

Integration of Intelligent Transportation Systems (ITS) with Conventional Traffic Management in Developing Countries

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Abstract: Traffic management is a global challenge, with traditional techniques proving inadequate to manage modern movement complexity and dynamism. Intelligent Transportation Systems (ITS) are being integrated into traffic management systems across different countries to address these major challenges. ITS technologies are addressing traffic challenges, such as route choice, real-time traffic information, augmented signage, fleet management, emergency vehicle management, and many more. While developed countries are experiencing positive outcomes from ITS implementation, it is much more challenging in developing countries, where variations in infrastructure, funding, technical expertise, and lifestyle must be considered. Despite these challenges, simple communication technologies such as GPS, Wi-Fi, microphones, cameras, accelerometers etc. can be used for feasible ITS implementation. The goal of this study is to find out feasible ways to include ITS in the traffic management systems of developing countries through the use of readily available technologies which can be used in procedures like detecting and locating potholes, providing additional safety and environmental news to road users, and monitoring traffic flow, etc. Adaptation of ITS in developing countries requires modifications compared to the Western ITS standards. This study thoroughly analyzes the many implementation techniques in developed countries and research works conducted in these domains and suggests potential adaptation techniques or strategies and required modifications which can be used to transform the conventional traffic management system of developing countries into a much more effective and efficient one.

Keywords: Transportation, intelligent transportation system, developing countries, technologies, traffic management

1 Introduction

Intelligent Transportation System aims to provide solutions to modern-day traffic management issues through the application of sensing, analysis, control, and communication technologies. Components of ITS are being effectively used all around

the world to tackle transportation problems and to improve safety, mobility, and efficiency. As the trend of vehicular travel increases all around the world, traffic issues including congestion, accidents, and other issues are worsening day by day [1]. Traditional methods used in the past to handle these problems are now proving to be futile due to the sheer complexity of the issues and the overall situation is worse in developing countries. Therefore, the broad use of ITS is becoming increasingly necessary for improving the overall performance of the road network.

In every country, mobility holds a significant value for individuals as it serves as a crucial factor for economic activities and social well-being. People perceive mobility as a valuable asset in their lives, enabling them to move with freedom, safety, efficiency, and affordability. By addressing traffic issues and implementing intelligent transportation systems and effective traffic management strategies, mobility can be significantly improved. Currently, ITS is being implemented in numerous countries worldwide to improve transportation systems and enhance mobility. The substantial investment made by the Japanese government in ITS has reaped remarkable benefits in improving the overall transportation system of the country [2]. Through the use of technologies like Vehicle Information Communications Systems (VICS) and Dedicated Short Range Communications (DSRC) services, Japan has deployed Smartway which has significantly enhanced the overall transportation system. The ITS program in the United States of America concentrates on various areas such as Telephonic Data Dissemination, IntelliDrive, Cooperative Intersection Collision Avoidance Systems, Congestion Initiatives, Integrated Corridor Management Systems, etc., and provides services to all Americans [3]. Australia focuses on using ITS applications to improve traffic scenarios and enhance traffic safety [4]. The United Kingdom adopted the MIRA Intelligent Transportation System as its foundational ITS architecture, utilizing military-grade self-healing communications network technologies and topologies to ensure the secure and reliable operation of intricate control systems [5]. The deployment of ITS varies across countries, but the underlying goal remains constant: to enhance transportation system performance by reducing congestion, improving safety, and increasing convenience for travelers. While many developed nations have successfully achieved the objectives of ITS implementation, developing countries have faced challenges in fully utilizing the usefulness of ITS due to several significant factors. But transportation systems of developing countries are generally more in need of ITS technologies to tactically handle the many challenges of travel demand than the developed countries.

The adoption of Western ITS standards and architecture in developing countries is challenging due to a wide range of factors such as a diverse range of vehicular velocities, poor lane discipline, heterogeneity of vehicles including pedestrian traffic, and high traffic density. All these factors combined with limited infrastructure, lack of public awareness, budget constraints, lack of accurate traffic data, and lack of regulatory and policy framework make it difficult to deploy advanced ITS standards in developing countries. However, the utilization of ITS has the potential to bring about a revolutionary change in the existing transportation systems of developing countries.

A wide range of ITS technologies can be used to optimize traffic flow, enhance road safety and enable efficient management of transportation networks. Overcoming the typical constraints faced by these countries would pave the way for Intelligent Transportation Systems to serve as the comprehensive solution to the traffic issues that currently affect their streets.

The process of integrating ITS into the traditional traffic management processes poses unique challenges in developing countries as the implementation process will face struggles that are not similar to the struggles faced by developed countries. Considering the multitude of benefits gained from the use of ITS technologies, dedicating efforts to implement ITS in developing countries is indeed a worthwhile endeavor. In developing countries, decision-makers often lack the necessary knowledge and understanding of Intelligent Transportation Systems (ITS), resulting in their ignorance regarding the potential applications, implementation techniques, and integration possibilities of ITS within their existing traffic management systems. Consequently, it becomes imperative to undertake a thorough exploration of the options available for implementing ITS in developing countries. By doing so, it is possible to bridge the knowledge gap and gain insight into the transformative capabilities of ITS, ensuring informed choices regarding the integration of these advanced technologies into the transportation infrastructure. This paper aims to delve into the various opportunities and prospects associated with integrating ITS into the traditional traffic management strategies of developing countries like Bangladesh which will provide decision-makers with the tools and information required to leverage the benefits and overcome the challenges associated with implementing ITS solutions.

2 Disparities in Traffic Management in Developing Countries

The implementation of ITS in developing countries is impeded by various factors. This is especially true in the context of Bangladesh, where specific factors further hinder the successful deployment of ITS. Therefore, it becomes crucial to thoroughly consider these factors in the application process to ensure the effective integration of ITS into Bangladesh's traffic management system. The following are some of the factors that hinder the implementation of ITS in developing countries and it will be crucial to consider these factors in the application process.

2.1 Lack of Technology

The availability of abundant data presents an opportunity for intelligent transportation systems (ITS) to transform into more powerful data-driven systems (D2ITS). Vision-driven technologies, utilizing input from video sensors, optimize performance in various ITS applications. Another approach involves analyzing data from auxiliary instruments like cameras, inductive-loop detectors, GPS receivers, and microwave detectors to enhance existing transportation infrastructure [6]. However, developing

countries continue to face significant challenges due to the lack of availability and high implementation and management cost of these technologies.

2.2 Heterogeneity of Vehicles

The complexity of interactions between vehicles in heavy traffic conditions highlights the importance of considering the heterogeneity of traffic systems. Developing countries, in particular, often experience mixed traffic conditions. Therefore, when designing Intelligent Transportation Systems (ITS) for these countries, it is crucial to account for their prevailing mixed traffic conditions to ensure the effectiveness and applicability of the ITS solutions [7]. In mixed traffic flow, both fast-moving and slow-moving vehicles coexist, including motorized vehicles like cars, buses, trucks, auto-rickshaws, scooters, and motorcycles, as well as non-motorized vehicles such as bicycles, cycle-rickshaws, and animal-driven carts [8]. Unlike homogeneous traffic, where vehicles generally move in single-file formation, mixed-flow traffic involves significant lateral movement, particularly among smaller motor vehicles. This lateral movement contributes to the dynamic nature of mixed traffic systems, further distinguishing them from homogeneous traffic systems [9]. Therefore, ITS technologies developed based on the traffic condition of developed countries may not be suitable for developing countries and modifications may be required.

2.3 Lack of Infrastructure

Developing countries in general lack the necessary telecommunication and road infrastructures to support the implementation of an intelligent transport system [10]. O'Neill [11], at a forum organized by the World Bank, presented the deficiencies observed in transport systems in developing countries: the lack of highways, the lack of telecommunications, the lack of management planning systems, and the insufficient public transport regulatory services. For example, studies have shown that ITS fails in the Indian situation due to a lack of freeways, non-uniformity of vehicle speed, and lanes created by ITS techniques in developed countries. A wide range of technologies can be utilized to aid traffic performance but the installation of infrastructure on the highways of developing countries such as India is often limited by space [12]. Another prominent challenge in the implementation of Intelligent Transportation Systems (ITS) is the extensive time required for planning, implementation, and integration. This process can be time-consuming to such an extent that the systems may become outdated before they are fully operational. For example, Shaaban [13] explained how Qatar was yet struggling to fully implement the ITS master plan in 2021, although the plan was initiated in 2011 and hence the technologies planned were already getting outdated before they were even fully implemented. This problem will be even more acute in developing countries. Also, the design of vehicular communication systems in ITS requires strong real-time data collection technologies and systems which are very costly [14]. All these shortcomings justify why it is difficult to implement intelligent transport systems in developing countries.

2.4 Lack of Management and Enforcement

One of the prominent factors contributing to the challenges faced while implementing ITS in developing countries is the lack of effective management and cooperation. Effective cooperation, communication, and an organized structure are essential to ensure the smooth performance of ITS systems. Lack of management may lead to ineffective performance or even failure of the total traffic network [13]. It is highlighted in [15] that the lack of a supportive instrumental framework poses a significant challenge to implementing Intelligent Transportation Systems (ITS) in developing countries. This framework is crucial for enforcing the necessary arrangements required to fully realize the benefits of ITS.

2.5 Lack of User Intellect and Awareness

A limited understanding of advanced ITS technologies is another significant contributing factor to the hindrance of ITS implementation in developing countries. A survey conducted for a study by Antoine [16] revealed that 73.78% of respondents lacked familiarity with ITS. This reflects the urgent need to raise awareness and educate the masses in developing countries about the vast scopes and benefits of ITS.

3 Scope of ITS in Developing Countries

Despite the challenges, ITS in developing countries holds significant potential for improving transportation systems, enhancing efficiency, and addressing various mobility challenges. Some of the opportunities for using ITS to overcome the transportation issues of developing countries, such as Bangladesh, are listed as follows.

3.1 Electronic Toll Collection

Electronic Toll Collection (ETC) is a modern technological method to collect toll payments electronically. In Iran, a study was conducted by Saffarzadeh [17] comparing Electronic Toll Collection to traditional toll collection techniques. It was discovered that ETC resulted in significant fuel savings, intercity traffic calming, and reduced travel time. Also, the introduction of cordon pricing can be a fruitful method of decreasing congestion. Studies showed that cordon pricing in London resulted in a daily decrease of around 60,000 cars entering the fee zone, with 50% to 60% of those vehicles opting for public transportation and 15% to 25% opting for carpooling, bicycles, or mopeds [18]. According to a US Department of Transportation (US DOT) report from 2000, the installation of an Electronic Toll Collection on the New Jersey Turnpike resulted in an annual fuel savings of 1.2 million gallons. These toll collection methods and pricing strategies can be a scope of effective implementation of ITS in developing countries as these practices are already available in many developing countries but only manually. By introducing Electronic Toll Collection in Bangladesh, specifically in major highways and bridges where tolls are currently collected manually, the collection

time can be significantly reduced. The manual toll collection process often leads to congestion, as vehicles are forced to slow down or come to a complete stop, causing delays and inefficiencies. However, by implementing Electronic Toll Collection systems, developing countries like Bangladesh can streamline the toll collection process, minimizing congestion and improving traffic flow. This modern technological solution would not only enhance the efficiency of toll collection but also contribute to reducing fuel consumption, alleviating intercity traffic, and enhancing overall travel time, similar to the benefits observed in other regions.

3.2 Intelligent Traffic Light Controller

Chavan et al. [19] proposed an Intelligent Traffic Light Controller that outperformed the conventional controller in several aspects. The proposed controller resulted in reduced waiting time for vehicles, increased distance traveled by average vehicles, and improved efficiency during emergency mode. Additionally, the system was designed with a simple architecture, fast response time, user-friendly interface, and potential for future expansion, which fits perfectly with developing nations' conditions. In Bangladesh, the traffic stream displays a remarkable heterogeneity, rendering the conventional fixed-time traffic signal system inadequate. The existing manual traffic management system, while prevalent, falls short in terms of efficiency. To address these challenges, there is a pressing need for an intelligent traffic light system in the country.

3.3 Communication Infrastructure

Reliable communication infrastructure can offer numerous benefits for developing countries. A study found that infrastructure-to-vehicle (I2V) communication resulted in an overall 22% improvement in fuel economy [20]. A study by Wang [21] establishes a new mechanism for parallel control and management of complex transportation systems, integrating concepts from various fields such as AI, intelligent control, computational intelligence, and cloud computing and the result shows a considerable improvement in the average vehicle speed when traveling in the specified area of research; the daily average vehicle speed has increased by 11%, from 58.5 to 64.3 km/h. The interconnection between vehicles and infrastructures facilitated by modern communication technologies can play a vital role in addressing the diverse traffic issues faced by developing countries, contributing to enhanced mobility, reduced congestion, and improved transportation efficiency.

3.4 Traffic Management Technology

Traffic management technology encompasses various tools and systems used to monitor, control, and optimize traffic flow on road networks. Due to the existing limitations of developing countries, it is necessary to choose suitable traffic management technologies as it ensures successful implementation and maximizes benefits while minimizing potential issues [22]. Implementing traffic management technology in developing countries requires investments in infrastructure, equipment,

and capacity building but all of these are worth it as these initiatives can revolutionize urban transportation systems by utilizing data-driven approaches to enhance efficiency. By utilizing information-centered management, transparency and accountability in the transportation system can be improved [23]. In a study, Kinane [24] highlighted that the integration of sensors into critical domains such as transportation, healthcare, and emergency response has been made possible due to advancements in sensor networking and the accessibility of affordable sensor-enabled devices. This integration empowers us with an unparalleled capacity to monitor, observe and manage our surroundings making traffic management way easier. A comprehensive approach to implementing an Intelligent Transportation System (ITS) was proposed in [25], which aims to promote organized transportation while reducing congestion, air pollution, fuel waste, and time inefficiency. The proposal includes the integration of traffic surveillance, vehicle surveillance, passenger surveillance, and driver surveillance. Integration of all these systems into the existing traffic management of developing countries has the potential to bring about a massive change in the traffic network performance and also in traffic law enforcement strategies. By leveraging traffic management technology, Bangladesh can address the challenges of increasing traffic volume, congestion, and road safety. Implementing these technological solutions can lead to smoother traffic flow, reduced travel times, improved road safety, and enhanced overall efficiency of the streets, making transportation more convenient and sustainable for its citizens.

3.5 Intelligent Parking Systems

Parking guidance and information (PGI) systems, or advanced parking information systems (APIS), have been utilized in Aachen, Germany since the 1970s [26]. In Japan, these systems offer real-time data on road accidents, traffic congestion, flow restrictions, and parking facility locations [27], [28], [29]. Toyota's parking guidance and information service in Japan optimizes limited parking facilities [30]. The USA's ATIS scheme focuses on equipment interoperability, information protocols, and smart card payment integration for parking facility management. In the context of Bangladesh, the improper and inefficient use of limited off-street parking facilities leads to on-street parking, which reduces road capacity and causes bottlenecks. By adopting intelligent parking systems, developing countries like Bangladesh can alleviate parking-related issues, optimize parking space utilization, and mitigate congestion. These transformative technologies remain untapped in developing countries, holding immense potential for revolutionizing parking systems.

3.6 Crowdsourcing

Crowdsourcing offers a valuable means to tap into the ideas and solutions of citizens or groups of people through Internet platforms [31]. In the context of rapid urbanization and smart city development, crowdsourcing becomes an asset, transforming overpopulation from a problem to an opportunity. Kumar's study [32] categorized 7 different methods of how crowdsourcing enhances transport systems in developing

countries. For instance, the utilization of loop wires and CCTV on major highways enables efficient traffic monitoring and congestion management. Through CrowdITS, these tasks, among others, can be performed by the crowd itself, comprising drivers or passengers utilizing interactive modes (e.g., voice) or ubiquitous modes (e.g., GPS logging), or a combination of both [33]. Given the widespread smartphone usage and the large population in Bangladesh, the country has a unique advantage in leveraging crowdsourcing to build a robust information network. By tapping into this resource, Bangladesh can generate real-time data and insights, enabling more efficient traffic monitoring, congestion management, and informed decision-making in urban transportation.

3.7 Smart City

The concept of a Smart City is gaining momentum these days as a novel approach to address current urban challenges and foster sustainable urban development [23]. Various studies have provided different interpretations and definitions of smart cities in different contexts [34], [35]. While numerous investigations and practical reports delve into the desirable characteristics of a smart city [36], [37], [38] and showcase cities that self-identify as "smart" or employ similar progressive labels such as intelligent or innovative [39], [40], [41], limited research has focused on developing a systematic understanding of the initiatives that truly make a city smarter. Consequently, there is a growing demand for effective governance mechanisms to oversee and manage these initiatives or projects aimed at achieving smart cities [42]. Odendaal's [42] case study revealed that smart governance facilitates collaboration, data exchange, service integration, and communication. In this regard, Intelligent Transportation Systems (ITS), powered by emerging technologies like social media and mobile communication, present new avenues to actively engage citizens in smart city initiatives. Works of literature have emphasized that the achievement of technology-enabled smart cities in developing nations is contingent upon the simultaneous implementation of socioeconomic, human, legal, and regulatory reforms [43]. Governments must enhance their endeavors in fulfilling the fundamental infrastructure requirements of their citizens, generating additional revenue streams, establishing robust regulatory frameworks to mitigate potential technological risks, cultivating human capital, promoting digital inclusivity, and fostering environmental sustainability to achieve the goal of a smart city in a developing country. Building a strong regulatory environment that fosters the confidence of investors and the trust of citizens is a key driver of smart city development in developing countries [44], [45], [46], [47]. Bangladesh needs to focus on holistic smart city planning, considering the specific needs and challenges of its urban areas through fostering collaboration among government agencies, private sector stakeholders, academia, and the community. Implementing ITS powered by emerging technologies, such as social media and mobile communication, can actively engage citizens in smart city. Building a strong regulatory environment that instills investor confidence and citizen trust is a fundamental driver of smart city development in developing countries. Developing countries, such as Bangladesh need to focus on

creating an enabling environment that encourages investment, innovation, and the adoption of transformative technologies.

4 Conclusion

This comprehensive review paper presents a thorough examination of the varied application scopes of Intelligent Transportation Systems (ITS) in traffic management within developing countries. ITS has emerged as a product of progress in social, economic, and technological realms, closely lined up with the era of information technology. [48]. In recent times, Intelligent Transportation Systems (ITS) have seen the implementation of various adaptable technologies, with continuous efforts dedicated to developing innovative solutions to address transportation challenges. As urban populations expand, the prospects for constructing new infrastructure are diminishing. Consequently, countries globally are shifting their focus from infrastructure development to optimizing the utilization of existing facilities, where ITS can play a significant and efficient role if effectively employed. However, despite the potential advantages and diverse applications of ITS, there exists a lack of universal understanding regarding its effectiveness, leading to gaps in its utilization, particularly in developing nations.

Despite the introduction of various ITS functions, there remains untapped potential for these capabilities, leading to a lack of awareness and hesitance to invest in ITS [49]. While ITS technologies offer significant advantages, such as enhanced comfort, safety, and reduced congestion, they also introduce serious concerns regarding security and privacy if not adequately addressed in the design process [50]. Cities in developing countries need to enhance their technical capabilities to effectively procure and monitor information services. When implementing innovative and often technically intricate smart transport solutions, these countries with limited technical capacity face the potential risk of becoming locked into a particular technology or being dominated by a powerful stakeholder, such as a major technology provider, who seeks excessive profits. Hence, it becomes crucial for cities to build a minimum level of technical expertise to mitigate this risk during the procurement and monitoring processes of these services [47]. Although the integration of ITS with traditional traffic management techniques of Bangladesh will face many challenges, it will all be worth it when the successful implementation of ITS will facilitate the promotion of effective and sustainable transportation practices. Through the use of ITS, developing countries, such as Bangladesh can unlock significant benefits in terms of improved transportation efficiency, enhanced mobility, and a more sustainable and resilient transportation system for its growing population. This study will aid researchers and planners in gaining a better understanding of existing ITS technologies and their suitability within the context of developing countries.

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