ones, that is to say on qualitative variables (large, small, medium, far , close, strong, etc.). Table 3 shows a comparison between fuzzy logic and other methods of estimating CO emissions.

Table 3: Comparative table: Fuzzy logic and other methods for estimating CO emissions [37]

	Methods cited	Fuzzy Logic
Mobility	NO mobility	Independent of places
Dynamic measurements and / or mesh of a site	Difficult	Easy
	Methods cited	**Fuzzy Logic**
Installation costs	High	No
operating costs	High	No
Given on the input parameters	A great necessity	NO
Reasoning on numeric variables	Yes	Yes
Reasoning on linguistic variables	No	Yes

CONCLUSION

The effective management of today's cities relies on the use of artificial intelligence techniques. In this article, we presented the approach, using fuzzy logic techniques. We showed the results of the simulation in different cases. This will help local authorities solve urban transport management problems without resorting to expensive means. Extraction of the expertise of the operators and experts was solicited in order to conduct a reliable and representative study. Unfortunately, this technique has various disadvantages. The most conspicuous one is expressing our knowledge in the form of rules in natural language (Henceforth qualitative) does not make it possible to prove that the system will have an optimal behavior. This method is very useful only if one is confronted with systems that are not difficult to model, or if we have a good level of human expertise. Indeed, it is necessary to provide the fuzzy system with a rule base expressed in natural language to allow reasoning and drawing conclusions.

It should be known that the fuzzy logic allowed us to estimate the emission of CO. In a future study, a sample of the data X = (M1 ...... Mn) will be chosen to evaluate the air quality performance using Six Sigma.

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