

# Network Traffic Lights with Telemetry and Wireless Connectivity Perimeter

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**Abstract.** The following research document seeks to show an alternative to vehicle control systems using existing technologies to develop a system that is efficient and reliable. The creation and operation of a traffic light network will be presented, which will be located in an area where there is traffic congestion. The following network will reorganize, optimize, and measure the vehicular flow in real time. In some countries, intelligent traffic lights have been implemented, with which they have obtained satisfactory benefits by improving the vehicular flow of the places where these systems are located; for this reason we consider it necessary to use smart traffic lights in our country.

## 1 Introduction

Traffic congestion is a recurring phenomenon in larger cities. In Peru, Lima and Arequipa are the most affected, but also presented elsewhere. This problem affects both passengers and cargo of commercial products and their costs include the waste of hours worked, loss of time off, loss of business transactions, increased fuel costs, environmental pollution, deteriorating health, accident. All this adversely affects productivity and competitiveness.

There are an estimated 2,700 traffic accidents each year, 720 hours lost per person (1 month) 682 lost lives, lost 1million dollars congestion, pollution and 5.280millones lost 442 violations per year [1] as shown in the Table 1.

Vehicular traffic and congestion that this entails affect all citizens, not just those who move on foot, but also to those using a non-motorized means. Therefore, always it will be necessary to cross an avenue to reach the final destination. [2]

At present we have developed intelligent control systems for fully autonomous vehicular traffic, based on data collected by a set of sensors inductive, capacitive, magnetic and acoustic type, among others. Although still rare, because far only been implemented in Bodegraven-Reeuwijk, Netherlands and recently in Miami, USA [3].

**Table 1.** Important facts to consider.

Traffic accidents	2700
Missed hours per person	720
Lost lives	682
Dollars lost by pollution	5280000000
Dollars lost due to congestion	1 million
offenses	442

In the previous table we take the most important facts considered with respect to vehicular traffic in the city of Lima that is so chaotic at the moment, the considerations that we will manage to reduce to the minimum thanks to this novel project. The most important considerations in vehicular traffic, as we can see in the table above, are the hours lost in vehicular traffic during peak hours and the accidents caused by it.

### 1.1 What is the cause of traffic congestion?

The root cause of congestion is friction between vehicles in the existing traffic flow on the roads. However, at higher volumes, each additional vehicle hinders the movement of other vehicles passing, it means, begins the phenomenon of congestion. Then, a possible objective definition would be: "Congestion is the prevailing condition if the introduction of a vehicle in a traffic flow increases the circulation time of others".

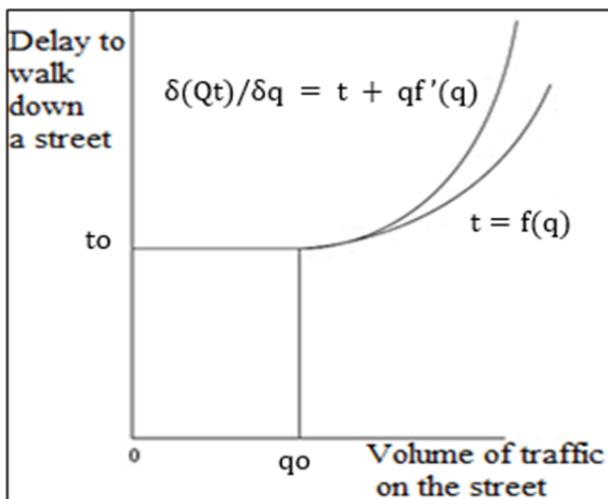
In relation with **Fig1**. As traffic increases in the track, are reduced increasingly strongly speeds of vehicles. Figure 1 shows, by function  $t=f(q)$ , the time required to travel along a street, to different traffic volumes ( $q$ ).

The other curve  $\delta(Qt)/\delta q = t + qf'(q)$ , is derived from the above. The difference between the two curves represents, for any volume of traffic ( $q$ ), increased travel time other vehicles that are circulating because of the introduction of additional vehicle.

It can be seen that the two curves coincide up traffic level  $q_0$ ; there, the change in travel time of all vehicles is simply the time spent by the incorporation. By otherwise, thereafter, the two functions diverge, being  $\delta(qt)/\delta q$  above  $t$ .

That means every vehicle entering experiences its own delay, but simultaneously increases the delay of all the others who are already circulating. Consequently, the individual user perceives only part of the congestion

caused, while the rest is in the other vehicles that are part of the flow of the time. In the specialized language is said that users perceive private costs, but social marginal costs. [4]



**Fig. 1.** Schematic representation of the concept of traffic congestion.  
 Source: Transport Unit of the United Nations Economic Commission for Latin America and the Caribbean (ECLAC).

### 1.2 Stress and public transport

Environmental psychology studies where the effects of vehicular traffic are on people, have found the following findings: In contexts of traffic jams, people significantly lose their ability to control situations and that creates uncertainty in people. On the other hand, the traffic noise affects the perception of the physical context, making the field of perception bilge, which favors the peripheral information is lost.

On the other hand, research has found that stress generated by exposure to vehicular traffic is associated with poor health status and major depressive symptoms, so it is considered to be related to the welfare of people living in areas urban.

Public transport in several Latin American countries has a number of shortcomings, because the system does not follow a strict regime nor is efficiently monitored by public authorities.

In that sense, there are vehicles poorly adapted, dirt, small spaces for passengers, high exposure to noise pollution and poor care of carriers, which show irresponsible and disrespectful behavior, often putting at risk the lives of passengers. These deficiencies lead to insecurity and discomfort in interacting agents within the transit system. That is why so public transport is recognized as an annoying situation that generates bad mood, despair, tardiness and nervousness, among other effects.

Studies agree that one of the most important reasons why this system generates discomfort is because it prevents people arrive on time to their destinations. It is leading to assume that the perception of lost time plays an important role. And it is expected that situations are

related to stress, because people have the feeling of wasting time and uncertainty of not knowing how long is waiting. [5]

### 1.3 How does this affect people?

92% of Lima residents said traffic congestion generates them stress, while 82% said that this problem takes away quality of life.

This health impact was recognized during a survey of people living in the north, south, east and center of the capital. Thus, 55% said traffic generates them a lot of stress, 21% and 16% quite some stress.

Faced with this problem, 57.3% of respondents said that chooses to use public transport, while 43% prefer to walk. Another key point is that the study reveals that 8.7% said has moved close to work or school for their children. [6]

### 1.4 Urban Traffic Noise

Noise pollution is the presence in the environment involving noise nuisance generate risks damaging or affect the health and human welfare [7], goods of any nature or cause significant effects on the environment [8].

Among the major health problems that occur by exposing people to high noise levels include diseases like stress, high blood pressure, dizziness, insomnia, speech difficulties and hearing loss [9].

Some categories of the population such as chronically ill and the elderly, who tend to need more sleep than others, are more vulnerable than others to noise. This phenomenon also particularly affects children and their learning capabilities [10].

The intensity of the various noises is measured in decibels (dB), the unit in which usually the sound pressure level, that is, the power or intensity of the noise is expressed. Decibels are also the smallest perceptible to the human ear sound variation.

The threshold measured dB Hearing has a scale which begins with zero (0) dB (minimum) and reaches its maximum 120 dB (which is the stimulus level in which people begin to feel pain), a comparable level of noise, for example, which occurs during a rock concert.

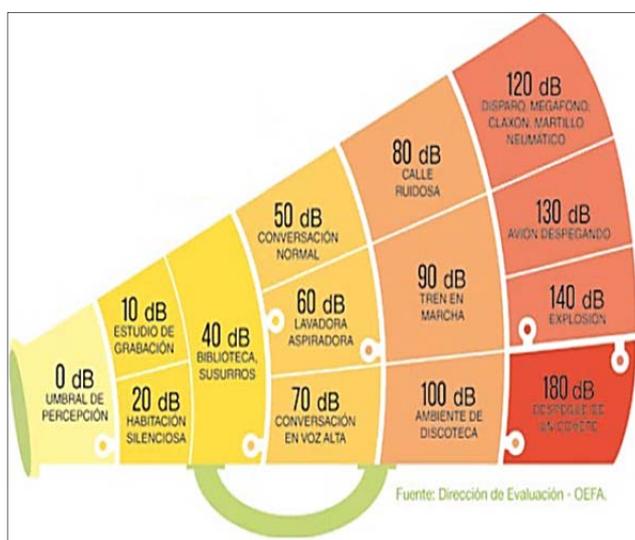
The World Health Organization recommends that the environment can be maintained within a threshold of 55 dB [10]. The following graphic examples of the relationship between the type of environment and the decibel level corresponding to them are presented.

As can be seen, different noise thresholds are different types of environment: zero (0) dB to 29 dB, the atmosphere is quiet; thirty (30) dB to 79 dB, the atmosphere is little noisy; eighty (80) dB to 99 dB, the environment becomes noisy; hundred (100) dB to 119 dB, the environment is considered nuisance; and 120 dB on, the environment is classified unbearable.

Noise pollution is a problem that has been growing over the last century, not only in Peru, but throughout the world. It is something that affects the development of our daily tasks and need to know and learn to control.

To this end, it is essential to know what tools are at our disposal to protect ourselves and what institutions can go. to different noise thresholds are different types of environment: zero (0) dB to 29 dB, the atmosphere is quiet; thirty (30) dB to 79 dB, the atmosphere is little noisy; eighty (80) dB to 99 dB, the environment becomes noisy; hundred (100) dB to 119 dB, the environment is considered nuisance; and 120 dB on, the environment is classified unbearable.

As shown in **Fig.2** Noise pollution is a problem that has been growing over the last century, not only in Peru, but throughout the world. It is something that affects the development of our daily tasks and need to know and learn to control. To this end, it is essential to know what tools are at our disposal to protect ourselves and what institutions can go.



**Fig. 2.** Examples of the relationship between the type of environment and the decibel level (dB).

Source: The Organization of Evaluation and Environmental Control (OEFA)

It has been found that there is a direct and exponential relation between the level of development of a country and the degree of noise pollution that impacts their population, that because the number of roads and vehicular traffic and noise from the sector industrial. Establishing Environmental Quality Standards for Noise for each application area as shown in Table 2.

US main noise source is external transport, followed by industry, construction, various human activities and animals. Population and urban growth has been an important aspect of vehicular noise pollution in this country, to the point that the USEPA proposed the following equation to estimate the noise level

$$Ldn = 22 + 10 \text{ Log } \{ \text{Population density} \} \quad (1)$$

Where: population density is expressed in individuals per square mile. While 14% of people lived in cities a century ago, today makes 50%, although in some developed countries and dwells between 75 and 80% of its population in these systems (UN, 2004).

Urbanization is a global phenomenon in advance in which one million square kilometers will be added to urban areas over the next 25 years, with the highest

growth rates in developing countries (2.3% per year vs. 0.5 % in developed countries).

Studies relating to the total increase of vehicular travel in cities, found among its main causes, population growth, urban sprawl, increased primarily owners of private vehicles and reduced occupancy vehicular situation has been growing since the early 60s meanwhile.

The main causes of the increase in private vehicle use include: household economic growth, which people perceive as a higher good cars and low quality of public transport. [11]

The decibel (dB) is the ratio of energy, power or intensity defined by:

$$\text{Log}(R) = 1/10 \quad (2)$$

To express a relationship in decibels (dB) energy, power or intensity, one must choose a reference value and then applying the definition. The term dB (decibel) and the dB scale are used throughout the world to measure sound levels.

$$\text{Level in dB} = 10 \log \left( \frac{\text{Quantity}}{\text{Reference quantity}} \right) \quad (3)$$

The acoustic power is defined as:

$$w = 10 \text{Log} \left( \frac{W}{W_{ref}} \right) \quad (4)$$

Being  $W_{ref} = 10^{-12}$  watts

### 1.5 Sound pressure level (Lp)

The relationship between the maximum and minimum sound pressure that the ear can perceive is 1'000000 times. (20 Pascal / 2 x Pascal) is therefore making it advantageous to use a logarithmic scale as it allows not handle very small or excessively large numbers.  $10^{-6}$

$$\text{Sound pressure level}(Lp)(\text{in dB}) = 10 \log \left( \frac{P_{rms}^2}{P_0^2} \right) \quad (5)$$

Where the reference pressure (Po) is 20 opa, Prms is the sound pressure. [12]

**Table 2.** National Environmental Quality Standards for Noise for each application area.

Application areas	Expressed values LAeqT	
	DAYTIME	Night time
Protection Zone Special	50dB	40dB
Residential area	60dB	50dB
Shopping area	70dB	60dB
Industrial zone	80dB	70dB

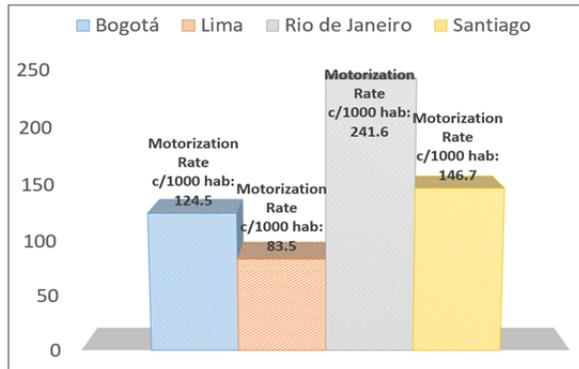
Note: The equivalent continuous sound level (LAeqT) is an indicator that describe the noise in a location.

### 1.6 Traffic Accidents

Traffic accidents are the second leading cause of death worldwide among young people aged 05 to 29 years old, and the third among the population aged 30 to 44 years.

They estimated about 1.2 million die annually in the world. Approximately 50 million people are injured. The global cost is estimated at US \$ 518 billion annually. [13]

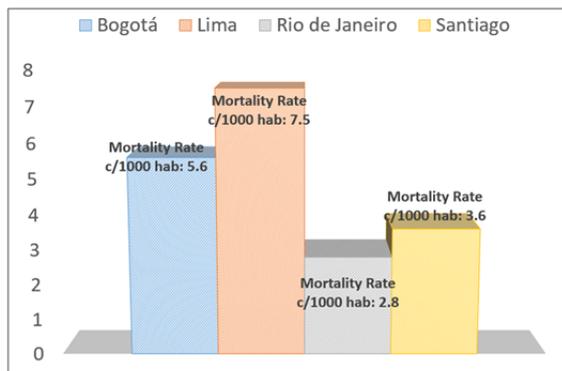
As shown In **Fig.3** we can notice that Lima is the 3<sup>rd</sup> capital of countries of South America that have the highest motorization rate.



**Fig. 3.** Motorization rate.

Source: Transport Unit of the United Nations Economic Commission for Latin America and the Caribbean (ECLAC)

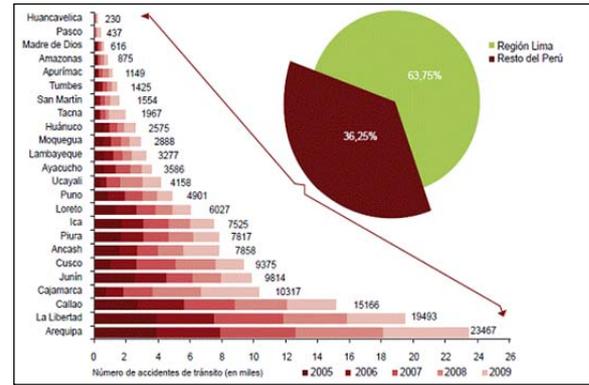
As shown in **Fig.4** the mortality rate in the main cities of South America are elevated and the city of Lima unfortunately leads the mortality rate which we will reduce thanks to this project.



**Fig. 4.** Mortality rate South America.

Source: Transport Unit of the United Nations Economic Commission for Latin America and the Caribbean (ECLAC)

As we can notice in the following graph **Fig5** that is the source of (MTC), the rates of traffic accidents due to vehicular traffic are high. The following chart represents accidents at the national level (PERU). We can notice that Lima is the place with the highest number of traffic accidents.

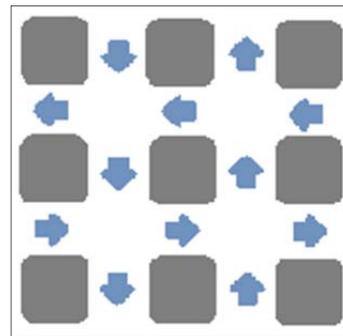


**Fig. 5.** Mortality rate Perú.

Source: Ministry of transport and communications of Peru (MTC)

## 2 Process

This will start analysing traffic lights, there are different types of intersections, we will choose the following in **Fig6** which is common in our country, especially in Lima which is the place we have chosen for this investigation.



**Fig. 6.** Type of intersection analysed.

After analysing where the installation of traffic lights will collect data from sensors installed that will allow the location and communication between traffic lights, these data are consistent it will take place as they do not change once installed traffic lights at the track.

Data:

- Location coordinates of the traffic lights installed.
- Streets in intervening and direction control.
- Designate the IP address and physical address.

To make the control scheme that will allow us to establish control traffic processing system responsible for acquiring images from cameras which will verify aspects such as the presence of vehicles, speed, direction and quantity of them.

In **Fig. 6.** We observe the network diagram semaphore were connected together by radiofrequency waves.

When a system detects one or more vehicles, communicates with neighbouring systems the same intersection to switch the lights change to clear the lane required.

Our system also has sensors capable of detecting the presence of cars by ultrasound and pressure sensors

placed on the asphalt, so we know the number of vehicles in each lane.

### 2.1 Measurements of vehicular traffic

In the field of object detection there are two main strategies related to vehicle detection task, the first estimate is based on the background and optical flow, while the second uses machine learning techniques. Estimating background analyses the difference between a predefined pattern (background) of an empty road and an image obtaining incoming traffic disturbances that overlap the predefined model and interpreted as vehicles. [14]

$$q = n/t \quad (6)$$

N = number of vehicles obtained from automatic counting in a period of time t

$$t = f/fps \quad (7)$$

Replacing in

$$q = nxfps/f \quad (8)$$

Where

$$fps = frame/s \quad (9)$$

and it is obtained directly from the video.

We use the Matlab environment to develop vehicle detection by image acquisition and digital processing of these.

By camera we can classify the type of vehicle dimensions and calculate its speed to determine if he is committing a violation of traffic laws.

f = frames processed in the video

Speed

$$v = \frac{d}{t} \quad (10)$$

$$v = \frac{stripe}{time} \quad (11)$$

Stripes in handling observe the image moves at a speed of a strip per frame; using optical flow obtain the displacement of an object between strips, the distance between the stripes is calculated by the algorithm.

The camera to detect vehicles and the speed thereof will have to analyse and recognize the plates and these data could be shared to the police station so that they can monitor vehicles infringements or have some order of capture, so it will be easier to track all types of vehicles.

The rate is calculated in terms of bands / time then

$$t = \frac{d}{fps} \quad (12)$$

$$v = \frac{dFr}{t} \quad (13)$$

$$v = \frac{dFr \times fps}{d} \quad (14)$$

d = distance found by the optical flow algorithm.

dFr = distance between stripes

The camera must have a depth sensor as infrared. Meanwhile depth sensor consists of two components: a projector infrared (IR) and a standard monochrome CMOS sensor. Both are aligned along the X axis of the device, a distance called baseline. [15]

For pressure sensors there are several alternatives, in this case pressure sensors similar to conventional piezo forces are introduced. All information will be stored in a

memory and compared with information from other perimeter lights.

In relation with Fig7, The structure of the control is very important because all data collected is redirected to a central data that contrasted with those who have been taken in the field before installation of traffic lights.

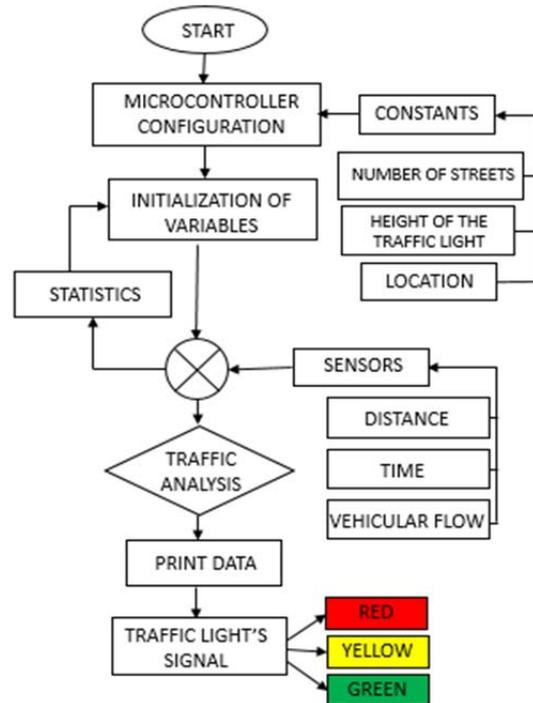


Fig. 7. Semaphore network diagram.

Something you have to consider is the priority that will have people wishing to cross from one corner to another. The semaphore commute the lights so that people can also move for example if there is no presence of vehicles on the roads, but if people trying to cross the traffic lights should remain in red light until the presence of a vehicle is detected and in conjunction with data collected from other traffic lights will switch back to thus effectively control the traffic.

The capacity of current computers allows greater number of processes in a very short time compared to 10 years ago, the media as large storage allow greater number of images to work, specialized programming languages in the technical and scientific area have facilitated the integration of personnel outside the computer field within their field or research. [16]

From the depth maps can extract features that provide valuable information on the shape of objects. [17]

The camera must have a depth sensor as infrared. Meanwhile depth sensor consists of two components: a projector infrared (IR) and a standard monochrome CMOS sensor. (In figure 8.)

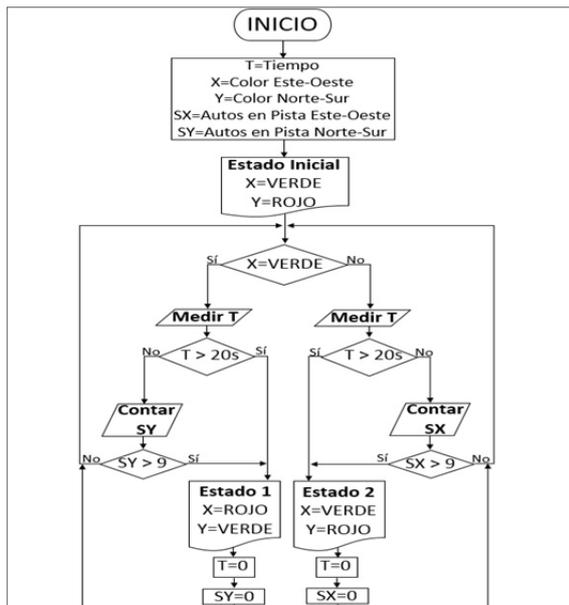


Fig. 8. Functional diagram of the semaphores (Abridged Version).

To be able to carry out the programming it is necessary a flow chart that graphically represents our algorithm, the previous graphic represents in a detailed and orderly way the sequence of the programming starting with the declaration of variables in the vehicular traffic, as it is the time and the number of vehicles that circulate through the transit route, then the initial states X for the traffic light in green and Y for red, according to the initial state of the traffic light and the number of vehicles accounted for with an infrared sensor, the program acts to decrease the vehicular traffic giving preferential to the most travelled roster. (In figure 9)

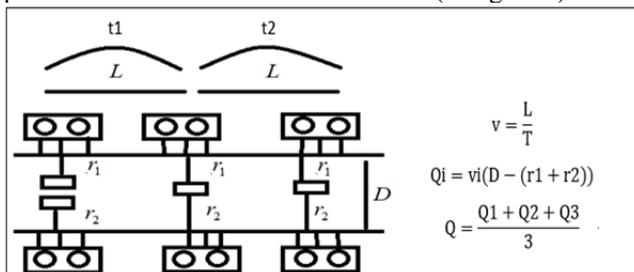


Fig. 9. Detection diagram of traffic flow.

$$Q_{traffic} = 15(8 - 1)5/18$$

$$0 \leq Q_{traffic} \leq 29.16$$

Formules obtained from the calculation diagram detection of traffic flow

In the previous graph we can calculate that the amount of traffic flow obtained is less and equal to 29.16 this means that there is a reduction in the amount of vehicle traffic flow which may decrease over time.

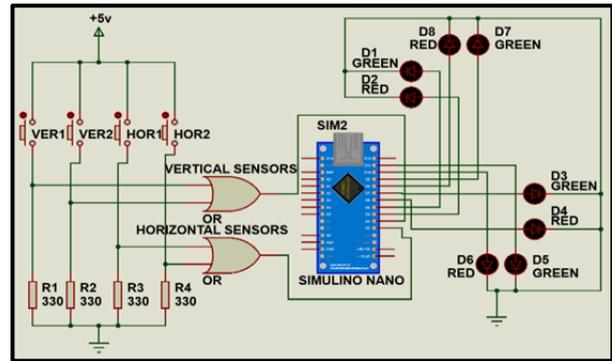


Fig. 10. Circuitual scheme of stoplights.

As we said before we use the Arduino for the programming of this project, in Fig10 we can observe four buttons that represent the ultrasonic sensors that we will use, that in practice these sensors would be activated when there is an obstacle, whose obstacle would be a vehicle. The eight led diodes would represent the semaphore itself. Therefore we have 4 entrances and 8 exits which are the necessary ones to analyse the vehicular traffic in a road intersection where the greater incidence of vehicular traffic in the city is presented.

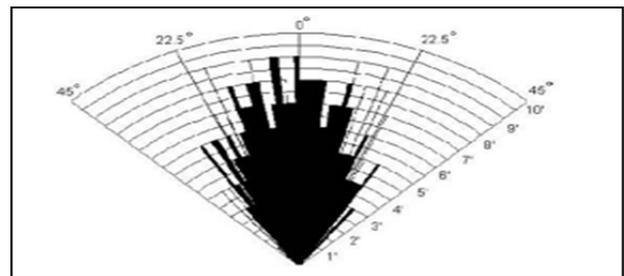


Fig. 11. Ultrasonic sensor angle performance.

Source: Datasheet of the ultrasonic sensor module hc-sr04 arduino

As we can see in Fig11 We will use an ultrasonic sensor instead of an infrared sensor since for an infrared sensor to work the obstacle or in this case the vehicle must be close to that sensor and its response speed is very slow, otherwise the ultrasonic sensor has a greater range, scope necessary to detect the passage of a vehicle on top of it, in addition the detection of presence is stable and its speed of response is faster which is necessary for the speed of the vehicles. In addition, as we can see in the previous graph, the ultrasonic sensor has an effective angle that is less than 15 ° compared to the infrared sensor, whose effective angle is almost.

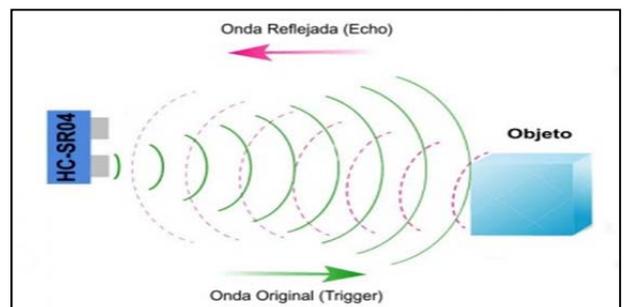


Fig. 12. Operation of the ultrasonic sensor.

In relation with **Fig12** With this ultrasonic sensor we can do two things, detect an obstacle simply waiting for Arduino to receive an "Echo" or count the time that elapses since the pulse is sent by the trigger until it is received, in this way, and knowing what is the speed of the sound, we can determine in a very simple way the exact distance to which the object in which the signal is bouncing is located.

$$\text{Speed}=\text{Distance}/\text{Time} \quad (15)$$

To clarify a little the multiplication factor that we are going to introduce in Arduino, suffice it to say that the speed is equal to the space divided by the time it takes to travel that space. The speed of sound is known (343m / s) and we will determine the time, as the time that elapses from the moment we make the shot until we receive the echo. (In fig. 13)

$$\text{Time}(s) = 0.0058 \times \text{distance}(m) \quad (16)$$



**Fig. 13.** Free height of a car.

As we can see the ground clearance of a light car is 210mm which is equivalent to 0.21m whose value varies depending on the model of a car, while a heavy vehicle its height does not exceed 1m, with these values we can calculate the response time of the ultrasonic sensor.

From the **formula (16)** applied to a light vehicle:

$$\text{Time}(s) = 0.0058 \times 0.21$$

Then the response time is:  $\text{Time}=0.0012s$

As we can see, the response speed is very fast, which makes the ultrasonic sensor efficiently useful for this project since the vehicles are in motion and not static.

Now in **Fig14** we are going to see part of programming, especially speed detection; that we have used in this project.

```
#define TRIGGER_PIN 12
#define ECHO_PIN 11
#define MAX_DISTANCE 200 /Calibracion de distancia

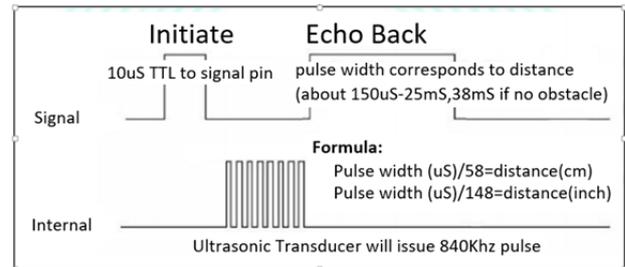
/*Crear el objeto de la clase NewPing*/
NewPing sonar(TRIGGER_PIN, ECHO_PIN, MAX_DISTANCE);

void setup() {
  Serial.begin(9600);
}

void loop() {
  // Esperar 1 segundo entre mediciones
  delay(1000);
  // Obtener medicion de tiempo y guardar en variable uS
  int uS = sonar.ping_median();
  // Imprimir la distancia medida a la consola serial
  Serial.print("Distancia: ");
  // Calcular la distancia con base en una constante
  Serial.print(uS / US_ROUNDTRIP_CM);
  Serial.println("cm");
}
```

**Fig. 14.** Programming for speed detection.

To program the ultrasonic sensor we first configure the pins and the serial communication to 9800, then the loop void loop () start by sending a 10us pulse to the trigger of the sensor, then receive the pulse response of the sensor by the Echo pin, to measure the pulse we use the function pulseIn (pin, value); The variable t, has the time it takes to get the ultrasound echo.



**Fig. 15.** Measuring the Trig pin.

In relation with **Fig15**. To start the measurement the Trig pin, that of the trigger signal must receive a five-volt pulse for at least ten micro seconds, this will indicate the sensor that transmits a burst of eight ultrasonic cycles at 40KHz and wait for the reflected burst when the sensor detects the ultrasound signal in the receiver will send a high signal (5v) through the Echo pin, this signal will have a delay (width) proportional to the distance, so to get the distance you should measure the Ton (high time on the Echo pin)

### 3 Results

When implemented the "Network traffic lights with Telemetry and Wireless Connectivity Perimeter" we observed a decrease in waiting times also give a flow of vehicles optimal all this because of its communication with traffic lights on its perimeter and its ability to adapt to events (real-time traffic) with these results could make a comparative table of advantages of this system compared to traditional as shown in Table 3.

**Table 3.** Comparison between Traditional Semaphores, Semaphore Intelligent.

Traditional semaphore	intelligent traffic light
Timeout established by the manufacturer	Variable Time adapting to real-time traffic flow
Routines for changing lights always on regardless traffic	Routines for changing lights waiting for events at q reduces accidents and also adapt some changes to the state traffic lights
Over the automobile is detected	Equipped with a vehicle detection system which translates into better decisions when optimizing traffic

Also with the "Network traffic lights with Telemetry and Wireless Connectivity Perimeter" could reduce noise pollution by 10dB according to OEFA, vehicular stress levels and the number of annual accidents was reduced to 3205 by SUTRAN

### 4 Conclusions

- Road users will experience a decrease in travel times between 5 and 8 minutes zones or defined corridors, minor arrests for red lights, lower degree of contamination by removing and vehicle stops and lower average wait times at intersections signalized.
- This research obtained as a result creating a control system intelligent traffic lights to control traffic, allowing improved traffic flow through the ability of vehicle detection and decision making that prioritize avenues more traffic flow.
- This system will manage and synchronize traffic lights in a city efficiently, easily and safely. Installation greatly improves traffic flows by reducing by 10% the undesirable effects generated by increased vehicle traffic.
- It is an innovative solution that helps cities in saving thanks to low costs of implementation and maintenance, and its 1.7 Watt consumption will be increased with 12 watts per light, compared with 180 Watt each traffic light with the current system.
- This technology also has an environmental impact which would reduce noise pollution by 10dB and the evils that causes the population as stress, high blood pressure, insomnia, hearing loss etc.

## 5 Observations

The logic used to for the selected intersection will not be the same as in other intersections, will have to be modified by assigning priorities area. For better results tempts network of traffic lights that have broad scope to control the different areas of the city. The project's success will also depend on the signs that pathways and compliance with these by drivers as reckless drivers to present the project's effectiveness would be nil.

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