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Overview and Recommendations for Road Traffic Data Collection Methods and Applications in Ghana

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ABSTRACT
Precision of traffic data is essential for supporting a large number of transportation-related decisions and is a significant and critical component for many traffic-related researches; and project planning, design, construction, operation, monitoring and maintenance. Historically, traffic data collection methods, both permanent and temporary, have evolved from manual, through mechanical and automatic and currently to complex and intelligent mechanisms in many parts of the world today. Though manual methods may be better suited for certain situations, automatic methods offer several advantages in the areas of accuracy, costs, and safety and are often preferred in such as areawide data collection. That notwithstanding, traffic data and its collection methods, whether manual or automated must be accurate, affordable, easy and sustainable such that every locality can apply the methods in its entirety. Most routine data collection methods in Ghana are still more manual than automated. This paper is a summary of a literature review of traffic data collection methods, advantages and disadvantages, similarities and differences, affordability and adaptation and some Intelligent Transport System collection methods that have been used in Ghana. The paper considers big data and recommends a shift to modern collection methods for an improved, more efficient and effective data for optimum project planning and management in the transportation system.

Keywords – automatic, collection methods, Ghana, Intelligent Transport System, manual, traffic data

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I. INTRODUCTION

Transportation (land, water, air) plays a direct role in poverty reduction, fostering regional integration and enhancing economic development by facilitating income generation activities linked to agriculture and many other sectors [1]. Collecting necessary roadway information has always posed a major challenge for state and local agencies [2]. Thus, it is imperative that traffic data collection related to research and actual implementation of road projects must be based on affordable, accurate, precise and easy collection methods. For many years, routine data collection was not considered important in Botswana for the development and management of the road network until the early 1970's when it realized that a wide variety of information is required in respect of traffic characteristics for proper, planning, design, maintenance and management of the national road network [3.4]. Municipalities of European countries have in the past detected lack of data on urban freight transport [5]. Except for data of HGV traffic counts which are relatively uninformative when attempting to develop suitable strategies and policy measures [6]. Inadequate and uninformative data or lack thereof often results in a limited insight from authorities into transportation operation patterns.

For optimal decision-making practices all over the world, improvements in roadway safety performance, general transportation system design, operation and maintenance, timely, adequate and accurate traffic data is expedient. It is on account of this that national transport policies, guidelines, road designs and maintenance manuals are drawn for the benefit of all road users. As explicitly captured by [7], "a better management of transportation services is an alternative strategy to satisfy the increasing traffic demand". Collecting traffic data has a double function in the decision-making process; providing information for new measures and policies and evaluating the implementation of such measures [4].

The character of traffic is random in nature by time, day, season and even the mood of the road user (driver). The effect of mood on traffic by some researchers has shown a positive relationship [8,9]. That notwithstanding, there are some established defined patterns that make it possible for traffic to be studied. Traffic and highway data needs are many and varied and span over volume studies, travel time and delay studies, spot speed studies, accident studies, parking studies among other studies. An analysis of the data may lead to project design and maintenance, road safety interventions, traffic operations and control and provide statistics for planning future projects that fits into the national transport plan. Data may also be necessary for assessing whether improvements made on the road networks have been effective or not [4].

Conventional methods of traffic data collection include manual with human enumerators and automated magnetic loop detectors such as piezo sensors, induction loops etc., radar technology and image detection technologies using image analysis and machine vision [10]. Traffic data collection by enumerators or human efforts require high demand of personnel who are exposed to road environment hazards and unsafe, harsh weather conditions such as sunburns and inhalation of exhaust fumes. Another disadvantage of the manual method is that it is only about 70-95% accurate depending on the effort invested and is greatly affected by length of survey, time of desired delivery of results, fatigue of staff, etc. making the error rate susceptible to changes in time [11]. The enormity of traffic data required is a determinant to the collection methodology adopted. Whereas larger amounts of data may entail more sophisticated and automated methods, manual methods may be more suitable for smaller data volumes.

Modern data collection techniques include those methods that are intelligent. These methods may be site specific or area wide. According to [10], the innovative Intelligent Transport System (ITS) probe vehicle, which has a GPS receiver embedded in it, is a eat for data collection. Many methods exist under modern ITS technologies. [12] grouped traffic sensor technologies into three broad categories; point sensors, point-to-point sensors and area wide sensors. The researchers [4] noted that point sensors are the most widely used detectors today and they span inductive loop detectors, radar/infrared/microwave/acoustic/ultrasonic sensors, video image detection systems and weigh-in-motion systems [12]. The point-to-point sensors, however, have the ability to detect vehicles at multiple locations as they traverse the network and they have such technologies as Automated Vehicle Identification (AVI), vehicle identification without driver corporation and license plate recognition using CCTV cameras as noted by [12]. [12] remarked that the area wide sensors though still under research looks promising and will involve cell phone and smart phone and Global Positioning Systems (GPS) technologies.

Considering the necessity of traffic data, it has become important over the years to research on the existing methods to settle on those that are affordable, efficient, effective, less time consuming, have fewer disadvantages and limitations over its advantages and most significantly those that give enumerators little or no exposition to dangerous roadway environments. [13] researched on different traffic flow data collection methods to using new technologies in Latvia and elaborated on macro, meso and microscopic methods of data collection.

With series of advancement in traffic and transportation engineering, it is worthy to note that paper-forms or mobile applications requiring manual inputs are still highly used for traffic surveys today [11]. In this study, the authors take a broad look at types, features and applicability of data collection methods, advantages and disadvantages of the different representations and the future of big data with the case of Ghana under consideration. The authors then look into the benefits of standardization of traffic data collection output/templates and prequalification for vendors.

II. TRAFFIC DATA COLLECTION METHODS

Types and Features of Data Collection Methods

The main aim for collecting traffic data is to be able to mimic traffic conditions on the ground to a form that can be analyzed to improve on the existing and future efficient operations of the roadway. Traffic data collection can either be manual, automated, and the use of road sensors in some instances. The manual methods have seen some progress in that there are mobile apps available which incorporates the time intervals automatically and prevents human surveyors in faking the counts during their lunch pause or so [11]. Road sensors are the most conventional and traditional way to collect traffic data but they are costly, disruptive to install and maintain, can be non-operational and give incorrect measurements at any one time, yet, they are an important part of the collection process upon which many cities rely [14]. [15] and [16] split traffic count technologies into two categories thus intrusive and non-intrusive while defining “in-situ” technologies as those using the help of detectors located along the roadside.

i. Intrusive Traffic Data Collection Methods

Intrusive methods consist of a data recorder and a sensor that either use loops embedded underground or tubes that are above the ground within or along the travelled lane. Intrusive methods are cheaper, self-contained, easy to deploy, widely used, acceptable accuracy, axle-based classification and can be deployed on bridges [17]. Amidst these advantages, the intrusive methods also present some serious disadvantages such as disruption of traffic causing safety and performance issues and the lifespan of roadways can be shortened if the intrusive sensor is not installed properly. In addition, it may be unsafe for data collection crews during sensor installation and when the pavement is in poor condition, the sensors may perform poorly and have a shortened lifespan [14]. These devices, located at predefined distance intervals, require frequent calibrations to avoid inaccurate readings [18].

ii. Non-Intrusive Traffic Data Collection Methods

Non-intrusive traffic data collection methods are based on remote observations consisting of small electronic units mounted in weatherproof housing and placed at different locations [17]. They are far easier to install, access and maintain. These methods have the possibility to capture and permanently visually record all desired traffic information. They are highly accurate and can detect in multiple zones. These systems have the ability to work in day and night conditions and can measure direct speeds. However, there are some drawbacks that are worth noting. The installation of above sensors is costly and may thus disrupt traffic flow and their inability to detect traffic in the farther lanes when large multilane roadways are being studied [17].

iii. Advantages and Disadvantages of Intrusive and Non-intrusive Methods

A summary of the advantages and disadvantages of intrusive and non-intrusive methods are presented in Table 1.

Table 1: Summary of Advantages and Disadvantages of Intrusive and non-intrusive methods

Intrusive Methods			Non-Intrusive Methods		
Method	**Advantages**	**Disadvantages**	**Method**	**Advantages**	**Disadvantages**
Pneumatic Road Tubes (rubber tubes placed across road lanes to detect vehicles from pressure changes produced in vehicle tire as it passes)	• Low cost, simple to maintain • Quick installation for permanent/temporary recording of data • Low power usage	• Limited lane coverage • Inefficient for low-speed flows • Efficiency subject to weather, temperature and traffic conditions • Inaccurate axle counting for high volumes of trucks and buses • Air switch temperature sensitive • Cut tubes resulting from vandalism and wear produced by truck tires	Manual counts (Trained observers gather traffic data by the roadside using count sheets)	• Suitable for small data samples • Preferable for shorter count periods • Not sensitive to geometric features	• Security for count enumerators cannot be predicted at night making it difficult to be used at night • Data is less accurate than the automated counts • Susceptible to human error
Piezoelectric sensors (Sensors placed in a groove along road surface of monitored lanes)	• Detect passing of the tire not the vehicle over the sensor • Suitable for measuring weight and speed of vehicles • Differentiates individual vehicles with extreme precision	• Disruption of traffic for installation and repair and failures • Road surface and utility repairs may call for its reinstallation • Sensitive to pavement temperature and vehicle speed	Passive and active infra-red (infra-red detects presence, speed and type of vehicles based on radiating energy from detection area.	• Installation does not require an invasive pavement procedure • Transmit multiple beams for accurate measurements of vehicle position, speed and class • Multilane presence detection available	• Limited lane coverage • Poor performance during bad weather and sunshine
Magnetic loops	• Not susceptible to	• Lane closure	Ultrasonic and	• Installation does	• Affected by tempe

(Loops embeded in roadways to generate magnetic field that sends information to a counting device placed on the side of the road)	bad weather conditions • Not susceptible to traffic stresses	during installation • Short life expectancy • Damageable by heavy vehicles • High implementation and maintenance costs	passive acoustic (use sound waves to detect vehicles by measuring the time the signal returns to the device)	not require an invasive pavement procedure • Can feature multiple lane operation	rature and bad weather • Occupancy measurements may be affected by large pulse repetition periods
Weigh in Motion (WIN) to estimate gross vehicle weight	• Can double as traffic data collection and weight measurements • Higher accuracy than piezoelectric systems • Lower cost than load cell systems • Does not require complete replacement of sensor except refurbishing every 5 years	• Not as accurate as load cell systems • More expensive than piezoelectric systems • measurements	Microwave radar (Detects moving vehicles and speed (Doppler radar))	• Not affected by weather conditions • Gives direct speed measurement • Multiple lane operation models available	• Cannot detect stopped vehicles • Performs poorly at intersections as volume counters
Passive magnetic (Magnetic sensors fixed under/top of roadbed to count number, type and speed of	• Less susceptible than loss to traffic stress • Can be used where loops are not feasible such as bridge decks	• Sensors have difficulty differentiating between closely spaced vehicles.	Video Image detection (video camera to record vehicle number, type	• Sensitive to the vehicle to road colour contrast • High accuracy	• Sensitive to meteorological conditions. • Vulnerable to viewing obstructions, shadows etc. • May
vehicles)			, speed		be susceptible to camera motions • Requires 50-60 feet mounting heights

Source: [15; 19; 20]

iv. 2.1.3 CCTV (Video Surveillance) Data Collection Method

Closed-Circuit Television (CCTV) also known as video surveillance data collection is one of the main back-bone of Intelligent Transport System (ITS). Wikipedia [21] defines ITS as an advanced application which, without embodying intelligence as such, aims to provide innovative services relating to different modes of transport and traffic management and enable users to be better informed and make safer, more coordinated and 'smarter' use of all transport networks. ITS may be employed to improve the efficiency of transport in a number of situations, i.e., road transport, traffic management, mobility, etc. [22].

The term (ITS) refers to information and communication technology applied to transport infrastructure and vehicles that improve transport outcomes, transport productivity, travel reliability, informed travel choices, social equity, environmental performance and network operation resilience [10]. When traffic data is collected by video technology two things are necessary for the data retrieval. The data may be retrieved by playback using a computer desktop screen or by using specialized software that have the capability to transfer the data from the Digital Versatile Disk (DVD) into Microsoft Excel or Statistical Package for the Social Sciences (SPSS) or any analysis package for further analysis.

III. IMPLICATIONS OF POOR DATA

Where insufficient, poor, or outdated data is only available for use by traffic engineers, it limits their abilities to accurately make projections for the efficient management of the traffic operations. The engineer's ability to respond to pressing traffic and transportation needs is therefore limited by the insufficiency of the data as well as evaluation techniques. In cases where there are missing data, mathematical models can be used to estimate the traffic volumes but the issue will always be whether there will be enough accuracy. What then will be the implication of making decisions based on potentially poor or inaccurate data? Where high data accuracy is required, then technical devices must be used [11].

In making selections therefore, the following considerations are necessary; accuracy – especially with regards to the person doing the count, expenses – in cases where the device can have multiple uses, then it may be worth it otherwise reconsider, and purpose of the survey- the data needed and the use must be ascertained.

IV. TRAFFIC DATA TYPE

Traffic data can be categorized into many types usually based on the way the data is collected and the use to which the data is put. Some pros and cons of some counts are enumerated thus:

Traffic/Pedestrian Volume Count: Traffic or pedestrian volume counts determine the count of actual number of vehicles or pedestrians traversing a section of the roadway or persons walking along the roadway [4]. The number can be expressed in terms of actual numbers or passenger car equivalent units and the data can be useful for the computation and assessment of capacity, peak hour, congestion, level of service, volume to capacity ratios. These help to estimate measures of effectiveness of the roadway. Volume counts whether vehicular or pedestrian can be classified or unclassified. The methods contracted for volume counts is dependent on the availability of manpower, technology or equipment, budget and the magnitude of data required and the selection determines the quality of the data obtained (See Table 2).

Table 2: Manual vrs Automatic: Volume Count

Manual	Automatic
Pros: easier on classification, can be used everywhere, no authorization needed, **Cons:** expensive on manpower, sometimes not feasible, changing error rate depending on length of survey, time of desired delivery of results, fatigue of the staff, inability to capture complicated traffic data or patterns **When/where preferred:** shorter count durations, inability to install machines, when efforts and expense on automatic counts are not justified **Accuracy:** between 70-95%	**Pros:** can classify, calculate modal split, counts can be stored, suitable for directional intersection surveys, speed, travel time, time-gaps and exact time of vehicle passage (for more detailed analysis), one person is enough to man the system, ability to capture complicated traffic patterns **Cons:** expensive to install, device has to be protected from theft, requires multiple sensors to capture complicated traffic patterns **When/where preferred:** longer count durations, large amount of data required **Accuracy:** Usually above 95% (affected by quality of input data – video footage)

Source [4]

Intersection Turning Movement Count: this is the counting of pedestrians, vehicles (motorized and non-motorized) passing through an intersection to gather data on the directions of flow such as left turners, right turners, u-turners and those moving through the intersection (see Table 3) [24].

Table 3: Manual vrs Automatic: Turning Movement Count

Manual	Automatic
Pros: easier on classification, can be used everywhere, no authorization needed **Cons:** several enumerators needed hence expensive on manpower **When/where preferred:** shorter count durations, inability to install machines, when efforts and expense on automatic counts are not justified	**Pros:** counts can be stored **Cons:** expensive to install, higher error margin due to differing angles of turn, device to be protected from theft **When/where preferred:** longer count durations, large amount of data required

Source [24]

Accident Studies: When an accident occurs, it is the prerogative of the persons involved in the accident to report the accident to the relevant bodies. An accident is said to have occurred when there is a collision on a public roadway involving at least a moving vehicle which may result in either or a combination of these, damage to property, injury and death. Accident data can be collected and analyzed manually and/or automatically. For manual data collection methods, the accident may be recorded on sheets of paper and should include the causes of the accident represented on a collision or condition diagram. A traffic management center (TMC) may also be employed to automatically record incidences for future analysis. Pros and cons are shown in Table 4.

Table 4: Manual vrs Automatic: Accident Studies

Manual	Automatic
Pros: can include causes of accidents, condition and/or collision diagrams. **Cons:** several enumerators needed for data collation and data entry, hence expensive on manpower, problematic estimates and inferences from under-reporting and under-recording **When/where preferred:** ad-hoc incident management analysis, inability to install machines	**Pros:** accidents are automatically logged on impact, the TMC can record and store data, under-reporting and under-recording can be minimized, reliability of data can enhance academic/organizational research **Cons:** expensive to install/manage/maintain equipment, skilled persons required **When/where preferred:** longer data durations, large amount of data required, where adequate and accurate accident data is required,

Source [17]

Speed Studies: Precise and accurate traffic speed information are critical for road traffic calming measures, passenger and pedestrian protection and general road safety and traffic management. Since speed is a major contributor to road traffic accidents, it is expedient to collect adequate quality speed data for analysis that will inform policy makers. The advantages and disadvantages are in Table 5.

Table 5: Manual vrs Automatic: Speed Studies

Manual	Automatic
Pros: can be used everywhere, no authorization needed **Cons:** enumerator visibility may compromise data quality, data collection inherent with human errors **When/where preferred:** ad-hoc incident speed management, inability to install machines, when efforts and expense on automatic methods are not justified	**Pros:** precise data, data storage simpler, voluminous data possible **Cons:** expensive to install, human errors eliminated **When/where preferred:** longer speed measurements, large amount of data required

Source [4]

Origin-Destination (O-D) Surveys: Origin – Destination surveys commonly referred to as OD Surveys are carried out to determine travel patterns of a geographical area. It basically examines the adequacy of existing routes and establishes alternative routes. The area is usually split into zones. Data gathered is presented as an O –D matrix for use in transport planning. While O-D surveys are mostly manual, there exists the number plate recognition system that is able to do the survey automatically (see Table 6).

Table 6: Manual vrs Automatic: O-D Surveys

Manual	Automatic
Pros: field organization is simple, data can be collected quickly **Cons:** delay to vehicular movement, **When/where preferred:** ad-hoc incident speed management, inability to install machines, when efforts and expense on automatic methods are not justified	**Pros:** time saving, model ready data **Cons:** may be expensive, data may be compromised, **When/where preferred:** precision is required, large amount of data required

Source [25]

V. APPLICABILITY OF TRAFFIC DATA COLLECTION METHODS

The applicability of traffic data collection methods is necessary to help identify when the manual methods may be more suitable than automated methods and vice versa. Interactive data presentation to analyze existing traffic, investigating problematic road locations and times and modelling minor changes in any transport networks (closures, new sections, capacity changes) are all important considerations where applicability is concerned. The traffic data collection method selection criteria must be considered. A selection matrix has been proposed by the authors in Table 7.

Table 7: Data Collection Method Selection Criteria

Criteria	Manual	Automatic
AI-based data capture/analysis		✓
Efficiency/Accuracy of data		✓
Financial Resources	✓ limited	✓ Unlimited/ Available
Availability of Time	✓ limited	✓ Unlimited
Data Usage	✓ Single Use	✓ Multi – Purpose
Data Collection/Analysis Complexity		✓
Danger	✓ Higher risk to enumerators	✓ Higher risk to equipment
Security		✓

VI. TRAFFIC DATA COLLECTION IN GHANA

Data collection in Ghana is largely manual; use of tally sheets with enumerators. No national electronic database (pockets of hard copies may be available) on traffic exists thus the difficulty in obtaining historical data and trends such as AADTs for use in traffic planning operations. A national policy guideline on the electronic traffic database is also non-existent. In addition, traffic study data and reports are not publicly available.

6.1 Traffic Data Collection Agencies in Ghana

The Ministry of Roads and Highways (MRH), established in 1997, is the ministry in charge of road transportation systems in Ghana. The Ministry has three main agencies that oversee the trunk, urban and feeder roads network in the country; the agencies are Ghana Highway Authority (GHA), Department of Urban Roads (DUR) and Department of Feeder Roads (DFR) respectively. The Building and Road Research Institute (BRRI) which is under the Council for Scientific and Industrial Research (CSIR) is a different body responsible for road traffic accident data collection. The Ghana Police Service (GPS) serves as the receptacle for all road traffic related accidents while the National Road Safety Commission (NRSC) serves as a repository for accident data. Traffic data collection is sometimes done by private consultants.

These agencies have the responsibility to plan, design and maintain the roads in their respective jurisdictions and implement road safety activities. The three agencies are therefore responsible for the data collection on all subject roads to aid in the delivery of their mandate. For many years now, data collection methods in the country have been largely manual with enumerators having to stand by the roadside with pencils and tally cards, recording traffic data. Occasionally, the

Police Department uses the speed gun to collect spot speed data on highways as a road safety measure.

Even though most of these technologies are not common in Ghana, a few have been tried. Figure 1 shows pictures of an automatic traffic count done in Kumasi, Ghana using magnetic loops placed on the road surface highlighting loop damage by the vehicle tires as explained in Table 1.

Fig 1: Using Magnetic Loops for Data Collection in Ghana

Pockets of automated data collection have been used in Ghana including video detection methods [23] yet, a larger chunk of the traffic data collection is done manually. This could be because of the perceived associated cost of automatic data collection methods and the data retrieval methods with its associated software costs.

6.2 Issues and Challenges of Data Collection in Ghana

The problems associated with data collection in Ghana include: time consuming; tedious; exposure to harsh weather conditions; high number of human resources required (especially for turning movement counts) and inaccurate data collected when enumerators are visible (Roads Department, 2004). In addition, stressed enumerators may begin to compromise on the precision of the data collected (Roads Department, 2004). The main advantage of the manual data collection method is its initial lower cost but can be counterproductive when large areas for data collection are required (Roads Department, 2004). Further, classification counts may be easier without requiring any adjustments as is the case of the automatic counters.

VII. COMPARING COST OF SOME ITS DATA COLLECTION METHODS

Cost of some available ITS data collection methods are presented in Table 8.

Table 8: ITS Methods: Cost Comparisons

Unit Cost Element	Lifetime (years)	Capital Cost in $1000 (source year)	O&M[1] Cost in $1000 (source year)
Inductive Loop Surveillance on Corridor (ILSC)	5	3.0 – 8.0 (2001)	0.4 - 0.6 (2005)
Inductive Loop Surveillance at Intersection (ILSI)	5	8.6 - 15.3 (2005)	0.9 – 1.4 (2005)
Machine Vision Sensor on Corridor (MVSC)	10	21.7 – 29.0 (2003)	0.2 – 0.4 (2003)
Machine Vision Sensor at Intersection (MVSI)	10	16.0 – 25.5 (2005)	0.2 – 1.0 (2005)
Passive Acoustic Sensor on Corridor (PASC)		3.7 – 8.0 (2002)	0.2 – 0.4 (1998)
Passive Acoustic Sensor at Intersection (PASI)		5.0 – 15.0 (2001)	0.2 – 0.4 (2002)
Remote Traffic Microwave Sensor on Corridor (RTMSC)	10	9.0 – 13.0 (2005)	0.1 – 0.58 (2005)
Remote Traffic Microwave Sensor at Intersection (RTMSI)	10	18.0 (2001)	0.1 (2001)
Infrared Sensor Active (ISA)		6.0 – 7.5 (2000)	
Infrared Sensor Passive (ISP)		0.7 – 1.2 (2002)	
CCTV Video Camera (CCTVVC)	10	9.0 – 19.0 (2005)	1.0 – 2.3 (2004)
CCTV Video Camera Tower (CCTVVCT)	20	4.0 – 12.0 (2005)	
Pedestrian Detection Microwave (PDM)		0.6 (2001)	
Pedestrian Detection Infra-red (PDI)		0.3 – 0.5 (2002)	
Environmental Sensing Station (Weather Station) (ESSWS)	25	29.0 – 48.0 (2005)	1.9 – 4.0 (2004)
Traffic Camera for Red Light Running Enforcement (TCRLRE)		75.0 – 136.0 (2001)	60.0 (2001)
Portable Speed Monitoring System (PSMS)	15	5.0 – 15.0 (2002)	
Portable Traffic Management System (PTMS)		80.0 – 100.0 (2003)	

Source: ITS Unit Costs Database (April, 2019), US DoT. (www.itscosts.its.dot.gov), [1] Operation and Maintenance

The costs in Table 8 were projected to 2019 averages using First Republic Bank historical interest rates in Table 9.

Table 9: Historical Interest Rates

	12 MAT[1] (%)	1 Month. LIBOR[2] (%)	PRIME RATE (%)
Average	3.653	3.664	6.309
Minimum	0.0113	0.0151	3.25
Maximum	8.71	10.099	11.5

Source: Historical Rates, First Republic Bank (April, 2019), (www.firstrepublic.com), [1]Monthly Average Treasury; [2] London Inter-Bank Offered Rate

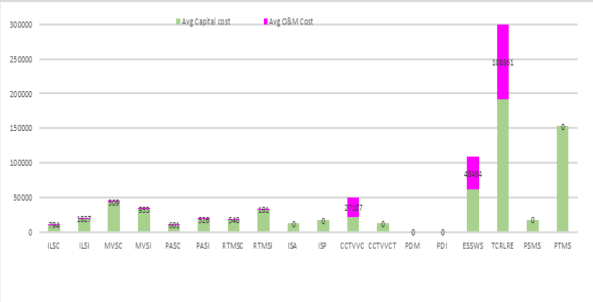

Fig 2: Average Current Capital and Operating and Maintenance Costs of Some ITS Technologies

Most ITS technologies have a combined capital and operation and maintenance costs of about USD 50,000 with an average lifetime of ten years (Fig. 2). This corresponds to a yearly spending of USD 5,000 on ITS technologies by road agencies and data collection institutions if faster, easier, modern, efficient and effective data collection is envisaged.

Selection of traffic data count sites are usually based on a need to count basis which sometimes put road agencies and decision makers in a tight spot. Investing in ITS solutions for traffic data collection will enable road agencies collect year-round data that will positively influence decision making in the transport industry of Ghana. One major justification for this is provided by [12] that ITS technologies provide additional types of data that were previously impossible and too difficult to collect with practical advantages over conventional data collection mechanisms such as lower cost, higher reliability and accuracy.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Advancing Intelligent Transport Systems for Traffic Data Collection: Undoubtedly, Intelligent Transport Systems have many advantages for today's data collection systems. The paper has shown that the capital costs when spread over the equipment/technology lifetime makes economic sense to invest. The authors have mentioned health and safety implications of personnel exposed to harsh weather conditions during manual data collection. It has been noted that enumerator fatigue usually leads to significant error margins in the data collected especially for big data over time. It is also evident that data collection through surveillance methods have gone past conventional loop detectors through video detection methods and available now are numerous emerging technologies. The paper recommends a necessary investment in ITS technologies to enhance decision making and improve on transportation operations management, effectiveness and efficiency.

National Traffic Database Creation: It has also been shown that manual data collection impedes the creation of a national database and accessibility to historical traffic information and patterns while an Intelligent Transport System (intrusive and non-intrusive) have many advantages for today's data collection systems.

Creation of National Traffic Data Collection Guidelines: The authors have also established that isolated project-specific data is available, however, there is no centralized local directory for traffic data and thus recommend the development of a national traffic data collection and analysis guideline to standardize traffic data collection by employing output templates for use by all traffic data collection agencies to ensure uniformity. The Ministry of Roads and Highways is encouraged to collaborate with industry and research partners towards traffic database creation and management.

Drones for Traffic Data Collection: With the piloting of drone technology in other sectors of Ghana, the authors propose that the Ministry of Roads and Highways considers the development of a Policy to gradually shift from manual to automatic data collection methods. Numerous video detection data collection methods and Drone technology have become progressively available and Ghana can explore this for use in the short term. The decision to change from manual to automated methods lie squarely with the Ministry to make it a policy for the road agencies to adopt or comply. It is about time!

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