ICT AS A TOOL FOR DEVELOPMENT OF TRAFFIC CONTROL SYSTEMS

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ABSTRACT

The application of Intelligent Transportation Systems (ITS) in Intelligent Traffic Control System (ITCS), is expected to improve the performance of road transportation significantly. Public policy makers, among others, are therefore increasingly interested in the implementation possibilities of these systems. However, current knowledge ITS implementation issues is poor with respect to technological requirements for its implementation. The contribution of ITS to general transport policy goals and the willingness of stakeholders to accept and use it is still low. This paper gives an overview of ongoing research at University of Dar es Salaam, on the role of ICT in Traffic Control Systems.

Key words: *pre-timed, adaptive logic, networked controller, cycle length, phases.*

1.0 INTRODUCTION

Transportation practitioners and researchers alike realized that road building can never keep pace with the increasing demand for travel. Many countries in the world who invested a lot in building road networks and infrastructure, and are now facing the challenge of revitalizing this huge network and making the best use of its already existing capacity before expanding further. Though there is another set of driving forces which is environmental related activities in the sector of transport, such as traffic emissions which has risen to an alarming levels. In all industrial countries, for instance, transport represents the single largest source of greenhouse gas emissions, accounting for 27 percent of the total emissions, which is estimated to increase to 42 percent by the year 2020. The problem is even greater in more car dependent societies where the escalating death tolls and injuries in traffic accidents each year are third set cause of death. For all these reasons, more road building is not always viable or desirable. Computer technologies is set to offer one attractive and promising approach, and hence the ITS. A healthy ITS industry would also have other non-traffic related society benefits, including stimulation of new information technology based industries and creation of new markets and jobs. Therefore, ITS is more than just intelligent solutions on the road. It is a new strategic direction for national and international economies.

2.0 LITERATURE REVIEW

Intelligent Transport Systems (ITS) combines transport technology and information systems, communication, sensors, and iteration methods with the surface transportation infrastructure. In addition to technological and systems issues, there are institutional issues that must be addressed. At some stage, government is required to implement ITS as an integrator of transportation, computer networks and communications systems in order to apply the system as a solution for transport problems in modern (Sussman, J. M., 1996).

Rush-hour conditions in cities are often extended throughout the day. Further, safety problems abounded, particularly highway safety. Also, city residents are concerned with the environmental impacts of transportation and the energy implications. Due to these compounded transportation problems, the need of new initiatives in the surface transportation emerged, taking into account social economics, environmental and energy issues. In addressing the social economic problem due to transport problems, ITS emerged .

2.1 ITS Basics

ITS can stand on four pillars

(i) *Data entry and collection points, which involves sensors which the presence and identity of vehicles in real-time on the road through roadside devices or Global Positioning Systems (GPS).*

(ii) *Communication and Networking points which collects the data and information transmits them through computer network.*

(iii) *Signal conditioner and process elements which receives transport data and process them.*

(iv) *Traffic information use and display device which outputs the information in a real-time in order to achieve better transportation network operations.*

By combination of logical and physical architect, the strategies for computer network control solution are developed. These architects compel one to think about road infrastructure and vehicles as a system, rather than independent components. One important attribute of ITS is that it is no longer restricted to civil engineers or to a single department or agency. Given the broad range of technologies involved, the ITS field is multidepartmental, multiagency, and multijurisdictional, cutting across the public, private, and academic sectors. This broadness certainly is enhancing potential, widening scope, and revolutionizing the way transportation systems are handled. It is also posing institutional challenges that must be prepared for taking ITS architecture in the transport network systems (Abdulhai, B., Kattan, L., 2004).

2.2 ITS Categories

ITS could either enhance the utilization of existing roadway capacity or increase capacity itself. Enhancing the use of existing capacity could be achievable through improved distribution of traffic, dynamically sending traffic away from congested roads to effectively utilize the road network, and the elimination of bottleneck causes at intersections and bus-stops.

Increasing the physical capacity could be possible through

- *traffic control automation.*
- *traffic coordination.*
- *elimination of the human behavior element which are detrimental to smooth flow of traffic.*

This is the promise of ITS that could potentially increase the number of vehicles which a road can handle.

From this perspective, ITS could be divided into two main categories of systems.

- *Traffic management and traveler information systems (TMIS).*
- *Vehicle control and automated highway systems (VCS and AHS).*

(i) TMIS

TMIS provides: -

(i) Extensive traffic surveillance and data acquisition.

(ii) Assessment of recurring congestion due to repetitive high demands, and detection of nonrecurring congestion due to incidents.

(iii) Traffic information and route guidance dissemination to drivers.

(iv) Adaptive optimization of control systems such as traffic signals.

The current trends in TMIS relies on centralized management in traffic management centers which gauge traffic conditions by receiving information from vehicle detectors throughout the network as well as the vehicles themselves. TMIS formulate control measures in the center and disseminate control to field devices as well as information and guidance to drivers. Newer trends of distributed computing control are emerging but have not crystallized yet. The main distinguishing characteristiçs of TMIS are real-time operation and network-wide multijurisdictional implementation.

(ii) VCS and AHS

VCS provide better control of the vehicle itself, either by assisting the driver or by automating the driving process in an auto-pilot-like fashion in order to increase capacity and enhance safety. Full automation of traveler information systems can result in higher speeds at lesser headways, and hence higher lane capacity. Automation can be applied to individual vehicles as free agents in a non-automated mix of traffic or as fully automated lanes carrying platoons of electronically linked vehicles. Although traveler information systems is technically promising, an array of unsettled issues remains, including legal liabilities in the event of incident due to any potential automatic controller failure, technical reliability issues, and social issues. Therefore, globally, traveler information systems is still underutilized at the current stage of ITS. The feasible alternative, however, is to use the technology to assist the driver, who remains in control of the vehicle that is, to make the vehicle smarter. Such intelligent vehicles will detect obstacles on the road, the blind spots and warn the driver accordingly, maintain constant distance from the vehicle ahead, and alert a sleepy driver who is going off the road. As technology improves further, the role of the intelligent vehicle can move from a simple warning to full intervention and accident prevention by applying the brakes or overriding faulty steering decisions.

The prime distinction between TMIS and VCS is that TMIS focus on smoothing out traffic flow in the network by helping the driver make best route-choice decisions and optimizing the control systems in the network, while VCS focus on the driver, the operation of the vehicle, and traffic maneuvers in the immediate vehicle vicinity. VCS focus on enhancing the driver's awareness and perception, aiding decision-making by providing early warning and potentially initiating action, and eventually using sensory inputs and computer control in place of human sensory reactions and control.

2.3 ITS Architecture

ITS Architecture is comprised of the logical architecture and the physical architecture, which satisfy a defined set of user service requirements. As the ITS is still growing, different research groups are pursuing its development. There is a risk of investing and adopting ITS technology and equipment locally. Similarly, if left without adequate guidance, ITS systems solutions could only be directed to local needs, which might be incompatible with global systems. For instance, an in-vehicle navigation system purchased in one country might not work in another country. Therefore, to ensure seamless ITS operation, some sort of global or national system architecture and related standards are needed. To maximize fully the potential of ITS technologies, system design solutions must be compatible at the system interface level in order to share data, provide coordinated area-wide integrated operations, and support interoperable equipment and services where appropriate (Nagatani, T. 2002) . An ITS architecture provides this overall guidance to ensure system, product, and service compatibility or interoperability without limiting the design options of the stakeholder. There are two types of architecture namely logical and physical architectures'

2.4 Logical architecture

The logical architecture defines the processes by activities and functions that are required to provide the required user resource sharable services. Many different processes must work together and share information to provide a user service. The processes are implemented via software, and hardware. The Logical Architecture is independent of technologies and implementations.

The logical architecture consists of processes, data flows, terminators, and data storages. Data flows identify the information that is shared by the processes. The entry and exit points for the logical architecture are the sensors, computers, human operators of the ITS systems. These terminators appear in the physical architecture. Data storages are repositories of information maintained by the processes. The logical architecture is presented via data flow diagrams, or process specifications.

2.5 Physical Architecture

The physical architecture which represents ITS interfaces, consists of two layers which are: -

(i) A transportation layer that identifies the transportation systems and the information exchanges that support ITS, and

(ii) A communication layer that identifies the communication technologies and systems that support the information exchanges.

The transportation layer forms a high-level structure around the processes and data flows in the logical architecture. The transportation layer defines the physical entities (subsystems and terminators) that make up an ITS. It defines the architecture flows that connect the various subsystems and terminators into an integrated system. The subsystems generally provide a rich set of capabilities, that would be implemented in different stages. Equipment packages break up the subsystems into deployment sized pieces (Hamisi, N. Y 2010, Nagel, K., and M. Rickert. 2001).

3.0 INTELLIGENT TRAFFIC CONTROL SYSTEMS (I.T.C.S.), CASE STUDY – DAR ES SALAAM

ITCS being one of the fundamental of the user resource sharable services described by UN. The surveillance, control, communications, and support system activities covered from the basic framework upon which many of the other user resource sharable services depend. ITCS provides the real-time transportation network performance information, which many of the other Intelligent Transportation Systems (ITS) services use. In particular, the data collected, processed, and used by ITCS are also needed virtually by all of the other services in the Travel and Traffic Management Systems, as well as various services in the Public Transportation Management and Emergency Management Systems (FHWA, 2007).

ITCS gathers data from the field, converts it into usable information, and uses it to assign right-of-way to users of the transportation infrastructure. The basic goal of ITCS service is to maximize the efficiency of people and goods movement through the road network. If implemented properly, it helps to alleviate congestion problems, and improve air quality. ITCS information are also disseminated to the general public and other service providers, laying the foundation for many other user resource sharable services.

Closely related services that can be used in conjunction with ITCS is to provide overall transportation management such as:-

- *the incident management.*
- *travel demand management.*
- *electronic payment services.*
- *weigh bridge services.*
- *public transportation management and*
- *emergency vehicle management.*

3.1 Traffic control signal

In Dar es Salaam, the emergency of traffic control signals was in early 1970. Around the world, the control of traffic at intersections by lights dates back to 1913 in Cleveland, Ohio - United States. The current format of three lamps showing red, yellow and green dates back to 1918 in Detroit and New York in United States. In the UK, the first manually operated signals were installed in 1925 in London and the first automatic system was installed in 1926 in Wolvethampton. Since then, traffic signals have become all pervasive, successfully regulating traffic in all major cities (Bell, M.G.H). The Manual on Uniform Traffic Control Devices (MUTCD) provides specific warrants for the use of traffic control signals. These warrants are detailed and is justified by the significant cost and impact of application of traffic signals as compared to other control devices (McShane et al. 1998). Traffic volume represents the key factor in the Manual on MUTCD warrants. Other factors, such as pedestrian volume, accident data, and school crossing, also play a significant role (Garber and Hoel 2002).

In Dar es salaam, where the modeling of traffic control signal study is conducted, the traffic flow data were collected manually and by a detector on a section of the road. The collected data involves (Nagatani, T. 2002):-

- *traffic volume*
- *speed of vehicles and*
- *road occupancy*

The mix of road users was considered as an important aspect of signal control design because, it varies not only from location to location within a city, but also from district to district. For example, in Buguruni, Manzese, Tegeta and Mbagala Areas, the problem is to control a large number of moving and parking public vehicles, alongside pedestrians, trucks, taxis and private cars. By contrast, in the City Centre, the problem is typically to control a large number of private cars and pedestrians alongside a limited number of buses. In other area of the City, the problem was typically to control a large number of small public and private cars, trucks and pedestrians alongside a limited number of buses at the intersection. The road user groups considered here are: cars and trucks; buses cyclists and pedestrians'.

The specific objectives were to properly simulate, and then place traffic signals to.

1) *Assign sequentially right of way by computer network, which in turn could*
2) *Increase capacity*
3) *Eliminate conflicts, thus reducing severity of accidents at intersections*
4) *Allow for coordination plans at designated speeds*
5) *Permit pedestrian movements*
6) *Permit cross-street movements*

However, the improperly operated traffic control signals result in the following short falls.

1) *Increase of vehicle volumes along the road.*
2) *Signals not functioning as safety devices; crashes will often occur.*

3) *Delays will increase.*
4) *Increase of operations and maintenance costs.*

To implement this, the Computer Based Master Control System (CBMCS) including interconnections and optimazation were used in the design.

In this research, the CBMCS was selected since it incorporated the other two methods to deliver the most cost effective solution for the operating environment.

3.2 Controller Types

According to the research done by A. P. Davol (2001), traffic control types were divided into two parts which are:

(i) *Control logic (Pre-timed, Actuated and Adaptive), and*
(ii) *Control Scope (Isolated intersection, Arterial Coordination and Networked Control).*

Fig. 1: Presents the matrix for traffic control types as per A. P. Davol

		Control Scope (Infrastructure)		
		Isolated Intersection	Arterial Coordination	Network Control
Control Logic (ICT Strategis')	Pre-timed	▣	▣	▣
	Actuated	▣	▣	▣
	Adaptive	▣	▣	▣ (hatched)

Figure 1. Types of signal control

Key:

▣ Point of coincidence between control scope infrastructure and control logic strategy.

[1] ▣ The part that is being pursued

3.3 Signal Timing for independent colour indication

Three different signal color indications which need different timings are Red, Yellow and Green.

1. Green interval determination

By implementing the necessary arithmetic and logic computations using several variables like cycle (cycle length), phase (signal phase), time intervals (fixed and variable), time lapse/offset, clearance intervals, peak-hour factor shown in (1) and saturation flow rate. 15 minutes within peak hour is used to determine the variability of demand.

$$PHF = \frac{\text{volume during peak hour}}{4 \text{ x volume during peak 15min within peak hour}} \quad (1)$$

In an ideal situation, the saturation flow (S_0), is taken as 1900 veh/hr of the green time per lane. In the real practical situation, the ideal data has to be adjusted in order to obtain the practical saturation flow for the lane group being considered.

2. *Yellow interval determination*

The required yellow interval is the time period that guarantees an approaching vehicle either to stop safely or proceed through the intersection without speeding. A bad choice of yellow interval may lead to the creation of a dilemma zone. For the dilemma zone to be eliminated, the distance X_0 should be equal to the distance X_c. Let ζ_{min} be the yellow interval (sec) and let the distance traveled during the change interval without accelerating be the product of u_0 and (ζ_{min}), with u_0 = speed limit on approach (m/s) the vehicle just clears the intersection, then

$$X_c = U_o \tau_{min} - (W + L_v) \quad (2)$$

Where X_c is the distance within which a vehicle traveling at the speed limit (u_0) during the yellow interval ζ_{min} cannot stop before encroaching on the intersection, W is the width of the intersection in meters and Lv is the average length of a vehicle in meters. Vehicles within this distance at the start of the yellow interval will therefore have to go through the intersection.

For vehicles to be able to stop, however, the situation is governed by (3).

$$X_0 = u_0 \delta + \frac{u_0^2}{2a} \quad (3)$$

Where X_0 is the minimum distance from the intersection for which a vehicle traveling at the speed limit u_0 during the clearance interval Y_0 cannot go through the intersection without accelerating. Any vehicle at this distance or at a distance greater than this has to stop. Also, δ = perception – reaction time (sec) and a = constant rate of breaking deceleration (m/s^2).

For the dilemma zone to be eliminated X_0 must be equal to X_c. Accordingly,

$$U_o \tau_{min} - (W + L_v) = \delta + \frac{U_o^2}{2a} \quad (4)$$

And

$$\tau_{min} = \delta + \frac{(W + L_v)}{U_o} + \frac{U_o}{2a} \quad (5)$$

Safety considerations normally preclude yellow interval of less than 3sec to encourage driver's respect for the yellow interval. It is usually not made longer that 5 sec. When longer yellow intervals are required, an all-red phase can be inserted to follow the yellow indication. The change interval, yellow plus all-red, must be at least the value computed from (5).

3. Determination of Cycle length for the intersection

Several design methods have been developed to determine the optimum cycle length. Two of which are the Webster method and the Highway Capacity method. In this research the Webster method is used.

Optimum Cycle Length. Webster (1958), has shown that, for a wide range of practical conditions, minimum intersection delay is obtained when the optimum cycle length is obtained when (6).

$$C_0 = \frac{1.5L + 5}{1 - \sum_{i=1}^{\phi} Y_i} \quad (6)$$

Where; C_0 = optimum cycle length (sec), L = total lost time per cycle (sec), $\varnothing$ = number of phases, Y_i = maximum value of the ratio of approach flows to saturation flows for all lane groups using phase *i*, i.e. q_{ij}/S_j and q_{ij} = flow on lane group having the right of way during phase *i*.

Total Lost Time: Initially, some time is lost before the vehicle start moving, and then the rate of discharge increases to a maximum. If there are sufficient vehicles in the queue to use the available green time, the maximum rate of discharge will be sustained until the yellow phase occurs. The rate of discharge will then fall to zero when the yellow signal changes to red. Dividing the number of vehicles that go through the intersection by the saturation flow will give the effective green time, which is less than the sum of the green and yellow times. This difference is considered lost time, since it is not used by any other phase for the discharge of vehicles; it can be expressed by (7).

$$\ell_i = G_{ai} + \tau_i - G_{ei} \quad (7)$$

Where; ℓ_i = lost time for phase *i*, G_{ai} = actual green time for phase i (not including yellow time), τ_i = yellow time for phase *I* and G_{ei} = effective green time for phase *I*. Then (8) gives L.

$$L = \sum_{i=1}^{\phi} \ell_i + R \quad (8)$$

Where, R is the total all-red time during the cycle.

Allocation of Green Times: In general, the total effective green time available per cycle is given by (9)

$$G_{te} = C - L = C - \left(\sum_{i=1}^{\phi} \ell_i + R \right). \quad (9)$$

where C = actual cycle length used which is the rounded off C_0 to the nearest 5 sec and G_{te} = total effective green time per cycle

To obtain minimum overall delay, the total effective green time G_{ei} *given by (10)* should be distributed among the different phases in proportion to their Y values to obtain the effective green time for each phase.

$$G_{ei} = \frac{Y_i}{Y_1 + Y_2 + \ldots + Y_\phi} G_{te} \qquad (10)$$

And the actual green time for each phase is given by (11)-(14).

$$G_{a1} = G_{ei} + \ell_1 - \tau_1 \qquad (11)$$

$$G_{a2} = G_{ei} + \ell_2 - \tau_2 \qquad (12)$$

$$G_{ai} = G_{ei} + \ell_i - \tau_i \qquad (13)$$

$$G_{a\phi} = G_{e\phi} + \ell_\phi - \tau_\phi \qquad (14)$$

3.4 Signal timing for adaptive system

By examining the possibility of traffic flow coordination in urban areas, where road junctions are networked. The signals should be timed so that when a queue of vehicles is released by receiving a right of way at the first intersection I(n), these vehicles will also have the right of way at the intersection I(1), I(2) and I(n-1) to I(n). This coordination will reduce the delay experienced by vehicles on the arterial. To obtain such coordination, all junctions in the network must have the same cycle length or multiple cycle length, in such a way that some junctions in the network may have cycle length equal to half or twice the common cycle length. It is usual for the common cycle length to be set, with an offset that is suitable for the main street. Traffic conditions at a given intersection are used to determine the appropriate phase of green, red and yellow periods for that intersection. The methods used to achieve the required coordination are the Simultaneous, Alternate and Progressive system. The speed of progression is important in determining the cycle length for each of these methods.

The speed of progression is the speed at which a platoon of vehicles released at I(n) intersection will proceed along the arterial intersection I(n+1). It is usually taken as the mean operating speed of vehicles on the adaptive network for the specific time of the day being considered. This speed is represented by the ratio of the distance between the traffic signals and the corresponding travel time.

Simultaneous System: All signals along a given adaptive network shall have the same cycle length and have the same green phase showing at the same time. When given the right of way, all vehicles shall move along the street in the greed direction of the adaptive network. The first vehicle shall travel from start and stop at the nearest signalize intersection when the right of way is given to the side street. An approximate mathematical relationship for this system is given by (15)

$$u = \frac{X}{1.47C} \qquad (15)$$

...cing for the signals (km),

...ed (km/hr), and C = cycle length (hr).

Several ... should
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...on on the arterial are formed into groups of one or more ... signals are then set such that successive groups of signals are ... way alternately. This system is known as the single-alternate with ...ely adjacent to it. It is known as double-alternate when the groups are ... two adjacent signals, and so on. The speed of progression in an alternate ... is given by (16).

$$u = \frac{nX}{1.47C} \qquad (16)$$

Where; n = 2, for the simple-alternate system, n = 4, for the double-alternate system, and n = 6, for the triple-alternate system.

Progressive system: The progressive system provides for a continuous flow of traffic through all junctions under the system when traffic moves at the speed of progression. The same cycle length is used for all junctions, but the green indication for each succeeding intersection is offset by a given time period from that of the preceding intersection, depending on the distance from the preceding intersection and the speed of progression for that section of the street. When the offset and cycle length are fixed (pre-timed control), the system is known as limited or simple progression system. When the offset and cycle length are changing to meet the demand of fluctuating traffic at different times of the day (adaptive control), it is known as the flexible progressive system [5].

3.5 Simulations

Junctions along all major roads such as Bagamoyo Road, Morogoro Road, Nyerere Road and Kilwa Road in Dar es Salaam city were simulated for analysed.

For Bagamoyo Road, the selected junctions were Maktaba, Nyumba ya Sanaa, Red Cross, and others up to Mwenge junction. The separating distances between junctions ranges between 100m to 1000m. Previous results shows that the separating distance of not more than 150m could allow arterial co-ordination and intelligent Arterial co-ordination could be extended up to 250m for two junctions (Hamisi et al, 2009).

Data collection and analysis of normal and peak hour traffic volumes was performed. Using the data presented in Table I, calculations of traffic control parameters (signal timing) for each intersection in the system were performed to obtain the control algorithm for intersection coordination.

Experiments started by identification of Traffic Volumes along Bagamoyo Road from Maktaba to Morroco as per Fig. 2. The phasing scheme and then an arbitrary phase assignment were selected. Table II presents the phasing scheme for one particular intersection.

TABLE I. EQUIVALENT MORNING HOURLY TRAFFIC FLOW FOR 10 JUNCTIONS

JUNCTION	CODE	PHASE A		PHASE B		PHASE C		PHASE D		TIME
		LT+TH	RT	LT+TH	RT	LT+TH	RT	LT+TH	RT	
MOROCO	10	1150	300	1000	250	900	200	600	500	AM
		500	250	1200				800	100	PM
NAMANGA	9	1300	500	1200				800	100	AM
		1300	500	1250				500	100	PM
KANISANI	8	450	50	1800				150	300	AM
		1500	250	1300				150	300	PM
UBALOZI	7	600	100	1850	50	300	800	750	50	AM
		1200	150	1150	50	100	400	150	50	PM
POLICE SA	6	700		2200	700	350	250			AM
		1500		2200	700	350	250			PM
PALM BEA	5	400	50	1500				100	500	AM
		1200	50	1300				100	500	PM
HINDU T	4	400	50	1500		100	100	100	500	AM
		1200	50	1300		100	100	100	500	PM
RED CROS	3	350	150	1700	100			200	100	AM
		1500	300	1200	100			200	50	PM
N Y SANAA	2	1000	300	1600				500	100	AM
		1300	250	1300				500	500	PM
MAKTABA	1	800	500	1100				500	200	AM
		900	500	1200				600	600	PM
STD I MEA		715								
		1210								

By using data presented in Tables I-III, the equivalent traffic flow with offset time between junctions for the 10 junctions using the phasing scheme was presented as per Table IV. For junctions along Bagamoyo Road which is 18 m wide, the maximum driving speed allowed in Dar es Salaam is 50km/hr (equivalent to 13.89m/s) and the average length of a vehicle is assumed to be 6m. The American Association of State Highway and Transportation Officials (AASHTO) recommend a deceleration rate of 3.4m/sec^2. Taking the driver reaction time to be 1.0 seconds, the minimum yellow time at the end of each green phase is obtained by substituting the values into (5). Substituting δ, W, L, U_0 and α in (5), τ_{min} is 5.92sec. Rounding the value to the nearest multiple of five we get a minimum yellow time of 6sec is needed.

TABLE II. DATA ENTRY FOR BAGAMOYO ROAD

	intersectID	phaseID	phaseName	greenTime	yellowTime	redTime	signalID	priority
1	Bamaga	PhaseA	Mwenge	55	5	2	1A	1
2	Bamaga	PhaseC	Sayansi	29	5	2	1C	3
3	Bamaga	PhaseD	Sinza	35	5	2	1D	2
4	Maktaba	PhaseA	N Y Sanaa	33	5	2	1A	1
5	Maktaba	PhaseB	Posta	33	5	2	1B	2
6	Maktaba	PhaseC	Bibi Titi	53	5	2	1C	3
7	Mbuyuni	PhaseA	Namanga	30	5	2	1A	1
8	Mbuyuni	PhaseB	Masaki	24	5	2	1B	2
9	Mbuyuni	PhaseC	Ubalozi	65	5	2	1C	3
10	Moroco	PhaseA	Sayansi	33	5	2	1A	1
11	Moroco	PhaseB	Sayansi	18	5	2	1B	2
12	Moroco	PhaseC	Namanga	38	5	2	1C	3
13	Moroco	PhaseD	Magomeni	23	5	2	1D	4
14	Mwenge	PhaseA	Lugalo	26	5	2	1A	1
15	Mwenge	PhaseB	Ubungo	12	5	2	1B	2
16	Mwenge	PhaseC	Bamaga	46	5	2	1C	3
17	Mwenge	PhaseD	Coca Cola	28	5	2	1D	4
18	N Y Sanaa	PhaseA	Red Cross	29	5	2	1A	1
19	N Y Sanaa	PhaseB	Movenpick	36	5	2	1B	2
20	N Y Sanaa	PhaseC	Maktaba	54	5	2	1C	3

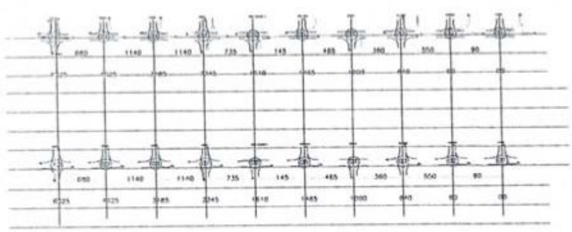

Figure 2. AM and PM Traffic Volumes along Bagamoyo Road from Maktaba to Morroco Junctions

3.6 *Determination of Minimum Yellow Interval*

Consideration has also been made for an all red phase. Since there are three to four phases per intersection, the total lost time per cycle per intersection is 2sec per red signal. For 4 Cycles, the total all red loss time is 8 sec, assuming that the effective green time is the same then the actual green time, will be given by (17).

$$L = \sum(Yellow + Red) \qquad (17)$$

Determination of Optimum Cycle Length

Using Webster equation described in (7), the optimum cycle lengths for 10 junctions were calculated.

CYCLE LENGTH DETERMINATION USING WEBSTER'S APPROACH

INTERSECTION CODE 01 - MAKTABA

	Phase A		Phase B		Phase C		Phase D	
Signal group	RT	TH+LT	RT	TH+LT	RT	TH+LT	RT	TH+LT
q_{ij}	500	800	0	1100	0	0	200	500
S_j	1615	3700	1615	3700	1615	3700	1615	3700
q_{ij}/S_j	0.03	0.216	0.04	0.297	0	0	0.124	0.135
Y_i	0.310		0.297		0.00		0.135	

Total cycle length : $\sum Y = 0.742$ (17)

Tmin= δ +(((W+L) / Uo))+ (Uo / (2*(a + G g)))= 5.92 sec (18)

R = 2 sec

L = 4(Tmin+R)= 31.69 (19)

$$C_0 = \frac{1.5L + 5}{1 - \sum_{i=1}^{\phi} Y_i} = 132 \text{ sec} \quad (20)$$

$Co - L$ = 132-32=100 sec (21)

Actual green time per phase i(th) is

	Phase A		Phase B		Phase C		Phase D	
Signal group	RT	TH+LT	RT	TH+LT	RT	TH+LT	RT	TH+LT
	48sec		40sec				18sec	

The effective green time was found to be 106sec which is the total green time for all phases. Subsequently, optimum cycle length for each intersection was computed, and obtained by repetition of iterations as presented in table II. Since cycle lengths are usually multiples of 5 or 10, the calculated value was rounded to multiples of 5 like 110sec, 115sec, and 120sec

3.7 Determination of Offset

Using the progressive system, the average distance between junctions and the average speed of progression are needed. The distance between each intersection and the offset that adaptive networked traffic for the first vehicle shall move from the first intersection to the next intersection are presented in Table IV, and vehicles are set to the average speed of progression of about 50km/hr ($\approx$13.89 m/s).

$$\text{Ideal speed} = \text{Ideal distance (m)/Ideal time (sec)} \quad (22)$$

3.8 Algorithm for Coordinating the Junctions

Using calculated values of effective green time and offset, an algorithm for coordinating the intersection in mode three of Fig.1 was developed as presented in Fig.3, which also led to the development of the model for controlling and coordination the traffic flow for more one intersection and corridor presented in Fig.4.

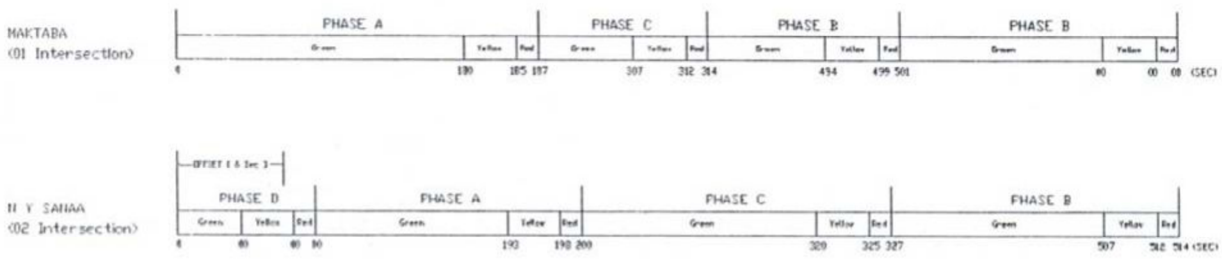

Figure 3. Green Phase timing algorithm for two adjascent intesection in aadaptive networked traffic conttrol

TABLE III. OFFSET TIME BETWEEN JUNCTIONS

S/N	Junctions	Ideal Distance (m)	Time (sec)
1	Maktaba & Nyumba ya Sanaa	90	6
2	Nyumba ya Sanaa & Red Cross	550	40
3	Red Cross & H Tample	350	26
4	H Tample & Palm Beach	465	33
5	Palm Beach & Salender Police	145	10
6	Salender Police & Ubalozi	735	53
7	Ubalozi & Kanisani	1140	82
8	Kanisani & Namanga	450	32
9	Namanga & Morocco	680	49

4.0 DISCUSSION

4.1 Client-Server Architecture

As presented in Fig. 4, we found the best method is to use the client–server model of computing which is a distributed application structure that partitions tasks or workloads between the providers of a resource/service, called Servers, and service requesters, called Clients. By visual basic program, Many Clients and one Server were programmed to communicate over a modeled computer network. A server was made to run visual basic program and shared its resources with clients. A client did not share its resources, but was made to request a Server's content/services and functions. Clients were made to initiate communication sessions with servers which continuously kept on waiting for the incoming requests.

4.2 Distributed Computing

The networked Client–Server architecture enabled distributed computing of independent computers connected to each other through the Intelligent Traffic Control System (ITCS) network. This created flexibilities in replacement, repair, upgrade, and server relocation. Clients remained either unaware or unaffected by Server changes. All data were stored on the Server, which generally had greater security controls than clients. Server was made to control access and resources, in such a way that only Clients with appropriate permissions accessed and exchanged data. Data storage was centralized, which made data updates easy. Issues of security, and interface were addressed as presented in Fig:4.

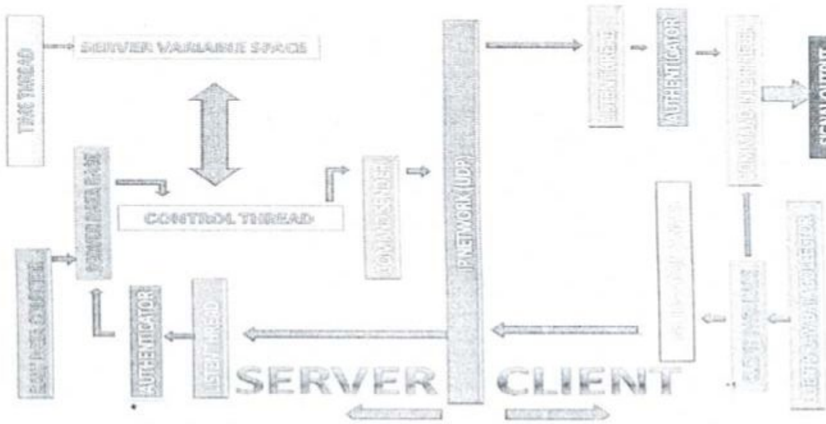

Figure 4. Client Server Architect

4.3 System constrains

With simulations of ten junctions at once, each Client generated about 12kb/sec and in total, the Clients Server Network generated about 120kb/sec at the Server Node.

By taking into account that there was data which was lost in transmission process. Then ITCS network occupied less than 1:100 or 1% of 1000Mbps (1Gbps) ITCS network total capacity when User Datagram Protocol (UDP) was used. By adding more Clients, the bandwidths across the network were increased in the same proportions.

TABLE IV. INTERSECTION INFORMATION TO THE NETWORK

	intersectName	intersectID	ipAddress	cycleLength	intersectType	intersectOffset
1	Bagamoyo - Shekilango	Bamaga	192.168.1.11	140	1	94
2	Bibi Titi - Azikiwe	Maktaba	192.168.1.1	140	1	0
3	A H Mwinyi - Haile Selassie	Mbuyuni	192.168.1.7	140	1	113
4	A H Mwinyi - Kawawa	Moroco	192.168.1.9	140	1	69
5	Bagamoyo - Sam Nujoma	Mwenge	192.168.1.12	140	1	94
6	A H Mwinyi - Ohio	N Y Sanaa	192.168.1.2	140	1	6
7	A H Mwinyi - Old Bagamoyo Road	Namanga	192.168.1.8	140	1	11
8	A H Mwinyi - Ocean Road	Palm Beach	192.168.1.4	140	1	105
9	A H Mwinyi - Ufukoni	Red Cross	192.168.1.3	140	1	46
10	A H Mwinyi - Ocean Road	Salender Bridge	192.168.1.5	140	1	116
11	Bagamoyo Road - Rose Garden	Sayansi	192.168.1.10	140	1	116
12	A H Mwinyi - Kinondoni	Ubalozi	192.168.1.6	140	1	29

TABLE V. SIGNAL TIMING FOR PLATOON FLOW FROM MAKTABA INTERSECTION TO MOROCO INTERSECTION

Intersection	Phase A	Phase B	Phase C	Phase D	Total	Ofset Time	Platoon Green Start Start	Platoon Red Signal Start
							Green	Red
Maktaba	22	33	28	0	83		0	180
						6		
N Y Sanaa	26	45	30	0	101		28	186
						40		
Red Cross	30	46	6	0	82		68	226
						26		
H Tample	21	70	0	9	100		94	252
						33		
Palm Beach	21	70	9	0	100		127	285
						10		
Police Salender	36	50	14	0	100		137	295
						53		
Ubalozi	27	15	29	17	88		190	348
						82		
Kanisani	21	46	9	0	76		272	430
						32		
Namanga	21	38	19	0	78		304	462
						49		
Moroco	21	38	29	29	117		353	511

4.4 Visual basic

During development, Visual Basic which has multithreading capabilities was used. Tasks involved were established in streams ready for execution. Lengthy tasks were divided into different segments. In so doing, the processors were optimized, thus avoiding idle time. On both Server and Client application, threads were used to provide concurrence for different processes.

4.5 Event Timers

The crucial event was the use timer to synchronize ITCS coordination across several road junctions. On the server, events were realised using timer. Visual Studio.NET and the .NET Framework.

Out of existing three timer controls (which are (i) the server-based timer (ii) the standard Windows-based timer and (iii) the thread timer), the server-based timer was designed for use with worker threads in a multi-threaded environment. Because they use a different architecture, server-based timers was more accurate than Windows timers. Server timers moved among threads to handle the raised events. Because the program design of ITCS was based on a Multi-threaded architecture, Server-based timer was used to manage the program flow and control time for junctions.

4.6 ITCS database for a single intersection

Intersection details and timing information was stored on a relational database on the Server as per Fig. 5. From sets of tables formulated from data collected from road junctions, formulations of relational database were carried. Fig: 4&5 presents ITCS data base information for one intersection which was formulated by using the Structured Query Language (SQL). SQL statements were used for interactive queries to insert and/or retrieve information from a relational database.

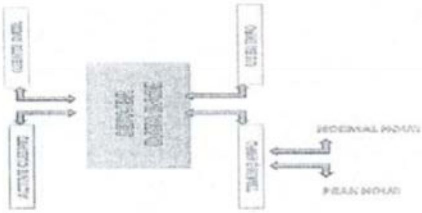

Figure 5. ITCS Database architect for one intersection

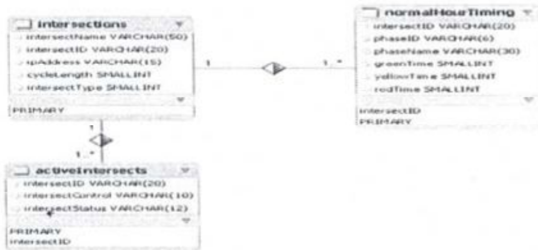

Figure 6. ITCS Database content for one intersection

The created ITCS database, made it relatively easy to create, access, and add new data category without requiring modifications of previous data.

5.0 ACKNOWLEDGMENT

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4.0 CONCLUSION

In this paper, a complete cycle for development of ICT as a tool for development of Traffic Control Systems by ITCS network has been presented. The design and methodology used for implementation was multithread client server programming for developing the ITCS. The paper proposes the applications of the system in the local (Dar es Salaam City) environment. Raw data which were used at first instance, could be used to initiate the system and keep the system running. With real time data acquisition, the data base can be updated and run ITCS accordingly. By using Webster Equation, data were computed and coded in order to build an algorithm for Socket Programming. Such algorithm, led to the development of the ITCS, which is part of ITS. It was found that the application of multithread client server networking has potentials to alleviate the present traffic signal control problems mostly facing the cities in developing countries. The practical implications of ITCS network could be upon improvement of usage of computer applications in solving heavy traffic problems we are facing. Furthermore, the complexity of adaptive networked controller which was said to be complex in 2000 (Davol, A. (2001) has now been realized by improving features of pre-timed and arterial logic.

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