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Full Length Research Paper

Deployment of Inductive Loop Vehicle Traffic Counters Along Trunk Roads in Tanzania

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ABSTRACT

As Tanzania's population grows, there is a greater demand for efficient, effective, and strong road design, as well as a smooth transportation system with a balanced traffic management network architecture. To plan for maintenance and expansion of such a vast network, a credible data inventory and network condition must be established. The deployment of vehicle inductor loop counters along Tanzanian trunk roads is presented in this paper. At test sites, inductor loop sensors and control cards were used to capture vehicle traffic data, which was then wirelessly sent using GSM technology for vehicle classification verification and storage for future road traffic management. The traffic count statistics from selected test sites acquired by the base station monitoring software were examined in real-time and the findings over a one-year period were provided. According to the study's findings, inductive loop vehicle counter technology can count and categorize vehicles along a section of roadway and provide reliable performance indicators for monitoring progress at the local, state, and national levels. The vehicle traffic data collected by this system will be used to project future situations within a transportation system and to keep a record of historical trends that will be used to project into the future what is likely to happen based on actual observations of the past and using other socio-economic data obtained from census information or economic indicators.

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INTRODUCTION

Traffic congestion is a significant problem that impacts modern living in major cities across the world. Road transport is the most often utilized mode of transportation in Tanzania (Kiunsi 2013). Road transportation has evolved as the most convenient method of transporting goods and people (Dekker et al. 2012). Despite its importance, road transportation has faced several obstacles as a result of traffic accidents. It not only restricts our movement, but it also pollutes the air, wastes fuel, and stifles economic progress (Runyoro & Ko, 2013). As Tanzania's population grows, there is a greater demand for efficient, effective, and strong road design, as well as a smooth transportation system with a balanced traffic management network architecture (Rozenberg et al. 2019; Likwelile 2017; Hallegatte et al. 2019). Furthermore, there is a great desire for adequate traffic congestion solutions that would improve people's lives (Olayode et al. 2020). Because of the ongoing rise in traffic volume and the restricted development of new highway infrastructure in metropolitan, intercity, and rural areas, maximizing the efficiency and capacity of existing transportation networks is critical.

Intelligent transportation systems (ITS) use information and communications technologies (lCT) to handle real-time data from vehicles and transportation networks that move people, commodities, and services (Annur & Ponnusamy, 2020). When these technologies are incorporated into the transportation system's infrastructure and vehicles, they reduce traffic congestion, improve safety, and increase production (Lin et al. 2017; Yan et al. 2012). ITS allows for the collection of real-time traffic data (Friesen & McLeod, 2015). Traffic data is utilized in highway design, transportation planning, maintenance operations, economic evaluation, transportation assessment, traffic modeling, highway/junction capacity assessment, traffic management, budgeting and financial planning /allocation, and public transportation planning (Gajurel 2014). To plan for maintenance and expansion of such a large network, a credible data inventory and network condition must be established. Since the real network maintenance demands are far more than the available funds, this entails the establishment of a system that will be utilized by maintenance management in their planning. Despite the benefits and potential provided by ITS, the main issue is how to implement them in developing nations where network infrastructure and economic constraints abound.

Traffic data are facts and figures on any aspect of the transportation system that results or is related with the movement of people, freight, and products from one area to another (Bellini et al. 2021). The data collected serves in establishing a baseline scenario for monitoring current system performance and detecting limits or operational issues such as congestion and safety. To project future situations within a transportation system, a record of historical trends is required, which is used to envision into the future what is likely to happen based on actual observation of the past and using other socio-economic data obtained from census information or economic indicators. Transport assessments are often required to support planning applications for large developments in the design of new projects. This study is based on a comprehensive travel demand projection for the planned development to identify any potential negative consequences from the beginning. Accurate data is necessary for decision-making bodies to make informed decisions, since it provides as a foundation for planning, analysis, and decision-making. The actual vehicle composition on a given road segment varies greatly, ranging from small passenger cars to buses and big trucks delivering commercial items.

Traditional traffic data collection methods are required but insufficient due to their limited coverage and high implementation and maintenance costs. Experts conduct manual traffic counts along a road stretch at properly selected observation points or counting stations (Al-Sobky & Mousa 2016). The traffic count survey is often a classified count in which each vehicle passing an observation station is recorded on a prepared sheet/form based on vehicle type, and each travel direction is recorded individually. Manual traffic counts are normally conducted over a short period of time (about seven days), as it is neither practicable nor cost effective to conduct manual traffic counts over a lengthy period of time (i.e., 24 hours a day, 365 days a year) (Komba et al. 2018).

Several technologies have been proposed in the literature for collecting traffic data, including two-axis fluxgate magnetometers, induction coil magnetometers, microwave radar, active infrared (laser radar), passive infrared, ultrasonic, acoustic, video image processors, and inductive loop detectors (Leduc 2008). Table 1 (Klein 2006) depicts a full comparison of different technologies in terms of their advantages and shortcomings. The inductive loop detector is the most often employed technology in current traffic control systems. Existing inductive loop detectors are only appropriate for lane disciplined traffic systems. When there is parallel movement of cars inside the same loop area and heterogeneous traffic with vehicles of different sorts occupying the same road space, these sensors will not function effectively. As a result, current loop detectors are only suitable in nations where motor traffic follows lane discipline and is homogenous.

Inductive loop detectors were chosen for this study owing of the advantages they have over other types of detectors and the variables they supply. Table 2 compares each technology in terms of the different metrics it provides, such as count, presence detection, speed, output data, vehicle categorization, connection bandwidth, and sensor purchasing
cost (Shunu 2020; Vitanov et al. 2011). Inductive loop detectors, as shown in Table 2, provide a cost-effective solution with a wide range of parameters. This technology's strength originates from high-quality real-time data acquired from thousands of cars across a broad road network at a far lower cost than existing approaches. The price of purchasing hardware and software are not the only expenditures connected with a sensor. Sensor choices should take installation, maintenance, and repair into account. Installation costs include fully burdened costs for technicians to prepare the road surface or subsurface (for inductive loops or other surface or subsurface sensors), install the sensor and mounting structure (if one is required for over-roadway sensors), purchase and install conduit, close traffic lanes, divert traffic, provide safety measures as needed, and verify the device's proper operation after installation is complete.

Inductive loops are wire loops embedded in the pavement that are linked to an inductive loop detector in the controller cabinet. The presence of a vehicle is identified by analyzing the raw signal processed by the vehicle detector and the distortion of the magnetic field surrounding the loop generated by a vehicle traveling through the loop. The inductance of a wire is determined by its perimeter, width, effective radius of cross-section, number of turns, and the permeability of the medium around it. Detection accuracy is determined by sensor setup, location, and sensitivity, regardless of sensor technology. The inductance of the loop is impacted by several factors, including weather, wire condition, and wire type. However, the variations in inductance induced by these variables occur slowly over time and have no effect on the loop's functioning.

Shunu (2020) presented a traffic management system that uses a wireless network to improve traffic flow. The VANET environment was used for the suggested system by utilizing the clustering technique. The proposed system's components comprise sensor node hardware, a vehicle detection system based on a magnetometer, and a UDP protocol for communication between the nodes. The system performance, however, was tested using simulation and was not realized in real-world implementation.

In general, traffic counting technologies are classified into two types: invasive and non-intrusive approaches. The invasive techniques essentially comprise of a data acquisition system and a sensor that is placed on or in the road, such as pneumatic sensors. To identify a vehicle, pneumatic sensors rely on a direct impact. Most of the time, "rubber tubes" are put across road lanes to detect cars based on pressure changes caused when a vehicle's tire passes over the tube. The generated pulse is captured and analyzed by a counter on the side of the road. The biggest drawback of this type is that it only covers a few lanes, and its efficiency is affected by weather, temperature, and traffic conditions. This method may also be inefficient in measuring low-velocity flows (Mimbela & Klein, 2007). Another disadvantage is the high wear factor of the tubes. The more vehicles that pass through the tubes, the more likely it is that tiny punctures will emerge. The constant change of seasons will cause the rubber to deteriorate faster than usual. Another disadvantage is that the tubes must be filled with a temperature-independent gas, such as nitrogen, so that the pressure inside them does not fluctuate when the environment changes (Shariff et al. 2016). In addition, if two or more automobiles collide with the tube at the same moment, the sensor will miscount. On the other hand, they are quite simple to deploy on the road. They require no further preparation (such as excavating the road or installation on poles) and are appropriate for short-term counts of low-traffic highways (suburb roads, etc.).

Non-intrusive approaches are those in which traffic counting sensors do not physically contact with passing vehicles. They need less planning, effort, and expense. The majority of them are positioned above the road lanes, while others, such as video image processing cameras, manual counting, and so on, are located below them (Divatankar et al. 2019). Video image processing is a method of detecting traffic and vehicles that uses a video camera instead of sensors. Images from the camera are transmitted through a cable (or wirelessly) to a distant station, where they are stored and analyzed. There are several techniques available for identifying automobiles on the road, such as signal processing, artificial neuron networks, bitmap processing, and so on. After detecting a vehicle, another algorithm is launched to determine its speed, direction, and even dimensions. This strategy can supply us with a variety of data. The disadvantage of this approach is that there are occasional miscounts, and the system is easily deceived. It is dependent on the weather conditions; for example, nothing will be detected if it is foggy or snowy (Šarčević 2014). Manual counting is a frequent way of traffic counting. It is not prohibitively costly and does not need any preparations. One or two professionally qualified individuals record data on paper or in a computer. However, it is not ideal for long-term data collecting or high-traffic roadways. Some counting errors may arise because of human mistake.

The main contribution of this study is the presentation of the design and deployment of inductive loop vehicle traffic counters along Tanzanian trunk roads. In crowded settings, the inductive traffic vehicle detector correctly recognizes and classifies vehicle types such as automobiles, trucks, buses, and motorbikes. To translate data into usable insights, traffic detector data may be analyzed, aggregated, and displayed utilizing intelligent insight software. These insights can be used by operators to make informed decisions that can help avoid safety issues, reduce traffic congestion, and improve the environment. Vehicle categorization and vehicle counting are critical elements for good traffic management, serving as the foundation for nearly all traffic analysis use cases. This data serves in strategic city planning as well as the generation of valuable insights for enhancing traffic management efficiency and dependability.

Table 1: Strengths and weaknesses of commercially available sensor technologies

Technology	Strengths	Weaknesses
Inductive loop	▪ Flexible design to satisfy large variety of applications ▪ Mature, well understood technology ▪ Large experience base. ▪ Provides basic traffic parameters (e.g., volume, presence, occupancy, speed, headway, and gap).	▪ Installation requires pavement cut. ▪ Improper installation decreases pavement life. ▪ Installation and maintenance require lane closure. ▪ Wire loops subject to stresses of traffic and temperature. ▪ Multiple loops usually required to monitor a location.

	▪ Insensitive to inclement weather such as rain, fog, and snow. ▪ Provides best accuracy for count data as compared with other commonly used techniques. ▪ Common standard for obtaining accurate occupancy measurements. ▪ High frequency excitation models provide classification data.	▪ Detection accuracy may decrease when design requires detection of a large variety of vehicle classes.
Magnetometer (Two-axis fluxgate magnetometer)	▪ Less susceptible than loops to stresses of traffic. ▪ Insensitive to inclement weather such as snow, rain, and fog. ▪ Some models transmit data over wireless radio frequency (RF) link.	▪ Installation requires pavement cut. ▪ Improper installation decreases pavement life. ▪ Installation and maintenance require lane closure. ▪ Models with small detection zones require multiple units for full lane detection.
Magnetic (Induction coil magnetometer)	▪ Can be used where loops are not feasible (e.g., bridge decks). ▪ Some models are installed under roadway without need for pavement cuts. However, boring under roadway is required. ▪ Insensitive to inclement weather such as snow, rain, and fog. ▪ Less susceptible than loops to stresses of traffic.	▪ Installation requires pavement cut or boring under roadway. ▪ Cannot detect stopped vehicles unless special sensor layouts and signal processing software are used.
Microwave radar	▪ Typically, insensitive to inclement weather at the relatively short ranges encountered in traffic management applications. ▪ Direct measurement of speed. ▪ Multiple lane operation available	▪ Continuous wave (CW) Doppler sensors cannot detect stopped vehicles
Active infrared (Laser radar)	▪ Transmits multiple beams for accurate measurement of vehicle position, speed, and class. ▪ Multiple lane operation available.	▪ Operation may be affected by fog when visibility is less than ≈20 feet (ft) (6 m) or blowing snow is present. ▪ Installation and maintenance, including periodic lens cleaning, require lane closure
Passive infrared	▪ Multizone passive sensors measure speed.	▪ Passive sensor may have reduced vehicle sensitivity in heavy rain, snow, and dense fog. ▪ Some models not recommended for presence detection
Ultrasonic	▪ Multiple lane operation	▪ Environmental conditions such as

	available. ▪ Capable of over-height vehicle detection.	temperature change and extreme air turbulence can affect performance. ▪ Temperature compensation is built into some models. ▪ Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds.
Acoustic	▪ Passive detection. ▪ Insensitive to precipitation. ▪ Multiple lane operation ▪ available in some models	▪ Cold temperatures may affect vehicle count accuracy. ▪ Specific models are not recommended with slow-moving vehicles in stop-and-go traffic.
Video image processor	▪ Monitors multiple lanes and ▪ multiple detection zones/lane. ▪ Easy to add and modify ▪ detection zones. ▪ Rich array of data available. ▪ Provides wide-area detection ▪ when information gathered at ▪ one camera location can be ▪ linked to another.	▪ Installation and maintenance, including periodic lens cleaning, require lane closure when camera is mounted over roadway (lane ▪ closure may not be required when camera is mounted at side of roadway) ▪ Performance affected by inclement weather such as fog, rain, and snow; vehicle shadows; vehicle projection into adjacent lanes; occlusion; day-to-night transition; vehicle/road contrast; and water, salt grime, icicles, and cobwebs on camera lens. ▪ Reliable nighttime signal actuation requires street lighting ▪ Requires 30- to 50-ft (9- to 15-m) camera mounting height (in a side-mounting configuration) for optimum presence detection and speed measurement. ▪ Some models susceptible to camera motion caused by strong winds or vibration of camera mounting structure. ▪ Generally, cost effective when many detection zones within the camera field of view or specialized data are required.

Source: **(**Leduc, 2008)

Table 2: Traffic output data (typical) communications bandwidth and cost of commercially available sensors

Sensor technology	Count	Presence	Speed	Output data	Classification	Communication bandwidth	Sensors purchase cost[a]
Inductive loop	✓	✓	✓[b]	✓	✓[c]	Low to moderate	Low[i] ($500-$800)
Magnetometer (Two-axis fluxgate)	✓	✓	✓[b]	✓		Low	Moderate[i] ($900-$6,300)
Magnetic (Induction or coil magnetometer)	✓	✓[d]	✓[b]	✓		Low	Low to moderate[i] ($385-$2,000)

Microwave radar	✓	✓[e]	✓	✓[e]	✓[e]	Moderate	Low to moderate ($700-$2,000)
Active infrared (Laser radar)	✓	✓	✓[f]	✓	✓	Low to moderate	Moderate to high ($6,500-$9,000)
Passive infrared	✓	✓	✓[f]	✓		Low to moderate	Low to moderate ($700-$1,200)
Ultrasonic	✓	✓		✓		Low	Low to moderate ($600-$1,900)
Acoustic	✓	✓	✓	✓		Low to moderate	Moderate ($3,100-$8,100)
Video image processor	✓	✓	✓	✓	✓	Low to high[h]	Moderate to high ($5,000-$26,000)

a Installation, maintenance, and repair costs must also be included to arrive at the true cost of a sensor solution as discussed in the text.
b Speed can be measured by using two sensors a known distance apart or estimated from one sensor, the effective detection zone and vehicle lengths.
c With specialized electronics unit containing embedded firmware that classifies vehicles.
d With special sensor layouts and signal processing software.
e With microwave radar sensors that transmit the proper waveform and have appropriate signal processing.
f With multi-detection zone passive or active mode infrared sensors.
g With models that contain appropriate beamforming and signal processing.
h Depends on whether higher-bandwidth raw data, lower-bandwidth processed data, or video imagery is transmitted to the TMC.
i Includes underground sensor and local detector or receiver electronics. Electronics options are available to receive multiple sensors, multiple lane data.

Source: (Leduc, 2008)

MATERIALS AND METHODS

This part provides a more detailed description of the entire system, as well as the critical role and operation of the key components of the proposed design.

Inductive loop detectors

An inductive-loop detector (ILD) detects the presence of a conductive metal item by inducing currents in the object, lowering the loop inductance. A vehicle passing through inductive detectors creates a variable-time signal, which is collected by a circuit. Signals produced by various types of vehicles varies in form, amplitude, statistical features, duration, frequency spectrum, and so on. This signal is known as the vehicle's magnetic profile, and it serves as the foundation for the data processing technique used to classify vehicles.

The inductive sensor is just a coil of wire rope installed beneath a road's asphalt surface and excited by an alternating current. The electric current applied to the coil creates a magnetic field surrounding it, according to Ampere's law. When a conductive object (metal mass) enters the coil's magnetic field, low intensity electrical currents are created in the object's conductive surface. These currents, according to Lenz's law, produce a magnetic field that opposes the magnetic field generated by the coil sensor. This opposition alters the coil's resonance frequency, lowering its external inductance. The electronic circuit that monitors the inductive loops can detect two variations: a rise in resonance frequency or a drop-in signal amplitude on the loop, both of which are related to the variation in inductance of external links. Fig. 1 depicts the total hardware system, which includes four inductive sensors and a limit switch for detecting the tempering of the enclosing box. There is no loop signal interference because the dual channel examines the loops in a predetermined sequence (multiplex mode), allowing just one loop to be active at any given moment. Temperature and humidity changes in loop inductances are automatically compensated.

The saw cut is a key aspect of the loop installation procedure. Typically, a 2-inch-wide blade is used to cut the pavement to a depth of around 2 inches. After that, the slot is washed with water and blasted out using compressed air. This ensures that no sharp particles remain in the slot. To avoid sharp edges from puncturing the loop wire, all square or rectangular loops should have 45-degree cuts. The cut is approximately 8 to 12 inches from the loop's corners. The wire twists are then inserted in the slot's bottom and secured with foam backer rod (See Fig. 2). This ensures that the wire remains in place when the sealant is applied to the slot. Loop wires were twisted at least 6 twists per foot from the point where they exited the loop and started down the lead in slot toward the edge of the roadway. The sealant used in the loop and lead in slot should be flexible and adapt to variations in pavement temperature. To depart the highway, the two wires exit the rectangular loop and are inserted in another slot. The main loop and exit slot wires must be one continuous piece. Splices are not permitted in any portion of the installation. The two wires are twisted around each other at least six times per foot before being inserted in the saw cut that exits the pavement. The sealant is applied to both the saw cut and the main loop. At the concrete pull box, the wires are spliced to the lead in cable. Soldering is required for all splices. The lead in cable is frequently the same loop wire that has been twisted with a drill to achieve at least the 6 turns per foot twist in the wire. To eliminate crosstalk between two or more detectors, all lead in wires must be twisted. Twisting all detector lead in wires for each loop will help to reduce other issues such as street loops with intermittent shorts to ground and/or radio frequency interference from devices unrelated to traffic control devices. Twisted lead in wire is especially critical when lead in wire from various loops is routed back to detectors in the same conduit. The sealant should completely fill the slot all the way to the road's surface. The backer rod's top should be at least 1 inch below the level of the pavement. Fig. 3 depicts inductive-loop installation marking on the road, whereas Fig. 4 depicts tarmac road slot cutting prior to inductive loop installation. Fig. 5 depicts the installation of inductor loop control cards within a data gathering cabinet positioned along a route in the Mwanza region.

When a vehicle completely covers the loop region, the detector will notice the greatest inductance change. In traffic applications where the detection zone must cover a big area, the vehicle detector sensitivity adjustment may need to be slightly raised for loops that cover an area larger than the vehicle's area. For the motorbike to be successfully detected by this huge loop, the detector sensitivity may need to be increased by one or two levels. The amount of wire turns utilized in the loop is mostly dictated by the size of the loop.

When a vehicle passes through ILD, it is counted, and its speed is determined. Knowing the speed, the controller determines the vehicle's length to determine its class. This technique categorizes vehicles into four groups: small vehicles, medium vehicles, heavy vehicles, and motorbikes. The categorization rules are as follows: To begin, this model computes the length of the vehicle with the same occupation, the rate estimated by the standard distance, and the travel time between the first and second sensors. The model then divides the cars into four groups based on their length.

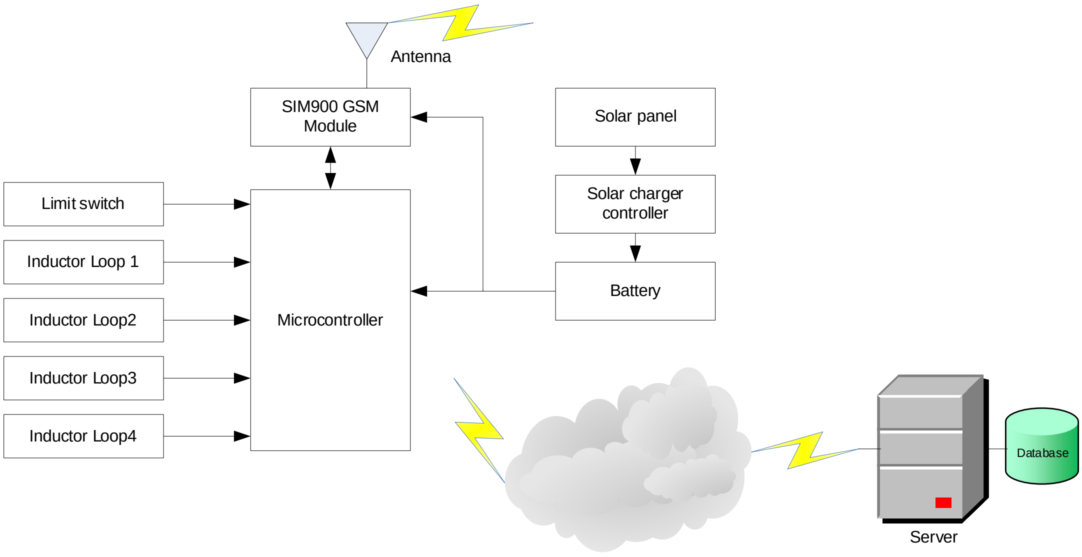

Figure 1: Overall hardware system description.

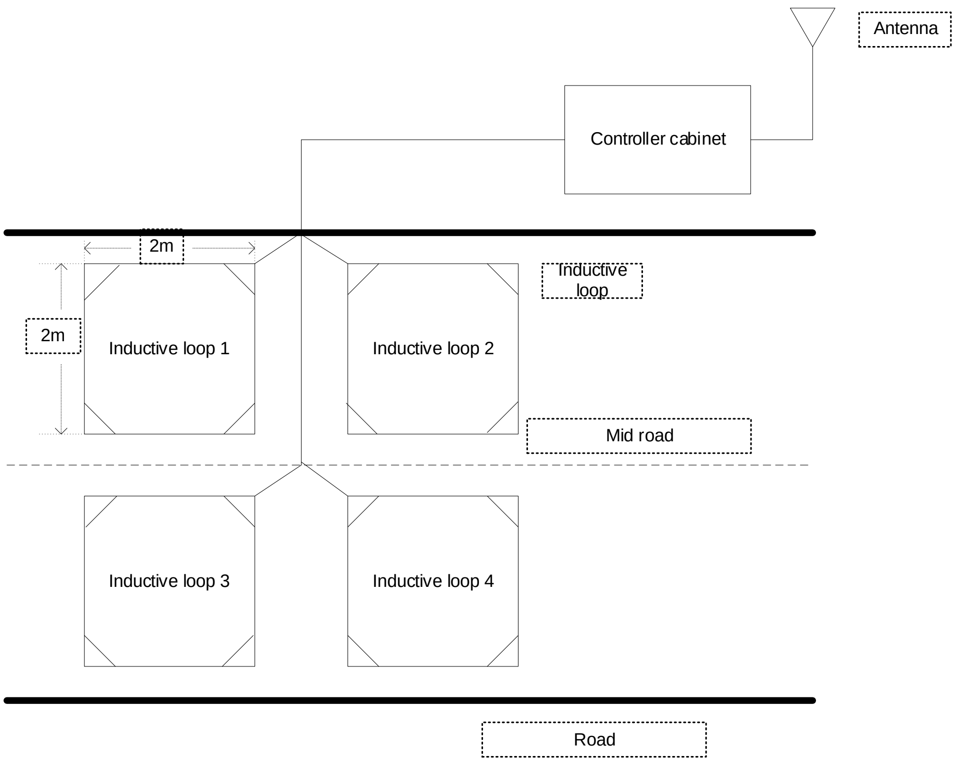

Figure 2: Inductive-loop installation.

Figure 3: Inductive-loop installation marking on the road.

Figure 4: Tarmac soad slot cutting before inductive loop installation.

Figure 5: Inductor loop control box installed along the road in Mwanza region.

GSM Technology

GSM is an open and digital cellular technology that transmits mobile phone and data services over frequency bands of 850MHz, 900MHz, 1800MHz, and 1900MHz. GSM technology was created as a digital system that communicated using the time division multiple access (TDMA) approach. A GSM digitizes and compresses data before sending it along a channel with two separate streams of client data, each in its own time slot. The digital system can handle data speeds ranging from 64 kbps to 120 Mbps. This infrastructure was used to transport data from the counter system's output port to the control center, and a comprehensive telemetry device was devised and created to accomplish this goal.

The following parameters are used to continually measure traffic parameters in real time:

- Occupancy: a time percentage of measurement interval in which a given vehicle remains in the detection zone.
- Traffic count: the number of vehicles traveling through a detection zone in an interval.
- Classification: the number of vehicles moving through each lane depending on the lengths of the vehicles, which includes:
  - Class A (Large): more than four axles
  - Class B (Middle size): Vehicles of medium size.
  - Class C (Small size): Vehicles that are small.
  - Motorcycles (Class D)
  - Speed: the average speed of cars passing in each lane.

Each time interval's measurements are sent in a 54-byte message through an RS232 connection with a transfer speed of 9600 bits per second. The counter module records and stores the time and content of transmitted messages. This device includes a robust backup battery with a 10-year life cycle, reducing the danger of data loss to the bare minimum. The counter records received data in binary format, and the program translates the retrieved data into ASCII text format, resulting in a data file with the "asc" extension being kept in memory. The data messages contain the time, date, ID number, station ID, Traffic Count, Occupancy Rate, average speed, and number of vehicles that went through the detection zone based on the class and location data, as well as the measurement scale utilized.

System power supply

The inductive loop detector electrical system is totally battery powered and does not require any external power supply. Photovoltaic (PV) panels charge the 12V battery. The 12V system consists of a single 60W 12V solar panel connected in parallel to a 12V MPPT solar charge controller. A solar charge controller prevents overcharging of the battery by controlling the voltage and current flowing from the solar panel to the battery.

The control card, microcontroller, and GSM/GPRS module are all powered by a 12V battery. The input voltage range is 4-35V, while the board's trimpot enables for output voltage adjustment between 1.25 and 30V. The regulator reduces the 12 V battery supply voltage to the lower 5V and 3.3V levels required by the microcontroller, GSM/GPRS module, and Analog to Digital Converter (ADC).

Monitoring software

The monitoring software is stored on a distant computer base station that is outfitted with data collecting software. The user interface includes functionalities for comprehensive real-time measurement, control, data processing, display result output, report printing, and other tasks. In each stage, the program continuously listens to the network port and collects received data. The data is subsequently transformed from HEX to ASCII format and stored in a SQL database. All received data is processed in the system database, and the results are provided in data files comprising quantitative values for numerous traffic metrics at 5-minute, hourly, and daily intervals for each lane. In crowded settings, the traffic detector correctly recognizes and classifies vehicle types such as automobiles, trucks, buses, and motorbikes.

RESULTS AND DISCUSSION

The research team deployed inductive loop controller cards and GSM devices and collected real-time data from four sites to evaluate system performance. The results of these experiments give critical information for the proper usage and installation of induction loop detectors on roadways. The experimental traffic count data were evaluated in real-time, and the findings from two sites in the Mwanza region and two sites in the Shinyanga region during a one-year period were reported. The traffic count data was continually changing, as could be seen. An analysis was performed to highlight the system's possible uses and how they increase the benefit when compared to a more conventional method. As a result, significant daily, monthly, and yearly changes in vehicle traffic count occur. Fig. 6 depicts real-time monthly vehicle count data for two stations in the Mwanza region. Fig. 7 depicts real-time monthly vehicle count data for two stations in the Shinyanga region. The curves represent the average monthly traffic count throughout the course of the year. The overall traffic count for sites 1 and 2 in Mwanza throughout the full data collecting period was 427,984 and 231,649, respectively. During the same time, the total traffic count for Shinyanga sites 1 and 2 was 353,514 and 388,679, respectively. Table 3 depicts the statistics data for traffic count for various sites.

Each set of data pertaining to vehicles was collected with high precision. In a set of 771 monitored data, 115 were classified as class A (Long size) vehicles with more than four axles, 147 as class B (Medium size vehicles), 197 as class C (Small vehicles), and 312 as class D (Motorcycles).

The experiment demonstrated that huge vehicles can be spotted with 100% accuracy.

However, there is a little inaccuracy in the motorbike count. This technology is more convenient than existing approaches for detecting vehicles in mixed traffic conditions. Therefore, the minor inaccuracy in counting bicycles may be disregarded.

Table 3: The statistical data for traffic vehicle count in Mwanza and Shinyanga regions

Item	Site 1			Site 2		
	Min	Max	Mean	Min	Max	Mean
Vehicle traffic count (Mwanza)	1019	1072	1054	516	631	572
Vehicle traffic count (Shinyanga)	771	919	871	914	997	957

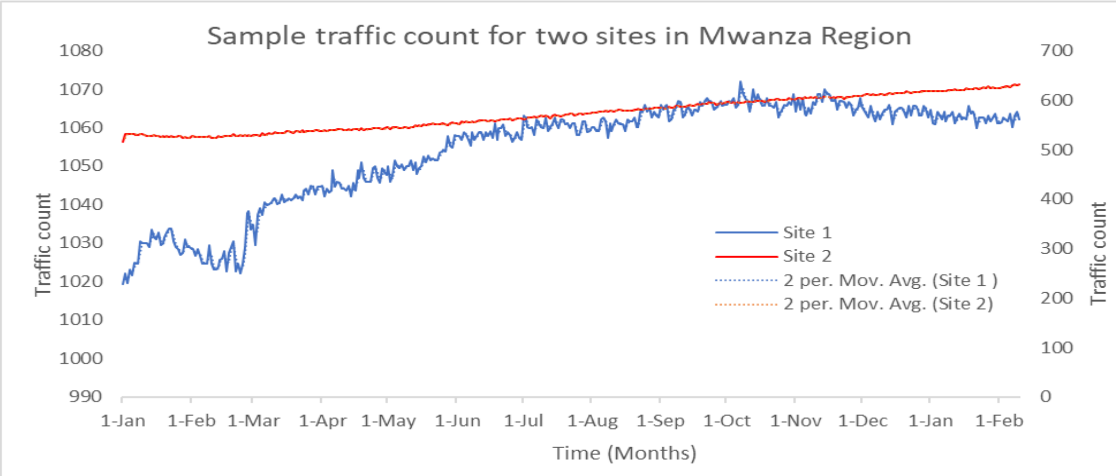

Figure 6: Monthly vehicle count data monitored for two sites in Mwanza region

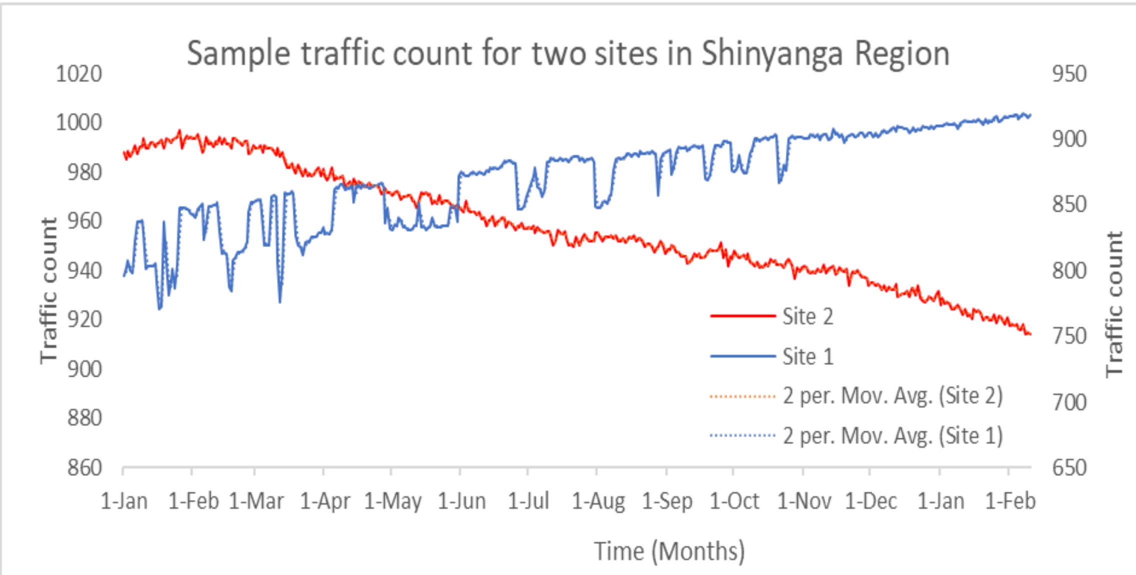

Figure 7: Monthly vehicle count data monitored for two sites in Shinyanga region

CONCLUSIONS

Decisions should no longer be made arbitrarily or without a demonstrable foundation, given the current state of the world, where best practices are being observed in every area.

This research has built and installed inductive loop vehicle traffic counters along Tanzanian trunk roads. The study was successfully completed, and the data acquired is being utilized to regulate traffic roads. Therefore, gathering traffic statistics as a prerequisite is the first necessity for resolving our traffic-related issues. This system will enable government agencies, consultants, and engineers to commence the process of collecting, storing, analyzing, and managing traffic data. The vehicle traffic data gathered by this system will be used to anticipate future circumstances within a transportation system and to keep a record of historical patterns that may be utilized to estimate what might occur in the future based on prior observations and other socioeconomic data derived from census data or economic indicators.

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