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Impact of Intelligent Road Traffic Control in a Technologically Connected Vehicle Environment

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ABSTRACT

As we move in the generation of smart cities where the both infrastructures and cars are connected; are equipped with intelligent technology for data exchanged in real time (Elrahman et al., 2016). This research paper concentrated on the impact of intelligent road traffic control in a technologically connected vehicle environment and the requirements in developing cities. Research reflected to the case of Rwanda-Kigali City, data have been collected using questionnaires, interviews and observations, collected data were analysed using Statistical Package for Social Sciences (SPSS). The findings showed that the main causes of traffic jams and congestion in Kigali city are the Traffic incidents ranked at 88.8%, and Volume of cars ranked at of 88.8%, the Behavior of car drivers ranked at 78.8%, Narrow roads ranked to 41.03%, lack of traffic control infrastructures ranked 60% in the Kigali city. Findings also identified devices that integrated for technologically connected vehicle environment are cameras and Radars ranked at 65.0% and the sensors 85.0%, and a control System to alert drivers ranked at 95%. The research also illustrated what are most important ads in road traffic control to mitigate traffic jams and congestions. research further advised that the use of blocking panels to deviate drivers and the use intelligent traffic lights will have a positive impact to Kigali city to mitigate this traffic jams and congestions as long as Kigali still have many narrow roads with many vehicles pass on them.

Keywords:- Intelligent Road Traffic Control, Connected Vehicle Environment

I. DEFINITION OF KEY TERMS

Connected vehicle (CV): Mainly, the connected vehicle (CV) or connected car is a car that is equipped with Internet access, and usually also with a wireless local area network. This allows the car to share internet access with other devices both inside as well as outside the vehicle (Elliott, 2014).

Vehicle-to-infrastructure (V2I): Vehicle-to-infrastructure (V2I) is a communication model that allows vehicles to share information with the components that support a country's highway system (Pete & Olivier , 2014).

Vehicle-to-vehicle (V2V): Vehicle-to-vehicle is an automobile technology designed to allow automobiles to communicate to each other (Pete & Olivier , 2014).

Vehicle-to-device (V2D): Vehicle-to-device (V2D) communication is a particular type of vehicular communication system that consists in the exchange of information between a vehicle and any electronic device that may be connected to the vehicle itself (Pete & Olivier , 2014).

Connected environment: Connected environment is one in which a user or an application is constantly co nnected to a data source (Choi et al., 2016)

The **Internet of Things** (**IoT**): is the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these objects to connect and exchange data. Each thing is uniquely identifiable through its embedded computing system but is able to inter-operate within the existing Internet infrastructure. (Brown, 2016)

II. STATEMENT OF THE PROBLEM

The traffic information system (TIS) is such a system that provides travellers with useful traffic information in order to assist their route decision making(SHA , 2012), integrate information and communication technology

(ICT) and Internet of things (IoT) technology in a secure fashion to manage a city's assets (Bagula, Castelli and Zennaro, 2015) , however with reference to the infrastructure and ICT, the NICI plan didn't capture any aspect of how roads will be monitored through ICT where the number of cars will keep increasing and surpass the proportion to roads.

According to the results of a simulator study conducted by van Eenennaam et al (2016) the congestion assistant was found to be very effective and efficient in improving both traffic safety and efficiency as well as unpleasant driver behaviour which is a part of the cause of traffic jam.

As NICI plan and other smart plans in Rwanda does not capture a problem of traffic jams and road congestions, this research discussed the impact of intelligent road traffic control in a technologically connected vehicle environment and the requirements in Kigali city.

III. CONNECTED VEHICLE TECHNOLOGIES

Connected vehicle technologies allow vehicles to communicate with each other and the world around them and sometimes allow communication to infrastructure which is controlled via a centralized unit (CAR, 2017). Your vehicle is likely already more connected than you realize through these different connections those can be combined to be used as "**Road vehicular traffic control under connected environment**". Navigation systems already include connected vehicle functionality, such as dynamic route guidance. GPS-based system receives information on congestion in the road ahead through cellular signals (4G LTE or 3G) and suggests an alternative route (CAR, 2017). The connected vehicle concept is about supplying useful information to a driver or a vehicle to help the driver make safer or more informed decisions. Use of a "connected vehicle" doesn't imply that the vehicle is making any choices for the driver. Rather, it supplies information to the driver, including potentially dangerous situations to avoid (Elliott, 2014). The United States Department of Transportation (USDOT) has been working on a CV program that communicates within a radio spectrum specifically allocated by the Federal Communications Commission in 1999 for this purpose. And by the end of this year, the National Highway Transportation Safety Administration will propose a rule mandating inclusion of 5.9 GHz-based equipment in all new vehicles to make them CV-ready. This technology has the potential to eliminate 80 percent of unimpaired crash scenarios that could save tens of thousands of lives each year (Murtha, 2015). Without compromising personal information, this technology will also enable transportation agencies to access vehicle data related to speed, location and trajectory enabling better management of traffic flow as the ability to address specific problems in real-time. So, in addition to sending information to the driver, CVs will send information to transportation agencies to enhance their knowledge of real-time road conditions, as well as generate historic data that will help agencies better plan and allocate future resources (which are typically stretched far too thin) (Goodall, 2013). By deploying roadside equipment, which reads and sends signals to and from these vehicles, transportation agencies can fully participate in the nationwide deployment of the connected vehicle system (Murtha, 2015). Traffic light and sensors control and coordination.

Figure 1: Connected cars MIT Technology review (2012)

i. Traffic light control

"The normal function of traffic lights requires more than slight control and coordination to ensure that traffic moves as smoothly and safely as possible and that pedestrians are protected when they cross the roads (Transport, 2008). A variety of different control systems are used to accomplish this, ranging from simple clockwork mechanisms to sophisticated computerized control and coordination systems that self-adjust to minimize delay to people using the road (Transport, 2008). A traffic signal is typically controlled by a controller mounted inside a cabinet. Some electro-mechanical controllers are still in use (New York City still had 4,800 as of 1998, though the number is lower now due to the prevalence of the signal controller boxes). However, modern traffic controllers are solid state. The cabinet typically contains a power panel, to distribute electrical power in the cabinet; detector interface panel, to connect to loop detectors and other detectors; detector amplifiers; the controller itself; a conflict monitor unit; flash transfer relays; a police panel, to allow the police to disable the signal; and other components. In traffic control, simple and old forms of signal controllers are what are known as electro-mechanical signal controllers. Unlike computerized signal controllers, electro-mechanical signal controllers are mainly composed of movable parts (cams, dials, and shafts) that control signals that are wired to them correctly (Chart, 2012). Aside from movable parts, electrical relays are also used. In general, electro-mechanical signal controllers use dial timers that have fixed, signalized intersection time plans. Cycle lengths of signalized intersections are determined by small gears that are located within dial timers. Cycle gears, as they are commonly known, range from 35 seconds to 120 seconds. If a cycle gear in a dial timer results in a failure, it can be replaced with another cycle gear that would be appropriate to use. Since a dial timer has only one signalized intersection time plan, it can control phases at a signalized intersection in only one way. Many old signalized intersections still use electro-mechanical signal controllers, and signals that are controlled by them are effective in one way grids where it is often possible to coordinate the signals to the posted speed limit. They are however disadvantageous when the signal timing of an intersection would benefit from being adapted to the dominant flows changing over the time of the day" (UK.D.T, 2009).

ii. Traffic Light Sensors

Every traffic light signal has either a timer or sensor which helps it direct traffic flow. In large cities where vehicles cross road intersections across the clock, traffic is usually dictated by traffic lights that use timers. But in the suburbs and up county roads, traffic signal sensors (detectors) are usually preferred because they not only manage the inconsistent traffic flow effectively, but also detect when cars arrive at intersections, when several cars are stacked at an intersection and when cars have entered turn lanes. These sensors use different technologies, from induction loops, microwave radar, cameras, lasers to rubber hoses filled with air (Chan and Takhar, 2008).

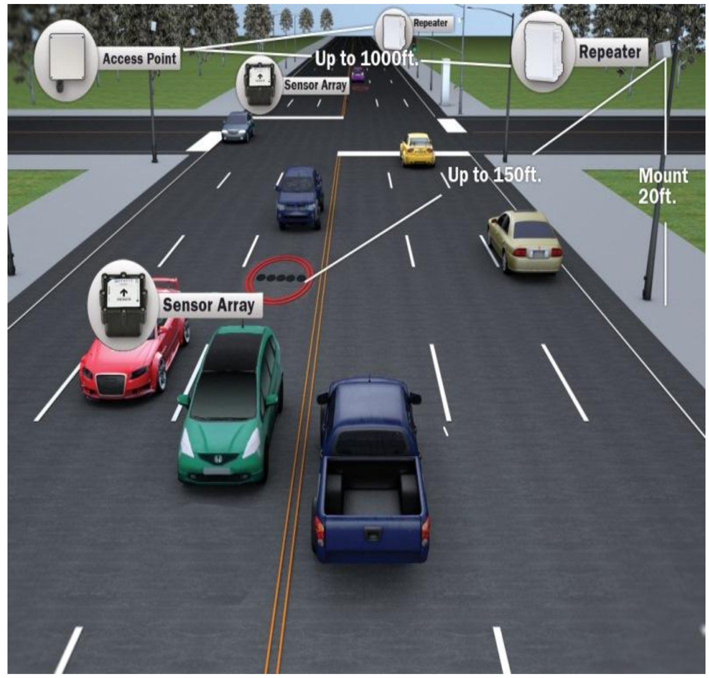

Figure 1:Traffic light sensors

iii. Induction Loops

The primary, reliable and most common traffic light sensors are induction loops. Inductive loops are coils of wire that have been embedded on the surface of the road to detect changes in inductance and convey them to the sensor circuitry to produce signals (Brian et al., 2014). The loop is usually fed with a given frequency from a generator, resulting in an induced magnetic field. And as the magnetic field continues to build due to continuous flow of current, the coils will achieve a stronger field that can last for a period even after the switch is opened (Brian et al., 2014). For an induction loop to achieve greater inductance and be more reliable in traffic detection, it should have several wire coils and an iron (magnetic material) core. The core is the material on which the wire coils are wrapped (Brian et al., 2014). When coils have been placed in the grooves and covered with rubbery compounds, they produce a specific quantity of inductance which can be measured using an inductance meter. But when a car stops on or drives over the loop, the larger steel (metallic) material making up the body of the car will act as the core of the induction loop. Since steel is a magnetic material, it will increase the inductance of the loop and cause a change in the current flowing through the sensor circuitry (Brian et al., 2014). Therefore, when the changes in the magnetic field are conveyed to the signal controller by the wire coils, they cause a change in traffic signal. Induction loops offer several advantages. They are not affected by the weather and are quite immune to accidental false positives. They can also cover lengthy parts of the lanes and can be localised according user need. Nevertheless, they may fail to detect bicycle traffic because of the little metallic component of bicycles (Brian et al., 2014).

iv. Microwave Radar Detectors

These devices detect a large object travelling towards or away from them and their use is increasing when compared with induction loops. They do not detect light which is probably a surprise for all the taxi drivers who sit there flashing their headlights hoping to make the lights change quicker. Microwave detectors used for "above ground" use is designed to detect vehicle movements within a pre-determined field of vision providing a vehicle's speed is greater than three miles per hour.

The choice of inductive loop systems compared with microwave systems is influenced by a number of different factors. Normally the method of detection is determined by the prevailing operational considerations which can vary from site to site. For instance, where obstructions in the form of overhead hanging objects or extremes of weather are prevalent, inductive loops are normally deployed. However, for less onerous situations, microwave radar systems are being utilised more and more because they are easier to install and maintenance routines are more economical (Chan et al., 2008).

v. Video Detection

Video detection involves the use of cameras connected to specialized cards that have been furnished with "detection zones" defined by specialised vehicle detection software. For instance, pole-mounted video detection cameras rely on video technology to detect cars (Todd, 2011). The video sensors are ideal for road surfaces where induction loops are impossible to install, such as gravel surfaces and bad road surfaces (Todd, 2011). However, video sensors are less popular because they are more vulnerable to bad weather, tend to register false positives because of the glare of car headlights and shadows of vehicles on neighbour lanes, and require more expensive cards (Todd , 2011).

IV. CONNECTED VEHICLES TRAFFIC SIGNAL CONTROL PATENT

"The new data available in a connected vehicle environment has many applications in both safety and mobility. Traffic signal control is one of the many areas that may benefit from individual vehicle location data. While traditional video and in-pavement detectors generally provide presence information, wireless communication allows vehicles to transmit a much broader range of information. By listening to a vehicle's Basic Safety Message, a signal controller can know a vehicle's location, heading, speed, and acceleration rate at least once per second within a 300-meter range. Whereas detector-based strategies must estimate current conditions from detector activity, connected vehicles allows essentially direct measurement of platoon size, approach speeds, and queue length. Using this high-resolution data, signal control strategies designed assuming ubiquitous V2I wireless communication has the potential to be more dynamic and responsive to real-time conditions. This section discusses several key concepts and traffic signal control strategies using wireless V2I communication." (Goodall, 2013).

1. Road Side Alert (RSA)

The RSA message is normally emitted from roadside infrastructure (e.g., RSU) to nearby mobile devices alerting them about roadway hazards. The actual content of the message is formatted in the International Traveller Information Standard (ITIS) code. Typical example messages would be "bridge icing ahead," "train coming," or "ambulances operating in the area." The IT IS standard (i.e., SAE J2540.1) contains the accepted phrases supported by the standard, which are all coded in standardized integer formats. In addition, the RSA message contains optional fields used to determine the relevance of the RSA message. A position vector is sent along with the ITIS phrases, which can be used by the receiving device to filter out irrelevant messages. A priority level for the message is also sent and determines the order and type of message presentation to minimize driver distraction. A spatial extent message is used to provide a gross level of applicability for the message over a distance (Zeng X. , 2012).

2. Vehicle to Infrastructure interaction and control
The Vehicle to Infrastructure interaction, similarly to V2V, is based on wireless communication technologies. The V2I communication (commonly called V2X) is also an extensively researched topic in the United States. The main traffic safety goals of such systems are well summarized by USDOT's (U.S. Department of Transportation) Connected Vehicles Program. (Berning, Richard, & Kathryn, 2014) V2I is the wireless exchange of critical safety and operational data between vehicles and highway infrastructure, intended primarily to avoid or mitigate motor vehicle accidents but also to enable a wide range of other safety, mobility, and environmental benefits. V2I communications apply to all vehicle types and all roads, and transform infrastructure equipment into "smart infrastructure". They incorporate algorithms that use data exchanged between vehicles and infrastructure elements to perform calculations that recognize high-risk situations in advance, resulting in driver alerts and warnings through specific actions. One particularly important advantage is the ability for traffic signal systems to communicate the signal phase and timing (SPAT) information to the vehicle in support of delivering active safety advisories and warnings to drivers. (Richard, 2014).

V. RESEARCH METHODOLOGY

This study focused on the opinion of respondents in order to identify the major factors of traffic jams, to analyse the impact of traffic jams-congestion on citizens life, to understand the structural operations of technologically connected environment review Technologies that can help traffic control systems to reduce jams and congestion in smart cities, to establish the relationship between technological connected environment and current vehicular traffic control technologies. The research approach is non-experimental, qualitative, exploratory-descriptive and contextual.
The following table shows population and sample size.

Population Category	Total Population	Sample	Sampling Method
RFTC	10 at office	10	Convenient
RTDA- staff	52 general Staff	52	*Simple Random Sampling
RTDA	8 Technicians	8	Purposeful
Traffic Offficers	10 Traffic officers	10	Convenient

Table 1: Populations and sample size

VI. PRESENTATION AND ANALYSIS OF RESEARCH FINDINGS

The Factors of traffic Jams and congestion in Kigali
Table 1: Factors of traffic Jams and congestion in Kigali

	Behavior of car drivers	Traffic incidents	Public transportation less efficient	Misuse of road and side parking	Narrow roads	Volume of cars
Count	63	71	31	36	33	71
Percentage	78.80	88.80	38.80	45.00	41.30	88.80

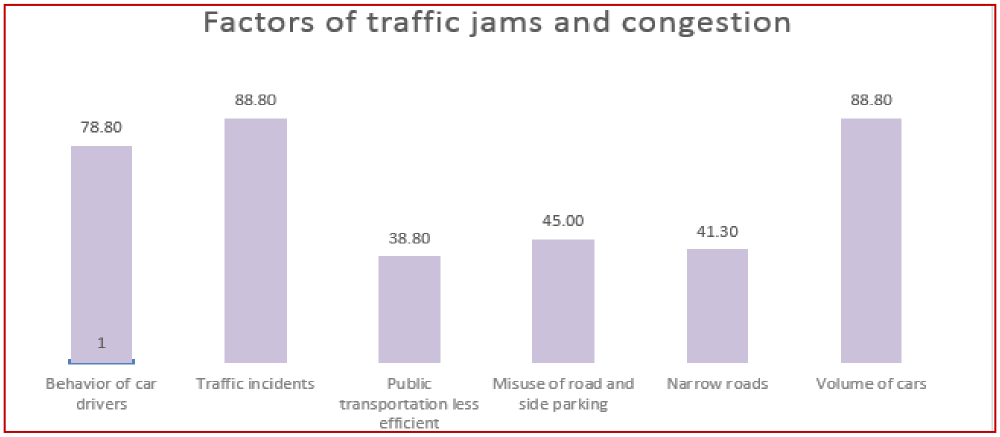

Figure 1: Factors of traffic jams and congestion

The impact of traffic jams-congestion on citizen's life

Table 2: Impact of traffic jams-congestion on citizen's life

	Delays	Fuel Consumption and Pollution	Poor time management	Loss in business or Job	Stress	Loose Trust	Road Rage	Fatigue
count	78	51	72	39	49	64	21	61
Percentage	97.50	63.80	90.00	48.80	61.30	80.00	26.30	76.30

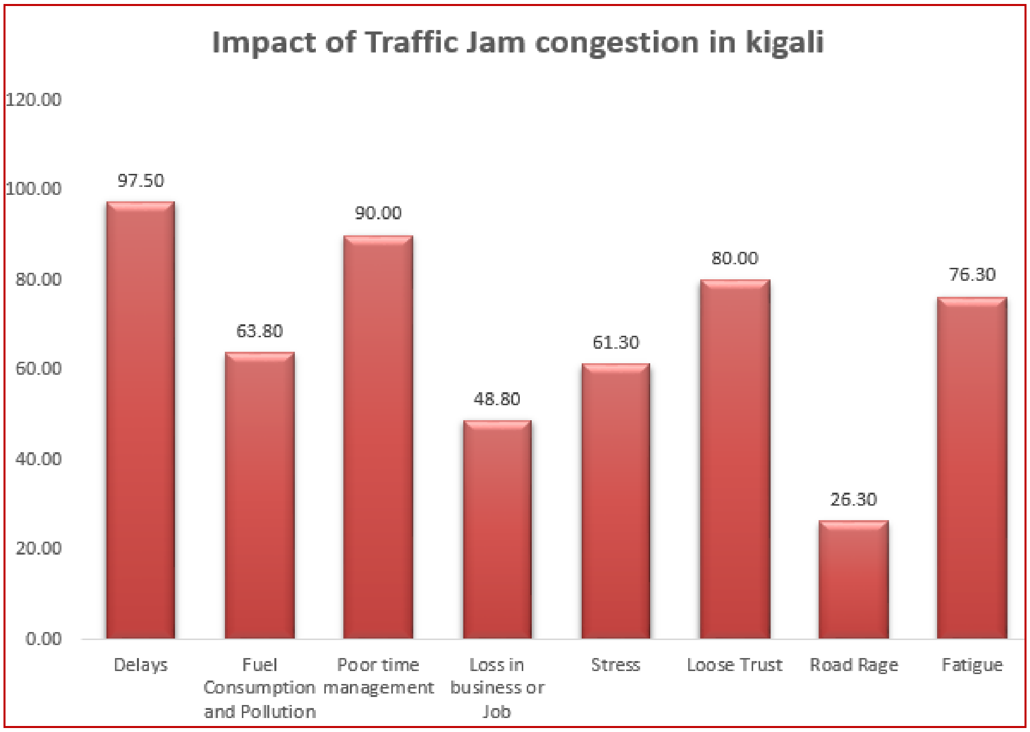

Figure 2:The impact of traffic jams-congestion

Techniques that can help traffic control systems to reduce jams and congestion in smart cities

Table 3: Review of the current techniques available

	Radars	Sensors	Traffic lights	Speed guvnors	Camera	To use common and public transport	System to alert drivers
count	0	0	15	19	12	2	0
Percentage	0.00	0.00	75.00	95.00	60.00	10.00	0.00

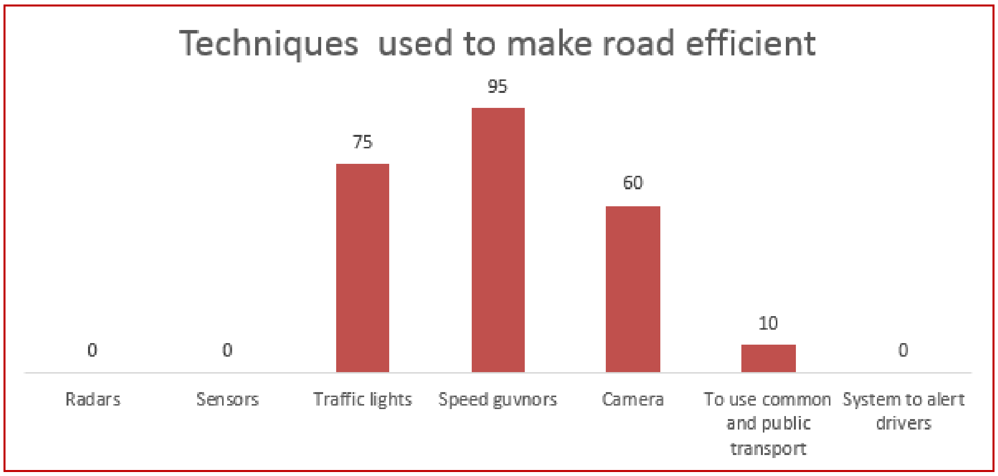

Figure 3:Techniques used to make road efficient

Jams and congestion Control algorithm

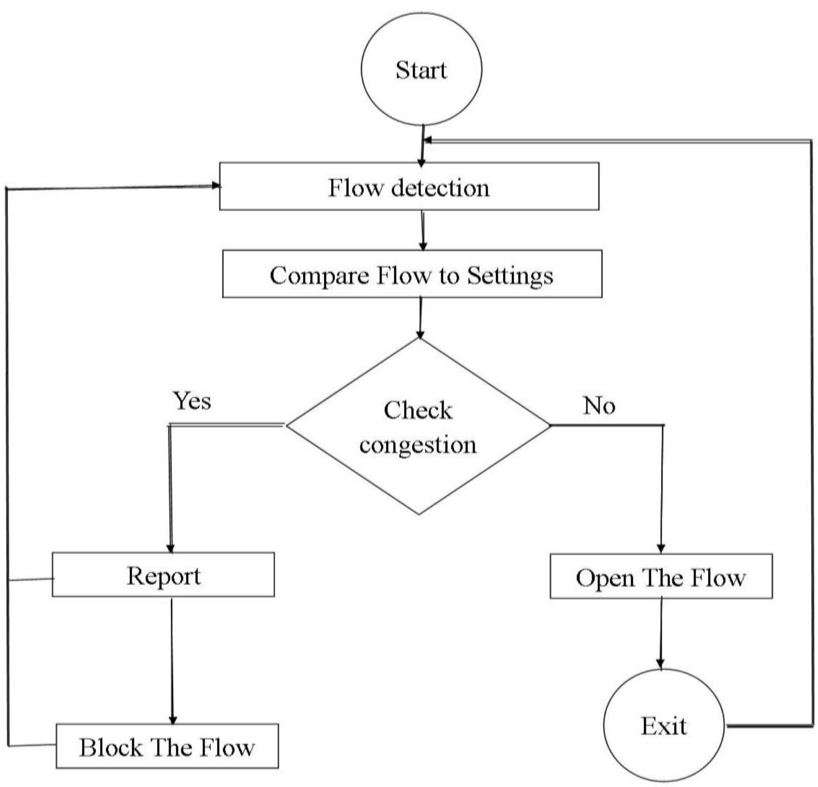

Figure 4: Suggested Congestion and jams Traffic control algorithm

```
Start:
Input A: Current size of flow
Input B: Reserved size of flow
Input C: Maximum size of flow
initialize
if(A+B=c)
{
Congestion is detected;
Throughput reported;
}
else if(A=C)
{
Jam is detected
Throughput reported;
The road is blocked
}
else if(A<(C-B))
{
Normal flow
Throughput reported;
}
else
{
Starvation;
}
: End
```

The flow detection is made by radars and sensors at the same time report to the central level which will alert and block the road from the intersection in order to allow drivers to be able to derivate this system is continuous as it is shown in the algorithm.

VII. SUMMARY OF FINDINGS

The study proven than most of time there is a jam or congestion in the main road while sub roads are not used the solution is to promote the use of sub roads to diminish the throughput in the main road. The cause of this may be lack of control system to be able to diminish that throughput and redirect to sub roads. This is solved by bring the system to alert drivers about the situation of the direction are taking to take another convenient roads. It is in that regard where some wireless devices are needed to be able to detect queue length, saturation, freeways and other traffic incidents to follow the control algorithms which will describe steps involved in congestion and jams control.

"The traffic jams occur during the beginning of working day to the midnight in some parts of the city, as a taxman, this mostly happened from 7:00 A.M when I start my job and I can say that in the weekend, no many cars in the roads which are mostly narrow by comparing to the huge number of cars." said by a Taxman.

The study showed that the 85% of responders said that it is obvious to increase the use of sensors. The 90% of responders said it will be good to use also Radar to detect every move of cars. 95% of responders said it will be good to use blocking panels to deviate drivers and 95% of responders said it will be good to use intelligent traffic lights. 60% of responders said Routers techniques can be used while 65% of responders mentioned the used of camera in the almost road of Kigali city.

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