Intelligent Transport System in Ethiopia: Status and the Way Forward

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Abstract. Vehicular transportation systems are used extensively to transport people and goods which is detrimental for faster, reliable and cost effective socioeconomic activity. However, there are major challenges associated with accelerated utilization of such systems. These include threat to safety of life and property; pollutions; congestion triggered reduction of road network utilization; reduced cost effectiveness of vehicles; and increased waiting and travelling times of passengers. This paper briefly surveys the above problems in international and national context. It then assesses deficiency of conventional methods of mitigating the problems. Next it proposes introduction of intelligent transport system (ITS) in Ethiopia as a better and cross cutting solution to the above problems. The paper analyses and presents verifications of the hypothesis that if ITS is introduced, the nation would achieve better safety to life and property; less pollution; more efficient mobility traffic control and management; and better utilization of road networks and vehicles.

Keywords: Intelligent transport system · Mobility traffic · Pollution Congestion · Safety · Utilization efficiency · Ethiopia

1 Introduction

Transportation of humans and goods have been playing important roles in people's daily lives and socioeconomic activities since civilization first formed and needed new means of reaching destinations [1]. Vehicular transportation eased and extended the living, working and entertainment environment people could reach in quicker, convenient and comfortable manner.

The mass production and affordability of vehicles resulted in a new era of modern life and as a consequence and perpetual reciprocation paved ways for modern town planning for efficient multifaceted services; construction of standardized road network infrastructure; use of essential standard traffic rules and signs; use of traffic control signalling systems; deployment of trained human power to drive, maintain, manage, monitor, control and enact laws; etc. all for the safe, cost effective, comfortable and smooth utilization of the vehicular transportation system.

Since the start of private, public and commercial transportation application of vehicles in late 19th century, the total world vehicle population in 2010 exceeded 1.015 billion 24 years after reaching 500 million in 1986 [2]. In 2011, the Organization for

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Economic Co-operation and Development (OECD's) International Transport Forum forecasted that the number of cars worldwide would reach 2.5 billion by 2050. This justifies vehicles to be the most important land based transportation carrier that would also be anticipated to continue in the foreseeable future.

In line with this global trend, the total number of registered vehicles in Ethiopia in 2010 had been 377,943. Out of this 231,619 (61.3%) are cars and 4-wheel light vehicles; 44,847 (11.9%) are motorized 2- and 3-wheelers; 81,193 (21.5%) are heavy trucks and 20,284 (5.4%) are buses [3]. With the economic development being observed, the vehicle population in Ethiopia is expected to grow.

Apart from vehicles, a major integral part of a vehicular transportation system is mobility traffic control and management system. It may be termed conventional and modern. Its essence is to ensure the smooth, safe, reliable and faster arbitration in the utilization of the existing road network among vehicles, bicycles, trains, and pedestrians. The conventional system has inflexible traffic signalling time duration adjustment. It is also incapable of automatic synchronization of the traffic signalling systems at intersections distributed throughout a road network of a city. The modern one, however, is capable of both functions and more.

The windows of opportunities for improving mobility traffic with the conventional method are becoming more and more ineffective. This fact naturally leads to a paradigm shift into a modern method called intelligent transportation system (ITS). ITS is becoming attractive one reason being the ubiquities of modern wireless communication technologies with which it can be readily implemented.

The objective of this paper is to study the introduction of ITS for mobility traffic control and management in Ethiopia. The scope is limited to vehicular transportation system. Accordingly, in the paper, the global and national challenges of vehicular transportation systems will be briefly outlined first in Sect. 2. Second, the characteristics and the deficiency of the conventional approach of traffic control will be analyzed in Sect. 3. Next, ITS will be described and its prospects will be introduced. Finally, recommendation of ITS applications will be proposed and discussed for Ethiopia.

2 Challenges of Vehicular Transportation Systems

Challenges associated with increasing utilization of vehicular transportation system include issues of

- increased need of maintaining safety of life and property;
- congestion triggered delays, pronounced pollution, reduction of road utilization, inefficiency of vehicles, and discomfort of drivers, passengers and pedestrians;
- increased burden of rehabilitating existing road facilities and traffic control systems failing due to aging and vehicle related accidents;
- increased need of new road network and mobility traffic control systems;
- increased drain of hard-earned foreign currency for fuel.

One can, however, easily conclude that the benefits of vehicular transportation system outweigh their drawbacks significantly. However, governments and society should give significant attention to minimize the ever-increasing problems. These include loss of lives, injuries, damages to property as well as to increased operational and maintenance costs. Some highlights on some of the above problematic issues are briefly supported from literature as follows.

2.1 Safety Issues

The main causes of vehicular transportation related accidents may be attributed to inefficient mobility traffic management and control systems; poor road conditions and congestion; and driving skill deficiency and unacceptable behaviour of drivers. Other causes include the technical insufficiency of vehicles; bad weather; and lack of sufficient awareness of pedestrians about traffic rules and drivers' behaviour.

According to [4], road traffic accidents caused an estimated 1.24 million deaths worldwide in the year 2010. The risk of dying as a result of a road traffic accident is highest in the African Region (24.1 per 100,000 population), and lowest in the European Region (10.3 per 100,000). Adults aged between 15 and 44 years accounted for 59% of global road traffic deaths and 77% road deaths are among men.

The Ethiopian situation is such that in 2010 the reported number of road traffic fatalities had been 2,581 of which 76% involved males and 24% females. In the same year, the estimated economic loss due to road traffic crashes is at 0.8–1.0% of the GDP [3]. According to [7], Ethiopia loses about 500 million Br (equivalent to $25 million) and 3,000 lives each year from road accidents. About 80% of these losses are caused by drivers' faults and the remaining due to vehicle technical problems, low quality of roads and other causes. Existence of unreliable mobility traffic control and management system may also be one cause.

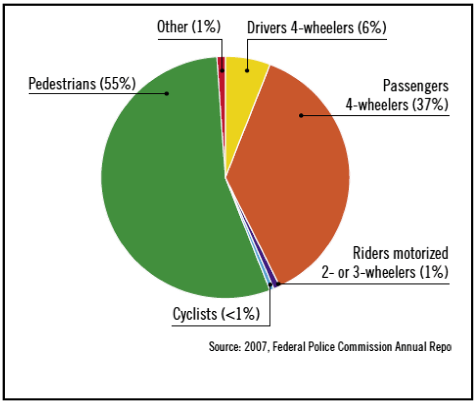

Fig. 1. Deaths by road user category [3]

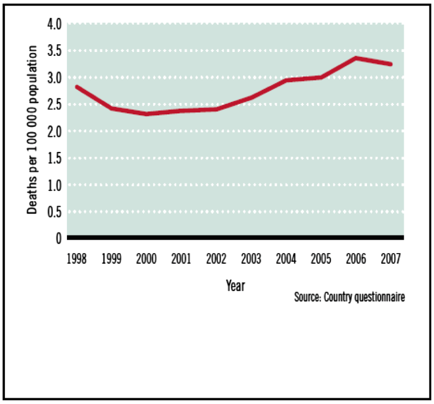

Fig. 2. Trends in road traffic deaths [3]

Organized data on traffic related deaths in Ethiopia in 2007 are depicted in Figs. 1 and 2 [3]. Figure 1 shows pedestrians are most victimized and Fig. 2 indicates the trend which is steadily increasing.

2.2 Environmental Pollution Issues

Transportation accounts for 23% of the world's greenhouse-gas emissions [5]. Congestion highly pronounces many forms of pollutions including over gas emissions, overheats and audible and vibration noises of overcrowded vehicles. Utilizing ITS as an effective mobility traffic control solution can significantly improve mobility and thereby reduce congestion.

2.3 Energy Exhaustion Issues

Some estimate, assuming current consumption rates, that current oil reserves could be completely depleted by the year 2050 [6]. One alternative solution, in the context of this paper, is to utilize systems that improve mobility as stated. When a vehicle moves at low speed, its efficiency reduces. Thus, mobility improvement would have the effect of preserving the existing oil resources from faster depletion.

2.4 Need of Improved Mobility Traffic Control and Management Systems

As the number of vehicles increases their monitoring and control would also grow. Repetitive stoppage of moving vehicles for long durations is mainly due to improper traffic light signalling times. This results in unnecessary fuel consumption, environmental pollution, increased delay, and reduction of productivity of people. As the number of vehicles grows, functioning of conventional mobility traffic control systems would not be suitable and cost effective. Accordingly, a modern way of mobility traffic control systems had been necessitated and implemented as witnessed in most developed nations such as the USA, Germany, and Japan to name a few.

2.5 Need of Rehabilitation of Existing and Expansion of New Road Networks

As population and economy of a nation grow, so does the mobility needs of more people and goods. To meet these needs, a first step would be optimizing all existing road networks, mobility control systems, and other facilities. This entails continuously servicing and maintaining them to their best status. This improves mobility while reducing congestion. If no more optimization is possible in response to increased vehicle population and congestion, the next step would be to construct additional roads. In addition, paradigm shifting from the conventional to the modern mobility traffic control and management systems with ITS would be effective.

2.6 Summarized Implications of the Above Issues Globally and for Ethiopia

The implications of the previous highlights can be summarized as follows. According to [8], if current transport related problems are left unaddressed with modern approach, the world might be continuing towards:

- 1.9 million road deaths annually worldwide by 2020, costing the world an estimated $100 billion each year.
- Close to 9,000 Megatons of global CO_2 emissions from transport vehicles will occur by 2030. This contributes significantly to climate change. Combined with other emissions, it would burden millions of people with health problems through air, water, soil and noise pollution; and
- 30% increase of traffic congestion by 2025 in some countries, costing society billions in fuel and overall economic penalties through time lost.

It could also be predicted that, considering the current level of development of the underdeveloped nations, Ethiopia would suffer in *its part* even worse than the summary implies.

2.7 Scope of Study of This Work

The servitude of vehicular transportation systems should be exploited in safer, cost effective, pollution free and efficient manner. This could be so if the too many problems stated in Sect. 2 are co-ordinately addressed. However, addressing these problems with a single approach and in only one discipline of study would be impossible.

This paper focuses only on mobility traffic control system as a cross cutting solution. It is supposed to address in some measure safety issues, operational and utilization efficiency of roads and vehicles, energy and environmental pollution, and mobility.

3 Mobility Traffic Control, Management and Its Status in Ethiopia

3.1 Overview of the Conventional Traffic Signal Control System

Some elements of the conventional system include traffic signalling lights, road side and on-the-road signs, weigh-in stations, and toll collection systems.

When the number of vehicles and pedestrians using existing road network is very low, the essence of traffic signalling would be minimal or not at all necessary. However, when the number of vehicles matches or outnumbers the required road network, then congestion would be prevalent. This distracts mobility of vehicles and pedestrians. The conventional system would be effective in this regard.

When very large number of vehicles and pedestrians as well as a large and complex road network is involved, the need for synchronization of multiple signalling systems becomes highly essential. For synchronized traffic control to be simple, sufficient and reliable data of mobility of vehicles, trains and pedestrians are necessary. It is with such conditions that the conventional method mostly becomes insufficient or even sometimes failing. This is mainly due to its major drawbacks some of which are:

- The traffic signalling time phases are usually constant for all times of the days. Some may be adjusted manually but may require study and many operators.

- The signalling systems at major road junctions are not automatically synchronized. This would bring congestion and its triggered problems.
- The conventional system has no automatic traffic related data detection and logging system that might be used to improve performance.

3.2 Status of Mobility Traffic Control and Management System in Ethiopia

The Ethiopian experience in using mobility traffic control and monitoring systems can be summarized as follows:

- A number of traffic signals are erected at critical road junctions.
- International traffic control signs have long been utilized for the same purpose.
- Some traffic police use walkie-talky to resolve traffic related problems.
- Most traffic polices control traffic related problems manually (when electrical operated signals are down or where there are no such systems).
- Some motor cycles are utilized to reach at abnormal traffic incident areas.
- Radar systems are used to limit vehicle speed in few intra-city movements.
- Attempt was tried on using GPS assisted navigation and guidance system built into vehicles in Addis Ababa city but no further development.
- GPS based fleet monitoring and controlling systems are being introduced in limited number by private companies.
- A toll based express way is constructed from Addis Ababa to Adama used to relive the highly-congested highway between the cities. The express way is equipped with fee charging station, monitor vehicles in road with CCTV, offer emergency service in case vehicles encountered problem or accidents, etc.
- The recently commissioned Light Rail Transit (LRT) in Addis Ababa introduced a relatively modern train vehicle traffic control system along its route.
- Public and private radio and TV broadcasts are being used to inform drivers and people about traffic updates.

The above facts imply that the current mobility traffic control and management system in Ethiopia is still conventional.

3.3 Analysis of the Conventional System

Already, too much congestion is being observed in arterial roads and junctions, particularly in Addis Ababa. This city is currently being renovated with the construction of new long and wide roads having a number of overpasses and underpasses as well as LRT railways. Similarly, new road networks are being constructed in other major cities. The population of vehicles, residents and passers-by in the cities are increasing. Though the expansion and renovation of the roads would improve the capacity of mobility, the outnumbering vehicles would exhaust this capacity soon to reinstate congestion.

Improvement of mobility in an existing road network may require a number of sequential or concurrent measures. This involves exploiting every possible window of opportunities. The first measure may be servicing and maintaining all roads and traffic control systems to their best status. Second is optimization of mobility and road utilization. This can be done through tuning of traffic control parameters, mainly signalling phase time durations of all traffic control signalling systems in the road network. Third, improving the synchronization of the various traffic control signalling systems at arterial roads may also be considered. The above measures would, however, have limits beyond which it becomes cost ineffective for further improvement. It may not at all even improve the mobility capacity of the road network.

The next higher measure in the conventional sense requires the expansion of road network infrastructure and allocation of land resource. These, however, are expensive. Furthermore, the more land is used for roads, the more congested towns become. Still worse is the usually observed lagging of the infrastructure deployment behind the increase rate of vehicles exacerbate the consequences of congestion. This leads naturally to a paradigm shift into the modern method called ITS, discussed next.

4 Intelligent Transport Systems (ITS)

4.1 What is ITS and Its Purpose?

ITS is the application of various technologies to the management of surface transportation systems in order to increase their efficiency and safety, whilst providing travellers with mobility options based on real-time information [9]. Another definition of ITS from Toyota [10] is as follows: "ITS are transport systems that use communications technologies to link people, roads, and vehicles with the aim of solving various traffic related issues such as preventing accidents, environmental measures, and energy conservation."

ITS helps reduce the time required to clear traffic incidents, the number of secondary accidents, queuing, congestion, fuel consumption and therefore air pollution. Efficiencies in traffic management are enhanced through techniques such as ramp metering to smooth peak traffic flows. Advanced traffic management systems along arterial roads, using computerized traffic signal systems, improve signal progression and synchronization - contributing further to the reduction of delays, fuel use and pollution [9].

The functional parts of ITS include: Traffic Management Systems, Traveller Information Systems, Public Transportation Systems, Vehicle Control and Safety Systems, Commercial Vehicle Operations, Emergency Management Systems, Vulnerable Individual Protection Systems, and Information Management Systems [1]. Many sub-systems are integrated into ITS. These include: CCTV cameras, variable message signs (VMS), vehicle detectors, highway advisory radio, ramp metering, telecommunications, management centers, automated vehicle identification systems, weigh-in-motion stations, and cashless (in-motion) toll collection system [9].

The development and implementation environment for ITS are plenty. It includes vehicular ad-hoc networks (VANET), vehicle to vehicle (V2 V) and vehicle to infrastructure (V2I) communication systems, wireless sensor networks, GPS and GPRS navigation and guidance systems, and cellular mobile network. It also includes sensors for vehicle and pedestrian detection, monitoring and security systems, as well as wireless technologies such as Wi-Fi, Bluetooth, and IR.

ITS contributes to all major transport policy objectives set by a nation. Many ITS applications are aimed at either optimizing the available supply of road infrastructure or reducing demand for it. The result of ITS technology is a more efficient and reliable road transport network that operates with a minimized effect on the environment. ITS also enables in both preventing accidents and mitigating their impacts.

A simplified description of the procedural steps in most ITS applications is [9]:

- **Data collection:** ITS is capable of capturing a range of roadway information from the number of vehicles passing a certain point. ITS can track the position of vehicles through, say, mobile phone or satellite.
- **Data transfer, processing and analysis:** ITS can communicate the data to central units. There, the data is aggregated and transformed into information used to determine future actions.
- **Informed decision-making:** The processed data can be applied in a number of ways to ensure the efficient operation of road networks. For e.g., a road operator may use ITS data for highway management; or a road user may alter his route from updated traffic data.

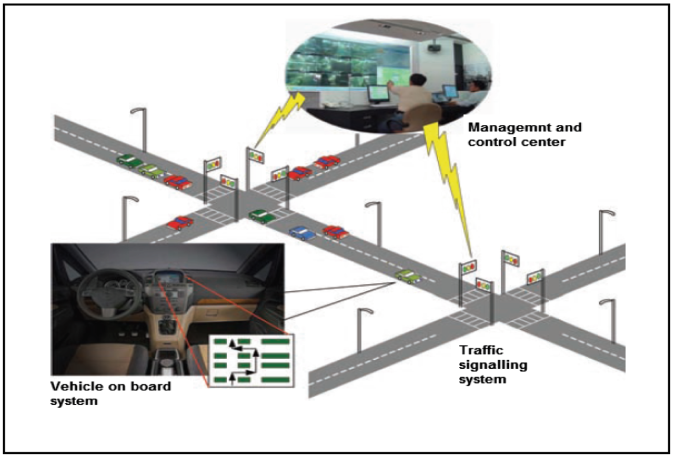

Fig. 3. Traffic management system [1]

Representing ITS with a single diagram would be too complex to accommodate in this short paper. However, the mobility traffic control and management function which is the core and foundation of ITS is illustrated in Fig. 3. above [1].

4.2 Benefits of ITS

With ITS in place, the following benefits may be obtained:

- Enables adaptive and real time control of mobility of vehicles and pedestrians that can minimize accidents, congestion, delays, and fatigue.
- Improved mobility results in improved efficiencies of vehicles and roads.

- Enables reduced road network needed than with conventional traffic control solutions for the same required mobility, safety, and energy efficiency. A fundamental debate exists between perceived needs to increase road supply and the increases in traffic flows obtainable by using existing capacities more intelligently [9].
- Drivers and passengers can get timely information on board of vehicles or from variable message boards as to which route to take that may be shorter and clearer.
- Easy detection and pinpointing of emergency.
- ITS platform enables communication of vehicles that help avoid accidents.
- Enables in-motion toll payment and weighting system that avoids stoppages.
- Getting information on nearest car parking plots.
- Integrated corridor management will entail highways, arterial roads and transit systems within a corridor to optimize people throughput within the corridor [9].
- ITS paves the way for "smart transport system" in which vehicles may be computer driven to move people and goods safer, faster and reliably.

Generally, successful ITS applications are to be found wherever there is significant road traffic. Precise priorities depend upon local circumstances, reflecting the structure of cities, relative distances, traffic densities and the balance of transport modes. All applications share common aims: increased safety, reduced emissions and improved traffic flows [9].

4.3 Global Applications Status and Future Prospect of ITS

ITS already exist and in many cases their successful applications are already deployed. They proved their worth in most major developed cities that have implemented such programs. Performance is readily measured in reduced accidents, reduced incident response times, reduced travel times, reduced emissions, reduced vehicle operating costs, increased traffic speeds, and increased on-time transit performance. For instance, in the Public Transportation Systems application of ITS in Sweden, a variable charging regime was introduced in the express public bus transport system. Charges were collected through automatic electronic fee collection system. Accordingly, this resulted in reductions of road traffic by 20–25%, travel times by 30–50%, and emissions by 10–14% [9]. ITS is being used as a cross cutting solution to address the multifaceted problems associated with vehicular and railways transportation systems. Some developing countries like Brazil, India and South Africa have also already deployed ITS [9]. Unfortunately, ITS technologies are not being used in anything like the scale and quantities that they need to be. Especially when one considers that such technologies are very cost-effective and cost-conservative by comparison with conventional solutions [8]. It is paradox that their utilization is slow, fragmented and uncoordinated.

A number of possible reasons may be enumerated for the slower adaptation of ITS. One reason may be that, developed nations have already invested too much on conventional mobility traffic control and management solutions to easily migrate to ITS. Another reason may be that there are already too many old model vehicles in operation that may need additional equipment to easily be integrated and utilize the advanced features of ITS. Still another reason may be lack of sufficient and consolidated international standard. Standards would have enabled users to easily decide and adopt or contextualize ITS technologies off the shelf. A final reason might be lack of proven universal business model to introduce ITS in the global market in full gear.

However, the ever-increasing problems not properly and intelligently handled by conventional solutions, is pushing many nations to migrate to ITS. This is witnessed by some nations whatever the cost but surely with un-matching benefits. The ubiquities and increased performance with reduced cost of the development environment for ITS is attracting nations to decide the deployment of ITS. Furthermore, another compelling condition to harness ITS is due to the advancement of modern vehicles. Most modern vehicles are coming with many sensors used to monitor, diagnose and guide each internal and external functioning of the vehicle. This enables them to be operated more easily, safely and reliably as well as maintained easily. These vehicles can be made to communicate among each other in V2V mode and with the road side infrastructure in V2I mode. This enables them to avoid collisions while at the same time operate at the maximum speed possible.

The built-in or the easy embedding of navigation, guidance, security and antitheft systems in them enables these cars to be easily controlled by human drivers and/or remote computer. The technology also helps easily pinpoint the exact time and location of incidents which is a requirement for smart transport system. Even old model cars can also use the blessings of ITS by adding into them the basic required hardware and software. A qualitative comparison of conventional and ITS based traffic signal control is tabulated below as extracted from observations in [11, 12] (Table 1).

Table 1. Comparison of conventional and ITS based traffic control systems

Comparison metrics	Conventional based traffic signal control systems	ITS based traffic signal control systems
Traffic signal timing	Fixed but operators may adjust them periodically	Adaptive that may account any time- of-a-day
Control scheme	Local, needing huge effort	Central configuration and control
Use of vehicular flow and speed detectors	Not used	May use detectors such as inductive loops and cameras
Synchronization of traffic signals at intersections	Done manually by operators periodically	Done adaptively by the system instantly to improve traffic
Vehicular traffic flow	Non steady, dominantly congested and saturated	Relatively steady, uncongested and faster
Informative-ness to drivers, passengers and pedestrians	Inflexible to update	Relatively flexible, adaptive and updated centrally
Accident (collision of vehicles and injuries)	Normal	Relatively reduced
Cost of implementation, operation, and maintenance	Normal	Relatively higher but worth the benefits it offers

5 Discussion on Prospects of ITS Applications in Ethiopia

The analyses described previously imply that modern mobility traffic control and management solutions for vehicular transportation system that use ITS would be more effective than the conventional. It is so, not only for the developed nations but also for Ethiopia.

There are a number of reasons for the need of introduction of ITS in Addis Ababa and other major cities of Ethiopia at the earliest possible. First, Ethiopia is currently a low income country whose 81% population still live in rural areas. Its road network and vehicle density can be said to be in their primitive stages. Addis Ababa and the other cities are currently being renovated and expanded almost anew with improved city master plans. This means that, a lot more road network would be constructed and this makes the process to consider ITS now or in the earliest possible.

Second, Ethiopia has about only half a million number of vehicles. This is a very small number compared with even other underdeveloped nations and only very few of them are modern. All newly imported and locally assembled brand new vehicles are increasing. Most of them are also expected to be modern with some ITS ready features so that they can be easily deployed in an ITS based control.

Third, there are already some resources and few expertise available in Ethiopia that serve as fertile ground. This enables to embark, develop and implement ITS which include:

- presence and expansive coverage of legacy to Long Term Evolution (LTE) mobile communication network
- existing conventional traffic signals that can possibly be integrated to the ITS system to be introduced
- presence of some experience with the Addis Ababa to Adama toll based express way corridor that is using some features of ITS
- the new Modjo-Hawassa express way being constructed is planned to have ITS elements including electronic toll collection (ETC) and CCTV systems
- existence of few expertise knowledge in ITS as well as in operating and utilizing this express way
- the recently deployed Light Rail Transit system with its own modern traffic control system and that can be integrated with the existing vehicular system.

Thus, rather than sticking to the relatively ineffective conventional way of mobility traffic control, it is recommended that ITS be incorporated in the master plans of Addis Ababa and other major cities. Their implementation can then be introduced at the early stage and in parallel with the execution of the master plans. It is expected that this would help optimize the utilization of the existing and newly introduced road networks than with conventional approach. It would also help curb accidents and pollution.

6 Conclusion

In Sect. 5, it has been attempted to justify the better merits of ITS over that of the conventional for mobility traffic control and management systems. Thus, if ITS is implemented in Ethiopia, as is done in many developed and few developing nations with reported successes of reduced accidents, reduced incident response times, reduced travel times, reduced emissions, reduced vehicle operating costs, increased traffic speeds, and increased on-time transit performance [9], then it would also do the same for Ethiopia.

This paper therefore strongly recommends that the issue of introduction of ITS be started in Ethiopia at the earliest possible. It is also proposed that discussion be held by all stakeholders through public- private-partnership approach. In this regards, establishment of a center of excellence on ITS composed of relevant disciplines and stakeholders might be necessary. This would help to fully understand, research, adapt and/or adopt its application to the Ethiopian context to exploit all benefits of ITS.

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