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The Design of a Traffic Management System for Ghana

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Abstract: Traffic congestion has become a menace in Ghana, especially, the Accra Metropolitan Area. Some issues that have been identified as having contributed to this include the rural-urban migration (with its resultant pressures on the planning of the metropolis), the displacement of residents from the central business district (to convert residential facilities there into commercial facilities), the poor road networks, the increasing number of vehicles, poor timing of traffic signals, and attitudes of road users. This project analyses the ICT intervention required for monitoring traffic on Accra roads with possible extension to other roads in Ghana. The methodology used includes reviews of various existing Intelligent Transport Systems of which Traffic Monitoring System is a subsystem, identifying what exactly constitutes congestion on the case study corridor, translating the identified problems into a network vision resulting in the design of a Traffic Monitoring System Architecture. Analysis is made of the data capture required, the issuing of alerts via Message Signs to road users, the communication network infrastructure and the associated facilities for multimedia data storage and retrieval. Considerations of collaborations with agencies for traffic incident management on the corridor to ease congestion has been analysed as well as the security implications of the various stages of the design.

Key words: Ghana road management, intelligent transport systems, traffic congestion, traffic monitoring, traffic system design

INTRODUCTION

Transportation systems are reaching the limits of their existing capacities due to the increasing demand for transportation worldwide. Traditionally, traffic management is local, usually without considering the effects on the rest of the transportation system or other side effects. In most cases, highways and urban roads are operated and maintained by different road managers. These road managers are only responsible for their own part of the network and do not have the incentive to cooperate. And in many cases, there is no ICT integration in their various aspects of traffic management (Berghout *et al*., 2002).

In this project, we investigate the extent to which ICT can be used in traffic management on roads in Accra, Ghana. The Tetteh-Quarshie-Ako Adjei (Sankara) Interchange Corridor, (hereafter referred to as the "Corridor") was used as a case study, with possible extension to the rest of the road networks in Accra. The project analyses and designs, conceptually, the various components implemented in a Traffic Monitoring System (TMS): the software, hardware and network infrastructure, data capture and storage/retrieval technologies, all aimed at managing the traffic on the Corridor by monitoring and alerting road users through Message Signs for road safety and traffic control (Dankwah *et al.*, 2011).

Accordingly, we find out what constitutes traffic congestion on the Corridor, what the related problems are, what form of traffic management is currently being used and what Traffic Monitoring System can be designed for the Corridor. The following questions arise for consideration, analysis and implementation for our system design:

- What services can be used in traffic management on the Corridor?
- What kind of data needs to be captured and how should it be done?
- How can real-time captured data be sent to the traffic management centre?
- How will the data be stored for analysis retrieval and archiving for future referencing?
- How can the data be processed for traffic control on a message sign?
- What are the security needs?
- What standards are available for TMS?
- What is the cost benefit analysis?
- Can the TMS for the Corridor be extrapolated to other road networks in Ghana?

THE BASIC CONCEPT OF A TMS

Traffic congestion may be defined here simply as having more vehicles on the road than the road was

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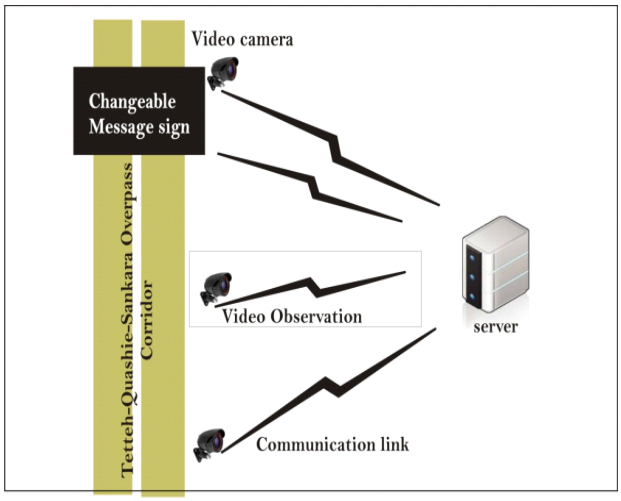

Fig. 1: Basic concept of ATMS

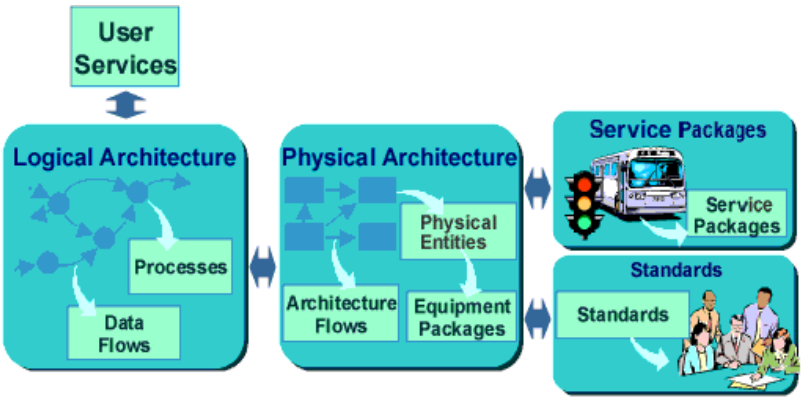

Fig. 2: ITS architecture framework (Transport Canada, 2010)

designed for. A temporary congestion may occur due to incidents such as an accident on the road, a stalled vehicle, two or more road users fighting on a road, a malfunctioning traffic control device such as a traffic signal, the police on traffic duties, etc. A permanent congestion may occur when the road has exceeded its designed carrying capacity, when proper traffic control devices are not used, when a traffic control device is wrongly used, (for instance, when a traffic signal is poorly timed), or a design flaw (such as the termination of a four lane traffic into a two lane traffic) (Baffuor, 2011).

Baffuor (2011), writes about traffic congestion in Ghana and indicates that in Accra the road network is inadequate, the traffic control devices are archaic, and the driving public is ignorant of traffic rules. Figure 1 shows the basic concept of the design of ICT infrastructure for traffic management by video monitoring (with respect to the Corridor). Information captured from the Corridor using video detection methods will be transmitted to the Traffic Monitoring Centre via appropriate communication media. Management will be done by the display of alerts on various message sign posts. Collaborating organisations such as the Fire Service Authority, the Police, etc. will be alerted for intervention where appropriate.

Intelligent Transport Systems (ITS): Traffic monitoring may be considered as a subsystem of Intelligent Transportation. As such, the general principles of Intelligent Transportation Systems (ITS) would form a good basis for modelling a Traffic Monitoring System. Our study is thus, aligned according to general ITS architecture principles. Intelligent Transportation Systems can be defined as the application of advanced sensor, computer, electronics, and communication technologies and management strategies - in an integrated manner - to improve the safety and efficiency of the surface transportation system. Highway traffic monitoring may hence be subdivided into sensor technology, data

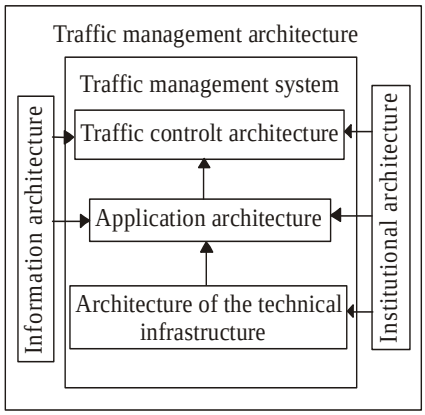

Fig. 3: The Dutch TMA

Fig. 4: A variable message sign

recording and transfer, and data sampling and analysis. (Gardner, 2011; Hendrickson and Ritchie, 1998).

ITS architecture: For the operation of interrelated systems, an ITS architecture defines user services that ITS subsystems and applications are expected to perform, the entities in which these functions exist and information / data flows that connect the functions and entities (Transport Canada, 2010). ITS subsystems are individual pieces of the overall ITS that perform the particular functions. Information flows define information that is exchanged between subsystems (such as traffic information, incident information, or surveillance and sensor control data). Many ITS standards and architecture have been written to make these subsystems and interfaces consistent.

Traffic control architecture processes start with defining the common traffic management targets for a specific region, indicating the problems to be tackled, and translating these into a traffic control strategy for the participating organisations (like the police, ambulance service providers, fire officers, etc) in that region. This control strategy should unite the separate targets that these participating organisations want to achieve in that region. It must therefore balance the needs from all road users and the objectives of all road authorities.

ITS architecture framework: ITS system architecture can be generally represented by Fig. 2. The User Services are the target services which the ITS system and applications are expected to deliver. The Logical Architecture seeks to clarify all the processes, data flows, and data stores between users and systems. The Physical Architecture defines all subsystems, equipment packages, architecture flows and their connections with the Logical Architecture components. The Service Packages are the packages and their relationships to the various subsystems and equipment packages, and Standards safeguard interconnectivity and interoperability of the various subsystems in the Physical Architecture (Transport Canada, 2010).

The Dutch traffic management architecture: Henk *et al*. (2008) elaborates on traffic monitoring architecture using the Dutch approach and identifies the main difference between it and others, such as the US National Architecture, the European KAREN Architecture and the Japanese HIDO. From his point of view, the Dutch approach is more user-oriented as compared with the more technological-approach of the others.

The Dutch Traffic Management Architecture (TMA) consists of five sub-architectures, each describing one aspect of traffic management (Fig. 3). The Traffic Control Architecture defines the traffic management measures while the Application Architecture integrates the hardware and application software. The ICT services are described by the Architecture of the Technical Infrastructure. The Information Architecture deals with the exchange and use of information and the Institutional Architecture relates organizations/institutions required to facilitate traffic management.

ITS data capture, handling and messaging: Field devices included in a TMS project can vary tremendously. Once the types of equipment have been chosen, the next step is to decide on the best and optimal placement for each device and good maintenance plans. Some considerations taken include traffic volume and highway interchange/intersection density.

For data capture, Closed Circuit Television (CCTV) Cameras and Digital Video Encoders (DVE) are used for monitoring traffic and confirming incidents (Mimbela *et al*., 2007; Thomas and van Berkum, 2009). They are typically installed along congested highways or at specific intersections. The camera video is transmitted to the TMS Control Centre where operators will view the images for indications of problems on the roadways and verification of incidents. The operators then use this information and deliver to users what pertains on the road for them to make informed decisions to choose other road indications of problems on the roadways and verification

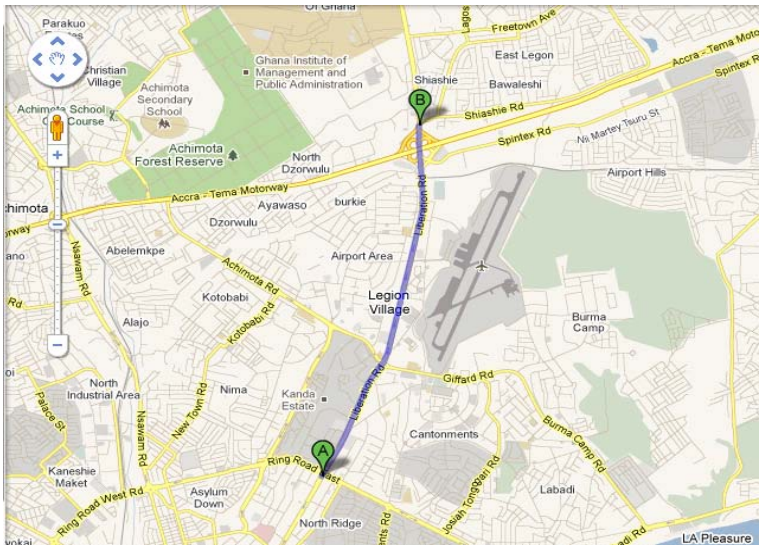

Fig. 5: Google earth map TTQ- Ako Adjei corridor

of incidents. The operators then use this information and deliver to users what pertains on the road for them to make informed decisions to choose other road alternatives. Issues considered during the site location process of CCTV cameras include visibility, quality of coverage, electric power sources, possible obstruction from surrounding trees or buildings as well as maintenance.

Apart from cameras, vehicle detection systems may also be used to sense pedestrians and vehicles. Data from the detectors are transmitted to the Control Centre through communications networks for road incident management. Detection systems can calculate traffic characteristics such as volume and speed. By detecting anomalies in traffic flow, like unexpected reduction in speed or flow, the systems provide input to traffic operators who use the information to identify and address incidents (Knibbe *et al*., 2005). With vehicle detection, the most useful information is gathered when each lane is detected individually. Vehicle detectors are of either intrusive or non-intrusive types. Intrusive detectors are installed directly in the roadway pavement and include inductive loops or micro loop probes. Non-intrusive detectors are installed off the roadway and include ultrasonic, acoustic, infrared, microwave, radar, and video image detectors. Cost is a major factor in determining which lanes have detection devices at each location. Having detection on all lanes provides the most traffic information and guarantees that all vehicles in a lane are detected.

The objective of a Traffic Monitoring System is to keep track of activity on the roads. Data captured by the system has to be modelled, analysed and presented to the road users in such a way as to enable them make predictive and informed decisions. The analysed data is relayed to t he user through Variable Message Signs (Fig. 4). A Variable Message Sign is an output field device used to convey information to motorists about events. Their primary purpose is to alert vehicles of congestion or an incident on the upcoming segment of roadway. Such signs warn of traffic congestion, accidents, incidents, roadwork zones, or speed limits on a specific highway segment.

VMS may also ask vehicles to take alternative routes, limit travel speed, warn of duration and location of the incidents or just inform of the traffic conditions. VMS are typically located in advance of major interchanges where diversion may need to take place, and at intermediate points between major interchanges. These may include high crash locations, interchanges and in the median on multi-lane roads (Arash *et al*., 2009).

A control centre is often set up where the ITS monitoring, data handling and messaging are done. Responsibilities (which depend on installed devices) may include monitoring CCTV camera images, posting messages on VMS, issuing of alerts, incident data updates in database and traveller information. Monitoring and control may be done from multiple locations, including laptops, individual offices, and the control centre.

ITS security: There are security needs required for all stages of ITS Architecture development. These include the areas of Service Design (to make sure that the security objectives are met), Functional Requirements (to protect the confidentiality, integrity, and availability of the connected systems and the data that will pass between them), Interconnections (to protect the interfaces between ITS elements), and Information Flows (to safeguard information flow when the systems are integrated) (Transport Canada, 2010).

Accra TMS design :Coming now to the main objective of our project, we have adopted the Dutch Traffic Management Architecture (Henk *et al*., 2008) for the design of the Accra Traffic Management System (ATMS). The methodology adopted involves the study of what constitutes congestion on the Corridor, the analysis and design of a Traffic Monitoring System Architecture, the design of the data capture system, an analysis and design of the required network infrastructure, consideration of data storage and security considerations for the system.

Causes of congestion on the corridor: In order to define the ICT services to be provided by the TMS for the Tetteh-Quarshie - Ako-Adjei Corridor, it is important to first investigate what exactly constitutes congestion there. The Corridor is situated within the Accra Metropolitan Assembly (AMA) administrative jurisdiction and it has a travel distance of about 6.5 km with nine major traffic intersections (Fig. 5).

According to Ralph (2004), employmnt needs and urban migration have brought pressure on Accra and its environs resulting in problems of housing, development control, transportation and traffic management, etc. Since inner city residential areas are converted into commercial centres, people tend to settle kilometres away and commute to work, leading to traffic congestions, especially at various entry points into the city. Furthermore, there are many small passenger-capacity vehicles, private cars, taxis and mini buses (locally called *trotros*) plying the roads of Accra. Various factors have been identified as causes of congestion on the Corridor.

Road network effects: A common phenomenon is that, road users shy away from one road link at a time supposing that there is less traffic on another. This sometimes results in the dreaded road being free and traffic congesting on the other. Secondly, all road networks that diffuse traffic from the central business district and must interchange at the Corridor seek the closest possible entry to the interchange, thereby jamming that entry point. This has the end effect that during prime times, traffic is seen to be heavy in one direction and light or empty in the opposite direction.

Timing of traffic lights: Inadequate timings at traffic intersections create temporal build-up of traffic; traffic does not clear from intersections fast enough for others to have their right of way. Secondly, insufficient timing at pedestrian crossings at double lane roads gets pedestrians caught midway on the road. Sometimes the pedestrian volume is more than the capacity of the signal and all of them want to cross the road at that instance. Drivers have to stop or reduce speed in order to wait for them.

Attitudes of drivers: In Accra, various bad attitudes of some drivers cause other drivers to reduce speed and thereby cause traffic jams. Examples of these include: disregard for traffic signals (especially by motor cycle riders), use of road shoulders during traffic jams and then attempting to join the traffic, delays in take off, (either through lack of attention at the wheel or the roadworthiness of the vehicle, sluggish takeoff of vehicles when the lights turn green resulting in less number of vehicles crossing than the design capacity), driving in wrong lanes and forbidden turns (e.g., a vehicle in an outer lane attempting to leave the intersection through a left turn resulting in the hold-up of traffic until such a vehicle manages to leave the scene), inter-driver conversation or quarrels, (e.g., drivers stopping side by side on the road to either converse or quarrel), flouting of road regulations and non-adherence to road signs, driving under the influence of alcohol, wrong parking, etc, all these force other drivers to reduce speed thereby causing traffic congestion.

Attitudes of pedestrians: At pedestrian crossings, some pedestrians tend to cross the road when they do not yet have the right of way. To avoid accidents, drivers have to reduce speed and thereby cause traffic jams.

Other road incidents: Other incidents that force drivers to reduce speed and thereby cause traffic congestion include cases of vehicles breaking down in mid-stream traffic, occasional cases of vehicles on fire, disturbances from street hawkers, cart pushers and commercial activities.

ICT services for above factors: Some ICT services required to manage the above congestion causing factors include:

- Traffic situation reports (including congestion, vehicle speeds, broken-down and unwarranted stationary vehicles), traffic information and route guidance may be given via Variable Message Sign (VMS) and other methods. Route guidance may be via SMS, e-mail, or mobile telephony to drivers. Information may also be provided via website, telephone or radio. There may also be pictorial view of traffic via mobile web services.
- Dynamic signal control methods of traffic lights with override facilities from the Traffic Monitoring Centre may be needed for effective signal timing.
- Video imaging and remote vehicle identification methods may be used to monitor attitudes of drivers and incidents. Lanes may be monitored (via CCTV) to ensure proper usage.
- Pedestrian presence detection methods may be used to allow crossing and also to ensure safe pedestrian clearance from the roads. Misconducts may be monitored by video and reported to the law enforcement agencies for action. ICT can also be used to assist pedestrian crossing.

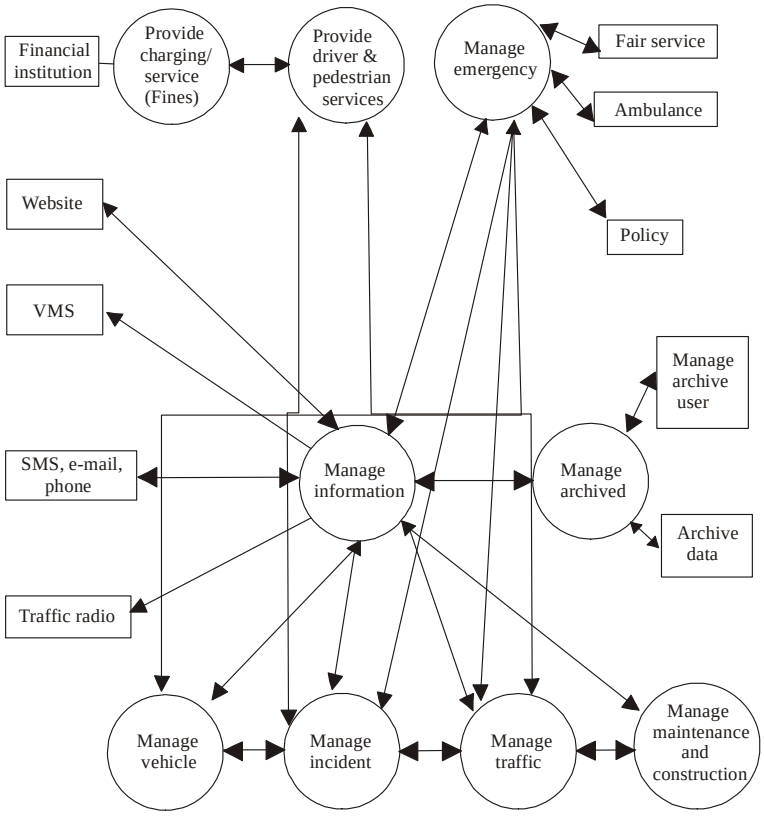

Fig. 6: ATMS logical architecture

Table 1: High level user services

Manage traffic	Manage incident	Manage emergency
-	-	Manage maintenance
-	-	Manage flouting of road regulation Legislature
-	-	Manage archives
-	-	Manage fines
-	-	Manage information
-	-	Manage pedestrian
-	Manage signalling, etc	Dynamic signalling, etc, etc.

- Monitored data may be stored electronically for present use and archived for future reference. This will enhance road-safety campaign and driver/road user education.

ATMS ARCHITECTURE DESIGN

The procedure of constructing a system architecture for the Accra Traffic Management System (ATMS) is to:

- Define the details of User Services
- Construct the Logical Architecture
- Construct the Physical Architecture
- Prepare Standardization Candidate Areas (Ghana Highways Authority, 2009)

Defining ATMS user services: Defining User Services is to identify the details of user-related activities to be analyzed for constructing the logical architecture. The methodology applied here is to translate the congestion factors identified and the ICT services required into a network vision. Various action points are grouped and sub-grouped. For example, since we are in a Traffic Monitoring System, all processes have a central target of "Manage Traffic". "Manage Incident" is a subgroup of "Manage Traffic". "Manage Emergency" is a subgroup of "Manage Incidents". The Police, Fire Service Authority or Ambulance Service is alerted to act on emergency. Thus, for example, given a fire emergency situation, the User Service data flow would be: Manage Traffic -α Manage Incident -α Manage Emergency -α Manage Fire -α Report to the Fire Service Authority The management of Incidents affects the management of Traffic. Emergency information received requires emergency action on it and will also affect traffic management. An alert to Fire Service Authority would be required to be responded to by them. This action also, ultimately, affects traffic management. This methodology would be followed through for all the ICT services resulting in a data table as in Table 1.

Table 2: Lower level user services

Manage emergency	Broken down vehicles	Report to the appropriate authorities
	Manage accidents	Report to the police
	Manage fire	Report to the fire service authority
	Manage route request	
	Over stayed stationary vehicle alerts	Appropriate authorities
Manage maintenance	Manage Information	Road user notifications
		Road agencies notification
Manage flouting of road regulation	Careless driving	Police
	Delays in take off	
	Driving in wrong lanes and forbidden turns	
	Driving on road shoulders	Police
	Inter driver conversation	Police
	Jumping of red light	Police
	Manage street hawking	AMA
	Manage vehicle	Detect over speeding
		Number plate Identification
	Other road regulations	Police
	Wrong parking	Police
	Unwarranted cart pushing	Report to the appropriate
Legislature	Financial institution	Charging/payment of fines
Manage archives	All processed data	
	Manage archive users, etc	Traffic monitoring center Staff
		National security
		State protocol
		Ghana fire service authority
		Ghana police
		Accra itan authority etc

All starting group headings, e.g., "Manage Traffic", are aligned in the same column. All items in the third column that have further extensions are placed in another subgroup as shown in Table 2. This process continues until every translation reaches its final action point. ATMS logical architecture: The ATMS logical architecture aims at explaining the configuration of services, without worrying about how it will get done. It would take the form of a series of Data Flow Diagrams (DFDs) which would clarify information flows between the user services identified above (Table 1 and 2), ie. the users and sub-systems and how they would be processed in order to offer each specific service. Figure 6 shows the DFD for the Corridor logical architecture. Logical processes are shown as circles, entities as rectangles and data flows as arrows.

ATMS physical architecture: A TMS Physical Architecture is achieved by making a common combination of the functions (taken out in the Logical Architecture) and the information (processed in the functions among specific User Sub-services) in order to integrate the entire system (Atsushi and Teruyuki, 1999). Based on the Dutch Architecture, we realize the Physical Architecture shown in Fig. 7. The analysis of the causes of congestion (on the Corridor) and the ICT services required to deal with them have yielded an architecture in which stakeholder organizations (such as the Fire Service Authority, Police Service, Ambulance, etc) would be required to collaborate in various ways to ensure free flow of traffic on the Corridor. The implementation of Information Architecture is to receive needed information and disseminate information for traffic management on the Corridor (Terry, 2008).

ATMS standards: The various architectures can be looked at as separate modules which could be implemented singularly or decentralized at various segmentations of the road network, most likely in regional traffic control centres, to link seamlessly to a national traffic management centre. As such, for interoperability, standards would need to be adhered to at various stages of the detailed design of the modules in the ATMS architecture. The Dedicated Short Range Communication (DSRC) is a basic standard for all vehicle communications that needs to be implemented in a system architecture (ITS Standards Advisories, 2003).

ATMS architecture analysis: Considering both the logical and physical architectures (Fig. 6 and 7), one can make the following comments regarding the Ghana road situation.

- Passing of laws and by-laws regarding offending road users is the prerogative of the Accra Metropolitan Authority (AMA) and the Ghanaian Legislature.
- Offensive attitudes of drivers and pedestrians and all incidents relating to violation of road user regulation would be reported to the Police for redress.

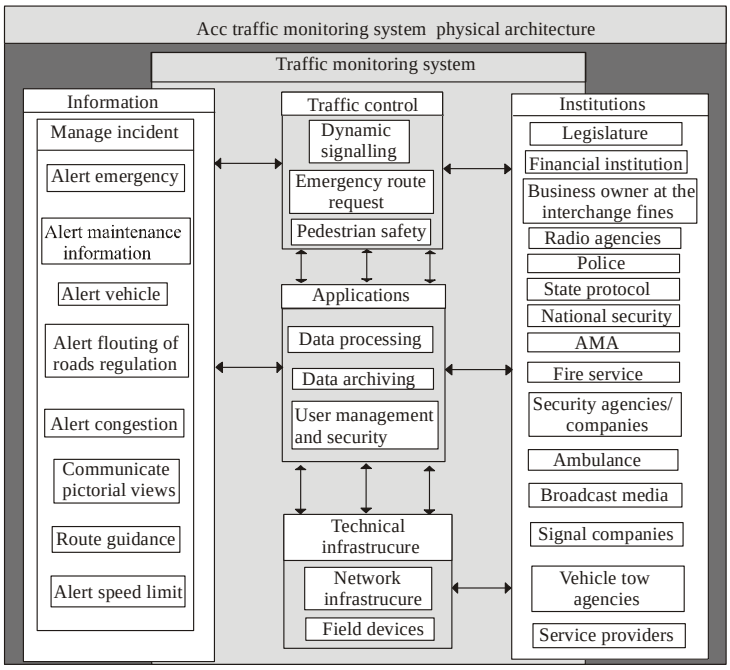

Fig. 7: TMS physical architecture

- Any form of fire incident is required to be relayed to the Fire Service first. The Ghana Fire Service Authority would be responsible for the organizational framework needed to discharge calls to attend to fire incidents. This may include a call to the Police or Ambulance Service or any other collaborative organization.
- All road accidents not involving fire would be directed towards the Police Service for attention. Any further required collaboration such as with the Ambulance Service would be the responsibility of the Police accident response mechanism.
- Vehicles that have been stationary over a stipulated period of time would be reported to the Police. However, vehicles that have broken down would be reported to the AMA's existing institutional collaboration for towing vehicles off the road.
- The receipt/dissemination of information from / to road users culminate ultimately in traffic control and thus have a relationship with Traffic Control Architecture.
- Information received form road users either via SMS, phone or website does not directly affect Technical Infrastructure. It, however, affects processing of information (Application Architecture) and traffic control (Traffic Control Architecture). Institutions such as signal companies who carry out installation and maintenance of traffic signalling devices would be required to interact with the Technical Infrastructure.
- The Traffic Management System Architecture would make use of an Application Infrastructure which receives information from road users, organizations and the technical infrastructures and process these to disseminate information to the road users and organizations.
- All organizations involved in this ATMS design would constitute an Institutional Architecture; the road network, signalling equipment and devices, communication network infrastructures, data capture devices and Variable Message Signs will constitute the Architecture of Technical Infrastructure.
- All information inflow and outflow would constitute the Information Architecture.
- The Application Architecture would comprise application programs needed and the hardware to go with them, data storage, archiving and retrieval, and access control.

ATMS data capture: The data capture system in the ATMS for monitoring the Tetteh Quarshie - Ako Adjei Corridor analyses various technologies for gathering data relevant to the effective monitoring of the Corridor. The planning and design of this data capture system involves a closer look at the Corridor. Before a new TMS component can be installed, it is important to know the components already existing in the vicinity. The "vicinity" may be considered as the Corridor itself and 200m along the major road that crosses it (Fig. 5). Traffic conditions on these major roads may influence the operation of the TMS on the Corridor and therefore affect

the design of the TMS. In addition to knowing the location of these existing elements and field devices, it is also useful to have some information about their mode of operation in order to make sure that any new devices would be compatible with them if integration is envisaged. The main components identified are as follows:

- **Manage incident:** Of concern here is the use of vehicle detection systems to capture and check over-speeding vehicles, wrongly parked and stationery vehicles on driving lanes, jumping of red light at traffic-light controlled intersections and driving on the shoulders of the road. The appropriate devices required to manage incidents must be selected, taking into consideration factors like the nature of the road, pavements design and others such as environmental and electric power needs.
- **Manage information:** To make direct inputs in the information gathering of incidents on the Corridor, there would be the need for toll-free telephone hotlines, E-mail addresses and SMS alerts, etc, for the public to provide any information on any incident they observe, directly to the ATMS Control Centre.
- **Manage pedestrian:** Pedestrian behaviour on the Corridor would have to be monitored by CCTV cameras. Video images would need to be captured to analyze pedestrian behaviours to find out whether they cross the road at the approved pedestrian crossing points, as well as other pedestrian misconducts and incidents (like unwarranted cart pushing in lanes and street hawking).

Manage emergency: Again CCTV cameras may be used to capture and confirm emergencies such as vehicle collisions, fires and other accidents.

ATMS messaging: As stated earlier, data captured by a Transport Monitoring System has to be modelled, analysed and presented to the road user through Variable Message Signs (Cheng, 2002). In our Accra TMS, the VMS system will present predicted information on the following road conditions among others; the time of the day traffic is most prevalent, the rate of vehicular traffic on the Corridor, the category of incidents that occurs in the Corridor, the most prevalent incidents, the rate of accidents and the types of vehicles involved in the accidents. The VMSes will also provide information about the following; alternate routes, crashes, stalls affecting normal flow in a lane or on road shoulders, debris on roadway, vehicle fires, short-term maintenance works, pavement failure alerts, travel times and variable speed limits.

Several locations may be marked for the mounting of VMSes. Location points may include high crash locations, interchanges, on multi-lane roads with sufficient median width (signs may be placed in the median for additional visibility). One would need to choose a site prior to major route decision points (e.g., ramps and highway-to-highway interchanges) so that drivers may take alternative routes. Signs should be placed where they are visible long enough, irrespective of weather conditions. Also the VMS site should be safely accessible to maintenance vehicles, should the need arise (Rämä *et al*., 2001).

ATMS NETWORK DESIGN AND ANALYSIS

The design of a Traffic Monitoring System will require the transfer of captured live images and other statistics from strategically positioned input devices such as CCTVs and sensors on the roads. These images and statistics are then monitored, stored and analysed at the Traffic Monitoring Centre and deductive information further displayed on Variable Messaging Sign (VMS) devices for road users to make informative decisions. The Traffic Monitoring Centre, based on captured road incident will liaise with other relevant authorities and aim at controlling, managing and providing road users an efficient communication network.

Network architecture and logical topology: With reference to the Tetteh Quashie - Ako Adjei road network, the logical topology of the network design will have all data traffic converge and leave a central point, which is the data processing centre of the Traffic Monitoring Centre (TMC). The topology adopted will be more of a star logical topology. Data captured from CCTV cameras, sensors, and road user incident reports are all sent to the Data Centre of the TMC by network communication links (Fig. 8). Based on the combination of the chosen transmission media and technology, a broadband connectivity can be obtained to link the TMS.

Broadband connectivity speed is normally faster than a typical dial-up modem (Corning, 2005) The deployment of a broadband infrastructure thus facilitates faster and bigger capacity data, audio and video transfer support, of speed 2 Mbps and beyond, across the Internet or on any wide area network setup. The Traffic Monitoring System will use broadband network connections between the edge network input devices (such as video and image capturing CCTV cameras) and the central servers at the traffic monitoring centre. Various transmission media are however, suitable for this communication, including open wire, twisted pair, coaxial cables and optical fibre 41.

In Accra, various network design options are possible for this vicinity, including the use of Next Generation IP base networks, ADSL technology on PSTN lines, WiMax wireless communication, Cellular connectivity (3.5G),

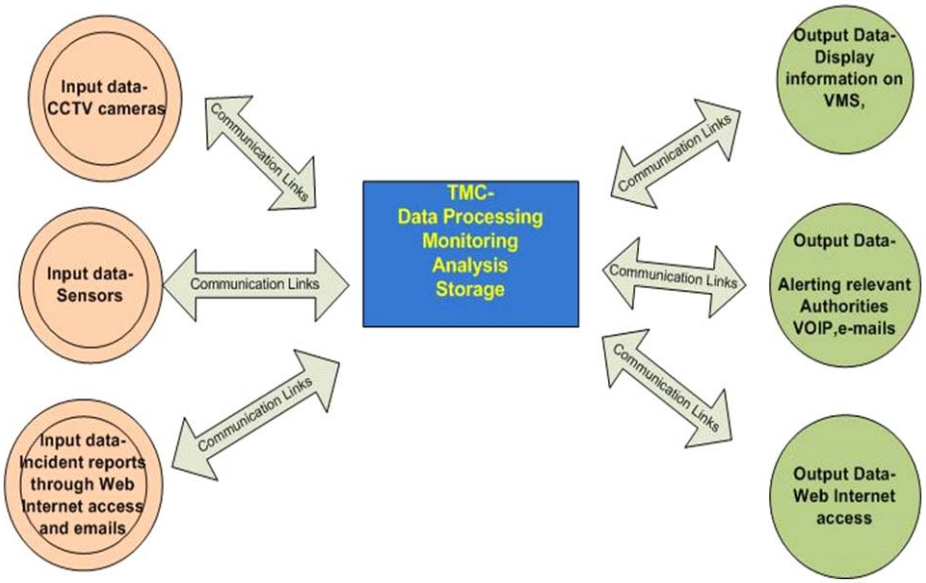

Fig. 8: Logical network topology

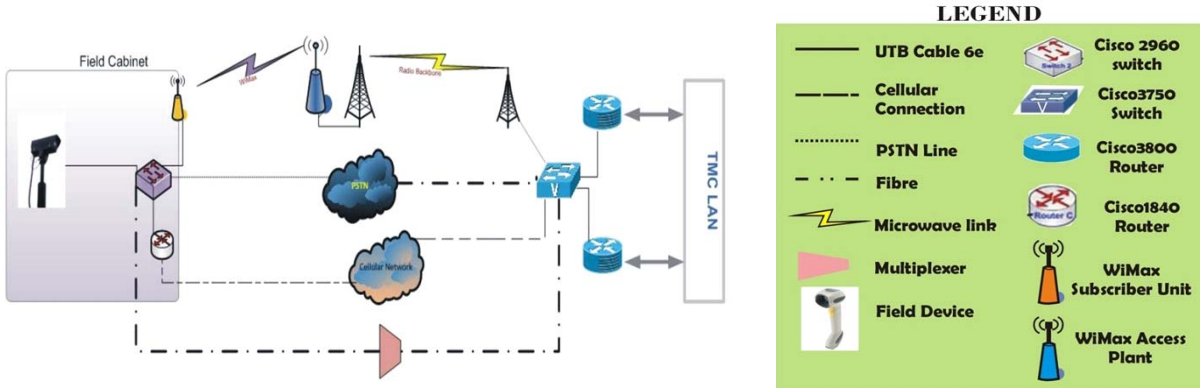

Fig. 9: ATMS WAN- Tetteh Quashie - Ako Adjei corridor

Satellite broadband (for remote parts of Ghana) as well as Fibre as Last Mile (Allotey and Akorli, 2011). With these considerations, the TMS wide area network design for the Tetteh Quashie - Ako Adjei Corridor may be captured in the diagram of Fig. 9.

ATMS data centre LAN design: All traffic from the various field devices finally converge and leave the TMC. It is therefore important to build a resilient Centre. The links connected through the WAN switches can be sent to the server LAN for processing, monitoring, analysis andstorage. The Centre may then access the server LAN from a different VLAN (Fig. 10).

ATMS data storage: Captured traffic data of the Accra Traffic Monitoring System needs to be stored, retrieved and passed on as message to the road user. A centralized data storage system is usually easy to establish and maintain. However, centralized control is not reliable; if the central server breaks down, the whole system goes down with it. On the contrary, distributed control is difficult to establish and maintain. It has the advantage of reliability, that is, a single station failure will not impact on the performance of the remaining stations. To balance the cost and performance of these two types of controls, a hybrid unicast server system may be adopted (Tewari *et al*., 1996).

Security implications: One also needs to assess the security implications of the ATMS network device locations. Ensuring physical and environmental security would prevent unauthorized physical access, damage, loss

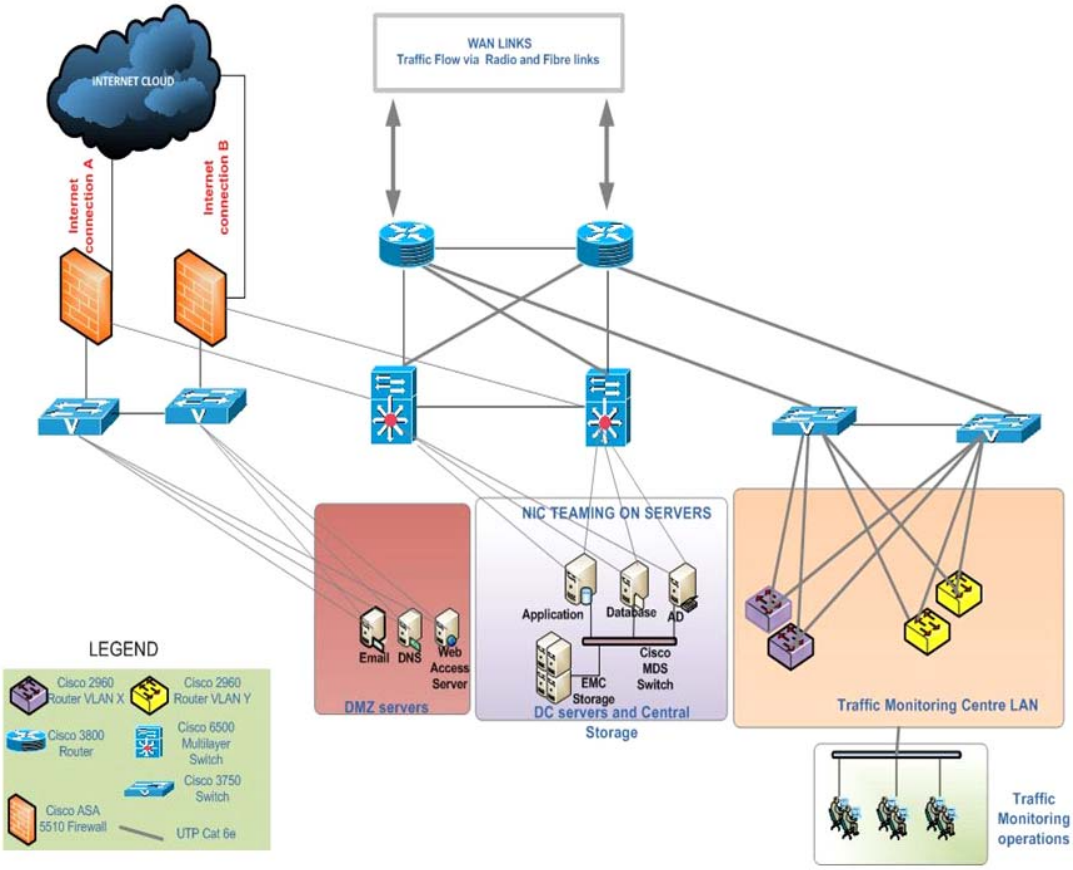

Fig. 10: ATMS central office LAN design

and interference to the premises where the equipments would be mounted. For example, security cameras may be fixed in and around the whole Corridor to prevent unauthorized access with control mechanisms, such as bars, alarms, locks, on the equipments, manned reception areas, a control centre strong room, intruder detection systems, etc. Adequate data back-up and restoration facilities could also be provided to ensure that all essential information and software are recovered in case there is a disaster or media failure. Various security measures would also need to be applied to off-site equipment.

Cost considerations: Considering the expected cost/benefit ratio, the Ghana Government could implement this project and sustain its running on an annual budget. The Ghana Highways Authority and the Accra Metropolitan Authority can support it through road user fees. Petroleum levy can also be used as a source of revenue. Radio and television stations can subscribe to traffic radio and prime time adverts. Technically, broadband service providers can also be used as the backhaul to provide network connectivity as a high bandwidth will be required for video data. Fibre optic services are also available on the Corridor. The market for road user services in Ghana will continue to rise and provide the enabling environment for traffic management on the roads and the Corridor for that matter, to pay for any expenses incurred.

CONCLUSION

The objective of traffic management systems is to monitor activity on the roads and provide information to road users to enable them make informed decisions. The goal of this project is to design a Traffic Monitoring System for the Accra Tetteh-Quarshie - Ako Adjei Interchange. There has always been congestion on this Corridor and this project attempts to use ICT to provide solutions by analysing the ICT intervention required for monitoring traffic. The project reviews existing Intelligent Transport Systems, identifies what causes congestion on the Corridor, and designs a Traffic Monitoring System Architecture. Analysis is made of the traffic data capture methods required, the issuing of alerts via Variable Message Signs to road users, the communication network

infrastructure and facilities for data storage and retrieval. These ICT solutions, when implemented, will achieve the results of easing the traffic congestion on the Corridor (and hopefully, on all Accra roads), providing road users with real time information on road traffic flow as well as improving on road safety and control of congestion.

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