Chapter 40
Review of Recent Developments in Sustainable Traffic Management System

Bhawini Sharma and Jai Kumar Maherchandani

Abstract Nowadays, rapid growth in vehicles on the road causes traffic congestion, a considerable problem. Accidents, noise, long lines at intersections, health damage, and other facets of the transportation sector of modern society are all impacted by this problem. A reliable traffic management system (TMS) is needed in the contemporary world to resolve traffic-related issues and improve the transportation systems' safety and overall efficiency. TMS collects data from various sources and analyses it using various techniques like artificial intelligence, optimization, data analysis etc., to identify hazards and then provides services to mitigate them. In light of this, this article reviews the recent developments, challenges, and potential prospects of implementing a traffic management system.

40.1 Introduction

In today's society, moving fast is everyone's goal. Everybody wants to find the fastest way to reach their destination and, in that transportation, plays an important role. People use the vehicle of every form to reach their destiny.

Rapid growth in the number of vehicles due to population increases causes a severe problem in the transportation system, and traffic congestion will have become a pressing issue. This problem will need a very efficient traffic management system to manage vehicles to reduce congestion, waiting time on lights, efficient fuel consumption, etc.

Bad weather, work zones, accident events, and poor traffic signal scheduling are examples of direct traffic influencing events. In contrast, lack of efficient transportation facilities, such as poor road conditions, are indirect traffic influencing events [1]. As a result, large cities with heavy traffic depend on TMS to solve their traffic management problems and ensure smooth city transportation.

Along with long queues at intersection and traffic jams, weather conditions like fog, snow, and rainfall are significant problems for a driver. These factors affect

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traffic flow, speed etc.; intelligent traffic management addresses issues like water logging, narrow roads, and weak drainage systems [2, 3]. Another major issue in developing countries is toll booths. A manual toll system results in slow speed, jams, and lengthy queues [4]. So, an automated toll system is also a part of the intelligent traffic management system. This paper presents a brief review of some recent TMS approaches.

The remainder of the paper is as follows. Section 40.2 gives a brief idea of the concept of TMS with an explanation of its three phases. Section 40.3 reviews some of the traffic management systems found in the literature, explaining each type of technique in brief. Section 40.4 gives the idea of various challenges that remain to be addressed in traffic management systems. And lastly, Sect. 40.5 concludes the article.

40.2 Traffic Management System

A traffic management system is a platform to solve traffic-related problems. TMS defines various algorithms and models related to traffic issues. The main problems concerning increasing traffic for which we need TMS include traffic congestions and long traffic jams, providing a smooth path for medical emergencies, reducing waiting time at intersections, and reducing fuel consumption and lane management [5]. Over time, various TMSs have been introduced and implemented. TMSs consist of mainly three phases. First is the information gathering step in which different information related to traffic is gathered and collected. In the second step of information processing, the traffic hazard is identified, and the data collected is used accordingly. Lastly, the third step of service delivery solutions is given for the identified problem [6]. Figure 40.1 shows the three phases of the traffic management system, and a brief about all three steps are given as follow.

Information gathering: This phase collects data from different traffic-related sources like roadside units, traffic lights, roadside sensors, etc., as in vehicles, various inbuilt sensors like speedometer, GPS, etc., provide traffic-related data. Then, the data is sent to the information processing unit to process it.

Information processing: Following the information gathering process, the data must be effectively used to predict various traffic-related hazards. The data must be aggregated in the information processing phase to enhance data quality and provide services as required.

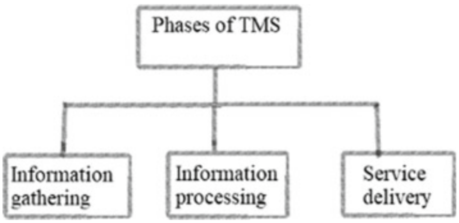

Fig. 40.1 Phases of traffic management system

Service delivery: This phase provides services related to the hazard identified in the information processing phase. The service provided by this phase helps in controlling hazards and improving overall traffic efficiency.

40.3 Recent Traffic Management Systems

This section contains a summary and qualitative study of some of the literature-based TMSs. Figure 40.2 shows the different techniques used by researchers in the area of the traffic management system.

40.3.1 Artificial Intelligence (AI)-Based Models

AI-based solution for traffic management problems is presented in [7]. A design is produced for variable signal timing and special requirement for medical emergencies. It is proposed that signal timing be adjusted based on density and traffic

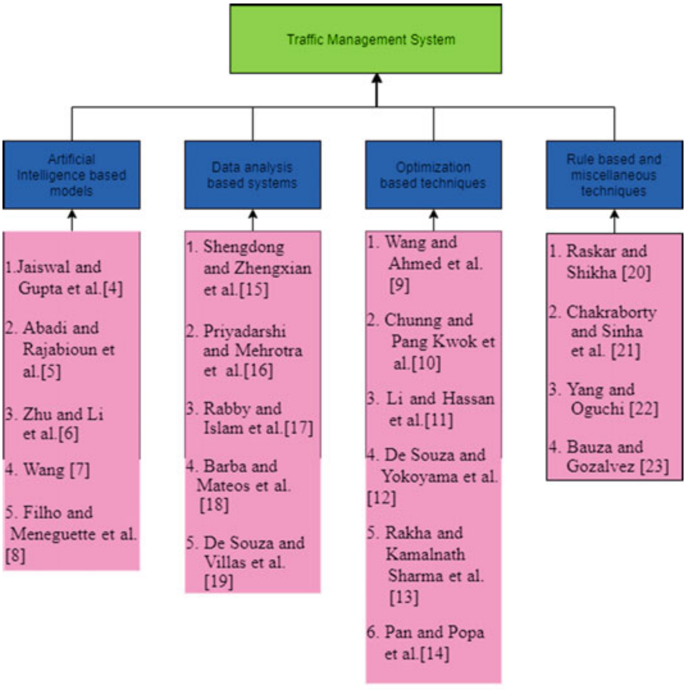

Fig. 40.2 Techniques for traffic management system

demands. In medical emergencies, traffic from the corridor should be diverted to provide a smooth path for ambulances. A technique for predicting traffic flow for all connections in a transportation network over a limited time horizon is proposed in [8]. The first step is to produce traffic flow data at all links using a dynamic origin–destination matrix, and then future traffic flow is projected using the collected data.

A new generation of intelligent transportation systems (ITS) based on parallel transportation management and control systems (PIMS) is proposed in [9]. Existing transportation systems and artificial transportation systems are linked in PIMS, and experiments are carried out on the latter. It is a simple way to apply optimization and evaluation. The public may use a crowdsourcing platform for transportation to obtain or release travel-related information anytime they need it. Lastly, the MapReduce framework technique is used to predict traffic flow.

Three major techniques for the ITS are presented in [10]. First, hierarchical intelligent control systems were used to decompose complex issues in traffic networks. Second, networked traffic controllers of street intersections and freeway entry and exit, the agent-based control (ABC) system, and the concept of "local easy, remote complex" were used to provide a low-cost, high-performance, and intelligence method. Finally, the artificial transportation systems (ATS) idea was implemented to provide an in-the-loop emulation of real-time traffic information to support traffic decision making.

An inter-vehicular solution is developed in [11] to help during vehicle traffic congestion problems in cities. To minimise congestion problem, qualitative and quantitative data is obtained to gather knowledge. Then, vehicle to vehicle (V2V) communication is established to determine which vehicle should change its route to avoid congestion.

40.3.2 Optimization-Based Techniques

A discrete-time stochastic dynamic model is proposed in [12] to explain urban traffic dynamics. The term "congestion broadcast stage" (CBL) is used for the first time. As soon as CBL exceeds the prescribed limit, congestion will be announced. An objective function is made of throughout and waiting time. An optimization problem is formulated and solved by dynamic programming to describe the effectiveness of the mathematical model.

A hybrid intelligent traffic light system for Hong Kong is presented in [13]. The aim is to dynamically monitor the traffic light system by measuring vehicles and pedestrians at the intersection using object recognition. A simulator is formed to demonstrate the effectiveness of road users for fixed cycle traffic light systems and intelligent traffic light systems. The parameter collection is optimized using an evolutionary algorithm to reduce the average waiting time for all road users.

A traffic control mechanism is devised in [14] that is responsible for intersection congestions. A hierarchical framework for optimizing traffic signal setting based on a multi-agent system was proposed. The work creates an intelligent real-time traffic management mechanism that incorporates online changes and offline optimization to customize traffic signal settings.

In [15], an intelligent traffic system is proposed that detects when a congestion is forming and systematically manages traffic to distribute the density of vehicles so that congestion in the near future is avoided. A framework based on vehicle to infrastructure (V2I) communication is proposed in [16], which enhances fuel consumption. The driver is assumed to follow instructions thoroughly to get optimum fuel consumption. Through optimization, the algorithm system computes the maximum acceleration level from net force computation. The work presented in [17] gives five different rerouting algorithms and compared them with a standard algorithm to check their efficiency levels.

40.3.3 Data Analysis-Based Management System

Designing an intelligent transportation cyber-physical cloud control system is presented in [18]. The data is first collected and sent to a cloud control platform, after which it is intelligently processed to produce prediction results and control schemes, which are then sent to an intelligent traffic system for tracking, management, and decision making.

Issue of rapid transit of vehicles, emergency vehicles and stolen vehicle recovery are dealt in [19]. The concept of roadside unit (RSU) and on-board unit (OBU) was used. It is assumed that every vehicle is attached with an RFID tag, which contains all its information to help retrieve the vehicle if it is stolen. The reader reads the RFID tag and displays vehicle density on LCD to make traffic flow management smart. Every emergency vehicle will have a transmitter through which its arrival will be detected, and the lane will be cleared.

An IoT-based intelligent traffic management system is explored in [20] by considering sensor fusion techniques and image data streaming from multiple cameras installed on different traffic system parts. The cameras and sensors work as eye and ear for the car. The system is based on the attainment of traffic information from various sources, analysis of traffic data, monitoring and proper control of traffic operation and data storage, and information presentation.

In [21], a framework has been developed where intelligent traffic light (ITL) system gathers information from passing vehicles and update traffic information of city and report strategies to vehicles. It also sends warning messages to vehicles to avoid any further collisions in case of accidents.

40.3.4 Rule-Based and Miscellaneous Techniques

A new traffic management system using an intelligent barricade system is proposed in [22]. The idea is to make the extra lane available dynamically in such situations, such as traffic congestion or an accident. In this work, the barricade movement is decided by a rule-based system. A communication system consisting of the V2I and V2V communication is used.

An algorithm that determines the green light duration and handles emergency vehicle management is proposed [23]. The algorithm uses a wireless sensor network (WSN) for input. The algorithm works in four steps that decide queue length, determine if an ambulance or priority vehicle is present, assign green light to the most appropriate phase, and calculate green light time.

A multilevel integrated TMS manages large scale on the road-connected vehicles to reduce road congestion and vehicle travel time proposed in [24]. The system divides the entire network into three levels to gather traffic data and monitor individual vehicles with three vehicle control systems: lane shifting assistance during road collisions, optimum lane selection, and dynamic routing with turning cost estimation. The system also gives different instructions to linked vehicles at different levels, such as route and lane choices, to reduce individual vehicle travel times. Furthermore, the system is tested at a city-level road network with the integration of microscopic traffic assignment and simulation tools to understand its effects on individual vehicles at various levels.

40.4 Challenges and Future Perspective

Despite the introduction of so many traffic management systems, some challenges remain to be stated. Figure 40.3 shows the different challenges in the traffic management system.

Some of the challenges are listed below.

40.4.1 Security and Privacy

Data generation is the fundamental step in any TMS. Data regarding vehicles contain much personal information about the vehicle as well as the owner. So, the security of data gathered from different sources is one of the major challenges in the

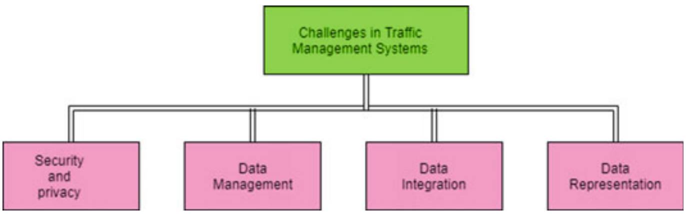

Fig. 40.3 Challenges in traffic management system

TMS. Several requirements need to be satisfied to assure safety and privacy to the vehicular ad hoc networks (VANETs) [25]. To prevent messages containing malicious data, data integrity verification tests the legality and consistency of messages. In [26, 27], various issues related to information privacy and security in intelligent traffic management system are discussed.

40.4.2 Data Representation

After gathering data from different sources, it is accumulated and studied to gather knowledge. The knowledge gathered should be represented in proper form to make it easy to understand. This defined data is used to identify many of the hazards. Accurate representation makes identifying hazards easy and helps to stop them in time.

40.4.3 Data Management

Since TMS must deal with many data, data representation standardization is critical to the system's efficiency. Some of the challenges faced in data management are:

(a) Each source may have different measurements and formatting.
(b) Asynchronous data reporting from many sources.
(c) Data flow to different systems from the same source.

TMSs must have efficient mechanisms to fuse, aggregate, and exploit data to deal with various data types generated from heterogeneous sources.

40.4.4 Data Integration

Acquiring data from sources that are not integrated is a significant challenge in TMS. The biggest issue is figuring out how to achieve this integration. Many different systems and sources can exist with no integration, resulting in a massive amount of data with no standardization.

40.5 Conclusion

Improving transportation efficiency is still a significant research area and needs study. Traffic management system mainly relies on the data collection and data management system. Collecting data from a wide variety and number of sources is a huge problem that still needs some work. The same can be said for data management; using data, gathering information from collected data requires a systematic and efficient system. These issues still need to be explored more to make TMS efficient and reliable.

This article has explored the various aspects of the traffic management system. First, it gives a brief idea about the traffic management system and related critical issues. A review of the various works done by researchers in this area is organized by the technique used. Finally, the challenges faced by TMS and possible solutions are discussed.

New techniques can be explored for traffic management during bad weather conditions. Research on traffic management with automatic vehicles can be done as unmanned vehicles are the new future of the transport sector. Accidents due to the same lane for heavy vehicles and cars is a major issue to be acknowledged. More advanced techniques can be explored for systematic lane management to reduce travel time as well as accidents.

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