PREDICTIVE ANALYSIS OF DEMAND OF ELECTRIC VEHICLES IN MALAYSIA AND ITS POTENTIAL

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DECLARATION

This work has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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PREDICTIVE ANALYSIS OF DEMAND OF ELECTRIC VEHICLES IN MALAYSIA AND ITS POTENTIAL

ABSTRAK

Bagi tujuan penyiasatan ini, maklumat berkaitan isu dan punca kadar pertumbuhan Kenderaan Elektrik (EV) akan diperoleh daripada jurnal penyelidikan dan artikel yang telah diterbitkan sebelum ini. Sumber-sumber ini akan memberi tumpuan kepada kelebihan dan kekurangan kenderaan elektrik (EV) secara umum, dengan perhatian khusus diberikan kepada kelebihan untuk pengguna EV, seperti ketersediaan stesen pengecas awam, jumlah jualan EV, dan pengeluaran minyak (iaitu diesel, petrol). Pelbagai faktor menyumbang kepada peningkatan mendadak dalam permintaan untuk kenderaan elektrik (EV) di negara perindustrian. Memandangkan lebih ramai orang membeli kenderaan hibrid elektrik atau plug-in sepenuhnya, terdapat peningkatan yang mengiringi dalam permintaan tenaga. Bagaimanapun, bilangan kereta elektrik di jalan raya di Malaysia tidaklah setinggi yang sepatutnya. Tujuan kajian ini adalah untuk menyiasat aspek-aspek yang akan menjelaskan sebab-sebab mengapa ini berlaku serta cara-cara yang berpotensi untuk mengubahnya. Untuk menentukan hasil yang paling berkemungkinan, banyak hasil yang berpotensi akan disiasat. Dalam artikel ini, analisis ramalan akan dibuat berdasarkan banyak senario yang telah membawa kepada kedudukan ini, dan kami juga akan memperincikan kemungkinan penyelesaian kepada masalah yang timbul. Ia menunjukkan bahawa EV akan meningkat jika kadar pengeluaran minyak yang berkurangan kerana ini akan menyebabkan kadar harga petrol meningkat dan lebih banyak infrastruktur pengecasan untuk EV dibina di Rehat & Rawat (R&R), kompleks membeli-belah dan kawasan luar bandar

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ABSTRACT

For the purpose of this investigation, information regarding issues and causes of growth rate of Electric Vehicle (EV) will be sourced from research journals and articles that have been previously published. These sources will focus on the advantages and disadvantages of electric vehicles (EVs) in general, with particular attention paid to the advantages for EV users, such as the availability of public charging stations, the volume of EV sales, and the production of oil (i.e., diesel, petrol). A variety of factors are contributing to the precipitous rise in the demand for electric vehicles (EVs) in industrialised nations. As more people purchase completely electric or plug-in hybrid vehicles, there has been an accompanying rise in the demand for energy. However, the number of electric cars on the road in Malaysia is not nearly as high as it should be. The purpose of this study is to investigate the aspects that will shed light on the reasons why this is the case as well as the potential ways in which it might be changed. To determine what the most probable outcome will be, many potential outcomes will be investigated. In this article, prediction analysis will be made based on many scenarios that have led to this position, and we will also detail possible solutions to the problems that have arisen. It shows that EV will increase if less production rate for oil(per gallon) as this will cause in risen in petrol price rate and more charging infrastructure for EV is built in Rehat & Rawat (R&R), shopping complex, and rural area.

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LIST OF ABBREVIATONS

EV	Electric vehicles
GHG	Greenhouse gas
CO2	Carbon dioxide
PHEV	Plug-in Hybrid
IEA	International Energy Association
BEV	Battery electric vehicle
ICV	Internal combustion vehicles
MAA	Malaysia Automotive Association
IPCC	The Intergovernmental Panel on Climate Change
COP21	United Nations Climate Change Conference
MARii	Malaysian Automotive Robotics and IOT Institute
PEKEMA	Malay Vehicle Importers and Traders Association of Malaysia
TNB	Tenaga Nasional Berhad
MGTC	Malaysian Green Technology and Climate Change Centre
ICE	Internal combustion engine

CHAPTER 1

INTRODUCTIONS

1.1 Overview of Electric Vehicle in Malaysia

Electric vehicles (EVs), an emerging technology, have received increased attention because of greenhouse gas (GHG) emissions, climate change, and urban air pollution[1]. The increased demand for EVs introduces new benefits and problems to individuals' city lives. Electric mobility is advocated as a future transportation alternative with environmental and economic benefits, as well as a means of encouraging sustainable urban transportation The balancing of demand in the electrical energy distribution system, charging schedule, dynamic pricing, and various types of charging stations alter the priorities of city life. A comprehensive strategy must be developed by local officials to handle the new regulations and complete the permanent shift from gasoline-powered cars to EVs. Currently, several cities in various nations have released their strategic plans with the goal of obtaining a 30 percent market share for EVs by 2030[2]. These initiatives concentrate on methods to optimize the benefits of EVs and raise citizen awareness.

In addition, research conducted by the European Union indicates that the transportation industry is accountable for approximately 28 percent of the world's total carbon dioxide (CO2) emissions, with road transportation being responsible for more than 70 percent of the transportation industry's emissions[3]. As a consequence of this, the governments of the majority of industrialised countries are beginning to encourage the use of electric vehicles (EVs) in an effort to lower the concentration of air pollution[4], CO2, and other greenhouse gases. To be more specific, they promote environmentally responsible and economically viable modes of transportation via a range of programmes, most often in the form of tax rebates, purchase incentives, or other unique measures like as free public parking or free highway use. The acceleration of Malaysia's economic expansion has been accompanied with a significant worsening of the country's environmental situation. As sales of electric vehicles and plug-in hybrid electric vehicles continue to rise, more thought must go into determining whether or not these vehicles will be improved or reorganised. Therefore, the location of the pollutant source may have a significant impact on the health impacts and environmental justice repercussions that are associated with a vehicle with the same pollutant emission characteristics as another vehicle.

To reduce the amount of pollution that is caused by the transportation sector, the government of Malaysia is placing greater emphasis on electric and plug-in hybrid vehicles. The amount of energy that was used for transportation in Malaysia saw a significant rise between the years 2000 and 2020. The overall growth rate was 5.7 percent, which accounted for roughly 39 percent of the total energy consumption in the nation.[5] with an average growth rate of 8.7 percent in newly registered private automobiles [2]. According to a study on automotive internal combustion, just 12.6 percent of total energy is utilised for meaningful effort[6]. As a result, the government must prioritise developing successful methods for greening the transportation sector as part of its overall strategy for sustainable and green economic growth. Electrification is seen as a critical solution for reducing carbon emissions and increasing energy efficiency in the transportation industry. Work on strategy and roadmaps, such as the National Green Technology Policy and the Electric Vehicles Infrastructure Roadmap, has highlighted several interesting ideas that might help reduce emissions and utilise energy more efficiently. The last question is how the future will unfold and how it will be controlled. To overcome the multiple barriers to radical future transportation technologies and manage public acceptability, a comprehensive and systemic policy approach for technology development and deployment is necessary.

It is anticipated that electric cars would be promoted to the mass market in Malaysia as one of the solutions to minimise dependency on fossil fuels and carbon emissions generated by transportation sectors, particularly personal transportation. There is a growing consensus that electric cars are a viable and sustainable approach for decarbonizing personal transportation while also improving air quality and green technology that is "near to market"[7]. However, in order to turn a profit, it will be necessary, in addition to increasing the supply of electric cars on the Malaysian market, to win the acceptance of the people. Motivated by a desire to promote and support the use of electric cars in Malaysia, the researchers wish to analyse and find the factors that affect electric car use intention via this study. Their objective is to promote and encourage the use of electric vehicles in Malaysia.

For the purpose of this research, we will collect data from previously published articles and scholarly journals that discuss the advantages and disadvantages of electric vehicles (EVs) in general, with a particular focus on how their levels of performance, efficiency, and carbon footprint compared to those of conventional automobiles powered by internal combustion engines. This study aims to further explore the adoption and acceptance rate of electric vehicles (EVs) among Malaysians in general, with an emphasis on demand and potential, using data collected from studies that have been published in the past.

1.2 Overview of carbon footprint made by electric vehicle

Electric vehicles, which combine both internal combustion and electrical engines for propulsion, appear to have a very promising future. Furthermore, PHEVs/EVs are now developing as a solution to the problem of reliance on conventional fuels, growing CO2 emissions, and other eco-friendly issues. Therefore, this sort of vehicle gives an advantage in the struggle to lower carbon emissions by up to 30–50 percent while boosting fuel economy by 40–60 percent. These facts are offered by the makers, according to [8]. The entry of electric cars into the Malaysian market has launched the automobile industry into an entirely new dimension based on decreased dependency on petroleum and greater fuel efficiency [9].

Though (Falvo et al.) [10] indicated that electric cars may lower total tailpipe emissions, the gains in terms of overall emissions are small if conventional power generation continues to utilize coal as a main source. Since exposure to PHEVs/EVs is relatively new in Malaysia, no prior research study or analysis on Malaysian drivers has been undertaken to evaluate public acceptance as well as user intentions of this unique and contemporary technology. Researchers propose that the outcomes give a noteworthy impact in giving the visions to benefit the policy makers and consumers to better comprehend the importance of reinforcing the environmental sustainability ingenuity to recuperate the accomplishment of such efforts. Researchers feel that the outputs have a substantial influence in offering visions to assist policymakers and consumers better comprehend the necessity of enhancing environmental sustainability ingenuity in order to recover the success of such initiatives[11].

The demand for electric vehicles (EV) is fast expanding in industrialize nations due to a variety of causes. As the number of completely electric or plug-in hybrid vehicles increases, so does the need for electricity. However, the number of electric cars in Malaysia is still quite low. This study aims to look at elements that will throw further light on why this is the case and how it might be improved. Various situations will be investigated to provide a probable conclusion. Predictive analysis will be done based on various scenarios that have been led to this matter and on how to resolve the problems will be also discussed in this paper.

1.3 Objective

The main objectives of the study are:

i. Investigate and assess the worldwide and Malaysian demand for electric vehicles, as well as the primary causes for present electric vehicle acceptability and adoption in society.

ii. Analyse the potential demand of electric vehicles in Malaysia with the influential of energy use, deployment of electric vehicle-charging infrastructure, and global market share.

iii. Make a projection of potential demand of EV with each potential influences.

1.4 Problem Statement

The percentage of the global market that is held by electric vehicles has seen meteoric growth over the last decade, and we anticipate that this pattern will continue. Between the months of January and June of 2021, electric vehicles and plug-in hybrid electric vehicles accounted for 14% of the total sales of automobiles in Europe[12]This serves as evidence of how strong the demand really was. On the other hand, there were only around 500 electric vehicles operating on Malaysian highways[13]. As a result, the purpose of this article is to do a prediction analysis on the demand for electrical cars in Malaysia and to study various scenarios in order to create alternative outcomes owing to the low demand for electrical vehicles in Malaysia.

1.5 Scope of Work

The gathered data from the official International Energy Association (IEA) website will be first analysed. From the website, all the data for worldwide and southeast Asia (Malaysia) EV vehicle stock and sales may be accessible. The data is subsequently transferred to an excel spreadsheet. After importing our data from the IEA website, we will sort our data for EV stock, EV Sales, accessible public charger, and oil production according to their respective years and nations and deployment of electric vehicle-charging infrastructure. As for independent variables for the scenario made, the estimation growth/drop of 10 years step will be made through the block diagram in Simulink. From the prior sorted spreadsheet, the data will be imported into MATLAB to proceed with the predictive analysis according to the scenario for each variable.

CHAPTER 2

LITERATURE REVIEW

2.1 An Overview of Existing Methods for Life Cycle Cost Estimation

The purpose of a life cycle cost analysis is to provide a framework for analysing the total costs associated with a product across its entire life cycle (from inception to final disposal). There are a wide variety of approaches to doing a life cycle cost analysis. These methods may be broken down into three classes: conceptual, analytical, and heuristic[14]. Assumed interaction is included into the life cycle cost analysis conceptual approach to provide a qualitative foundation.

The conceptual method is advantageous since it may be used to many different kinds of systems. The cost features of any system may be evaluated using the conceptual approach to life cycle cost analysis, which does not need many specifications. The analytical approach to life cycle cost analysis, in contrast to the conceptual method, involves the development of mathematical terms used in product description. Many different studies on the life cycle assessment of EVs and other alternative vehicles are included in Table 1.

Table 2.1 Summary of life cycle cost estimation

System	Study Objective	LCC Methodology	Study Outcome
BEV	To provide a framework for conducting life-cycle cost analysis of electric and intercity vehicles.	An integrated Model	If production costs can be reduced and battery life extended, electric vehicles (EVs) might become competitive with conventionally powered vehicles (ICVs), according to the research.
ICV, and various hybrid vehicles	To examine the relative cost effectiveness of advanced hybrid alternatives to conventional, stand-alone ICVS	The LCC was calculated by adding the initial cost of the vehicle to the discounted value of the parts and labour needed to maintain the vehicle during its lifespan.	In the research, it was shown that different types of advanced hybrid vehicles had lower lifespan costs than ICVs.
HEV	An examination of the total cost of ownership for hybrid gas-electric cars	Analysis of ADVISOR High-Performance Electric Vehicles	When compared to the baseline cars, hybrids' total life cycle costs were much lower.
BFVs, FCEVs, FCHEVs	To compare the study of life cycle costs for BEVs, FCEVs, and FCEVs.	Cost Prediction analysis	It was discovered that BEVs and FCHEVs had lower life cycle costs than FCEVs.
ICVs, HEVs and EVs	To calculate the total cost of ownership for ICVs, HEVs, and EVs.	The total cost of ownership was determined as the sum of the purchase price plus running expenses less the resale value.	The total cost of ownership of hybrid and electric vehicles is less than that of ICVs.

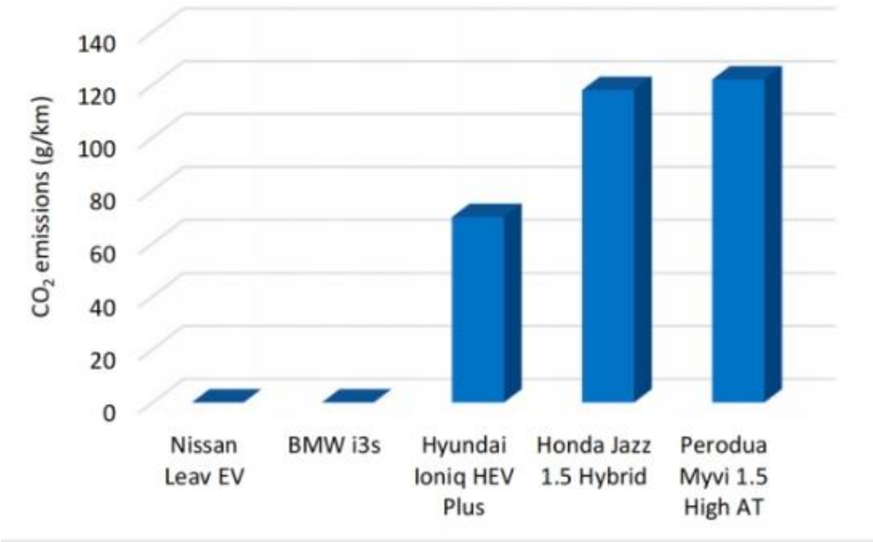

Figure 2. 1CO2 emissions from the various vehicle adopted in this study

The levels of carbon dioxide emissions produced by each of the several kinds of vehicles that were investigated for this research are shown in Figure 1. As can be seen in Figure 1, electric vehicles produce much less carbon dioxide emissions than hybrids and ICVs. Hawkins et al[15] revealed that the kind of power source affects the amount of CO2 that is emitted by electric vehicles. According to the conclusions of their analysis, electric vehicles (EVs) that are fueled by the European power mix generate a much higher amount of carbon dioxide than convectional internal combustion vehicles (ICVs). In addition to this, Girardi et al. [16] showed that, depending on how Italy mixes its energy sources, the CO2 emissions from EVs and ICVs are the same. Concerns about the environment, as Sang et al.[17], are one of the most important things that make people aware of EVs. According to a study by the Malaysia Automotive Association, only 2.2% of all units sold in 2018 were electric vehicles. This is much less than what is seen in other Asian countries. EVs haven't become very popular in recent years for a few different reasons. Sang et al. [17] cited social impact, performance features, financial rewards, environmental concerns, demography, infrastructure preparedness, and government action as some of the elements influencing EV uptake in Malaysia. This lack of understanding has greatly impeded the expansion of Malaysia's EV sector. Aside from a lack of knowledge, one major problem that has been cited as a disadvantage is a lack of charging facilities.

2.2 Climate change scenarios in Malaysia

The Intergovernmental Panel on Climate Change (IPCC) says that climate change poses several risks to humanity. It is important for governments and the public to plan for and take steps to protect themselves from a drastically changed climate. But as the dangers of human-caused climate change have become clearer, the need to educate the public about these problems has grown. [18]. Countries (like Brazil and Bangladesh) that are most at risk from the consequences of climate change have a greater level of anxiety about the phenomenon. As a consequence of this, Malaysia needs a strategy for community engagement in order to contribute to the mitigation of the negative effects of climate change. [19].

Despite the lack of knowledge around the effects of climate change, Malaysia is using precautionary principles in its efforts to mitigate its effects and adapt to them. Malaysia has made significant headway in developing a legal framework for the voluntary disclosure of environmental information and the mitigation of the effects of climate change. For instance, in 2010, the nation of Malaysia adopted a National Policy on Climate Change in order to centralise the country's various initiatives in this subject and provide a framework for those actions[19]. In addition, the government of Malaysia committed RM51 billion to "increase resilience" against the effects of climate change as part of the 10th Malaysia Plan (2011-2015). A National Climate Committee has been created in Malaysia with the mission of developing and implementing actions to combat climate change at the national level. Among the remedies that have been created to prevent deforestation and sea-level rise include policies on the use of energy, increasing public awareness of climate change, maintaining an adequate food supply, and effectively managing forests and coastal areas. In addition to the national policies that have been approved, adaptation plans are necessary in order to deal with the impacts that climate change will have on certain industries. In advance of the United Nations Climate Change Conference (COP21), which will take place in Paris, Malaysia has provided the United Nations with its plan of action on climate change.[19]. According to a paper, Malaysia's goal was to reduce the intensity of its emissions of greenhouse gases by 45 percent by the year 2030. As one of the key tactics to fight global warming and climate change, the government of Malaysia has recently established a low-carbon economy as one of its primary initiatives. This whole thing was carried out with the goal of mitigating the effects of climate change.

2.3 Trends and Developments in Electric Vehicle Markets

In 2020, the global stock of electric vehicles reached an all-time high of about 10 million units, capping off a decade of steady expansion in the EV market share. When compared to the prior year, this is a 43 percent gain (2019) [2]. Despite the ongoing COVID-19 outbreak, global electric vehicle sales have surged by around 70%, with a 4.6 percent market share in 2020. Around 3 million new electric vehicles were registered, with Europe leading the way with 1.4 million, followed by China with 1.2 million. Approximately 295 thousand new electric vehicles were registered in the United States during the same fiscal year[20]. Several factors might explain why EV sales were so high even as the world confronted COVID-19; for starters, legislative support for automotive sales from EU countries was exceptional. Purchase incentives for electric vehicles have been increased, notably in Germany. Furthermore, the drop in battery pricing for these EVs is one of the reasons EV sales increased during COVID-19. Following the second phase of the worldwide shutdown, as the global economy started to recover, electric vehicle sales surged, reaching 4.6 percent market share by the end of 2020.

2.4 Global EV sales for 2021

In 2021, EV sales will increase three to eight times faster than the whole light vehicle market in every region and most countries. From 3% of global light vehicle sales in H1 2020 to 6.3 % this year, BEV+PHEV sales have increased steadily [12] Europe (EU+EFTA+UK) is in the lead with a share of 14 percent for electric vehicles for the first six months, which is an increase from 7 percent a year ago. There is one notable exception, which is that plug-in hybrid electric vehicles (PHEVs) account for fifty percent of sales of electric cars in Europe, while completely electric vehicles account for eighty percent of sales everywhere else. Whatever the catalogue value says, the actual emissions that come out of the tailpipe of PHEVs are totally dependent on how their owners charge their vehicles and how they drive them. Countries that have a strong percentage of the PHEV market often also have a high share of the BEV market, which works to their benefit. It is anticipated that global sales of electric vehicles would continue to behind the trend in 2019 and 2020. Both the demand for and the supply of popular bargains were hampered as a result of "regulatory storms" that slammed Europe and China in 2019. The introduction of the WLTP standard in Europe required many well-known plug-in hybrid electric cars to undergo e-range enhancement maintenance. In China, government authorities have criticised products for having inadequate levels of safety and functionality. The sales of several different models were halted, and a number of competitors went out of business. [21]. The first wave of COVID-19 in 2020 caused an unprecedented decline in the number of automobiles sold while simultaneously winning the approval of lawmakers. If everything had gone according to plan, annual sales of electric vehicles (EVs) would have been higher in both years.

2.5 Adoption of PHEVs/EVs in Malaysia

A number of government-led projects aimed at reducing carbon dioxide emissions have already been put into motion in various countries throughout the world. On the other hand, there is a growing corpus of research that is concentrating on carbon dioxide emissions in relation to financial incentives for the purchase of electric automobiles[22]. Despite this, a statistical study that was carried out in Nanjing, China, by the author Zhang and others found that [8], stated that there is no evidence of legitimate authority encouraging people to acquire electric cars as an influential factor. This is the conclusion reached by the study. In contrast, Sierzchula et al. [23] discovered that financial incentives had a marginally favourable influence as well as a statistically significant one. In the year 2012, they carried out a cross-national research study (from a statistical point of view) to evaluate the elements that influence the adoption rates of electric vehicles in thirty different countries. In accordance with the findings of Graham-Rowe et al. [24], Incentives that are less than $2,000 have very little influence on the adoption of plug-in hybrid electric vehicles or electric vehicles. In the Asia Pacific region, there are various initiatives and programmes being undertaken at the national level to increase people's knowledge of electric vehicles (EVs). These measures include establishing strong targets, providing subsidies for the purchase of electric vehicles (EVs), sponsoring research and development as well as demonstration projects, standardising, regulating, and offering tax benefits, and conducting public education campaigns. According to a recent study conducted by Pike Research, these activities will help drive the area's developing market for plug-in hybrid electric vehicles (PHEVs), with total sales of plug-in hybrid electric vehicles and alternative fuel vehicles in the Asia Pacific region exceeding 1.4 million units from 2010 to 2015. In spite of the fact that the demand for environmentally friendly products is on the rise in Malaysia, very few of them are actually bought. Again, despite year-over-year improvement in hybrid vehicle sales, hybrid cars have only managed to acquire a minuscule portion of the market share held by the automotive sector (about 50,000 units delivered since 2008)[13]. Nevertheless, only 18,967 hybrid cars were sold in Malaysia in 2013 [25]. [Citation needed] On the other hand, sales of hybrid vehicles in the United States (which have been on the market for more than 15 years) reached around 88,000 units in the year 2014.[25].

2.6 Infrastructure Readiness

The availability of public DC chargers is another worry for buyers in Malaysia, in addition to the cost of the product. Their reservations about driving an electric vehicle will be alleviated if there is sufficient DC charging infrastructure in Malaysia, which will help increase the adoption rate of electric vehicles and make them more accessible. DC chargers are the most important piece of equipment for electric vehicle travellers, despite the fact that AC chargers are convenient for overnight charging. The government, linked agencies, and connected business have all been made aware of this problem thanks to previous efforts. 2021 saw the beginning of a number of different efforts aimed at resolving the problem. The Malaysian Automotive Robotics and IOT Institute (MARii) and the Malay Vehicle Importers and Traders Association of Malaysia (PEKEMA) have recently signed an agreement to establish a network of 1,000 DC quick charging stations across the nation by 2025. The deadline for the completion of this project has been set for 2025 [26]. The cooperation will also investigate the ecosystem of the country's infrastructure, which will create opportunities in various fields of business and employment throughout the nation. In a similar manner, Tenaga Nasional Berhad (TNB), which is the biggest energy utility company in Malaysia, has focused on providing the vital infrastructure in Malaysia via partnership with a variety of Malaysian stakeholders. [26] TNB is also willing to work with private sectors that plan to make the switch to low-carbon mobility in order to help Malaysia make the transition; for instance, TNB recently worked with DHL

Express Malaysia to install charging stations along DHL's service routes as a first step toward the future transition.

There are now around 500 public AC chargers and 9 public DC charges in Malaysia, according to a study from chargEV. [27], chargEV currently has Malaysia's largest AC charging network available to its customers. The Malaysian Green Technology and Climate Change Centre (MGTC) is responsible for the construction of the chargEV network, which is Malaysia's infrastructure for providing free public charging for electric vehicles. The chargEV network presently offers 303 AC chargers in the states of Johor, Kedah, Kuala Lumpur, Melaka, Negeri Sembilan, Pahang, Perak, Penang, Putrajaya, Sarawak, and Selangor. The power output of the AC chargers may vary anywhere from 3.7 to 22.0 kW. chargEV gives its users with their very own mobile applications that make it easy to locate charging stations around the country as an additional means of assisting and catering to their needs. MGTC has collaborated with BMW to provide mobility services in Malaysia. These services are centred on the process of identifying charging stations for BMW electric vehicle (EV) customers. These services are based on the chargeEV platform. Shell Recharge is a free electric vehicle charging service that is offered in cooperation with ParkEasy. This service is offered in addition to chargEV [28]. Seven distinct locations around the metropolitan areas of Kuala Lumpur and Selangor each had an AC charging station put in a smart parking spot.

EV Connection Sdn Bhd, a company that specialises in EV charging, has been providing EV charging solutions in Malaysia since 2016, and it has plans to expand its installation over the next three to five years. In terms of DC chargers, the company has been supplying EV charging solutions in Malaysia since 2016 [29]. Along the North-South Expressway, which runs through the states of Perak, Kuala Lumpur, Melaka, and Johor, the corporation operates the most extensive network of DC chargers that are presently available in

Malaysia. In the meanwhile, Shell and Porsche are working together to deploy 180 kW DC chargers at six different Shell stations in Malaysia and Singapore by the year 2022 [30].

2.6.1 Slow chargers

Installations of slow chargers, which provide a charging capacity of less than 22 kW, increased by 65% in China in 2020, reaching over 500,000 slow chargers that are open to the public. This accounts for more than half of the slow chargers that are now available in the market. Europe is in second place with over 250,000 slow chargers, and it is anticipated that the number of installations will grow by one-third by the year 2020. The Netherlands has the slowest chargers in Europe, with roughly 63,000 of them. By the year 2020, the number of slow chargers available in Sweden, Finland, and Iceland had risen by a factor of two in each country. The number of slow chargers installed in the United States reached 82 000 in 2020, representing a growth of 28 percent over the previous year. The number of slow chargers installed in Korea rose by 45 percent to 54 000 by the year 2020, putting it in the second place worldwide.[31].

2.6.2 Fast Chargers

The number of fast chargers installed in China increased by around 44 percent in 2020, reaching approximately 310 000, which is a lower rate of annual growth than the 93 percent rate seen in 2019. The relatively large number of publicly accessible fast chargers in China aims to compensate for a shortage of private charging choices and to support attainment of targets for rapid EV adoption. These goals were set to meet China's ambitious goals for the rapid adoption of electric vehicles. In Europe, rapid charging stations are being installed at a faster rate than slow charging stations. More than 38,000 public fast chargers are available now, representing a 55 percent increase from the number available in 2020. Of these, around 7,500 are in Germany, 6,200 in the United Kingdom, 4,000 in France, and 2,000 in the Netherlands.

CHAPTER 3

METHODOLOGY

The data will be first sourced from the official International Energy Association (IEA) website. The website will provide the data for global Electrical Vehicle (EV) car stock and sales from 2010 up until 2020 that can be obtained. The data can be downloaded into excel spreadsheet. Then, the summary of passenger & commercial vehicles produced and assembled in Malaysia for the year 2010 to September 2021 can be obtained from Malaysia Automotive Association (MAA) website. Lastly, we gain the data for Installation of publicly accessible chargers expanded sevenfold in the last ten years and total registered EV in Europe from IEA website and download the data into excel spreadsheet.

After importing our data from the IEA website, we will begin to sort our data for EV Stock, EV Sales, summary of passenger & commercial vehicles produced and assembled in Malaysia, and Installation of publicly accessible chargers by year and country. Because we are doing an overall data analysis, we will only evaluate data from the Global section, which has already accounted for global EV stock, sales, summary of passenger & commercial vehicles produced and assembled in Malaysia, total registered EV in Europe, and Installation of publicly accessible chargers.

We will import our data file into MATLAB for additional analysis from the previously sorted spreadsheet. Following that, we will launch a callback sequence to retrieve our data and enter it into Simulink using the 'Lookup' Block command. We will use the 1-D Lookup Table for further simulation because our data is merely a fixed integer versus Year. We can now access data for EV stock and sales for a certain year in real time by inputting the year and the relevant parameter.

3.1 Projected Growth of Independent Variables

In scenario simulation, we will assume several situations and enter them into the model to observe how the model would perform in the future. In some ways, this will give us with anticipated statistics for EV stock and sales, as well construction of accessible public charger and total registered vehicles in Malaysia. The situations that will be used are as follows:

- Increase in accessible public charger by 3% from the year 2020 up until 2030
- Decrease in oil production per day (per gallon) by 5 % from 2020-2030
- Global market share has a constant increase

Since the input data is a constant number of integers every year, we may use a 1-D Lookup Table for our modelling needs. We can now get real-time data on EV stock and sales for a certain year by specifying that year and the relevant parameter, such as EV Stock or Sales. The accompanying block diagram shows how to precisely calculate the number of EVs in circulation each year; for example, 2010. This is also valid for every other year between 2021 and 2031.

3.2 Forecasting Multivariate Time Series

3.2.1 System Identification Toolbox

To help users build mathematical models of dynamic systems from observed input-output data, System Identification ToolboxTM contains MATLAB® functions, Simulink® blocks, and an app. It enables you to model dynamic systems that are difficult to represent using just basic principles or specification. Input-output data in either the time domain or the frequency domain may be used to determine a process model, a state-space model, or a transfer function for a system that operates in continuous time or discrete time. Online parameters estimate procedures are also available as part of the toolbox's comprehensive set of features.

Maximum likelihood, prediction-error minimization (PEM), and subspace system identification are some of the identification methods included in the toolkit. Hammerstein-Weiner models and nonlinear ARX models with wavelet network, tree-partition, and sigmoid network nonlinearities may be estimated to characterise nonlinear system dynamics. The grey-box system identification performed by the toolbox may be used to estimate user-defined model parameters. The resulting model may be used in Simulink to better forecast system responses and simulate plants. Time-series data modelling and time-series forecasting are also supported by the toolkit.

3.3 Data Description

In a multivariate time, series, there are more than one variable that change over time. Each variable depends not only on what it has been in the past, but also on what other variables have been. We use this dependency to predict future values. The data is a bivariate time series consisting of collected data of for global EV stock, sales, summary of passenger & commercial vehicles produced and assembled in Malaysia, total registered EV in Europe, and Installation of publicly accessible chargers. a year for 10 years.

3.4 Load the time series data.

```
load testev.mat
z = iddata(m,[],1,'TimeUnit','years','Tstart',0);
```

z is an iddata object containing two output signals, y1 and y2, which refer to the number of registered EV in Europe and accessible EV public charger in Europe, respectively. The OutputData property of z contains the population data as a 11-by-2 matrix, for instance, that z.OutputData(:,1) is the total EV registered in Europe population and z.OutputData(:,2) is the accessible public charger built in Europe.

3.4.1 Plot the data

```
plot(z)
title('EV Production-Public Charger Data')
ylabel ('Registered EV in Europe')
```

Use the first half as estimation data for identifying time series models.

```
ze = z(1:10);
```

Use the remaining data to search for model orders, and to validate the forecasting results.

```
zv = z(11:end);
```

3.5 Estimate a Linear Model

Create a linear autoregressive model of the time series. With the use of programmes like ar (only for scalar time series), arx, armax, n4sid, and ssest, it's possible to build linear models in either polynomial or state-space form. First, detrend the data, since non-linear models (those with a conditional mean that is not zero) fail to capture the data offsets.

```
[zed, Tze] = detrend(ze, 0);
[zvd, Tzv] = detrend(zv, 0);
```

Specification of model orders is necessary for identification. The arxstruc command may be used to discover appropriate ordering for polynomial models. As arxstruc is limited to models with a single output, the model order search must be repeated on each output independently.

```
na_list = (1:10)';
V1 = arxstruc(zed(:,1,:),zvd(:,1,:),na_list);
na1 = selstruc(V1,0);
V2 = arxstruc(zed(:,2,:),zvd(:,2,:),na_list);
na2 = selstruc(V2,0);
```

In particular, the arxstruc command recommends order 7 and 8 autoregressive models.

Using these model rankings, estimate a multi-variable ARMA model in which the cross terms were selected at random.

```
na = [na1 na1-1; na2-1 na2];
nc = [na1; na2];
sysARMA = armax(zed,[na nc]);
```

$sysARMA =$

$Dicrete - time\ ARMA\ model$:

$Model\ for\ output$ y1: $A(z)y_{1(t)} = -A_{i(z)_{i(t)}} + C(z)e_{1(t)}$

$$A(z) = 1 - 0.885\,z^{-1} - 0.1493\,z^{-2} + 0.8089z^{-3} - 0.2661\,z^{-4} - 0.9487\,z^{-5} + 0.8719\,z^{-6} - 0.2896\,z^{-7}$$

$$A_{2(z)} = 0.3433\,z^{-1} - 0.2802\,z^{-2} - 0.04949\,z^{-3} + 0.1018\,z^{-4} - 0.02683\,z^{-5} - 0.2416\,z^{-6}$$

$$C(z) = 1 - 0.4534\,z^{-1} - 0.4127\,z^{-2} + 0.7874\,z^{-3} + 0.298\,z^{-4} - 0.8684\,z^{-5} + 0.6106\,z^{-6} + 0.3616\,z^{-7}$$

$Model\ for\ output$ y2: $A(z)y_{2(t)} = -A_{i(z)y_{i(t)}} + C(z)e_{2(t)}$

$$A(z) = 1 - 0.5826\, z^{-1} - 0.4688\, z^{-}2 - 0.5949\, z^{-3} - 0.0547\, z^{-4} + 0.5062\, z^{-5} + 0.4024\, z^{-6} - 0.01544\, z^{-7} - 0.1766\, z^{-8}$$

$$A_{1(z)} = 0.2386\, z^{-1} + 0.1564\, z^{-2} - 0.2249\, z^{-3} - 0.2638\, z^{-4} - 0.1019\, z^{-5} - 0.07821\, z^{-6} + 0.2982\, z^{-7}$$

$$C(z) = 1 - 0.1717\, z^{-1} - 0.09877\, z^{-2} - 0.5289\, z^{-3} - 0.24\, z^{-4} + 0.06555\, z^{-5} + 0.2217\, z^{-6} - 0.05765\, z^{-7} - 0.1824\, z^{-8}$$

```
sysARMA =
Discrete-time ARMA model:
  Model for output "y1": A(z)y_1(t) = C(z)e_1(t)
    A(z) = 1 - 0.2233 z^-1

    C(z) = 1 + 0.3117 z^-1

  Model for output "y2": A(z)y_2(t) = C(z)e_2(t)
    A(z) = 1 - 0.6405 z^-1

    C(z) = 1 + 0.6808 z^-1

Sample time: 1 years

Parameterization:
   Polynomial orders:   na=[1 0;0 1]   nc=[1;1]
   Number of free coefficients: 4
   Use "polydata", "getpvec", "getcov" for parameters and their uncertainties.

Status:
Estimated using ARMAX on time domain data "zed".
Fit to estimation data: [11.98;29.08]% (prediction focus)
FPE: 1.34e+13, MSE: 2.474e+08
```

Construct a 10-step-ahead (1-year) anticipated output to verify the model throughout the estimate data's time range. Since the data was detrended for estimating purposes, these offsets must be specified for predictions to be valid.

```
predOpt = predictOptions('OutputOffset',Tze.OutputOffset');
yhat1 = predict(sysARMA,ze,10, predOpt);
```

The predict command validates the validity of an estimated model by predicting the response throughout the time span of collected data. Using measured values at moments t = 0,..., t-10, the response at time t is calculated.

3.6 Plot the predicted response and the measured data.

Note that the compare command may be used to automate the development of expected response and its display with observed data.

```
plot(ze,yhat1)
title('10-step predicted response compared to measured data')

compareOpt = compareOptions('OutputOffset',Tze.OutputOffset');
compare(ze,sysARMA,1,compareOpt)

forecastOpt = forecastOptions('OutputOffset',Tze.OutputOffset');
[yf1,x01,sysf1,ysd1] = forecast(sysARMA, ze,10, forecastOpt);
```

The figure provided by compare additionally displays the normalised root mean square error (NRMSE) in percentage form.

After confirming the data, predict the output of the sysARMA model 100 steps (10 years) beyond the estimate data and compute the standard deviations of the output.

```
forecastOpt = forecastOptions('OutputOffset',Tze.OutputOffset');
[yf1,x01,sysf1,ysd1] = forecast(sysARMA, ze,10, forecastOpt);
```

The expected response, yf1, is given back as an iddata object. The predicted values are in yf1.OutputData.

A system like sysARMA, but in state-space form, is called sysf1. When sysf1 is simulated with the sim command and the initial conditions x01, the expected response yf1 is reproduced.

Standard deviations are represented by the ysd1 matrix. It quantifies the degree to which the influence of additive disturbances in the data affects the accuracy of forecasts (as measured by sysARMA). Uncertainties associated with the mapping of historical data to the beginning conditions required for forecasting, as presented by the getcov(sysARMA) function.