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Beyond the Current State of the Art in Electric Vehicle Technology in Robotics and Automation



Abstract: - The improvement of electric vehicles and their parts is currently the subject of several recent innovations, with an emphasis on advancements in batteries, energy management systems, autonomous features, and charging infrastructure. The current logistics and transportation (L&T) systems comprise heterogeneous fleets made up of both conventional internal combustion engine cars and other vehicle types that use environmentally friendly technology, such as electric and plug-in hybrid vehicles. This helps significantly to the development of the upcoming generations of electric vehicles and promotes a more sustainable and effective ecosystem. This article offers insights into the most recent advancements in the field of electric cars (EVs) as new and innovative EV technologies based on data and statistics from science that may prove to be technically possible by 2030. Potential design and modeling techniques, including digital twins with linked IoT, are discussed in this paper. Additionally, all EV-related topics are covered, including hard-core battery material sciences, power electronics, and powertrain engineering, as well as market and environmental considerations and prospective technological obstacles and research gaps. This investigation is interesting since it offers thorough information on every facet of EVs. In conclusion, we offer to the readers several open issues in the field of EV as well as specific research directions to wrap up our work.

Keywords: Vehicle routing, logistics, Transportation, Electric vehicles, ecosystem, electronics.

I. INTRODUCTION

The automotive industry has undergone significant changes in recent years. Millions of lines of code and more computational power than early NASA spacecraft are found in today's spacecraft. Every five to seven years over the last 20 years, software has expanded in size by a factor of 10 [1]. Inside the ECUs, which are tiny computers built into the car, is 1 gigabyte of software. Over the same period, the several Electronic Control Units (ECUs) have increased from about 20 to over 100, forcing automakers like Volvo to update their vehicles' electrical design to handle this level of sophistication.

The global economy depends heavily on the logistics and transportation industry, which also plays a major role in the advancement of society's social and economic structures. The L&T business is very prevalent because of its steady expansion and influence on the GDP (gross domestic product) of the region. Specifically, as globalization and international trade have grown, so too have road logistics and transportation (L&T) operations using motorized vehicles. L&T systems have been extensively researched by the Activities Research/Computer Science (OR/CS) community for decades to increase their efficiency. One of the most common subjects in the

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L&T literature is modeling and optimizing vehicle tour assignments because of its possible relevance to real-world operations. The Vehicle Routing Trouble is the term for this.

This subject has been tackled in many different forms during the past few years. The most basic variation is known as Capacitated VRP (CVRP), in which a customer's demand must be met without going over the vehicle's full capacity. By giving the depot and clients time slots, the VRP with Time Windows expands upon the CVRP [2]. The traditional VRP has been redesigned in several ways to take into consideration more real-world factors; these new versions are frequently referred to as Rich VRPs or multi-attribute VRPs. Despite the wealth of literature in the VRP field, the majority of the works written to date have assumed that the fleet under management consists solely of internal combustion engine vehicles (ICEVs), which is not the reality as it stands at the moment. All other subsystems are contained inside the five primary subsystems. A high-level system block diagram of autonomous robot systems is displayed in Figure 1.1.

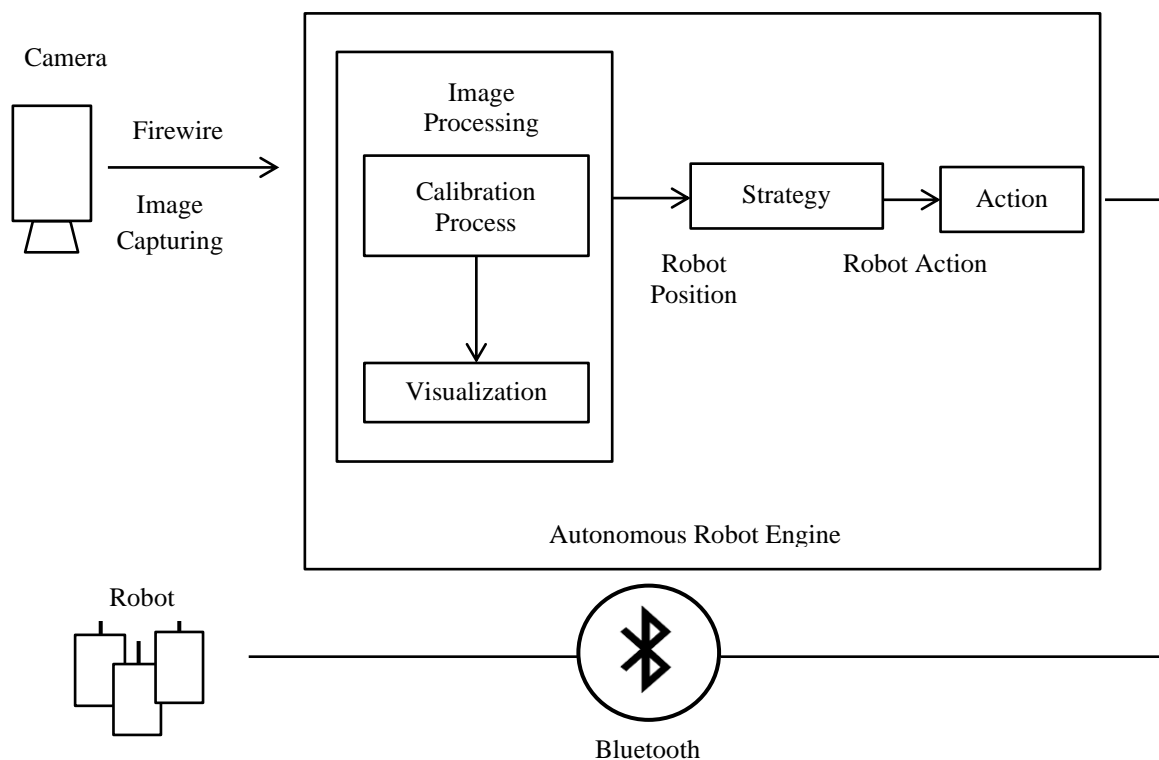


Figure 1.1. An Autonomous Robot Systems Block Diagram

The little league, robot football, is played on a pitch the size of a table tennis table. Five little robots make up each team. The teams on the other side of the field use the full image of the game captured by a camera above the field to provide data to their computers. Using the balls and the other robots' color coding, a world map is built from this image. The football we use is an orange golf ball. The various robots' activities are programmed and sent to them using this world model. This league usually features fast-paced, chaotic matches.

Robots can initiate strategies in response to obstacles and other robots' positions on the field thanks to the strategy system. This information from the vision system is received by that device, which then computes it to decide what kind of strategy to implement. The objective is to give the robots strategic capability and develop various algorithms to fit various scenarios in which our robots may need to complete the assignment.

The robots were connected to the computer via wireless communication, and the on-board control system used this communication to receive information from the strategy system. The distance, guidance, and degrees of orientation were calculated by this subsystem using the values from the approach system that were provided in the protocols. To enable the robots to carry out actual movement, this system receives information from the camera system, which is then passed through the strategy system and communication system. The communication system can update & move in real-time with the help of the strategy and vision system, which updates the data continuously [3]. When robots are given commands to stop, move, or rotate, an above camera is

used to monitor their positions. Robots are controlled by robotic systems, which will finish the job. The initial movement concept is centered on a robot that can travel alone and avoid collisions. The robot only moves in the desired direction by using its sensor and the information that the camera has recorded. To propel itself from the starting position to the destination point without colliding, the robot creates the necessary velocities. The required input information is obtained from the vision system in real-time at each time step. The reference longitudinal and angular acceleration to the target location is then produced by the robot.

The subsequent portions of the essay are arranged as follows. Section 2 presents the research on the literature review work. Section 3 covers the features of the proposed system, which include its suggested system architecture, implementation model, components of the graph-based approach, and data analysis. The effectiveness of the system is assessed and the implementation environment is described in Section 4. Section 5 presents the resolution.

II. LITERATURE REVIEW

The fundamental idea of inductive charging is based on the idea of a transformer, which transfers energy using two coils placed in opposition to one another. This allows for wireless power transfer. Today, the equipment is widely used in a variety of low-transfer-power consumer goods [4], like as smartphones and toothbrushes. More charging power is needed while charging a vehicle, which presents several difficulties. Similar to consumer-level remedies, inductive charging systems for cars operate on the same principle: a primary coil is fixed and placed at the charging station, while an additional coil is put under the car. The method offers great comfort and frictionless charging because it requires no human operation for connection.

Decentralized algorithms and methods for distributed production system control have previously been the subject of extensive research. The leads of this architecture in comparison to the central, hierarchical systems that are in place today have been studied. Since the existing central architectures are inadequate to manage flexible production, customized products, and intricate product standards, several scholars have noted the necessity for decentralization in the future [5]. Decentralised control, according to them, works well in dynamic contexts because it can adjust to changes fast. They do, however, also list the drawbacks of this kind of decentralized architecture. The primary disadvantage of decentralized management is the additional work required to coordinate the efforts of all those distinct organizations as they pursue their individual objectives.

In 1961, George Devlop, an American inventor, created the first industrial robot, which he called "Unimate." The robotic arm known as "Unimate" revolutionized the automobile industry and was integrated into the assembly line of General Motors. Because "Unimate" relied on hydraulic power for lifting, it was unable to keep up with the improvements in electric robots [6]. This was its demise. Electric-powered automotive industrial robots have been produced since the 1960s as a result of research and the need for ever-improving manufacturing methods. The FANUC M2000, the most powerful robotic arm in the world, is the result of this advancement. With a lifting capacity of 2,300 kg, this 6-axial machine can operate in any production facility.

The introduction of intelligent vehicles can have a significant positive impact on public transportation by lowering last-mile transportation costs, reducing traffic, increasing user satisfaction, and enhancing safety in metropolitan settings [7]. Even though autonomous vehicle technology is still in its early stages of development, commercial cars are increasingly equipped with sophisticated driver-assistance systems every year because driverless vehicles have long attracted the attention of businesses and industry. On the one hand, the societal ramifications of a revolution of this magnitude will elevate our standard of living by altering our perception of transportation systems.

Consumer acceptance of electric vehicles has increased steadily and sharply, even though EVs currently only make up a small portion of all vehicle sales. As per the 2018 IEA Global Electric Car Microsoft Outlook, there was a 575 percent surge in new EV registrations from 111,320 in 2013 to 750,490 in 2017 [8]. According to a 2018 AAA poll, the number of Americans who would consider buying an electric car has increased from 15% in 2017 to 20%, or 50 million, in 2018. This indicates that consumers are becoming more interested in electric cars. Incentives for the use of electric vehicles have contributed to this rise in popularity in several nations. Due to these advantages, as well as the sharp decline in battery prices and the expansion of driving range between charges, EVs are becoming more and more popular among customers, as evidenced by the rise of interest in them.

Automated driving features can be used in both automobiles and infrastructure. Both options have benefits and cons, depending on the particular application. Improving road networks may give advantages to that kind of transportation which is reliant on repeated and prescheduled routes, such as public transportation and industry robots. However, the case of extended road networks used by private vehicles; it necessitates intricate and costly organization and management [9]. Ad hoc environment structuring is only viable for a smaller portion of the roadways, such as when developing a completely automated highway that is exclusive to the use of automated cars, whether they be private or public.

A chronology of the well-known agricultural commercial hybrid electric tractor, for instance, International Harvester debuted the Farmall 300 tractor in 1954 to accommodate farm equipment and machinery that runs on electricity. Intriguingly enough, Allis Chalmers' 1959 tractor was the first fuel cell car ever created [10]. This was outfitted with 212 units of nine alkaline fuel cells each, grouped in four banks, totaling 3008 individual fuel cells. This was enough energy to run a 20-horsepower direct current engine. Furthermore, the New Holland Company unveiled the NH2, an FC concept vehicle, in 2011.

III.METHODS AND MATERIALS

3.1 Categorization of Concepts of Vehicles

It is useful to classify various concepts because the category of automated micro-vehicles for urban logistics includes a wide range of vehicle types. Vehicle concepts are most frequently referred to as "delivery robots" in literature and the media, even though these vehicles vary significantly in terms of size, sensing technology, and driving style about applicable infrastructure. Six different kinds of micro-vehicles have emerged during step two. The main distinction between AMVs is their use on and off roads. While some cars are meant to be driven on roads, others are meant to be used on walkways or bike paths. The type of vehicle is the next distinction. The original basic vehicle serves as the basis for this distinction. However, the goods vary even within the same vehicle class. While some AMVs are designed to operate autonomously and be watched from far away, others require a human to serve as a reference for their sensors [11]. These differences amongst AMVs lead to the possibility of classifying automated micro-vehicle concepts. In the accompanying image (Figure 3.1) clear types of self-driving micro-vehicles for urban commodities movement are shown. Naturally, cars designed for driving cannot follow a strolling human.

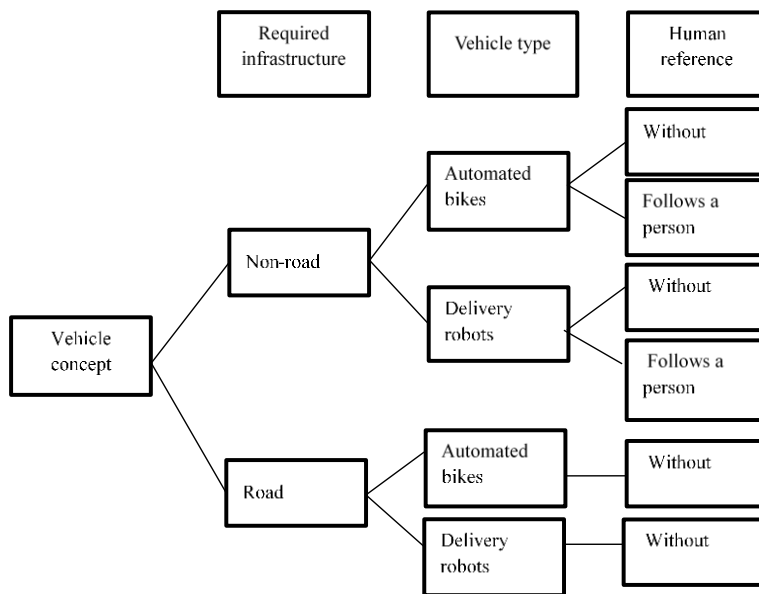


Figure 3.1. Categorization of Various Vehicle Concepts

The automated motorcycles (AVMs) fall into six categories: automated motorcycles without human reference on non-roads (AB-WH) automated bicycles following for regard on non-roads (AB-follow), automated motorcycles on roads (AB-road), and automated motorcycles without human reference on non-roads (DR-WH). First, there is

the "vehicle concept," which emphasizes technical features [12]. It makes comparing various micro-vehicle initiatives possible. The goal of the "modes of applications" point is to identify various logistic application opportunities. The examination of "business models" and "client groups" is crucial for comprehending the fundamental objectives and working principles of every firm. To learn about the most recent advancements in automobile technology, the analysis point "experiences" is developed. "Requirements for the use" is the last analytical point to help better define the various vehicle concepts.

Each manufacturer's corporate website and communication methods have been examined to obtain detailed product information. A good way to find out about new products is to watch company speeches on video platforms and attend technological events. Emails and phone calls were made to manufacturers and relevant parties regarding any discrepancies and to request additional information. The findings from January to June 2018 will determine the results shown in the following sections. As a result, they only provide an overview of the data that was made accessible to the public during this time (Appendices A), rather than a comprehensive compilation. Particular details may not be current since manufacturers update their vehicle configuration and technology based on real-world testing that occurs periodically.

3.2 *Other Drivers*

CAVs, or unequipped cars, bicycles [13], and walkers are examples of additional road users.

3.2.1 *Additional Autonomous and Networked Cars*

Multi-vehicle cooperation occurs when two or more CAVs work together. The previously mentioned SAE J2735 standard is primarily focused on awareness and safety applications. More complex protocols are needed for advanced vehicle collaboration, such as cooperative awareness and multi-vehicle formations, and these standards are still being developed. One market that is attractive for a friendly automobile is freight travel; heavy-duty vehicles with automated driving and vehicle-to-vehicle communication.

3.2.2 *Cyclists, pedestrians, and non-cooperative vehicles*

CAVs do not differ significantly from other self-driving cars when communicating with non-cooperative road users; in this scenario, perception system consciousness of the environment encompasses non-cooperative vehicles, cyclists, customers, and any other road user. New methods and research are focused on achieving a certain degree of collaboration with cyclists and pedestrians, allowing safe communications between vehicles and mobile devices.

3.3 *Automated and Networked Vehicle Control Architecture*

A control system for automated and connected cars (CAVs) with an emphasis on energy-efficient and safe operation is shown in Figure 3.2. There are remote and on-board functional blocks in the design.

3.3.1 *Control and Planning In Real-Time*

The on-board functional blocks must be used immediately since they are safety-critical. The real-time layer does all the real-time calculations that enable a CAV to be dependable and resilient to unexpected events. It also connects with the vehicle actuators and gathers measurements from on-board instruments.

3.3.2 *Control of the Drivetrain*

Depending on the kind of powertrain, gear shifting, electrical motor control, and engine control are examples of power plant control.

Engine controls influence the so-called "tank-to-wheel" energy transfer and meet the car's real-time power needs. Reactive controls use the present power demand to determine which powertrain operating points to use. When predictions are provided, energy use can be increased in the short and long terms (speeding and power profiles from transverse control).

3.3.3 *Motion Management*

The steering system and engine controls are interfaced with the motion control block, which controls the vehicle's transverse and lateral motion. Typically, a higher hierarchical level specifies the desired vehicle motion, and motion control makes sure the reference behavior is carried out robustly. Security and the so-called "wheel-to-distance" energy conversion are impacted by controlling motion.

3.3.4 *Making choices and Organizing Movements*

Manoeuvre, route, and trajectory planning are all included in the decision-making and motion-planning block. The driving situation also affects these tasks, and it's difficult to define their bounds. The availability of traffic, signal, and other vehicle trajectory projections can greatly enhance both efficiency and security [14]. The motion

control block can also take advantage of these forecasts. To make things simple, one may assume that the motion planning and decision-making block manages its relationship with the surroundings and creates workable trajectories, which the motion control block then tracks.

3.3.5 Remote Scheduling and Directing

In Figure 3.2, the remote layer facilitates access to external data sources and executes longer-term calculations that primarily impact performance and are typically not time-sensitive. The navigation and scheduling algorithms are part of these calculations.

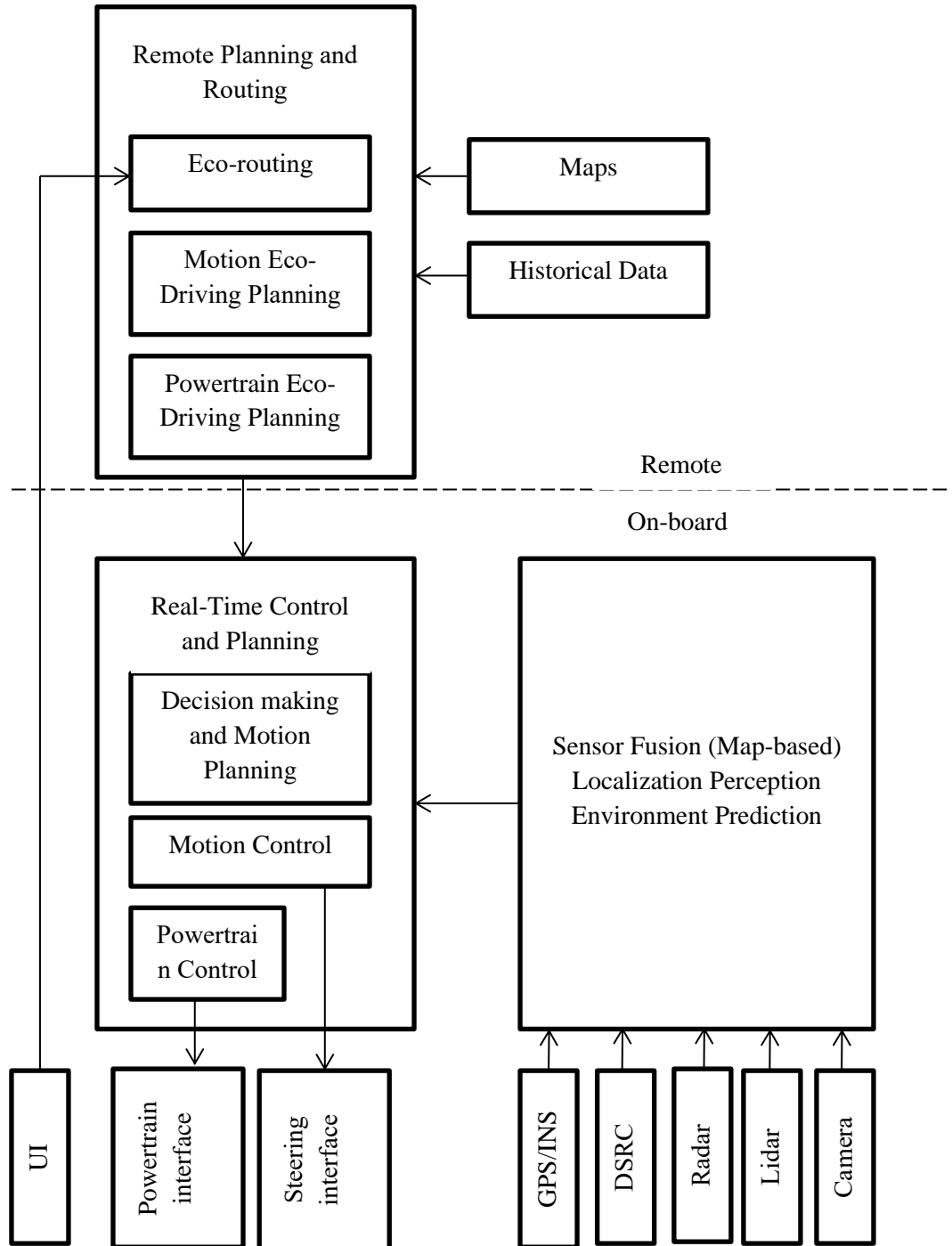


Figure 3.2. Architecture for the Deployment of Connected and Automated Vehicles (CAVs): Light Grey Blocks Represent Data Sources, Like Databases and Sensors; Dark Grey Blocks are Functional Blocks

3.3.6 Design for eco-Driving Powertrains

If the CAV is an electrified, hybrid, or plug-in hybrid electric car, then a long-term management of the battery charge path can stop the vehicle from using its stored energy less efficiently. If the range permitted by the present battery charge gets exceeded, the software may notify the driver, ask to reroute the path, or schedule a stop at a charging station. In the case of an electric car, this system can simply forecast the driving range using the route data. There is an internal combustion engine in hybrid and plug-in hybrid electric cars; route data can be utilized to maximize fuel and battery usage during the journey.

3.3.7 Eco-driving motion planning

Using route data, the vehicle's eco-driving planning block calculates an initial velocity trajectory for the on-board systems.

This block's significance lies in its application of long-term projections and its consideration for limitations like maximum velocity and journey time. Certain restrictions are dependent on the driving situation, such as going through a signalized intersection when the light is green. Performance can be enhanced by using past data. The ego-CAV can work with other CAVs in several driving conditions. Grouping, in which a collection of vehicles move on a specific road section at decreased range gaps, is an instance of multi-vehicle cooperation. Reducing aerodynamic drag or maximizing the use of the road surface (and subsequently throughput) is the two possible goals. In the multi-vehicle instance, the eco-driving block employs the identical information, but the issue is often more complicated.

3.3.8 Environmental Routing

Given user specifications and map information (e.g., road level, traffic speed, junction delays, gasoline or charge stations), the eco-routing block calculates the best energy-efficient route. The ideal route, or a series of waypoints containing junction places, maximum speeds, and road grade, is output by this module.

IV. IMPLEMENTATION AND EXPERIMENTAL RESULTS

4.1 Electric Machines, Batteries, and Power Electronics

Modern life is heavily reliant on electrification, and industries including production, electronic goods, automation, and electric vehicles all use electric motors and other machinery. Modern lithium-ion batteries with better performance, longer lifespans, and cheaper costs are one factor in the popularity and success of EVs in recent years. EVs with longer electric ranges and faster speeds at lower cost premia are drawing in customers thanks to enhanced energy and power performance, extended cycle and cycle life, and lower expenses. The current state of the art for batteries, power electronics, electric machinery, and electrically powered drives is outlined in this part along with some research difficulties, future directions, and goals. It also covers expenses, efficiency, energy and power weight, and dependability.

Figure 4.1 shows the actual price of lithium-ion battery packs from 2010 to 2018, as well as projected prices through 2030 [15]. The U.S. Department of Energy (DOE) estimates that parity with ICEVs can only be reached at battery costs of roughly \$200 kWh². At that point, EVs should have both a buy- and a lifetime-operating-cost gain over ICEVs. Such cost benefits are likely to trigger drastic increases in sales of electric vehicles.

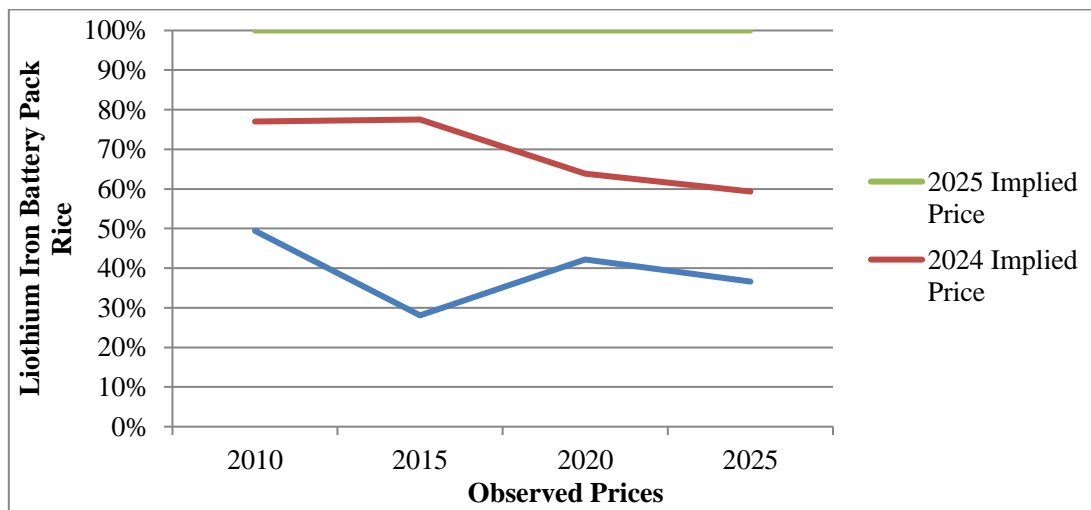


Figure 4.1. Battery Pricing Evolution over the Past Ten Years and Forecasts for the Future

A pack of lithium-ion batteries costing more than \$1000 kWh⁻¹ in 2020 only costs \$256 kWh⁻¹ at the end of 2020—a almost 80% decrease over the previous ten years. A lithium-ion battery cell's particular power, on the other hand, nearly quadrupled in the same time period, going from 140 Wh kg⁻¹ to 340 Wh kg⁻¹. The creation of techniques to boost steadiness for greater durability and enhanced safety, the use of substances with higher capabilities and currents, and technological advances are the primary causes of both price and performance gains. Costs can be reduced, and efficiency can be enhanced with advancements in cell, component, and pack architecture. Cost savings are mostly a result of increased manufacturing volume brought about by EV sales. However, reaching those lower-battery-cost forecasts might be hampered by price rises for some metals, such Ni and Li. Furthermore, various battery compositions can result in drastically varying prices and energy outputs.

4.2 Life-cycle Expenses And Emission

When it comes to emissions, EVs are different from traditional ICEVs. EVs do not emit tailpipe emissions, while ICEVs powered by petrol or diesel do emit greenhouse gases and other pollutants when they operate. More broadly, EVs are still connected to so-called "upstream" pollutants from the production, transmission, and distribution of the power needed to charge them. Upstream "fuel-cycle" pollutants from the extraction, transportation, and refinement of raw materials as well as the final product delivery operations that result in petrol or diesel fuel being sold at retail pumps are also a part of the process of fueling an ICEV. The term "well-to-pump" emission originates from these fuel-cycle pollutants.

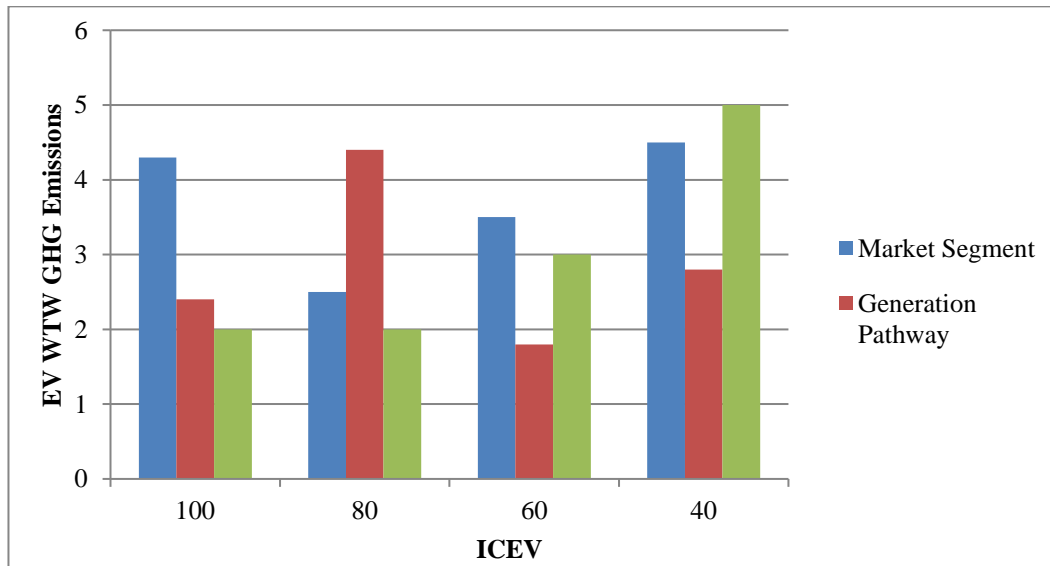


Figure 4.2. Average weight-to-weight GHG emissions of EVs relative to equivalent ICEVs, with illustrative Variation by Market Sector, Electrical Power Generation Pathway, Grid Mix, and Climate

As a result, a "well-to-wheels" (WTW) life cycle assessment provides a useful framework for evaluating emissions from ICEVs and EVs. For a standardized functional unit and temporal period, WTW takes into account both immediate emissions from vehicle operation and downstream emissions from the fuel cycle. For more than thirty years, WTW studies have been used to assess both direct and indirect emissions connected to fuel supply and vehicle operation. WTW emissions are commonly reported as emissions per mile or per kilometer during the estimated life of a vehicle.

Electricity-carbon magnitude, charging habits, vehicle attributes, and even the local environment are some of the numerous variables that affect the variation in EV WTW pollutants and predicted reduction potential relative to ICEVs. Figure 4.2 pits the WTW GHG emissions of EVs against similar ICEVs to highlight these variations. In general, heavier cars see greater relative emission reductions. Lower carbon emissions with the practice of EV recharge. Similar to how battery costs are predicted to continue falling, future EV costs are also anticipated to drop. Additionally, new mobility options like ride-hailing will increase car usage, strengthening the argument for highly effective EVs over internal combustion engines.

V. CONCLUSION

The present investigation examined some of the literature that has been written about the use of electric vehicles in road transport, with a focus on the following topics: the effects on the planet; new operational and strategic difficulties; the use of hydrogen-powered vehicles as an alternate to other forms of electric vehicles; and novel approaches to the well-known vehicle routing problem that result from the introduction of electric vehicles into distribution fleets. This analysis makes it clear that using renewable energy sources in road operations and transportation is more important than ever and is essential to the development of a world that is stable both economically and environmentally.

For many on-road applications, EVs have a tremendous deal of potential to replace ICEVs. EVs can reduce greenhouse gas emissions, lessen dependency on petroleum, enhance driving pleasure, and improve local air quality, among other advantages. The electrification of vehicles is in line with the general trends of electrification and decarbonisation. It also works in harmony with other developments in mobility, such as automation, urban micro-mobility, and mobility-as-a-service. Since EVs can assist power system design and operations in several ways, their successful integration into power systems offers many prospects for improving the effectiveness and economy of both electric mobility and electrical power systems in a synergistic manner. Due to the potential for widespread deployment in the future, fully using the beneficial interactions between EVs and VRE sources provides a route towards universal access to inexpensive, clean energy and transportation.

We found that most technologies lacked experimental validation. Even while testing on public roads is still quite difficult, modern technology makes it possible to use sophisticated algorithms on actual cars. One non-trivial outstanding challenge is how to choose testing scenarios that are comparable to real-world situations. This perspective appears to be supported by the current approaches taken by government agencies, commercial enterprises, and scholarly academics, and field validation of the subjects covered in the present research is anticipated soon. Ultimately, the quest for experimental validation must be supported by thorough, extensive simulation studies that are grounded in real-world traffic information. As is customary in other research groups, defining one or more benchmarks may enable a more objective assessment of novel approaches.

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