Intelligent Transportation Systems Infrastructure gap in Nairobi City

James Ogutu Aloo[1]

[1] NAS International Holdings Limited, P.O. Box 7514-00200, Nairobi
[2] Kenya Engineer, Intercontinental Publishers, Nairobi, Kenya
jimogutu@gmail.com

Abstract
Kenya has witnessed an expansion in its transportation infrastructure. Within Nairobi city, commuter rail service has been refurbished and plans are underway to increase its connectivity. The urban road network has improved and introduction of bus rapid transit (BRT) system is underway.
This has necessitated the use of information technology to ensure optimal and efficient utilization of the transportation infrastructure. The Kenyan government for instance has deployed electronic traffic control on certain intersections in order to improve performance and safety. The information technology infrastructure has however been rolled out on a case by case basis and is not being built to fit a master plan that would expand to meet future needs.
This paper uses comparative indicators from government and private agencies' documentation to establish current status of ITS infrastructure capacity and opportunities for improvement. This paper further presents the findings on the gap between the necessary and available qualified personnel, data server resources, control centers, software solutions, communication bandwidth and network necessary for full ITS implementation.
The conclusions and recommendations of this paper address steps that can be taken to establish a foundation for the needed infrastructure for ITS with specific consideration to cost effectiveness, efficiency and data security.

Keywords: Intelligent systems, Internet of Things (IoT), Artificial Intelligence, Smart Cities, Connected Infrastructure

1 Introduction

Nairobi city has witnessed an expansion in its transportation infrastructure. The road network continues to be expanded, the commuter rail transport system has been refurbished and plans are underway to introduce the bus rapid transit (BRT) system. This expansion has necessitated the incorporation of information technology to ensure efficient and safe utilization of the transportation infrastructure. The Kenyan government for instance has already deployed electronic traffic control on some select intersections in order to improve performance and safety for road users. The refurbished commuter rail system has also been fitted with traveler information systems which aim at informing the travelers on a real time basis, the train schedules and expected time of arrivals.

Information technology enables elements within the transportation system including vehicles, roads, traffic lights, message signs to become intelligent by embedding them with sensors, processors, algorithms, and actuators and thus empowering them to communicate with each other through various technologies. These technologies improve transportation system performance by reducing congestion, increasing safety and traveler convenience (Ezell, 2010).Intelligent transportation systems (ITS) has been sub-divided into four main branches based on the relevant implementation in different aspects of transportation management i.e., Advanced Traveler Information System (ATIS), Advanced Traffic Management System (ATMS), Advanced Public Transportation System (APTS), and Emergency Management System (EMS) (Bhupendra and Ankit, 2015).

The roll out of the intelligent transportation systems infrastructure has however been done on a need by need basis and is not being built to fit a master plan that would expand to meet future needs thereby posing the threat of system incompatibility.

ITS requires the development of an integrated communication architecture that provides a common frame for the road and traffic infrastructure, environment and vehicle systems to work together through Information Communication Technology (ICT) in a manner that is both scalable and secure (Das *et al*., 2017). Therefore, the objective of this paper is to investigate the infrastructural components required to build a functional ITS in Nairobi city, and the gap between existing and required infrastructure for a full ITS implementation.

2 Components of an intelligent transportation system

An ITS system consists primarily of; sensors that gather data, a communication pathway that transmits data for storage and processing, a processing unit fitted with algorithms that process data and make decisions, actuators that implement decisions made by the processing unit and software applications that analyses the data and creates a communication interface with the users (Makino *et al*., 2016).

The table below shows the specific applications of each component;

Table 1: ITS components and applications

ITS Component	Items	Applications
Sensors	Traffic & CCTV Cameras Ultrasonic detectors Loop detectors GPS sensors RFID tags Smart phones	Traffic volume count. Red light violation monitoring. Number plate recognition for Origin-destination mapping. Occupancy detection. Travel time surveys.
Data transmission	Fiber optic Ethernet LAN Network WiMAX Low voltage cables	Sensors-controllers communication. Controllers-central control center communication. Controllers-actuators. Communication.
Processing unit	Parking lot management systems.	Processes the data

	Traffic control and Monitoring centers. Intersection controllers	and make decision based on programmed algorithms.
Data storage	Data servers	Store both raw and processed data
Actuators	Traffic lights Variable message signs & display units Parking barriers Variable road signs	Implement the decision made by the control unit and thus control the traffic
User applications	Smart phones applications Electronic payment systems Electronic traffic violation fine systems	Cashless transactions Automated fine systems for traffic violators

These components are integrated to come up with various modes of traffic management systems, depending on the scope and objective of implementation.

3 Methods

In a bid to assess the existing infrastructure gaps for a comprehensive ITS implementation, documents from government agencies such as the Communication Authority of Kenya (CAK), Kenya Urban roads authority (KURA) and the Nairobi County government (NCC) were reviewed and select officials within these agencies were orally interviewed. Literature review on the current traffic scenario and ITS architecture was conducted from published literature available to ascertain the current needs for a functional ITS system. Reports and other documentations from transportation stakeholders and projects relating to research in ITS were also reviewed.

4 Results

4.1 Communication infrastructure

Kenya urban roads authority identified 100 critical intersections that would be connected to the ITS infrastructure (Gauff Consultants, 2017). Based on the list of fiber ready roads and intersections published on myisp website (http://www.myisp.co.ke/fiber-ready-locations/), 92% of the 100 intersections are fiber ready.

The bar graph below displays the fiber ready intersections as a comparison to the total number of intersections selected in various corridors for ITS implementation.

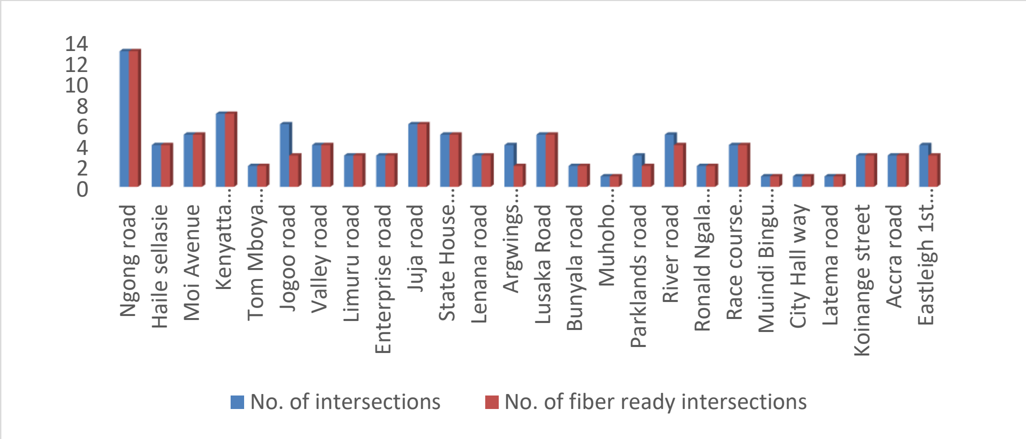

Figure1: Fiber ready status analysis for ITS 100 intersections

As at 2010, 25.9% of the population in Nairobi were reported to be active internet users out of which 27.8% of the users had internet access on their smart phones. 72.8% of internet usage in Nairobi was reported to be for private use and that 91.9% of Nairobi residents owned mobile phones (Kenya National Bureau of statistics, 2010).

Internet access on smart phones relies on cellular network which has a wide and stable coverage within the city due to a massive infrastructural investment by the telecommunications service providers (Malungu, 2014).

A total of forty-two CCTV cameras have been installed within and around the central business district for security surveillance. These CCTV cameras are linked to a central monitoring center for continuous monitoring (Kienyere, 2018).

4.2 Data storage

The traffic data center housed by the Kenya Urban Roads authority has a storage capacity of four terabytes. The servers are used to store traffic data obtained from seven intersections along western ring road which form part of the ITS pilot project. The storage is therefore sufficient for the scope and will be increased to meet the expanding demand. The servers are however not cloud based and are currently strictly for local access by the government agency and therefore not available for third party utilization.

4.3 Intelligent transportation components

The table below indicates the status of the intersections selected for ITS implementation in terms of the available infrastructure.

Table 2: Status of signalized intersections within Nairobi

Status	**Quantity**	**% out of 100 selected junctions**
Unsignalized intersections	60	60%
Signalized intersections	40	40%
Currently functional intersections	34	34%
Fixed time/Isolated intersections	20	20%
ITS enabled intersections	14	14%

Based on an oral interview conducted with the officials from the Nairobi Metropolitan services and Kenya Urban roads authority it was established that the controller technologies deployed on these intersections are from different technology providers with different hardware and software architectures and that the controllers within the CBD were not fully handed over to the county government hence making it difficult to adjust the signal timings and scaling them to adopt new functionalities.

4.4 Qualified personnel

The table below compares the execution of traffic signalization deployment and maintenance works between foreign expertise and local Kenyan expertise.

Task	Quantity	% out of 40 signalized junctions
Intersections deployed by foreigners	18	45%
Intersections deployed by Kenyan engineers	22	55%
Intersections maintained by foreign engineers	0	0%
Intersections maintained by Kenyan engineers	40	100%

4.5 Intelligent transportation systems standards

The Kenya roads board rolled out a program in 2019 to develop a national traffic and travel survey framework to be used by all transportation stakeholders (ttps://www.krb.go.ke/tenders/Revised RFP Traffic and Travel Survey Framework). Once the process is complete, there shall be a framework for data collection and storage thus making traffic data available for analysis and decision making.

Technical standards for ITS components like controllers, communication protocols control software and control logics have not been developed.

5 Discussion

Based on the results of the research findings, Nairobi city has the pre-requisite infrastructural requirements for a successful Intelligent Transportation systems implementation. The results indicate that 92% of the intersections selected for ITS coverage are fiber ready and the other 8% can be easily connected to the fiber network. This indicates that with a phased implementation of ITS across the selected intersections, it will be possible to connect all the intersections to the ITS network to enable them communicate with each other and with the control center.

The results indicate that 40% of critical intersections marked for ITS are already signalized thus already having the necessary structural, mechanical and electrical infrastructure. However, the controllers installed under the Nairobi county government have an opaque technology in which the user cannot modify algorithms and scale the system incase other functionalities are required thereby making them extremely inefficient and may not meet future demands. Controllers are very important aspects of the ITS system, since the algorithms deployed in them make decisions at the local intersection level and therefore must be fully transparent and scalable, properties that these controllers were found to lack.

It was also observed that 91.9% of Nairobi residents use mobile phones and 25.9% of the population are active internet users. 27.8% of the internet users were found to use smart phones. This reality makes it possible to take advantage of mobile phones and smart phones to collect data and relay information of interest to the users.

Public CCTV cameras have been installed on forty-two locations within and around the central business district. The cameras were installed primarily for security surveillance; however, the system can be upgraded so that the system can be used for number plate recognition for purpose of origin-destination mapping and for traffic volume count.

The government through Kenya Urban Roads Authority has created an ITS department with trained personnel and have already developed a strategic plan to roll out ITS across one hundred intersections. The pilot deployment phase which covered seven intersections and a traffic control center is already complete (Gaufa consultants, 2017).

A total of 40 intersections have so far been signalized out of which 55%, were installed by Kenyan engineers and technicians while 100% of the signalized intersections are maintained by Kenyan engineers indicating that there has been a successful knowledge transfer and that further deployments can be successful carried out by local Kenyan expertise

6 Conclusions

The findings of this paper show that the gap that needs to be bridged so that a full ITS implementation can be realized in Nairobi city is minimal but critical. Nairobi city has the advantage of an elaborate internet connectivity which is the very backbone of ITS.

There is also an already existing institutional and strategic framework to handle future ITS works and that makes Nairobi city well poised to efficiently deploy ITS technologies. This paper has identified critical gaps and has given suggestions on how those gaps can be bridged.

7 Recommendations

Fiber optic cables ought to have dedicated ducts in order to reduce vandalism of the cables during road construction and maintenance works. This approach would also assist in maintenance works so as to ensure highly minimized network downtimes.

KURA ought to make the data servers cloud based so that the data is shareable with various authenticated application programs for purposes of data analysis and user engagement.

. The government ought to develop technical and operational standards for all ITS components so as to ensure compatibility across all platforms used. The deployment process should equally be standardized to ensure best practices during deployment and full transfer of knowledge in cases of imported technology.

The government can invest in a mobile application that can be used as a communication interface with users both to collect traffic data and to dispatch information, this would make incident reporting and traffic re-routing faster and more efficient.

In a bid to cut down on future costs on technology, there should be a public-private partnership to engage in a long-term plan of manufacturing certain components the ITS architecture locally. This approach would guarantee cost reduction, data security and national income in the long run

Acknowledgement

The author would like to appreciate the Kenya Urban Roads Authority (KURA) ITS department who furnished me with the relevant information in good time, NAS International Holdings Limited for providing the resources for conducting the research.

References

1. Bhupendra, S., & Ankit G. (2015). Recent trends in intelligent transportation systems: a review. Journal of Transport Literature, 9(2), 30-34,
2. Das, D., Tom. S., & Honiball, J. (2017). Futuristic intelligent transportation system architecture for sustainable road transportation in developing countries
3. Gauff Consultants. 2017. Consultancy Services for The Design, Tender Documentation and Implementation Supervision of An Intelligent Transport System (ITS) And Associated Civil Engineering Works for Nairobi County (Report No. NB-ITS17-009)
4. Kenya National Bureau of statistics. 2010. National ICT survey report.
5. Kienyere, P. (2018). Influence of information communication technology on sustainability of the national surveillance system project: a case of closed circuit television(CCTV) project in Nairobi county
6. Makino, H., Kamijo, S., Shin, C., & Chung, E. (2016). Intelligent Transport Systems (ITS) Introduction Guide.
7. Malungu, C. (2014) ICT infrastructure sharing framework for mobile operators in Kenya
8. Myisp, http://www.myisp.co.ke/fiber-ready-locations , last accessed 2020/11/02
9. Ezell, S. (2010). Intelligent Transportation Systems.