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Optimizing the Infrastructure of Electric Vehicles and Developing Business Models for Sustainability

Nishant Dhir, Savas Genc, Hans Rüdiger Kaufmann

(MA Student Nishant Dhir, University of Applied Management Studies, Mannheim, DE, nishant-dhir@hotmail.com)
(Prof. Savas Genc, University of Applied Management Studies, Mannheim, DE, savas.genc@hdwm.org)
(Prof. Dr. Hans Rüdiger Kaufmann, University of Applied Management Studies, Mannheim, DE, hans-ruediger.kaufmann@hdwm.org)

1 ABSTRACT

Transportation is one of the major sources of economy for any country. But the main problem with the vehicles is the amount of pollution conducted by them. One needs a particular source that creates Net Zero Carbon Emissions. Electric vehicles are becoming a popular source of transportation as they do not produce any carbon emissions. But due to a lack of proper infrastructure and customer awareness, consumers hesitate to decide on an Electric Vehicle to date. The paper also covers the expansion of VANET Technology that can improve the traffic management system and reduce the number of accidents. For this reason, this paper aims to identify the area of improvement in building the infrastructure of electric vehicles with economic policies.

Keywords: management systems, VANET, mobility, sustainability, transportation

2 INTRODUCTION

As the climate is changing rapidly, a growing concern can be seen for the environment. The fuel market is unreliable, and electrification of the transport system entails a major systemic overhaul in a country. Strategies are being discussed by every major country to reduce the overall CO2 emissions and go all-electric by 2030. The paper introduces an overview of the present electric vehicle (EV) market scenario. This market follows certain standards like charging standards, safety standards, and grid integration (Das, 2019). The EV infrastructure covers certain things like power, control, and communication. As different companies are producing these vehicles, each vehicle will impact the power system, which is why grid system optimization is summarized. Lastly, the paper will cover challenges and suggestions for the development and challenges for future vehicles. It refers to major aspects from the perspective of the world being ready to go for EVs and will introduce the idea of bringing smart grid technology to charging stations. Moreover, to build a sustainable infrastructure what policies should be taken for the charging stations, use of renewable energy and connecting it with smart grids, and VANET Technology (Das, 2019).

3 RESEARCH GAP

According to Das and Rahman (2022, p. 24), “future research could be done on implementing in expansion in VANET technology along with a well-developed business model which can be beneficial for EV owners, users as well as utility companies”. A further gap is provided by Ahmad and Iqbal (2022, p. 16) stating that “future research and challenges faced are related to include optimal places and sizing of charging stations with renewable energy sources and integrating the load for power management problems”. Consequently, this study aims to investigate the factors that lead to a solution for optimizing the infrastructure for electric vehicles and closing these gaps.

Four research questions are derived from the literature to achieve the research objective:

(1) How can renewable energy play a major role in providing clean energy to EV charging stations?

(2) What role does a charging station play in creating a sustainable business model?

(3) How can we provide VANET Technology to improve traffic Management systems?

(4) How can we establish a radio communication channel by reviewing security challenges and testing VANET in a critical case scenario?

4 LITERATURE REVIEW

The chapter deals with previous studies on the elements leading to increasing sales of Electric Vehicles in the past decade. It provides a clear picture of previous research initiatives having identified some major problems related to the infrastructure and availability of charging stations. To find relevant literature for this paper, the research was done in different phases. At first, several articles and journals were looked at by

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using keywords like Renewable Energy, Charging Infrastructure and Policies, VANET Technology, and Electric vehicles on open platforms. For the research, data were filtered via journals and articles from Google Scholar, Research Gate, and IEEE Explorer.

4.1 Renewable Energy

Today, global warming has become a major issue that needs to be urgently resolved. With a vision of having a clean environment-friendly energy source, it has become a prime topic of interest to many environmentalists. With a rise in population, it is becoming difficult for governments to fulfill the need for electricity as our society is progressing towards high standards of living. According to Elavarasan et al. (2020, p.1), "the power systems energy production sector contributes nearly 75% of total CO2 emissions in the world which contributed to Greenhouse Gas (GHG) emissions as well as in Global warming".

4.1.1 Role of Renewable Energy

With a dramatic rise in the purchase of EVs, the demand for the use of EVs globally has increased dramatically. The global electric car market has shown a significant jump in sales as people are more concerned about zero carbon emissions. But this upsurge has created a problem with the provision of proper charging infrastructure as people are using the current charging system. The latter is pressuring the load on transformers, especially during the night, as people charge their vehicles overnight. One of the drawbacks of renewable energy is its inconsistency to offer energy all the time. To tackle the problem, it is required to get optimal planning for allocating EV charging stations. The proposed solution could be to use solar energy panels by creating a "Green Roof" that will create a balance in the temperature due to its ecological benefits. At the same time, solar panels can provide a clean source of energy to charge EVs.

4.1.2 Renewable Energy Transition in EU by 2050

The European Union is a key influencer in reducing carbon emissions by 2050 to meet the target of climate change to have a competitive, efficient, and sustainable source of energy supply network. The Paris Agreement is a step towards the transition in energy supply to achieve the goal of a carbon-neutral EU. As we know, dealing with climate change is one of the major challenges in modern society. Therefore, the European Commission proposed a target of net GHG emissions to neutralize climate change by 2050. The Paris Agreement aims to reduce global warming below 2 degrees Celsius, but the preferred number is 1.5 degree Celsius (Sanja, 2021).

Supply of Renewable Energy Networks and Large-scale Biofuel Production

There are some extensive studies in past years relating to the development of renewable technology and optimizing technology on a large scale with a supply chain of networks. This is confirmed in the study conducted by Sanja (2021, p. 14), "This study shows that a significant amount of additional land (about 6%) is needed to achieve a climate-neutral EU. Therefore, further development of technologies should aim at minimizing land use. Offshore wind turbines and PV panels do not require additional land, full electrification of the transport sector and mastering fusion-based nuclear reactors could be examples of such technology". This study was based on criteria including geographical locations, biofuels, and renewable energy, driven by the research objective to achieve biofuel production by 2050.

Critical Analysis of Biofuel and Technology

The author Sanja et al. (2021), p. 14 "To implement the technology, there are several things that need to be considered. At the first stage, some existing technologies are available like dry goring which is a commercialized system that can be installed all over the world. Several other technologies like sugar fermentation could also be considered. The second stage, which is the most challenging stage, is the availability of biomass in abundance. To make biofuel, biomass must be available in large amounts to meet the demand and supply for clean energy. However, the production cost of the energy will be lower". To implement a sustainable energy network there must be the availability of cultivation areas along with machinery through which we can extract the oil and can store it in large facilities to ensure an uninterrupted supply chain of oil so that it can reach the end users.

4.2 Charging infrastructure and policies

In recent years, the world has faced serious climate change problems, leading to the burning of forests, drought, and floods in most of the world. These climate changes occur due to the overuse of fossil energy as most countries are today using this source of energy to power their nation. With the emergence of greenhouse gasses, most of the countries like China, India, USA, and Germany are reducing their dependencies on the use of fossil fuels. The countries have signed a cause to reduce the use of fossil energy and adopt better ways or green sources of energy to power their countries (Jang, 2020).

4.2.1 Characteristics of EV Batteries

Today, EVs are mostly equipped with Lithium-ion batteries which are the leader of the market due to their high energy lifecycle and efficiency. These batteries consist of a large number of single battery cells which are arranged in serial or parallel ways. To monitor the charging, a battery management system must be installed to manage and protect the Li-ion battery while charging. It is considered that the ideal charging with the operating range is 90% within such management.

4.2.2 EV Charging Habits

EV charging habits are one of the major concerns when it comes to sustainability. The use of energy depends on the consumers' habits of charging their vehicles. The frequency of charging a vehicle matters: the more often it is charged, the more electricity will be consumed. As the number of EV users is rising over the period, the use of energy and power is also increasing (Andresen, 2021).

4.3 VANET technology

Vanet (vehicular ad-hoc network) is a modern technology that allows vehicle-to-vehicle communication through the Internet in which various networking and communication channels are transmitted among cars. The technology was first introduced in 2001 and operates on a similar concept of mobile networking which is known as MANET (mobile ad-hoc networks). Vanet is an integral part of the intelligent transportation system as it works with the help of the Internet of Things (Shrestha, 2018).

4.4 Expansion on VANET

VANET being a modern technology could help to better traffic management in cities, especially cosmopolitan ones like New York, Frankfurt, and Mumbai. To do so, it requires further improvement and expansion as its main criteria are road safety and vehicle entertainment. As VANET is working on ad hoc networks, the system will pass the information via the wireless medium of a network (IoT) to the devices which can help to predict the possible circumstances of moving vehicles. This will form a chain of networks (Saleem, 2019) like a node that will transfer the information to other nodes. Once the information is received, it will be transferred to other nodes and this process will go on. These nodes will be an open source of networks that will be free to join or leave due to high vehicle mobility conditions.

4.4.1 Testing VANET in Critical Scenarios

It is important to test this technology to ensure its reliability in different case scenarios. While testing this technology, there must be certain variables such as the number of vehicles in a particular area, weather conditions, road temperature, and wind speed should be considered (Saleem, 2019). As stated by Duarte et al. (2021), "automobile environments are spending new set of requirements on today's wireless communication system".

The scenario explains to us that two emergency vehicles are approaching from different directions towards the intersection. They will reach the intersection almost at the same time and at least one EV may be at the intersection. Now the system should cope with this situation to avoid conflict if more than one EV shows up. To do this, it is considered that the transmitter will communicate with the traffic light controller that can control the state of traffic lights based on intersections. The transmitter will send the controller the relevant information related to EV status like speed, position, and direction. The controller will decide to handle and proceed to coordinate traffic lights to ensure a safe journey (EDUARDO, 2021). Finally, as the EV clears the intersection, Roadside Unit (RSU) will alert with a specific message from the EV or via Basic Safety Message (BSM), and this process will be broadcast continuously.

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5 INITIAL CONCEPTUALIZATION MODEL

Derived from the literature review an initial conceptualization has been developed to be validated by the empirical research stage (figure 1).

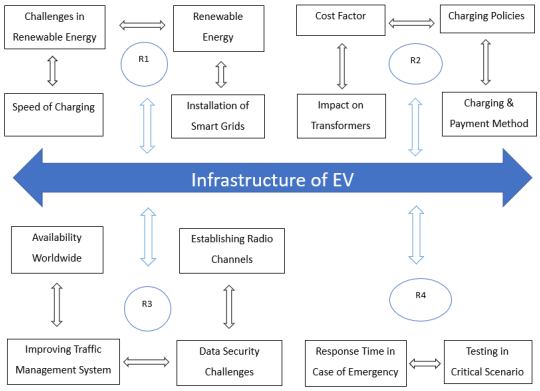

Figure 1: Initial Conceptualization Model, Image Source: Morton2021, Lee 2020, VINEL 2021.

6 RESEARCH METHODOLOGY

6.1 Research design

The objective of this research is to explore factors that reduce carbon emissions and build a sustainable infrastructure that would provide a feasible solution by eliminating different challenges as described in the literature. The research also aims to optimize the infrastructure and improve the existing technology to make it more reliable by providing examples for different scenarios. As this study is exploratory in nature, the qualitative approach is the best fit to narrow the gaps for this study.

6.2 Data collection

For data collection, 7 semi-structured interviews were conducted with open-ended questions to understand and interpret each interviewee's thinking. Purposive and Snowball Sampling were chosen as the sampling method for obtaining data information. The selection was done based on the people who are industry experts in the field of sustainability and the automotive industry. The age group from 25 to 40 years covered mostly EV Charging Experts, Senior Managers, Low Carbon Vehicles & Fuels advisors, and ambassadors for Clean Mobility.

6.3 Data analysis

Interviews that were conducted were manually transcribed and analyzed by MAXQDA. All the information like the respondent's body language, tone of voice, expressions, and gestures was considered during the process which resulted in the richness of data collection. The exchange of information and ideas from both sides was highly appreciated and showed a belief in the research. A qualitative technique was followed for analyzing the content standards, Qualitative techniques are simple, transparent, and highly reliable to master content analysis. The data were evaluated by the content analysis method suggested by Kuckartz (2019). The following categories emerged as a result of the analysis.

Categories	Procedure	Presentation	Anchor Example
Renewable Energy	Deductive	All passages mentioning about renewable energy sources, types, and challenges.	Renewable energies like solar and wind are the most crucial and dynamic solutions to fill the gap and support the charging infrastructure.
Battery Characteristics	Deductive	The passage mentioning about battery type and lifecycle in the market.	EVs are mostly equipped with Lithium-ion batteries which are the leader of the market due to their high energy lifecycle and efficiency.
Location	Inductive	The statement given by the respondent emphasizes the country's location.	"Location plays an important role and of course the climate. For example, if it's a bright sunny day, you can charge your vehicle easily".
Data Centres and Cyber Attacks	Inductive	The statement given by the respondent emphasizes data security.	"Not all the countries have capabilities to build data centers".

Table 1: Categorization Table

6.4 Renewable energy

To recap, the purpose of the study was to connect the infrastructure with renewable sources of energy that can help the environment to reduce carbon emissions and meet sustainability goals. After interviewing seven experts in the domain, it was noticed that many respondents were in favor of using renewable energy like Solar and Wind as they believed it is the cleanest form of energy. Unanimously, R1, R4, R5, and R6 highlighted the importance of renewable energy.

6.4.1 Transition

To begin with, the transition phase is a phase from which we need to switch from 1st Generation fuel to 2nd Generation fuel. Second-generation fuels are much cleaner and produce low carbon emissions. R2 emphasizes this aspect: “More energy transitions and natural development employing current enterprise resources”. The respondent also highlighted that the “European Union has advanced on developing lots of policies and with the current situation in EU, they have passed some budgets to go fully on their natural resources”. On the other hand, R3 mentioned: “The grids are coping in the world with all these transitions from lower to high consumption”.

6.4.2 Policies

Policies are critical to creating since they drive the project in the appropriate path. In this regard, R2 has stated that "environmental regulations from the United States and China are the biggest polluters in the work like didn't like Stein?? The situation is unclear. The European Union is establishing environmental regulations to rely entirely on natural resources such as wind energy."

6.5 Supply chain

6.5.1 Labour

The aspect focuses on the manpower to build the infrastructure. This could include anyone who relates to the project like managers and workers. R1 highlights this factor: “The installation is huge, and the biggest element is the labor aspect of implementing this”.

6.5.2 Raw Material

The raw material involves the supply of things that are required in the infrastructure. R1 emphasizes the availability of raw materials: “You’ve got to install a lot of wires, lot of cables to make it work. You know, we got to think also of the supply of the materials as the material comes from China”.

6.5.3 Covid and War

One of the major concerns is to affect the supply chain of raw materials and to build the infrastructure. One of the future concerns that needs to be addressed is to develop a solution. R1 highlights “The supply chains have been affected since COVID and obviously with China being in lockdown for a couple of months as well that says affected”. R2 says “Right now like with all like let’s say the crisis with Russia and the Ukraine War, all the energy transitions are becoming slower, and the Issue for the EU is to move from Russian Dependency and have multiple suppliers of energy for Temporized from Africa”. R3 was not sure if the raw materials were available it stated, “Since the war in Ukraine, I think it must be available”. So, we can see a major impact on the supply chain due to these situations and must ensure that in the coming future, we must have different suppliers or supply chains available as a backup and not just be dependent on one variable only.

6.6 Cost

6.6.1 Household Income

An area addressed by another respondent was household income. R2 stated in this context: “Companies are taking new strands and they will be like it is necessary to reduce the consumption of the personal car. But I think it is a long process. Like me, at least in Europe, for middle- and lower-income households, just like it happens. Maybe like once in 10 or 20 years, of course, every household will change and adapt. There is time for implementing electric vehicles and creating an infrastructure around them in Europe”.

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6.6.2 Budget and Investment

Funds are the most essential part of any infrastructure. R1 stated: “Investments need to happen to build the infrastructure. Any specific region may have specific investment requirements which need to be considered, and there are a lot of opportunities as well”. R2 confirmed the view of R1: “There is a cost of infrastructure and there will be a need for funds to make it”. Furthermore, R4 supported this view as well: “You need a huge investment capital to build the infrastructure”.

6.7 Location

6.7.1 Inner-city

R1 state concerning inner-city travel: “There are a lot of opportunities available and to adapt this technology by looking at the current infrastructure and charging capabilities and existing charging stations, one needs to discover the aspect on how inner-city mobility can relate to the charging. Energy renewable aspects can influence our people who may don’t even have an opportunity to charge their vehicle overnight”. R2 also highlights the city situation: “I am from Rome, and let's say there is traffic in the city, I believe that there should be traffic management systems linked in a trampoline creating more less energy consumption and strategically since it should be possible to introduce traffic management system so that every time a person is encouraged to reduce the demand for power and energy consumption”.

6.7.2 Country and Climate

This section highlights the importance of climate estimates in various countries. R1 mentioned: “I think this matters a lot as some of them are utilizing, depending on where geographically, they are utilizing solar power to generate some power back to the units”. R3 states: “In Singapore, there are 100s of 3-wheelers driving with a 5kW hour battery pack and an onboard charge is only 3.2kW. The customer doesn’t require any big and fast change. The charging also depends on vehicle type and battery size”.

6.8 Charging frequency

6.8.1 Charger Types

As we know, for charging EVs, there are multiple types of chargers available. R3 emphasized: “To make charging simple, there must be a solution with a single segment charger for each EV segment. For me, the perfect charging speed is always 50 kW below as the speed doesn’t degrade”. R4 expresses it in simple terms: “Slow charging is healthy charging as it generates less heat due to steadiness and has a very steady way of pumping energy inside”.

6.8.2 Habits and Patterns

Charging of vehicles is directly connected with people’s and cultural habits and it is important to track the patterns of charging the vehicle. R1 highlighted - supported by R5: “Some people like to leave the battery running flat before you charge it and then some suggest you better keep topping it up”. R2 states: “People mostly charge their vehicles overnight which is the peak hour, but it also depends on the class like working class, they still charge their vehicle at night”.

6.9 VANET

6.9.1 Artificial Intelligence

This category describes the role of Artificial Intelligence. R1 responds: “Reacting to an incident, AI has a big impact”. R2 - supported by R3 - responds: “The system based on Artificial Intelligence could help in prioritizing the emergency levels for a vehicle, and I think GM is implementing this technology”. R5 - supported by R6 - says: “Artificial Intelligence can help in finding alternative routes during peak hours and measure the response time in case of critical emergency”.

6.9.2 Testing VANET

To implement this technology, it is important to test it in a real scenario. R1 specifies: “It will require high-performing computers as the camera will capture billions of photos in a real-time scenario”. Similarly, R3 confirms the usefulness of the technology: “This is a very useful technology as GM is already using it as it

beeps and alerts driver before the collision". In the same vein, R5 -supported by R6- said: "It's hard to tell what the situation is. As vehicles are getting smarter, the technology will be programmed in such a way that it could alert the driver or programmed with all the possible situations that could tell the vehicle how to react before the collision".

6.10 Technology

6.10.1 Radio Communication

Radio communication will help VANET in guiding the technology to send signals over radio communication channels. R1 points to the important role of telecommunication companies: "Telecommunication companies can play a major role and they will require huge investment. It will give more chances for new talents to hire network communication experts. We can also use 5G, and 6G technology in the future". R5 relates to an infrastructural component: "We can put a communication tower near each data center to actively communicate with the vehicles".

6.10.2 Data Centers

Data centers are the structures in which all the information will be stored, and they will manage all the operations of the technology that will be available. R1 mentions in this context: "Not all the countries have capabilities to build data centers". R4 stated: "There must be a traffic management system that could logically balance the traffic".

7 DISCUSSION

Renewable energy like solar and wind can fill the gap to support the infrastructure but some areas need to be explored like the use of nuclear-based energy, and sustainable energy from Bio- Fuel. The amount of energy consumption must be calculated as the charging of an Electric Vehicle majorly depends on the Speed of charging and the impact on transformers that are transmitting the energy into the EV. During the interviews, it was found that the speed of charging can be still controlled as there are different types of chargers with specified kW's that can reduce the impact on transformers which I found to be consistent. During the research, it was important to address synergistic as well as adverse mutual effects and the overall micro-climate of the build-up area. This area was left undiscovered as it was not discussed in the interviews and it would be interesting to see how this factor will be considered during future research. Location and Data Centers were both new categories that were discovered during this research. These categories were innovative as they covered very detailed levels of information related to the inner city, country, and a center point where all the collected data will be stored that can further be used to make our EVs smarter by constantly feeding them with different data. This will make our EVs smarter as they would be programmed through blockchain on how they can react in the possible situation which can reduce the number of accidents.

8 CONCLUSION

As climate conditions are changing, it has become important to focus on Sustainability. One of the concerns was the lack of awareness amongst people about renewable energy. As pollution is increasing at an alarming rate, its effects can be seen in different parts of the world. With the Paris Agreement, the European Union along with other countries are taking some serious measures towards the environment. India is one of the major concerned nations and has strengthened its knots with Germany to achieve the goal of Carbon Neutral by 2050.

With the rise in demand for Electric Vehicles, it is important to develop and focus on new technology that is environment friendly and fulfills the need for energy production. So far undiscovered new technologies like VANET can prove very helpful in many ways. With the proper traffic management system, there will be a reduction in air pollution. Solar and Wind energy are the main source of renewable energy. As the population will rise, the energy demand will get higher which could create problems like load-shedding or blackouts in many countries.

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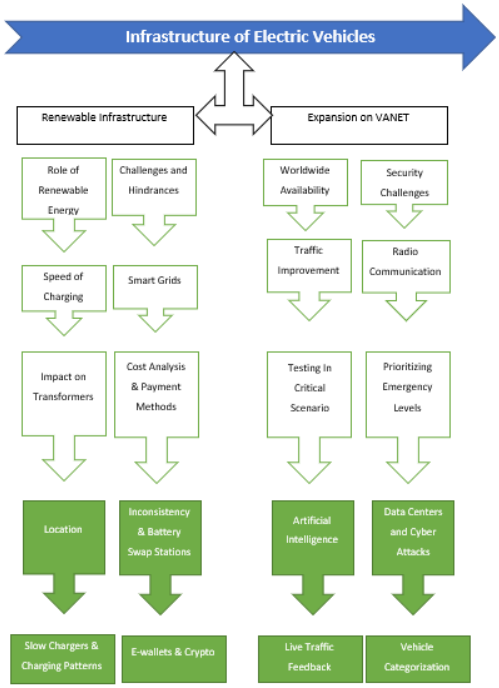

Figure 2: Final Conceptualization Model.

9 LIMITATIONS AND FUTURE RESEARCH

The research was exploratory in nature and the sample size was small based on a global sample lacking national or cultural differentiation. As a result, all interviews had to be performed online rather than in person. Future research could be done on an expansion in VANET technology along with more detailed well-developed business models as it was difficult to cover both aspects due to time limitations. There were some discussions on heat island effects in literature reviews but it also seems necessary to address synergistic as well as adverse mutual effects and the overall micro-climate of the build-up area. Future research is also suggested on how developed countries can help developing nations adapt to technology. Moreover, studies on the use of hydrogen and biomass as 2nd Generation fuel are suggested.

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