A Review of Artificial Intelligence-Enabled Electric Vehicles in Traffic Congestion Management

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Abstract. Artificial Intelligence (AI) has been widely used in many sectors, including in the field of transportation. AI is used not only in manufacturing automated smart vehicles but also to optimize power in electric vehicles. In the same way, various types of electric vehicles, such as Battery Electric Vehicles (BEV), Hybrid Electric Vehicles (HEV), etc., are increasingly being developed for environmentally friendly vehicles. In this review, AI can help optimize the power of electric vehicles when traffic congestion happens. Based on the literature review, Traffic Congestion Management with AI technology on electric vehicles can detect several conditions. These conditions can be occurred in traffic congestion such as stress on drivers. While waiting for traffic jams, the drivers requires alternative road solutions and offers entertainment options. AI will predict how long the traffic congestion will last.

Keywords: artificial intelligence, electric vehicles, traffic congestion

1 Introduction

Entering the era of 2025, the presence of electric vehicles has become a compulsory need in every country, as the existence of green living is sustainable and committed to Zero Carbon 2030 [1] [2]. To address issues such as rising pollution, global warming, the depletion of natural resources, etc. These vehicles are viewed as a potential alternative for the present generation of transportation. The technology for electric automobiles is progressing quickly [3]. The idea of electric vehicles has been around for a while. Over the past ten years it has attracted a lot of attention because of the rising carbon footprint and other environmental effects of fuel-powered vehicles, together with a level of technological improvement. One of them is the ability of artificial intelligence in helping with safety and security [4]. In the regulation of traffic jams, many obstacles occur during the event such as wasteful of fuel, air pollution, noise pollution, driver's emotions, and others. In this study, we tried to peel off from Electric Vehicle (EV) Artificial Intelligence (AI) in overcoming congestion. EVs have arrived in the Southeast Asian market with several categories: BEV, PHEV, and HEV [5].

1.1 HEV (Hybrid Electric Vehicle)

A hybrid vehicle that combines an electric propulsion system with a traditional internal combustion engine (ICE) system is known as a hybrid electric vehicle

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(HEV). Internal Combustion Engines (ICEs) and electric motors are both features of HEVs. In this type of electric vehicle, the battery powers the motor instead of the fuel used in internal combustion engines such as gasoline, etc [6]. Both the gasoline engine and the electric motor work together to turn the gearbox that drives the wheels. HEV batteries can only be charged by Internal Combustion Engine (ICE), wheel movement, or a combination of both, making them different from BEVs and PHEVs. There is no charging connection, so the battery cannot be charged from outside the system (eg the network). It features a fuel tank and can use regular gasoline to power the engine. The electric motor is also powered by a set of batteries. The transmission can be rotated simultaneously by an electric motor and an ICE electric motor. This is an example of a HEV that already exists in Southeast Asia, particularly in Indonesia, as shown in **Table 1**.

Table 1. An Examples List of HEVs in Indonesia

Manufacture	Model Type
Toyota	Camry Hybrid
Toyota	Corolla Altis Hybrid
Toyota	Corolla Cross Hybrid
Toyota	C-HR Hybrid
Mercedes-Benz	E300e EQ Power

1.2 PHEV (Plug-in Hybrid Electric Vehicle)

PHEV features a fuel tank and can use regular gasoline to power the engine. The electric motor is also powered by a set of batteries. The transmission can be rotated simultaneously by an electric motor and an ICE electric motor. Similar to an HEV in that it has an ICE and battery set up [7]. However, the PHEV battery has a higher capacity than that of a standard hybrid so charging is done via plugging into an outlet or charging station. A PHEV can cover a reasonable distance on electric power alone thanks to a bigger capacity battery. The battery can be electrically charged by connecting it to a power outlet or an electric vehicle charging station (EVCS). A PHEV can typically be driven in at least two different modes: an electric mode, in which the car's engine and battery supply all of its power; and a hybrid mode, in which gasoline and electricity are both used. PHEVs normally begin in an all-electric mode and operate off of the electricity in the batteries until the batteries are exhausted. Some vehicles enter hybrid mode when traveling at highway cruising speed, which is often greater than 60 or 70 mph [8]. The vehicle starts running as a traditional ICE car as a non-hybrid as soon as the battery empties. In addition to being connected to an external power source, PHEV batteries can also be charged by an internal combustion engine or through regenerative braking. The battery is powered by the electric motor using energy produced during braking. Since the electric motor supplements the engine's power and improves fuel efficiency without compromising performance, smaller engines can be used. This is an example of a PHEV that already exists in Southeast Asia, particularly in Indonesia, as shown in **Table 2**.

Table 2. An Example List of PHEVs in Indonesia

Manufacture	Model Type
Toyota	Prius PHEV Gen-2
Mitsubishi	Outlander PHEV 2.4L

1.3 BEV (Battery Electric Vehicle)

A battery pack and an electric drive/electric motor system provide all of the power for a battery electric vehicle (BEV), often referred to as an all-electric vehicle (AEV) [9]. This particular model of electric vehicle lacks an internal combustion engine (ICE). These energies are kept in a sizable battery that is charged by plugging it into an electrical source. The battery pack then drives one or more electric motors, which in turn power more electric motors. The DC battery's electrical energy is transformed into the AC motor current. To control the speed of the electric car, the controller receives a signal from the accelerator pedal and modifies the frequency of the alternating current going from the inverter to the motor. The wheels are turned by the motors, which are connected by gears. The motor transforms into an alternator when braking or slowing down, sending electricity back to the battery [5]. This is an example of a BEV that already exists in Southeast Asia, particularly in Indonesia, as shown in **Table 3**.

Table 3. An Example List of BEVs in Indonesia

Manufacture, Model Name	Charging Duration	Battery Capacity (kWh)
Hyundai, IONIQ 5 Standard Range	Fast Charging, 30 mins	58
Hyundai, IONIQ 5 Long Range	Fast Charging, 30 mins	72.6
Hyundai, KONA Electric	Fast Charging, 57 mins	100
Wuling, mini EV Standard Range	Normal Charging, 8.5 hours with 2.0 kW AC	17.3
Wuling, mini EV Long Range	Normal Charging, 4 hours with 6.6 kW AC	26,7
DFSK, Gelora Electric	Normal Charging, 8 hours	42

1.4 Artificial Intelligence (AI)

Artificial Intelligence (AI) is one of the success factor features of EV sophistication. Currently, Artificial Intelligence is employed to optimize the batteries that power electric vehicles. Battery optimization aims to provide safer, longer-lasting, and more ecologically friendly batteries compared to the current lithium-ion batteries. AI presently makes it feasible for electric vehicle recharging at gas stations, but it will soon be accelerated. Comau, a corporation that specializes in automation, is aiming to improve the manufacturing and assembling of batteries [10]. Their objective is to increase electrical resistance while lowering energy loss and heat generation, which may be related to problems with efficiency and safety. Before the final assembly, the batteries' joints are evaluated for surface flaws and electrical resistance using artificial intelligence (AI) technology to pinpoint problems that need to be fixed. Electric vehicles will soon be as expensive as conventional combustion-energy cars due to AI technology. This will lower their price and significantly reduce the amount of pollution in metropolitan areas. AI that can be considered for use in EVs is found in the explanation section related to Artificial Intelligence in the Automotive Industry.

1.4.1 SVM (Support Vector Machine)

An algorithm for supervised machine learning is the Support Vector Machine (SVM). The goal of SVM is to predict the classification of query samples based on labeled input data, which is divided into two group classes using a margin Specifically, to transform the data to higher dimensions and use a support vector classifier as a threshold (or hyperplane) to separate the two classes with minimal error [11]. Support Vector Machines are used in traffic congestion management to find the path using various statistical metrics, including precision, specificity, sensitivity, false positives and false negatives, positive likelihood ratio, negative likelihood ratio, positive predictive value, and negative predictive value congestion point at the intersection. [12].

1.4.2 IoT (Internet of Things)

IoT integration makes it easier to create centralized control networks, optimizes vehicle distance, finds better and safer routes during emergencies, efficiently manages materials, supplies, and purchase orders, and overall boosts the amount of money made by the transportation sector [13]. One industry that is quickly adopting IoT technology is public transportation, which stands to gain the most from increased operational efficacy, cost effectiveness, safety, and security. The automobile sector also faces few problems and boasts cutting-edge technology that are advantageous to the transportation sector. The Internet of Things (IoT) is anticipated to have a substantial impact on traffic efficiency as cities integrate wireless technologies into traffic control and emergency response.

1.4.3 ITS (Intelligent Transportation System)

The most recent wireless, electrical, and automation technologies are part of intelligent transportation systems (ITS). These technologies have the ability to combine users, infrastructure, and vehicles (including buses, trucks, and personal automobiles) (roads and public transport) [14]. Automated guide rails, collision avoidance systems, and precision bus docking are just a few examples of on-board innovations. Numerous ITS solutions can help travelers travel more efficiently (route guidance), travel less miles unnecessarily, use more alternative forms of transportation, experience less traffic, and depend less on foreign oil [15].

1.5 Traffic Congestion Management (TCM)

In recent years, traffic congestion is as severe as it is, especially in Southeast Asia. There are many annoyances or shortcomings in anticipating congestion. The congestion that occurs can be seen in several patterns, both daily and annual [16]. The field of prediction-based research is expanding, particularly in machine learning for AI. Due to the massive amounts of data generated by stationary sensors or probing vehicle data that have emerged during the last few decades, this research topic has significantly increased. The evaluation of several traffic factors is used to anticipate traffic congestion, particularly short-term traffic congestion. The majority of studies on anticipating traffic congestion use historical data. The two core steps in forecasting traffic congestion are data collecting and prediction model construction. Each step of the process is essential and, if done incorrectly, could affect the results. After data collection, data processing is crucial for building the training and test datasets. Depending on the research, different case areas are used. After being constructed, the model is tested using additional base models and actual data [17].

A concept known as "smart systems" is also employed in traffic congestion management. These systems, which are blessed with a variety of technologies, can support several algorithms used in machine learning (ML) and the Internet of Things (IoT). A wide variety of sensors can be employed to collect data in a modern city. When the volume of data being collected increases, algorithms used in machine learning enhance a system's capabilities and intelligence [18]. Over the past ten years, the main focus of the development of smart cities has been the reduction of traffic congestion. Short communication delays between vehicles and Roadside Units (RSUs), effective traffic flow, and road safety are the key challenges with ITSs. Traffic congestion and the number of accidents on the roads have increased due to the quick growth in the number of vehicles on the road. To solve this issue, Vehicle Networks (VNs) have developed a variety of cutting-edge ideas, including vehicular communications, navigation, and traffic management. By learning from data, machine learning (ML) is an effective method for discovering ITS's latent insights without explicit programming [19]. LoRa, also known as Long Range Wide Area Network, is a novel technology used for specialized Low Power Wide Area Networks (LPWAN) architecture and machine learning mechanism adaptable to a smart town's traffic control system. The researcher's goal is to offer a real-time testbed solution that will allow performance evaluation and verification of the applicability of our model in real-world circumstances. This example of ITS shown in the **Figure 1.**

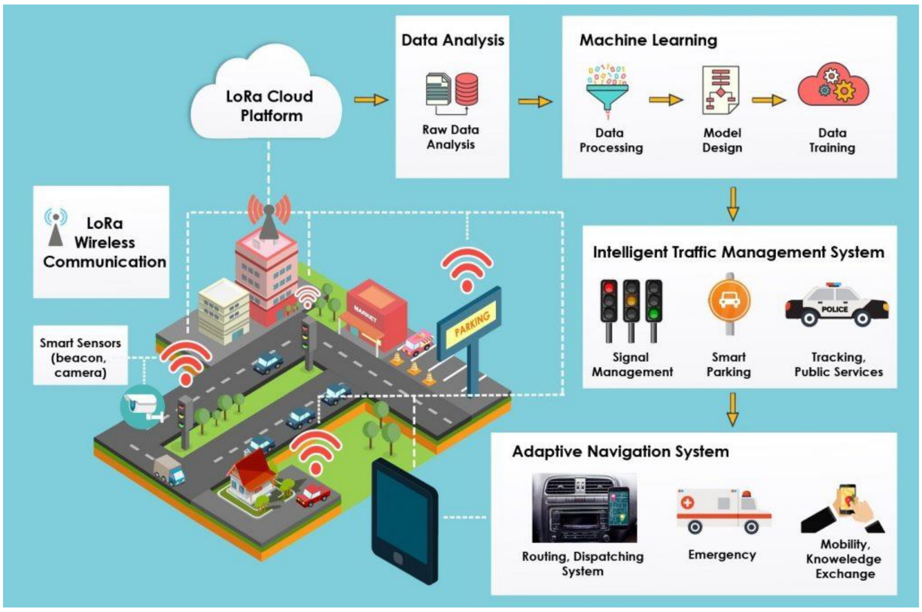

Figure 1. An Example of Intelligent Transportation System Called LoRa (source: cmte.ieee.org)

2 Material and Methods

This research is referred to as a systematic qualitative review, which compares qualitative study findings. This study studied findings related to existing EVs, these findings attributed to traffic congestion management.

3 Results and Discussion

3.1 Artificial Intelligence in BEV, HEV, and PHEV

A battery pack and an electric drive/motor system provide all of the power for a BEV. This specific electric vehicle model does not have an internal combustion engine (ICE). Plugging a large battery into an electrical socket will allow it to be charged. The battery pack fuels one or more electric motors, which are in turn powered by one or more electric motors. In comparison to vehicles powered by traditional internal combustion engines (ICE), pure electric vehicles (BEVs) are considerably simpler and easier to operate. The simplest driving system architecture consists of a high voltage battery, an electric motor with an electronic power controller, and a single speed gearbox. To distinguish them from HEVs, which have a hybrid powertrain that combines an internal combustion engine and an electric motor, BEVs are also referred to as pure electric vehicles. The battery in a complete

BEV must still power all vehicle components, so typical BEV capacities range from around 40 kWh to 80 kWh, although some batteries now have capacities as high as 200 kWh [20].

Hybrid electric vehicles (HEVs) use both an electric motor and a gasoline engine to propel the vehicle. Regenerative braking, which recovers energy lost while braking to assist the gasoline engine when accelerating, is how the battery receives all of its energy. This braking energy often escapes from conventional combustion engine vehicles as heat in the brake pads and rotors. Hybrid Electric Vehicles (HEVs) combine the benefits of an electric motor and a gasoline engine, and they can be designed to accomplish a variety of objectives, including enhancing fuel efficiency, boosting horsepower, or offering more auxiliary power for electronics and power tools. HEVs do not require electrical plugs to charge their batteries; they just use fuel. Modern hybrid electric vehicles (HEVs) pair an internal combustion engine with one or more electric motors to power the vehicle. In HEVs, the range and power of conventional vehicles are paired with high fuel efficiency and low exhaust emissions. [21].

3.2 Artificial Intelligence in Traffic Congestion Management

Traffic congestion management is now changing rapidly as AI technology can help multiple parties monitor the condition of highways, especially when there is congestion. Various models of systems using artificial intelligence have been proposed and studied, as shown below. A proposed model called the TCC-SVM system model facilitates the analysis of traffic congestion in smart city environments [22]. The following layer, referred to as the sensory layer, then gets data from sensors and the cloud with input parameters to discover congestion points. Signal data from one node is delivered to another and modified using this pattern. The model is a machine learning based IoT system for managing traffic congestion on roads. The proposed model has four different tiers. When information is acquired from sensors and the cloud, the raw information is delivered to the object layer, where it is enhanced by handling missing values before being sent to the preprocessing layer, which finally provides the information to the application layer. This layer is composed of a prediction layer and a performance layer. The prediction layer analyzes congestion using support vector machines, and the performance layer evaluates the results of this analysis. Drivers will be informed of congestion points using RFID sensors. Traffic congestion is directly impacted by bad weather because a road's condition deteriorates along with it. Unfavorable weather can be caused by a number of different things, including rain, humidity, temperature, etc. The TCC-SVM system model predicts these congestion points with the aid of SVM used in ML. The proposed TCC-SVM model can be seen in **Figure 3**.

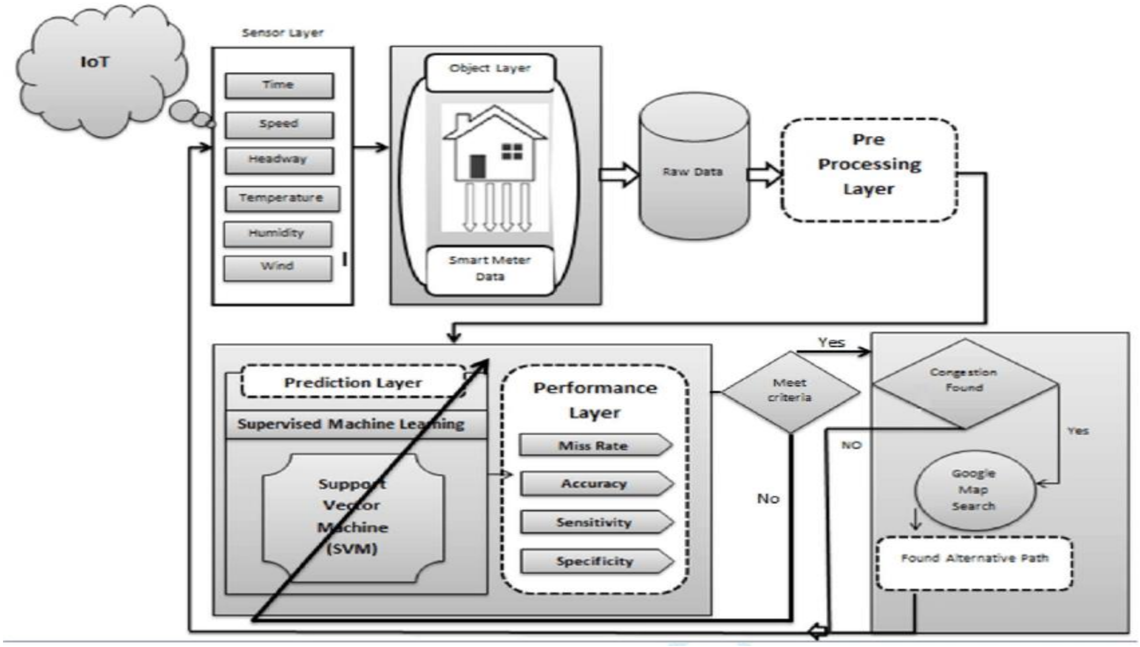

Figure 3. The TCC-SVM system model (source: researchgate.net)

3.3 Artificial Intelligence in the Automotive Industry

Although driverless cars are often the first thing that comes to mind when discussing AI in the automotive sector, there are numerous more ways that it may be applied. It enables us to maintain a connection with our vehicles and with other vehicles on the road for routine upkeep, economical driving, or passenger safety. The use of AI in the automobile sector can assist expand company potential by enabling features like manufacturing and cloud services [23]. One of the most recent trends is the adoption of "connected automobiles," which are AI-based and learn by observing their surroundings and modifying user behavior. For instance, to prevent conclusions, it can follow and evaluate the path, figuring out where the car is and how far from the nearby barrier is from it. For electric vehicles, the "energy optimum" route is one that maximizes energy recovery or one that passes by charging stations with the lowest charging costs. There are two examples of major players in the AI automotive industry applying for AI assistance in vehicles. DATARPM uses machine learning to anticipate machine failure. In order to speed up the development of an autonomous vehicle for driverless vehicles [24], NUTONOMY assists in negotiating challenging traffic circumstances. It comprehends machine regular patterns and behaviors and is able to foresee upcoming troubles and failures, saving time and money. Even in the most complicated traffic scenarios, it can handle vehicles in a flexible and human-like manner thanks to its technology [25], an example of navigating complex traffic situations can be seen in **Figure 4.**

Figure 4. Navigating Complex Traffic Situations (Source: mathworks.com)

3.3.1 Intelligent Autonomous Systems (IAS)

IAS is a new generation of computer systems capable of thinking and learning like humans [26]. They can store and use large amounts of data, understand natural language, and make quick decisions. IAS will be implemented in vehicles for a number of reasons including safety, driving experience, and cost savings [27]. Because they don't utilize fuel, electric automobiles are more efficient than other kinds of vehicles. This is possible because they are lower to the ground, so there is less air resistance. When the car battery is exhausted, it automatically switches to battery mode and can then be recharged. Companies are also starting to see AI as a gateway technology for self-driving cars.

3.3.2 Driver Monitoring AI

AI could make it possible for automobiles to do more than just observe the road; it could also encourage drivers to keep their eyes on the road by periodically alerting them to the dangers of doing so. The car can conform to the various preferences of drivers within the same family, including the adjusting of seats, mirrors, or temperature, thanks to facial recognition. [28].

3.3.3 Battery Use Case for Artificial Intelligence

When it comes to extremely quick charging for electric vehicle batteries, StoreDot is the industry leader, utilizing revolutionary nanotechnology that is enhanced by organic molecules. The initial attempt by StoreDot to use machine learning into drum designs produced impressive outcomes. The group creating the first-generation ultra-fast charging FlashBattery technology found using ML that a few minor adjustments might boost a battery's cycle count from 300 to over 600 [29]. The following generation of electric automobiles will now use this remarkable result. Combining cutting-edge AI-driven data science with knowledge of electrochemistry, battery construction, anodes, cathodes, and electrolytes can lead to more sophisticated results. Implementing it in the vehicle running software would be a unique and intriguing use for it, since it would continuously monitor the battery's performance and condition and provide feedback on the information in order to improve the result. Additionally, battery management systems can learn about their "state of health" and even update batteries or modules as necessary by developing smarter batteries with built-in sensing and self-healing capabilities. AI aids innovators in reaching findings that conventional statistical analysis is unable to by enabling them to change numerous components at once and analyze data more quickly. This proof makes it possible to design software more quickly and solve issues that would otherwise be insurmountable. To overcome one of the major consumer hurdles to EV adoption, this capacity is essential. The entire electric vehicle sector may undergo a revolution if battery charging times were cut using machine learning techniques.

The Toyota Research Institute has declared that it may use artificial intelligence to speed up battery research. 400 separate battery studies can now be carried out concurrently by TRI. [30]. Another startup, GBatteries, has used a different approach. Rather than changing the battery, they create an adapter-like device that can filter the energy entering the battery pack in accordance with waveforms defined by the algorithms based on real-time measurements [31]. Using algorithms and big-data visualizations, DOX compares the battery manufacturer's data sheet with the battery's actual performance. Companies and drivers could learn more about batteries by carrying out what they have dubbed "anomaly detection." The AI keeps records of past user signatures, driving patterns, and quick charges. The information is broken down to the cell level, by location, vehicle type and model, chemistry, and a wide range of other elements of the battery supply chain. Knowing when to change a battery or keep driving could make all the difference. It also has advantages for the environment. Taking into account the resources needed to extract the raw ingredients, distribute, and dispose of EV batteries. There may be a significant decrease in CO_2 emissions.

A machine learning-based approach that was created by a Stanford-led research team reduces testing time by 98% [32]. To find the best method for charging an EV battery in 10 minutes while improving the battery's overall lifetime, the researchers developed a program that, based on just a few charging cycles, predicted how batteries would behave to different charging techniques. Additionally, the software made real-time decisions about which charging techniques to emphasize or ignore. The testing method was reduced by the researchers from roughly two years to 16 days by shortening both the length and quantity of trials. The team took advantage of the power of the machine learning technique, which determines when to investigate, what to explore, or try new and alternative approaches without making too many mistakes, in two important ways. It was utilized to shorten the duration of each cycling experiment. They discovered that they can anticipate a battery's lifetime after just the first 100 charging cycles, rather than having to charge and recharge every battery to do so. Given that the early data showed trends that might forecast how long a battery would last, this is plausible. Instead of testing every charging strategy equally, the computer quickly found the best protocols after learning from its errors.

4 Conclusion

Artificial Intelligence not only plays an important role in ITS used in monitoring the general and extensive traffic situation on the road but also has an important role in the development of EVs that can be used, especially in times of congestion. AI not only helps drivers find other shortcuts but also monitors the state of the vehicle and makes decisions such as battery usage and optimization, monitors the driver's condition, and creates alternative solutions for the driver so that the driver can still drive safely and comfortably. Further research focuses on component points in Artificial Intelligence assist for Electric Vehicles.

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