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Investigating key challenges in managing inventories of spares in the EV sector

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I am so thankful to my respected supervisor who guided me a lot to complete the dissertation. I am also grateful to my friends who helped me to overcome the difficulties during the project. I would like to give thanks to my family especially my parents who supported me a lot during conducting this study.

Abstract

Exploring the major issues in spare inventory management in the EV industry is the main purpose of the study. The current practices and challenges associated with inventory management of spares in the US EV sector have been investigated in this study. A "secondary qualitative data collection" method along with an exploratory approach has been utilised in this study to drive the study in a proper way to achieve a successful outcome. The collected data has been analysed in terms of using a thematic analysis. Objective and research questions specific themes have been generated to analyse the collected secondary data. It has been observed that the EV industry in the US mainly struggles with the issues of providing adequate replaceable batteries to customers due to improper spare inventory management. The old stocks are dumped in the inventories and there is no space to keep new spare parts. The waste production rate is high in the inventories of the EV industry in the US. It has been found that the use of technological innovations like predictive analytics is beneficial in optimising the workflow in managing inventory of spares. The production of hybrid models is beneficial in eliminating the issues faced by customers in getting replaceable batteries. However, it could be concluded that improved spare inventory management is significant in shaping the perceptions of consumers and convincing them to opt for EVs in the US market.

Keywords

Electric Vehicles, Inventory Management, Spare Parts, Supply Chain, Demand Fluctuations, Closed-loop Supply chain, United States EV Market, Resource Dependency Theory, Resource Onion

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Chapter 1: Introduction

1.1 Background of the study

The electric vehicle (EV) market in the United States (US) has witnessed significant growth in recent years. As per the International Energy Agency, EV sales in the US jumped by 55% in 2022 compared to 2021 with the total sales share reaching 8% (IEA 2024). In 2024, the EV market in the country is estimated to generate more than $82.5 billion in revenue (Statista 2024). Moreover, the projected annual growth rate for the US EV market between CAGR 2024 -2028 is more than 18% reaching over $161.5 billion by 2028 (Statista 2024). As such, the US EV market is experiencing a massive growth period with current and estimated future sales accelerating rapidly. However, the adoption of EVs has been estimated to have a significant impact on the supply chain of the US electric vehicle sector. This is evident from the report by McKinsey & Company which highlighted inventory management problems in the form of a shortage of factories to produce raw materials (Breiter *et al.* 2022). Thus, this study has presented the key challenges in managing inventories of spares in the US electric vehicle industry.

1.2 Research Problem

The EV market in the US faces the problem of managing inventories of spares effectively with changes in the supply chain. As identified in the previous section, a shortage of factories and raw materials can be considered a major barrier posing a threat to the supply chain. Hence, the management of inventories of EVs in the US spares faces the challenge of a shortage of batteries and semiconductor chips which are key components. As per Erickson (2022), the need for semiconductors is further aggravated by difficulties in obtaining the major metals needed to develop the batteries for EVs. The demand for EVs in the US (Figure 1.1) is rising considerably and future estimations are also positive. However, at the same time, the challenges for manufacturers to meet the rising demand due to poor inventory management are also rising significantly. Thus, this is a crucial problem for the EV sector of the UK in efficiently managing their spare parts inventory.

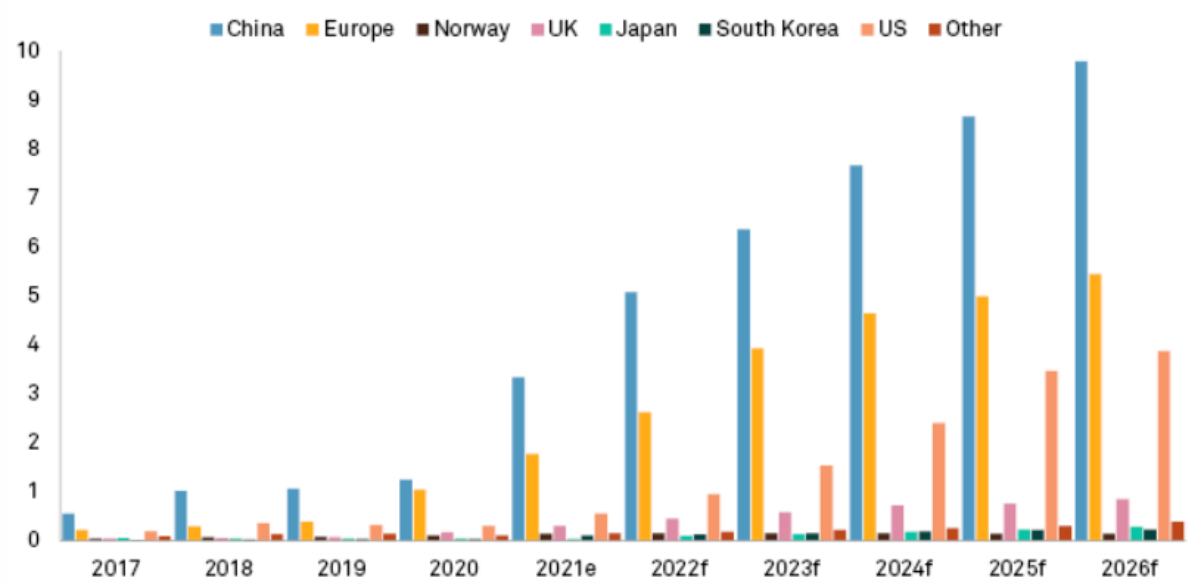

Figure 1.1: Current and Projected Demand for EVs in the World

(Source: Erickson 2022)

1.3 Research Rationale

The research focuses on finding the challenges that the US electric vehicle market is facing in managing inventories of spare parts. In this context, Zhang, Huang, and Yuan (2021, 1) identified increasing attention in this field of inventory management due to the goal of reducing waste and achieving sustainability. It means that efficient inventory management of EV spares can increase the life of the vehicle and contribute towards waste reduction. Moreover, it will also contribute towards reducing the wait time among the buyers contributing to the enhancement of their buying experience. As a result, the sales of EVs in the US will increase even more to accommodate any uncertain situations. Therefore, it becomes important to conduct detailed research on the key challenges faced by EV manufacturers in managing their spare parts inventory in the US. It will not only help in understanding the nature and impact of the problems but also help in developing countermeasures. The US electric vehicle sector will be able to improve its competitiveness in the market by addressing the concerns in spare parts inventory management. Therefore, the rationale behind this study is to find problems in EV spare inventory management for the long-term sustainability of the sector.

1.4 Research Aim

This research aims to identify the major problems arising for EV manufacturers in the US in managing their inventories of spares to find effective solutions.

1.5 Research Objectives and Questions

1.5.1 Objectives

The objectives for this research have been outlined below.

- To identify the importance of managing inventories of spares of EVs in the US
- To determine the key challenges in managing inventories of spares in the US electric vehicle sector
- To study the current inventory management practices for spare parts used in the US electric vehicle sector
- To develop effective solutions for overcoming the challenges of managing spare part inventories in the EV sector of the US

1.5.2 Questions

The key research questions for the study have been stated below.

- Why is it important to manage inventories of spares of EVs in the US?
- What key challenges exist in the management of inventories of spares in the US electric vehicle sector?
- What are the current practices in spare part inventory management in the US electric vehicle sector?
- What effective solutions can be deployed to overcome the challenges of managing spare part inventories in the EV sector of the US?

1.6 Research Significance

This study on the challenges that EV manufacturers and distributors face in managing spare part inventories is highly crucial for the overall growth and development of the

sector. In 2023, more than 92,000 EVs were in stock of the US dealers which is a number that is three times higher compared to the previous year (White and Klayman 2023). The total new vehicle inventories in 2023 also increased by 74% in comparison to 2022 (White and Klayman 2023). The challenges in inventory not only affect the storage and sales of EVs but also impact the overall growth of the sector. This research will help in understanding the most pressing problems requiring urgent attention in the US EV sector. The analysis will be in-depth enabling a more thorough review of the sector to identify opportunities to further improve. EVs are the drivers for the transition of the automotive sector to a sustainable future and this research has attempted to contribute to it. The identification of the key challenges in spare parts inventory management of the US EV industry can help to come up with responsive measures. Hence, this research holds a huge significance for the US EV market and the future of sustainability in general.

1.7 Dissertation Structure

This dissertation provides a detailed analysis of the problem of managing inventories of spares for EVs in the US. In doing so, there are a total of five chapters. The first chapter is the introduction which highlights the aim, objectives and questions of the study. Moreover, it has also provided a background and rationale for conducting the research. The second chapter will provide a review of the existing literature which will help in understanding the extent to which this area has been researched. Moreover, it will also assist in identifying the gap that exists in previous studies that need to be focused upon. The third chapter will explain and justify the methods and tools used in this research for collecting and analysing data. The fourth chapter consists of the presentation of collected data and its analysis. As such, it will also discuss the key findings of the study in relation to the research problem. The last chapter will provide an overall conclusion to the research by summarising the main findings, linking the objectives and identifying the limitations of the study. Hence, the conclusion will also recommend best practices for the US EV sector and highlight the future directions.

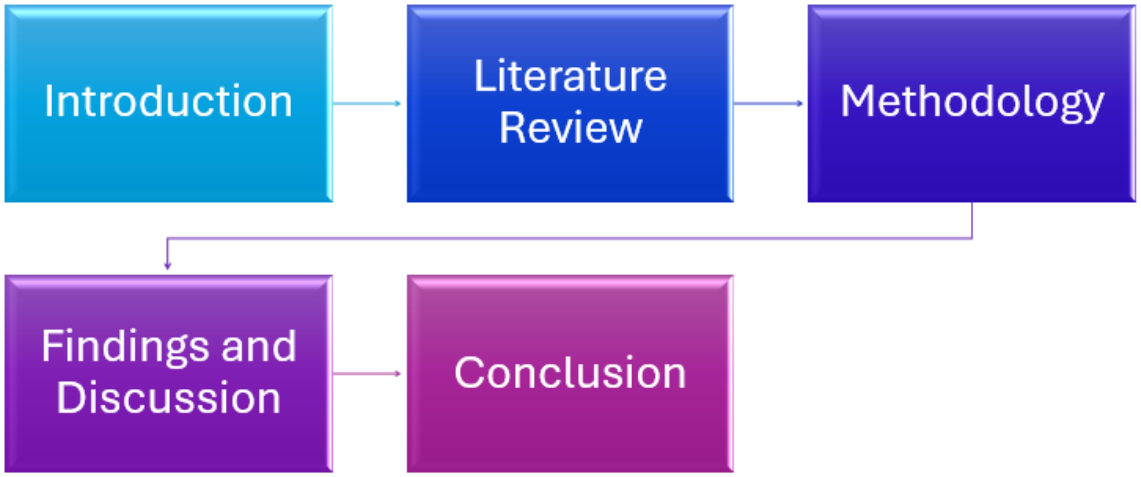

Figure 1.2: Dissertation Structure

(Source: Self-developed)

1.8 Summary

This chapter has highlighted the overall theme of the study with the formulation of objectives, questions and aims. Moreover, the background and rationale provide a strong justification for the significance of this research. Hence, this chapter has provided some crucial information about the field of inventory management of spare parts for EVs in the US to drive the research in the right direction.

Chapter 2: Literature Review

2.1 Introduction

This chapter will introduce the key concepts and existing research in the field of spare part inventory management in the EV sector. The literature review will help to identify the gap that will be the main focus of the study. Moreover, this chapter will also identify theoretical models that can assist the evaluation.

2.2 Concept of Inventory Management

The idea of managing inventory may be considered a waste for some businesses while a crucial area of operation for other businesses. As stated by Priniotakis and Argyropoulos (2018, 1), inventory management involves ensuring that all the resources are in place to meet the demands of customers. This is carried out by monitoring and controlling the levels of the inventories of businesses which helps in improving business performance and saving costs. Muller (2019, 2) argued that for businesses operating under the just-in-time approach, having an inventory is wasteful. This is because they ensure the stock levels are equally proportional to the current demand. However, Muller (2019, 2-3) further stated that businesses lacking strong cash flow or a strong relationship with suppliers require lead times and quality materials. Hence, the concept of inventory management becomes a critical requirement to operate and meet consumer demands in such environments.

The need for managing inventory and the expectations of businesses may differ but it is a major aspect that influences the performance of organisations. In this regard, Wild (2017) stated that every individual is managing their stocks for their purposes such as clothing, food items and more. In a similar way, businesses also manage their stocks such as products, additional items, raw materials and more to meet consumer demands efficiently. Further, Wild (2017) outlined cheap purchases, high-quality materials, enhanced customer service, bulk discounts, and security of stocks as key objectives of businesses in inventory management. As such, several reasons motivate businesses to manage their inventories. Moreover, the need for inventory management is outlined by

Priniotakis and Argyropoulos (2018, 1) stating that too much stock could affect the working capital of businesses. Similarly, having a limited stock could lead to difficulty meeting sudden demand spikes and missing profits. Thus, it can be stated that inventory management is a crucial business concept that influences the performance of organisations.

2.3 Spare part Inventory Management

The spare part inventory management approach has rapidly become a crucial approach for reducing waste and ensuring the continuity of products or services. In this regard, Zhang, Huang, and Yuan (2021, 1) defined spare parts as those stock items that are needed during the maintenance of a product or equipment. They ensure that the operational abilities and life span of the concerned products are extended. As such, in the EV sector, spare parts can be understood as maintenance equipment and components such as batteries, chips and more. These components are necessary for the continuity of electric vehicles without facing any problems. There have several studies on spare part inventory management in different industries identified by Guajardo *et al.* (2015, 331) such as oil, chemicals, aircraft, business solutions, commercial services and more. However, studies on EVs have been limited with scarce information obtained about spare part management. Nonetheless, spare parts inventory management can be considered an innovative approach garnering huge attention from different sectors.

Inventory management plays a critical role in maintaining the competitiveness of businesses to efficiently manage their supply chains. In this regard, Muniz *et al.* (2021, 41) outlined that spare part inventory management enables organisations to have better availability of production materials. Moreover, they are also able to balance their spending on stock items and the service quality for their customers. However, Muniz *et al.* (2021, 42) stated that there is a lack of rigorous research and development of efficient spare part inventory management techniques. Similarly, Bounou, El Barkany, and El Biyaali (2017, 182) also emphasised the challenging aspect of spare part inventory management for businesses due to limited knowledge about the concept. However, Mor *et al.* (2021, 1) stated that it allows businesses to provide the desired quality of service

to customers, reduces investments in inventory and lowers operational costs. Thus, the lack of comprehensive knowledge is concerning but spare part inventory management can considerably improve the competitiveness of businesses.

2.4 Importance of managing inventories of spares of EVs

The need for managing inventories of spare parts for electric vehicles also exists due to the benefits it can provide businesses and customers. In the opinion of Mor *et al.* (2021, 1), spare parts management could be highly beneficial for businesses to achieve optimum conditions for growth. It can allow businesses to ensure their working capital is not tied down due to excessive stocks and also reduce their investments in warehouses and other components of inventory management. As such, in terms of electric vehicles, the same concept is also applicable as excessive spare parts could affect operational cash flow and business performance. A similar view is expressed by Bounou, El Barkany, and El Biyaali (2017, 182) who emphasised that spare parts inventory is a necessity for businesses to gain a sustainable future. Therefore, managing inventories of spares of electric vehicles can enhance business continuity which can also improve customer service.

The failure of businesses to manage spare parts inventories efficiently could also result in dire consequences. In this context, Bounou, El Barkany, and El Biyaali (2017, 182) highlighted the losses of human and financial capital as a consequence of not managing inventories efficiently. The researchers further identified the failure of traditional inventory management models which focus on overall benefits leaving room for risks and bad profits. In line with electric vehicles, managing inventories of their spares becomes increasingly important to eliminate these risks and improve profits. Moreover, Muniz *et al.* (2021, 43) stated that spare parts play a crucial role in maintenance activities and could lead to severe repercussions. This is because it could lead to an increase in waste production as the vehicles would not be operational without spare parts. However, Muniz *et al.* (2021, 43) identify the need to determine when stocks should be kept and when they should be released. Hence, the importance of spare parts

inventory management for EVs arises to understand market demand and avoid consequential outcomes.

The need for EV businesses to manage spare parts inventories has become increasingly important due to the rising environmental concerns. These concerns are mainly due to the existence of internal combustion engine vehicles (ICEVs) and the transition to EVs has become critical. In this context, Huster *et al.* (2022) discussed the greenhouse gas (GHG) emissions from ICEVs can be reduced through the adoption of EVs. However, Dreyfuss and Giat (2017, 38) argued that battery recharging, wait time and other inconveniences act as barriers to EV adoption. As such, it can be stated that managing inventories of spares of EVs effectively could mitigate these barriers slowing down the transition from ICEVs to electric vehicles. The ability to stock items as per the requirements and demands of customers will not only improve the cost efficiency of businesses but also enhance customer perception. Thus, environmental concerns further increase the importance of managing inventories of spares of electric vehicles.

The importance of managing the inventories of spare parts for EVs can be understood through the quick and simple management ability it provides businesses. As stated by Guajardo *et al.* (2015, 339), spare part inventory management becomes crucial for businesses to control various parameters. The researchers found that collaborative approaches and methods for spare parts inventory management allow businesses to obtain a highly efficient demand and supply model. In this context, Zhang, Huang, and Yuan (2021, 1) stated that spare parts account for a large amount of the total costs of a product's life cycle. It involves the machinery, equipment, materials and resources which are critical components. As such, mismanagement could lead to financial as well as reputational losses which can impact the overall functioning of businesses. Therefore, spare parts inventory management of EVs can be assumed to hold considerable significance due to the recent focus on this area.

2.5 Challenges in managing inventories of spares of EVs

The EV sector is considered to play a significant role in reducing environmental problems compared to their ICEV counterparts. However, there are severe challenges

that affect the adoption of the EVs with inventory management of spare parts gaining rapid attention. In this context, Dreyfuss and Giat (2017, 38) outlined the problem of recharging batteries which increases the wait time. The researchers used a case study company to research the viability of replaceable battery ownership for customers and vehicle manufacturers. Under this approach, the customers could swap their empty batteries with charged ones at various stations which manufacturers would stock. Dreyfuss and Giat (2017, 38) stated that this approach could reduce the charging time and improve the adoption of EVs. However, the researchers further identified new challenges in inventory management. It will create a major issue in managing the spares of EVs as the number of spares would also have to be increased considerably to meet demands. Moreover, the fluctuations in demand would make it even more difficult to manage such a huge amount of stocks in multiple stations and warehouses. Thus, the fluctuations in demands and changing models and approaches towards EV adoption can be referred to as a significant challenge in managing inventories for spares of vehicles.

The above challenge of swappable batteries resulting in fluctuations in demand for spares of EVs is further enhanced by the changing consumer behaviour. Dreyfuss and Giat (2017, 38) talked about the concept of tolerable and intolerable wait times of consumers which is completely subjective. This view stated that customers generally have a wait time that they can tolerate for receiving batteries. If this wait time is breached, it becomes intolerable for customers to understand and cooperate. However, this wait time is purely subjective based individual behaviour of consumers making it difficult for businesses to measure and manage inventories accordingly. In the case of inventory management for spares of EVs including batteries, this becomes a critical challenge due to the ambiguity of the situation and the level of its consequences. Hence, the changing consumer behaviour and relevant ambiguity can be stated as another significant challenge which makes it difficult for businesses to predict demand.

As stated above, the problem of determining the need for spares also makes it highly challenging for businesses in the EV sector to manage spare part inventories. In this context, Aguilar Lopez, Billy, and Müller (2022, 1607) talked about hibernating stocks referred to those stocks which are not used but are yet to reach the end of their lifecycle.

For instance, new models of EVs are highly likely to be introduced which may lead to older models being replaced. As such, the need for the spares of older models of EVs will also reduce but not to the extent where it disappears. Hence, businesses face the challenge of understanding the demand with changes in consumer preferences and the requirement of spares for different EVs. In this scenario, the wait time concept of Dreyfuss and Giat (2017, 38) also makes this crisis even more difficult to manage the inventory efficiently. This is because variations in demand for spares of different EVs will also create longer wait times if businesses are unable to make quick decisions regarding their inventory. Thus, identifying the demand for spares is another significant challenge in spare parts inventory management of electric vehicles.

The limitations that exist in EVs due to the shortage of the natural resources needed to make key components like batteries and chips can also be considered critical challenges. Aguilar Lopez, Billy, and Müller (2022, 1611) outlined the rare metals needed to develop the components that power them such as aluminium, lithium-ion and more are scarce. This creates severe repercussions for the management of stocks for batteries of electric vehicles. Moreover, it also raises concerns regarding the future of the inventory management of spares in the EV sector. Similar concerns were also raised by Kumar *et al.* (2021) who identified the end-of-life (EOL) of EVs on top of limited natural resources being severe challenges. The researchers stated that the EOL of batteries is not reached when they are discarded for newer ones which makes it challenging as the minerals are not available abundantly. further elaborated that the consequences of a low supply of materials lead to higher waiting times for consumers. As a result, it can lead to inefficient usage of limited resources and a lack of abundant spares for the manufacturers. Hence, managing the wasted spares that are yet to reach their EOL and procuring sufficient spares amidst scarce resources is a significant issue in the spare parts inventory management of EVs.

2.6 Current inventory management practices for spare parts in the EV Sector

The inventory management practices for spare parts in the EV sector determine the challenges due to the existing inefficiencies. In this context, Mor *et al.* (2021, 8)

conducted research using the ABC analysis approach for meaning inventory. This approach is one of the traditional methods based on the Pareto principle where 80% of the investments by businesses annually go to stockkeeping units (SKUs). Moreover, the inventory items are given classifications based on their Annual Usage Value (AUV) to determine the level of investment. As such, they are divided into A, B and C class items depending on their values with the analysis determining the percentage of the inventory that values account for. For the EV sector, the A-class items can be identified to be batteries and semiconductor chips with the highest usage value. However, the model used by Mor *et al.* (2021, 8) offers a generalised approach to managing inventories which can be applied to any product. Hence, this approach does not specifically apply to EVs considering the various challenges and limitations of the spares.

The need for an innovative approach gave rise to the idea of swappable batteries which is evident in current inventory management practices. In this regard, Dreyfuss and Giat (2017, 39-40) highlighted the need for a swappable network comprising stations and warehouses to manage the batteries of EVs. This approach involves making several calculations based on factors such as the number of stations, warehouses, the difference between the stations and more to understand the optimal inventory requirements. Dreyfuss and Giat (2017, 43) outlined that this method of managing inventory will allow spares to be moved to the most optimal location based on the calculations. This will reduce the wait time for consumers while also reducing the wastage of batteries before their EOL. However, this approach does not consider the growing need for batteries with the rising consumption rate. Moreover, it is difficult for businesses to accurately define key criteria to calculate optimal numbers for spare parts allocation. Hence, this inventory management approach does focus on the variables in the EV sector but requires further improvements to resolve current challenges.

The management practices for inventories of spares for electric vehicles also consist of the remanufacturing approaches. D'Adamo and Rosa (2019, 8-9) discussed the concept of EV battery recycling and EV remanufacturing which can help businesses reduce uncertainty with spare part inventory management. This approach can be effective as the researchers predict the technological usage for refining could help in recovering

some materials. Li, Dababneh, and Zhao (2018, 279-282) also discussed a closed-loop supply chain (CLSC) model for remanufacturing lithium-ion batteries of EVs. This approach to spare parts inventory management is aimed at reducing costs and improving profitability at the same time for manufacturers. This approach of remanufacturing batteries to reduce EOL wastage of batteries could be extended to other spare parts of EVs such as semiconductor chips to improve their management. Thus, this approach is effective for improving the management of spare parts inventory of electric vehicles.

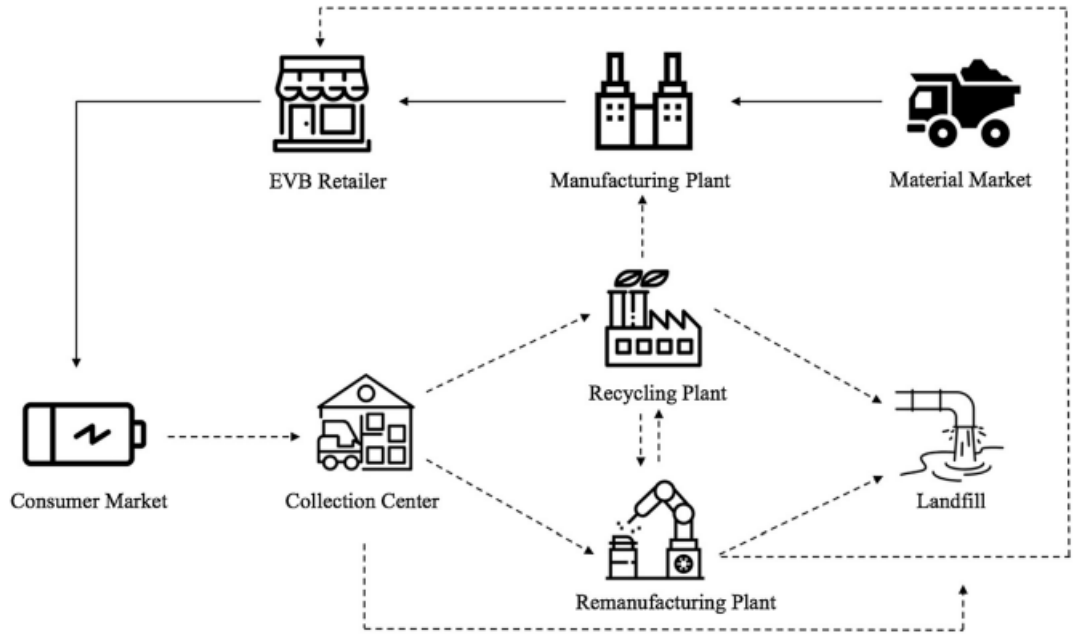

Figure 2.1: Closed-Loop Supply Chain Model for Inventory Management of EV spare parts

(Source: Li, Dababneh, and Zhao 2018, 279)

2.7 Effective solutions to overcome the challenges of managing spare part inventories in the EV sector

The challenges identified in the literature mainly arise due to the shortage of spare materials and changes in consumer needs. In this scenario, the responsive requirements entail innovative methods to overcome the crisis. Aguilar Lopez *et al.* (2022, 1606-1613) highlighted the use of the product-component framework (Figure 2.2) to increase the flexibility in handling the spares. The researchers identified components as spares

and discussed using independent functions that could alleviate strategies like reusing and replacing them. Aguilar Lopez *et al.* (2022, 1606-1613) further outlined the need for strong regulations on spare replacements to encourage more beneficial policies and models from spare manufacturers. As such, battery replacements and other spares need to have stringent policies to ensure their efficient utilisation and waste reduction. This would allow manufacturers to steadily predict demand and manage their inventories effectively. Thus, this approach can be beneficial to regulate the flow of spares and track the current demand to predict future needs.

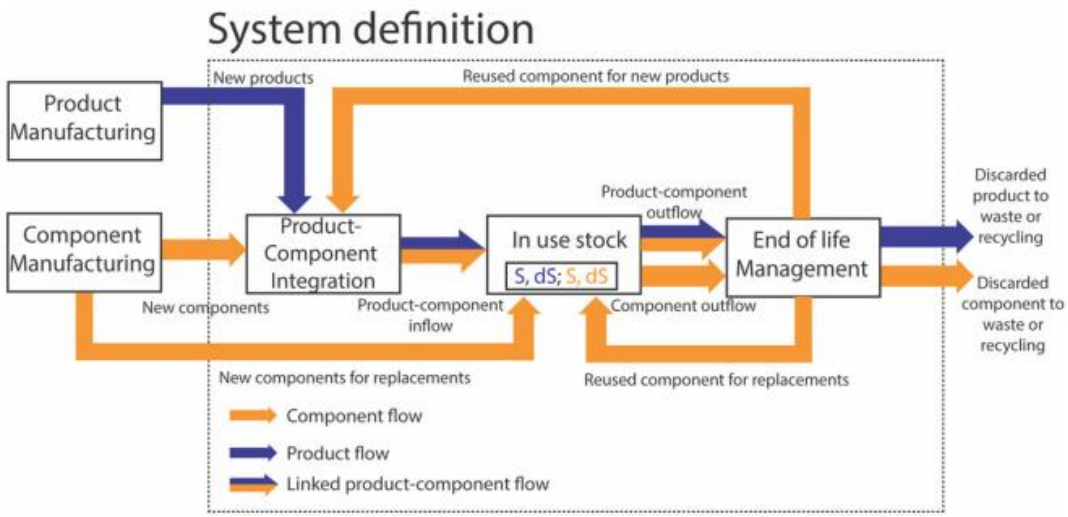

Figure 2.2: A Generic Product-Component System

(Source: Aguilar Lopez *et al.* 2022, 1607)

The above product-component model provides responsive measures to the problem of fluctuating demand due to spare parts being used to replace components before their EOL. This approach from Aguilar Lopez *et al.* (2022, 1606-1613) enables businesses to understand and forecast changes in demand with regulations and effective policies. However, this method does not consider the price fluctuations which can become a major barrier to inventory management. Contrastingly, AlAlaween *et al.* (2022, 1-3) proposed the use of the artificial neural network (ANN) which allows businesses to predict both the demand and price fluctuations of spares of EVs. As per AlAlaween *et al.* (2022, 1-3), ANN has the ability to showcase thinking patterns similar to humans making it highly efficient for complex data evaluations. Moreover, AlAlaween *et al.*

(2022, 5) also found that this approach takes into account, variations in the modes and types of vehicles as well as the unique parameters for their spares. Thereby, by deploying a complex set of critical data regarding the demand and price of the spares of EVs, ANN can succeed in predicting inventory needs.

The recent developments in technology can allow the use of innovative approaches for improving inventory management of spare parts of electric vehicles. Huster *et al.* (2022) opined the use of a simulation model to predict the life-cycle of spares and their demand. The use of various technological developments such as artificial intelligence (AI) and more can improve the simulation results. Huster *et al.* (2022) reimagined various scenarios and examined the use of batteries for old vehicles. As such, the need for spares can be understood along with the entire process and outcome through the simulation to obtain reliable data. Although this approach also entailed variables such as different lifetimes of spares and vehicles, it provided a more solid foundation for making decisions. This approach would reduce the burden on the supply chain through the remanufacturing of EV spares to extend vehicle lifetime. Thus, this approach can also be considered highly effective to overcome the challenges in EV spare parts inventory management.

2.8 Theoretical Framework

The problem identified in the above sections with inventory management for spare parts of electric vehicles mainly involves the scarcity of resources. As a result, there exists major fluctuations in demand and prices of the spares as well as concerns regarding future supply. In this scenario, the resource dependency theory (RDT) can be considered a valuable aspect for organisations to create a collaborative environment. Gao, Wong, and Lai (2023, 2) outlined the use of RDT for obtaining a sustainable ecosystem by emphasising collaboration with the surrounding environment. As such, the theory focuses on collaborative interactions with actors and institutions in the environment of an organisation to overcome uncertainties and complex problems. Hence, this theory creates a sense of interdependence between organisational and social actors.

The application of RDT in the context of inventory management of spare parts of electric vehicles can also enable manufacturers to depend on their surroundings. In this regard, Kim, Lee, and Hwang (2020, 1) discussed the integration of logistics in the supply chain from the perspective of RDT. It entails the extent to which businesses are able to collaborate with their partners and other forces in the environment to enhance their logistics and supply chain management. The application of RDT as a theoretical framework can allow businesses to seamlessly interact with the said forces and enhance their collaborative efforts Kim, Lee, and Hwang 2020, 2). Thus, the resource dependency theory (RDT) can also enhance the collaborative efforts for overcoming key challenges in spare parts inventory management of EVs.

2.9 Conceptual Framework

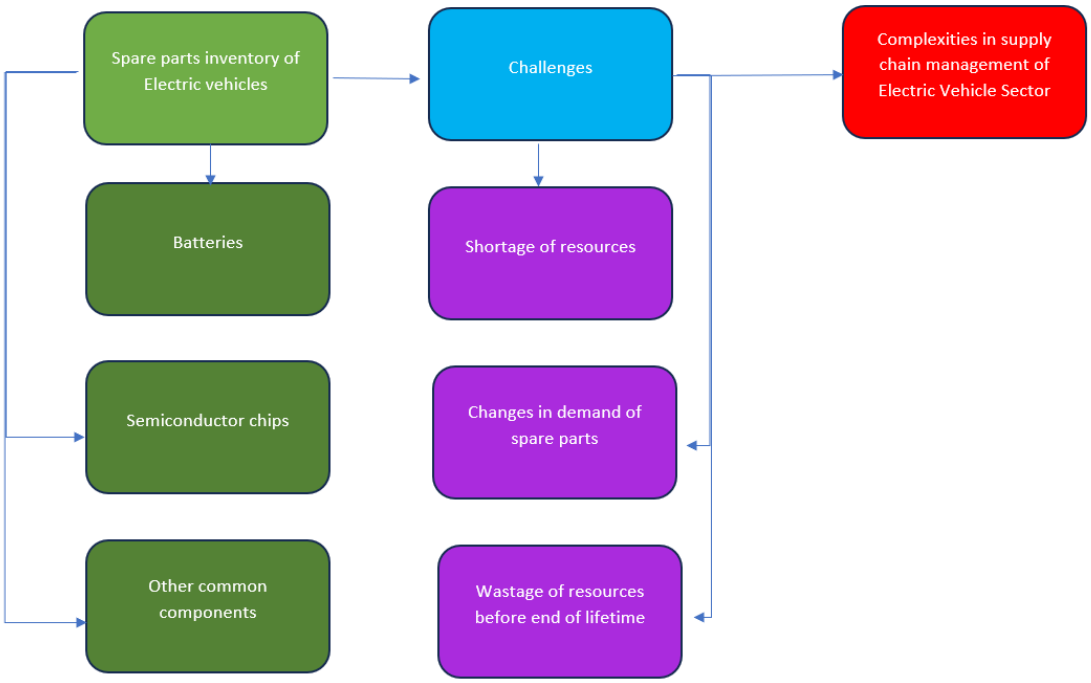

Figure 2.3: Theoretical Framework

(Source: Self-developed)

The above framework (Figure 2.3) highlights the key concepts and ideas obtained from the literature review. The spare parts inventory of EVs mainly consists of batteries and semiconductor chips among other common components. The challenges arise due to a

shortage of resources to procure or make these spares, fluctuating demand and their wastage before efficient use. Thus, these challenges lead to complexities in the supply chain of the EV sector.

2.10 Literature Gap

The literature review has provided a highly informative understanding of the current practices and challenges in spare parts inventory management of vehicles. However, as stated by Zhang, Huang, and Yuan (2021, 2) the literature on spare parts inventory is abundant, but they lack discussion from the perspective of supply chain management (SCM). This is a major gap in the current literature on the topic as fails to recognise challenges in the supply chain with greater detail. Moreover, the knowledge is mainly confined to inventory management of vehicles in general. As such, it does not provide specific data regarding electric vehicles' spare parts creating another gap that requires further research. Therefore, this study has been conducted to add to the current literature from the perspective of SCM by focusing on electric vehicles specifically.

2.11 Summary

The literature review has identified some key studies on spare parts inventory management illuminating the field with recent knowledge and understanding. This has also helped to identify that the literature lacks an in-depth analysis of spare parts inventory management and its relationship with SCM. Further, the review also lacks sufficient information on electric vehicles which will be the focus of this study.

Chapter 3: Methodology

3.1 Introduction

A specific logical framework is needed to accomplish the goals of the current study. The methodology is essential for conducting the study in a specific manner to investigate the major challenges in managing inventories of spares in the EV industry in the US. The different components of the methodology used in this study have been effective in driving the study in a proper way. A specific outcome was obtained after the completion of the study which was satisfactory in fulfilling the objectives of the study. Different components of methods which are appropriate in this study have been discussed as follows with proper justifications.

3.2 Research Onion

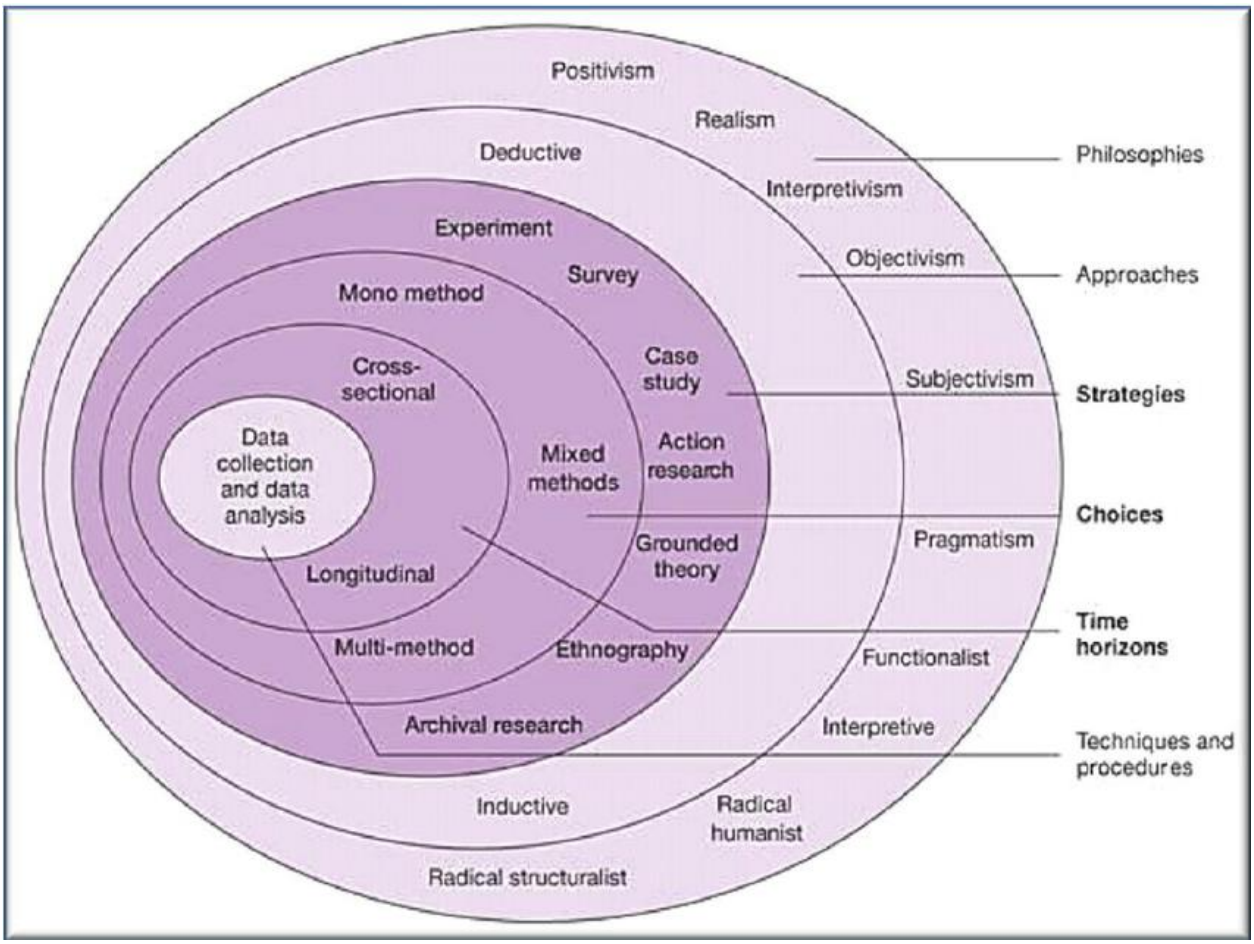

Figure 3.1: Research Onion

(Source: Saunders *et al.*, 2007)

Research onion is a major framework which is effective in shaping the perspectives of the researcher to make proper decisions in selecting specific methods to conduct a particular study. The different layers of the onion depict different components of the method which are philosophy, design, approach, collection of data, analysis of data and others. After the analysis of the different layers, researchers decide to select appropriate techniques to conduct the study. It has been found that in this research onion, three types of methods have been mentioned, which are mixed, mono and multiple methods (Saunders *et al.,* 2007). As this study has been conducted by applying a simple "secondary qualitative method", therefore, a mono-method is implemented in the present research. Moreover, this onion helped this study to reach a purposeful outcome which satisfied the questions of the research by generating proper insights. Specific logical justifications for chosen techniques provided a strong foundation of knowledge for the study. In this way, the key issues in managing spare inventories in the US EV sector have been properly investigated by applying a strong methodological approach.

3.3 Research Philosophy

A belief associated with various ways that are essential in accumulating and analysing information on a specific topic or phenomenon is termed the philosophy of the research. Specifically, positivism, pragmatism, interpretivism and realism these four kinds of philosophies are applied in the studies. In the current study, interpretivism has been selected as the appropriate philosophy which helped to drive the study in a methodical way to reach a purposeful outcome. This philosophy helps in diversifying the thoughts of the researcher to understand the different perspectives of the study in a detailed manner (Ryan, 2018). The different angles of the current study have been investigated by the researcher by using interpretivism philosophy. The importance and links between the key challenges of spare inventory management in the EV industry in the US and social facts have been well-established in this study by employing this philosophy.

On the other side, this philosophy is also beneficial in conducting this qualitative study. Other philosophies like pragmatism, positivism and realism are effective in performing mainly quantitative research. Therefore, these philosophies are discarded in the study and interpretivism has been accepted. On the contrary, as interpretivism states about the

subjective data associated with the real facts, the possibility of occurring bias was high in this philosophy. This drawback has been tactically discarded in the study by providing specific justifications for every fact.

3.4 Research Approach

Adopting a proper approach is required in planning and streamlining the study to reach a specific outcome. The detailed procedures of collecting, analysing and interpreting data are determined by the use of a specific approach. Abductive, deductive and inductive three approaches are widely used in research studies. Deductive is applied mainly in quantitative studies and it is effective in extracting information from the existing theories and facts. The abductive approach is also used in the empirical studies. So both approaches have been rejected in this study. The inductive approach has been found appropriate for this study. This approach helps in forming some theoretical perspectives in the studies by analysing the collected information (Azungah, 2018). The importance of managing inventories of spares in the EV sector in the US has been elaborated by adopting this approach.

Specific information has been gathered from different secondary sources which helped to understand the challenges faced by the EV industry in the US regarding managing spare inventories. The current practices utilised in spare part inventory management in the EV industry in the US have also been explored by generating specific insights by applying the inductive approach. Moreover, there was a chance of obtaining an incorrect conclusion due to misinterpretation of the collected information, which has been tactically managed during the study.

3.5 Research Design

The roadmap to achieve the purpose of the study by conducting the study in a proper manner is possible by adopting an appropriate design for the study. A series of designs are widely used in most of the studies which are descriptive, exploratory, correlational, explanatory and correlational. The present study explored the key challenges of spare inventory management in the EV industry in the US. So an exploratory design has been adopted in the recent study. This design is capable of exploring different aspects of

various variables mentioned in the topic (Mbaka and ISIRAMEN, 2021). The key issues of managing inventories of spares and their impacts on the EV sector in the US have been analysed and explored in detail by applying this exploratory design. A strong foundation of the study has been developed in terms of including this design in this study. However, the cost-effective feature of this design was also efficient in completing the study within the stipulated budget. As this design is used for analysing qualitative data, there is a high probability of generating judgemental decisions which could generate bias in the study. So this kind of cons of the study has been eradicated by providing honest insights during interpreting data.

3.6 Time horizon

The role of time horizon is essential in completing the study within the given period of time by collecting and interpreting data. Longitudinal and cross-sectional mainly two types of time frames are widely included in the studies. A cross-sectional time horizon has been found convenient for this study. This is a cost-effective process, which was useful for completing the study within the pre-planned budget of the study (Melnikovas, 2018). On the other hand, this time horizon is also more time-efficient than the longitudinal time horizon. That is why this cross-sectional time horizon has been incorporated in this research. This cross-sectional study helped in identifying the key factors which inhibit the performance of the inventory management of spares in the EV industry in the US. An enormous amount of data has been gathered and analysed in the study by adopting a cross-sectional time horizon. As the longitudinal time horizon is highly time-consuming, it has been excluded from the study by the researcher.

3.7 Data Collection

It is the most essential part of the method. Proper techniques of collecting data help in achieving the objectives of the study along with the questions of the research. There are specifically two kinds of data collection methods applied in the studies primary and secondary. Primary data collection is beneficial in conducting quantitative studies by conducting online surveys. Even primary qualitative data collection is performed by arranging interviews (Taherdoost, 2021). The current study is not based on numerical

data and there is no need to arrange surveys or interviews as the overall study is dependent on the secondary data sources. So the primary data collection method has been rejected in this study and a secondary qualitative data collection process has been included in the study.

According to the study by Kapiszewski and Karcher (2021), secondary data collection is less time-consuming as well as low-cost. So it was beneficial for the study to gather a huge amount of information on the major challenges faced by the EV sector in the US in managing spare inventory management. The secondary method of collecting data is effective in providing proper insights for the researcher by analysing the information. The data has been mainly collected from different reputed magazines and newspaper articles, government websites and others. The quality of selecting articles determines the data interpretation of the study. However, the articles and information published in the past 5-6 years have been included in this study. All the articles written in other than English have been rejected from the study. The data has been gathered by using the keywords “spare inventory management”, “EV sector in US”. “SCM of EV industry in the US” and others. Irrelevant information is filtered out and only the topic-specific information has been kept in the study.

The secondary qualitative data collection was efficient for the study to find out the issues in the supply chain management of the EV industry in the US, which prevent the overall growth of the EV sector. The viable strategies that could be important to reduce the issues of inventory management in the EV sector have also been accumulated from the collected data. The reliability and validity of the study have been enhanced in terms of adopting the secondary data collection method. The more the updated data is used in the studies the more is the credibility of the study.

3.8 Data Analysis

The effectiveness of analysing the collected data is beneficial in increasing the credibility of the study by reaching a successful outcome. A qualitative data analysis technique has been adopted in this study to satisfy the research questions along with the pre-defined objectives. Mainly a thematic data analysis method is included in this study. This type of method is essential in summarising the key findings of the collected

information (Castleberry and Nolen, 2018). A huge amount of information has been accumulated from the different articles regarding spare inventory management in the EV industry in the US. The data has been divided into various aspects in terms of building proper themes associated with the questions of the research. The themes are coded on the basis of the key information reflected in the articles collected from different newspapers and magazines. The patterns of the collected data have been organised and interpreted in a distinct manner by using this thematic data analysis method.

The key barriers to spare inventory management in the US EV sector have been identified and discussed thoroughly in this study by using the thematic data analysis method. Valuable insights are given against the various facts found in the study, which enables the diversity of the discussion. The potential measures which are effective in mitigating the issues faced by the EV industry in the US have also been explored in this study along with strong insights. Moreover, the efficiency as well as the accuracy of the study has been improved in this study in terms of adopting and implementing a thematic analysis of the data.

3.9 Ethical considerations

Ethical aspects are effective in negating the legal issues in performing a specific research. All the regulations of plagiarism and collusion have been obeyed in the study. Proper academic integrity is maintained throughout the current study. The regulations and boundaries of the data protection and copyrights have been thoroughly followed in the study which helped in maintaining the originality of the research. The important data associated with the study has been shared in the cloud database of the university. Besides this, a backup of the data has been copied into a portable USB drive to avoid accidental data loss. Proper references are given against the facts used in the study. The use of references helped to improve the authenticity of the study. The strong data protection techniques were useful for preventing leakage of the data. Therefore, maintenance of the strong ethical aspects helped to conduct this study without facing any kind of legal obligation.

3.10 Summary

The interpretivism philosophy helped the study to obtain contextual knowledge which was effective in satisfying the aim and objectives of the study. On the other side, an inductive approach was specific to elaborate different real-world facts in relation to the topic by developing some proper theoretical perspectives. Moreover, the exploratory design was beneficial in the study to diversify the discussion of the study in terms of analysing each variable in a systematic way. The secondary qualitative data collection was worthwhile for gathering a huge amount of information within a limited time span. However, the thematic analysis provided a strong framework while discussing the data with proper insights and logic. Obeying the ethical aspects helped the study to maintain the boundaries of the regulations.

Chapter 4: Findings

4.1 Introduction

The relevant facts and information have been collected in this section from different newspaper articles which are effective in satisfying the objectives of the study. A thorough analysis of the information has been conducted in this section which is useful to critically elaborating the different variables associated with the topic of the study. These findings made a base of the discussion which is beneficial in fulfilling the questions and objectives of the currently performed research.

4.2 Findings

Serial number	Themes	Links	Name of the Article	Author name	Year of publication
1.	Reasons behind managing inventories of spares of EVs in the US	https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/a-turning-point-for-us-auto-dealers-the-unstoppable-electric-car	“A turning point for US auto dealers: The unstoppable electric car”	Fischer *et al.*	2021
		https://www.bbc.com/worklife/article/20240311-evs-lost-their-	“EVs were once luxury vehicles. Now, they're for every	Doherty B.	2024

		luxury-status-symbol-reputation	driver”		
		https://www.bbc.com/news/business-58123729	“Can Americans pull the plug on petrol-powered cars?”	Thomas D.	2021
2.	Major issues faced by the US electric vehicle sector in managing inventories of spare	https://www.bbc.com/worklife/article/20231108-three-big-reasons-americans-havent-rapidly-adopted-evs	“Three big reasons Americans haven’t rapidly adopted EVs”	Morgan K.	2023
		https://www.bbc.com/worklife/article/20240228-are-us-ev-sales-a-disaster-or-a-booming-segment-the-answer-may-be-both	“Are US EV sales a disaster or a booming segment? The answer may be both”	Becker S.	2024

		https://www.reuters.com/business/autos-transportation/slow-selling-evs-are-auto-industrys-new-headache-2023-07-11/	"US EV market struggles with price cuts and rising inventories"	White J. and Ben K.	2023
3.	Current strategies adopted by the US electric vehicle industry in managing spare part inventory	https://www.bbc.com/future/article/20240130-wireless-charging-the-roads-where-electric-vehicles-never-need-to-plug-in	"Wireless charging: The roads where electric vehicles never need to plug in"	Paris M.	2024
		https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/goin	"Going small to go big: Micromarkets in US auto retail and aftermarket"	Kramer *et al.*	2023

		g-small-to-go-big-micromarkets-in-us-auto-retail-and-aftermarket			
		https://www.reuters.com/business/autos-transportation/us-automakers-race-build-more-hybrids-ev-sales-slow-2024-03-15/	"US automakers race to build more hybrids as EV sales slow"	White J.	2024

Table 4.1: Review of the chosen secondary sources

(Source: Developed by the author)

(The coding table has been incorporated into the Appendix 1)

Theme 1: Reasons behind managing inventories of spares of EVs in the US

As opined in the report by Fischer *et al.* (2021), the market of EVs is emerging in the UK market. It has been observed that in the second quarter of 2021, the sales of EVs increased almost by 3.6% with respect to the overall car sales in the US. Therefore, the market of EVs is gradually improving as the demands of the customers in the market are gradually increasing in the current days. Mainly people are adopting EVs to improve environmental sustainability in terms of lowering the overall carbon emissions in the air. As the demand for EVs in the US market is emerging, therefore, there is a specific need to improve the availability of spare parts for the vehicles. The need for managing

inventory of the spare parts of the EV is essential in capturing a strong position in the US market. Moreover, the parts of the vehicles are very expensive which sometimes acts as a barrier for the US customers to adopt EVs. So some specific inventory management should be adopted by the EV companies in the UK to reach a strong customer satisfaction level which would further help in the enhancement of the business in the highly competitive US market. Apart from this, the current article also stated that the servicing process of EVs is more complex than traditional vehicles. However, this study explained that US dealers are not well prepared for adopting EVs. The use of data analytics in the supply chain is required to identify the trends and demands of specific spare parts. Unavailability of the spare parts negatively impacts the perceptions of the customers. Therefore, optimising the spare parts inventory management is essential for the US EV sector.

On the other hand, the report by Doherty (2024), explained that once upon a time EVs were the premium vehicles and everybody could not afford these vehicles at that time. Tesla was one of the very first companies, which introduced luxurious EVs in market of the US. At that time EVs were treated as expensive vehicles. In recent days, the price of the products has been reduced and all the people can buy EVs. The main sales of EVs are increasing due to maintaining environmental sustainability by lowering the impacts of greenhouse gas emissions. Therefore, having adequate stocks of spare inventory is essential for the EV in the US as the market demands for the products are increasing day by day. Spare parts are essential for the EVs to properly maintain the conditions of the vehicles by changing the non-functional parts. As the frequency of service and maintenance is high for EVs, the US EV sector has to manage the overall spare parts inventory to optimise customer service in a streamlined manner.

On the contrary, Thomas (2021), stated in his report that most of Americans are not ready to buy EVs. Because there is no proper infrastructure in America to adopt electric cars. The main problems are associated with the challenges of insufficient charging stations. On the contrary, battery issues are high in these cars and the availability of spare batteries is also low. According to this study, there are only 100,000 public charging stations in the US to charge vehicles. The overall perceptions of the customers in the US are not up to the mark. Therefore, it is highly necessary for the EV sector in

the US to adopt modern technologies to shape their inventory management of spare parts. The availability of spare parts is beneficial in strengthening the confidence levels of the customers to buy EVs more than traditional fossil-fuel-driven vehicles. Different collaborative approaches in spare inventory management might play a decisive role in eradicating the current issues in the EV sector in the US and optimal market growth could be achieved by the industry. The overall economic growth of the US would also be increased in this manner.

Theme 2: Major issues faced by the US electric vehicle sector in managing inventories of spare

The report by Morgan (2023), stated that most of the people in America are not preferring to adopt EVs as much. Because the biggest issue is associated with charging. Excessive charging time is a problem. Therefore, a replaceable battery could be the solution to this problem. However, the lack of proper charging points is another issue which restricts US people from buying EVs. So people buy EVs besides their fossil fuel-driven cars. Swappable charged batteries could change the perspectives of the people in the US regarding improving the demands of the EV. On the other side, the price of EVs is higher than the price of traditional cars which is one of the biggest challenges for people in the US to afford the cars. Along with this, the prices of the spare parts of EVs are also high which a severe issue for Americans to buy EVs is also. Therefore, the issues of battery and charging points are the main issues faced by the EV sector in the US, which negatively impact customer behaviour.

The study by Becker (2024), explained that adopting EVs is slowed down in the US. It has become a political issue and many of the people in the US are not adopting EVs to protect the fossil fuel industry. On the other side, the lack of proper infrastructure is also a big reason for not adopting EVs in the US. The improper inventory management results in a scarcity of spare parts for cars in the market. This is one of the biggest problems faced by the EV sector in the US. The government of the US invested a lot of money in improving the infrastructure suitable for EVs. This could be effective in shaping the mindsets of the people in the US as the issues of unavailability of spare parts might be solved by improving the organisation of inventory management.

White and Ben (2023), stated in their report that managing inventory in the US market is a tough job in the EV industry. Price cutting affected the overall inventory management of the EV sector in the US. The excessive price cuts impacted the spare inventory management in the market. On the contrary, it has also been depicted in this report that the demands of EVs are gradually increasing in the US market which is a positive sign for the business growth of the sector. The high demand and low inventory management is one of the crucial issues for the EV industry in the US to meet the demands of the customers in the market. Failing to fulfil the needs of the customers might be detrimental to the prosperity of the business in the market. Therefore, proper inventory management is needed to satisfy the needs of the consumers in the market by providing them with their desired products.

Theme 3: Current strategies adopted by the US electric vehicle industry in managing spare part inventory

The report by Paris (2024), explained that a wireless charging road has been made in Detroit in the US. This road is beneficial for EVs to avoid the charging stations to recharge. The vehicles are automatically charged while driving on this road. The adoption of technology changed the whole perspective of the EV industry in the UK. Electromagnetic coils are installed under this road and these coils are attached to the power grids of the city. As a result, a strong electromagnetic field is developed. So when electric cars are driven on this road they are charged automatically. This type of strategy of making smart roads is advantageous for the EV sector in the US to convince more people to buy EVs. On the other hand, the issues with charging points and battery replacement could be resolved in a methodical manner. This could be helpful for the EV sector in the US to manage their inventory of spare in a specific way.

Kramer *et al.* (2023), stated in their article that the adoption of EVs is emerging in the US market. Identification of specific micro-market and macro-market areas in the US is essential for determining the intensity of the demands of EVs in specific regions. It has been predicted that almost 40% to 50% of the sales of new cars could be made up by EVs in the US. Therefore, it is necessary for the EV sector in the US to develop its inventory management by adopting technologies like blockchain, AI and big data. These technologies are crucial in demand forecasting which is necessary for the EV

sector in the US to understand the number of spare parts required in the market. According to the determined number of spare parts, the overall inventory could be managed. As a result, the supply chain management of the inventory would also be improved.

As opined in the report by White (2024), the automobile companies in the EV sector in the US adopted new a strategy to increase the growth of sales. It has been observed that the sales of EVs are slowed down in the US might be due to the lack of proper spare inventory management. The infrastructural issues are there, which create difficulties in charging the vehicles. Therefore, the automobile industry in the US started to build hybrid EV models which can use both charging and fossil fuel. These hybrid models are effective for users to avoid charge-out issues. The charging could be done by taking power from the fossil fuel. Moreover, the issues of battery replacement and spare parts issues could be easily eradicated in terms of adopting these cars. Therefore, a good consumer satisfaction level could be achieved which in turn would help to increase the business of the EV industry in the US market. These hybrid cars could also help the EV industry in the US to shape its inventory management in a better way.

4.3 Summary

Specific articles related to the research topic have been selected and the findings of the articles are analysed in-depth in this section. Themes are made based on the research questions which improve the overall credibility of the study. The key findings of the articles are analysed in this section in the context of the EV industry in the US. It has been found that most of the inventory management issues are associated with batteries and charging points along with proper infrastructure suitable for EVs in the US. The discussion of the findings will be conducted in the next chapter of the study.

Chapter 5: Discussion

5.1 Introduction

The major findings which are observed in the findings have been discussed and analysed critically in this part of the study. This discussion is effective in satisfying the rationale of the study by critically delivering insights against the key findings. However, this discussion is also effective in linking the findings with the information discussed in the literature review. The overall discussion has been made by elaborating and analysing the previously discussed themes in the findings. This chapter is important for reaching a specific outcome of the study which is efficient in satisfying the objectives of the study.

5.2 Discussion of the findings

Theme 1: Reasons behind managing inventories of spares of EVs in the US

Fischer *et al.* (2021), stated that the market of EVs is increasing day by day in the US. Therefore, taking care of the proper maintenance of vehicles is also a vital responsibility for the EV industry in the US. So the role of spare parts inventory is highly essential to improve the overall maintenance of the cars. Spare parts are needed to improve the sustainability of the cars by controlling waste production, which could hamper environmental sustainability. The study by Muniz *et al.* (2021), also depicted that spare parts are necessary for making the EVs operational and it could be useful in reducing the waste production rate in the environment. As a result, environmental sustainability is enhanced. So managing the inventory of spares is one of the most essential things in the EV industry in the US.

Doherty (2024), explained that EVs were expensive once and all people cannot afford these vehicles. Nowadays the prices of cars have been reduced and everybody can buy these cars. The increasing production of EVs is positive for the growth of the business of the industry in the US. On the contrary, the production of adequate spare parts is also necessary for avoiding any kind of maintenance issues for the vehicles. Therefore, keeping a proper stock of spare parts in the inventory is highly needed to enhance the buying behaviours of the customers. The unavailability of the spare parts might negatively affect the perceptions of the customers and sales of EVs could be lowered in

the US. Muniz *et al.* (2021), also depicted this fact associated with maintaining a stock of spares in inventory management. Keeping proper stock of spare parts by managing inventories is effective in reaching a strong customer satisfaction level which is beneficial for achieving promising growth of the EV market in the US.

According to Thomas (2021), battery charging issues are one of the vital challenges faced by the US EV sector. The charging time is high for EVs and there is also a smaller scope to find out replaceable charged batteries to mitigate this issue. Proper inventory management of the spare parts of the EVs in the US is required to lower the battery issues. On the contrary, the study also stated that there are only 10,000 charging stations in the US. So managing the stocks of replaceable batteries is essential for EV companies to optimise their inventory management and streamline the workflow in supply chain management. Dreyfuss and Giat (2017), also opined in their study that battery recharging delays are one of the major drawbacks of EVs. Specific inventory management is needed to overcome this issue by providing proper spare batteries to the EV customers.

From the overall discussion of the current theme, it could be inferred that spare parts inventory management is necessary for the US EV industry to boost customer perception levels in buying EVs. Specific inventory management of the spare parts in the US EV industry is also effective for streamlining the functions of supply chain management. On the other side, providing specific products to customers on time is effective in improving consumer satisfaction levels, which is one of the most vital factors in convincing customers to opt for EVs in the US. The spare inventory management of EVs in the US is also beneficial in reducing the impact of waste produced by cars on the environment by properly supplying the spare parts. The role of spare parts is necessary in maintaining the efficiency of electric cars. So the role of spare parts inventory management is significant in eradicating the key issues in the US EV sector.

Theme 2: Major issues faced by the US electric vehicle sector in managing inventories of spare

In the study conducted by Morgan (2023), it has been found that most of the customers in the US do not want to purchase EVs. The major drawbacks of the vehicles are

increased charging time. The lack of replaceable batteries in the stock creates a huge problem for customers as well as the EV industry in the US to buy electric vehicles. Hence, it portrayed the difficulties in the EV industry in the US associated with spare parts inventory management. The companies are not able to deliver specific replaceable batteries to fulfil the demands of the customers in the market. In the study by Dreyfuss and Giat (2017), the same facts have been elaborated. The fluctuation in the demand for the spare parts of EVs is creating a huge problem in managing inventory. Consumer dissatisfaction levels are gradually increasing in the US market due to a lack of streamlined activities in the supply chain of spare parts inventory management.

Apart from this, it has been observed in the report by Becker (2024), that political issues are high in the US market which slowed down the business of EVs in the market. Lack of infrastructure is also a massive reason behind the drop in the business of EVs in the US. Improper inventory management is a big issue in negatively affecting the behaviour of consumers in opting for electric vehicles in the US market. The hibernating stocks in the inventory create huge issues for the EV industry in managing the inventory of spare parts. The old spare parts are already stocked in the inventory and there is not enough space in the inventory to store new stocks (Aguilar Lopez *et al.,* 2022). The lack of replaceable batteries occurs mainly due to the scarcity of raw materials like lithium-ion, aluminium and others. According to Lopez *et al.* (2022), this is one of the vital issues in managing the stock of spare parts in the inventory. As a result, high waiting time is consumed by the customers to get replaceable batteries in the US market, which adversely impacts the buying intentions of the customers in choosing EVs.

On the other side, price cuts are one of the major issues faced by the EV industry in the US to manage spare part inventory (White and Ben, 2023). High demands for EVs along with low inventory management caused high customer dissatisfaction which adversely affected the business growth of electric vehicles. As a result, the lack in the supply of raw materials causes delays in getting the spare parts to the customers. Henceforth, the EV industry in the US failed to meet the expectations of the customers due to a lack of proper management in the spare parts inventory. The findings by Kumar *et al.* (2021) are also similar to the stated facts by White and Ben (2023). Therefore, managing the wasted spare parts of the EV is also a significant part of managing inventories. After

the end of the product life cycle, old spares should be dismantled and new stocks must be kept by the EV companies in the US to satisfy the needs of the customers by reaching a strong level of customer satisfaction.

It could be summarised from the overall discussion in this part, that battery issues are common in the EV industry in the US. Therefore, adequate stocks of batteries are required in the inventories to avoid the challenge in the US EV sector. Apart from that, clearing the older spares from the inventories and keeping new stocks are also advantageous for the EV companies in the US to reduce the waiting time of the consumers and provide their desired spare parts on time. This is beneficial in enhancing the customer satisfaction levels which would foster the market growth of the EVs in the market of the US. Adopting specific market forecasting is also worthwhile in reducing the challenges in spare inventory management of the EV industry in the US.

Theme 3: Current strategies adopted by the US electric vehicle industry in managing spare part inventory

Technological adoption is one of the specific strategies to avoid issues in the spare parts inventory. Paris (2024), stated that in the US, wireless roads have been developed. In this context, electric vehicles can be charged while driving on these roads. Mainly electromagnetic fields are developed in terms of using electromagnetic coils under the roads and those coils are connected with the city power grids. This type of technological advancement is effective in mitigating the issues of battery charging. As a result, the demand for replaceable batteries could also be minimised in the US. It becomes easy for the EV companies to manage their inventories of spare parts. On the contrary, Kramer *et al.* (2023), explained the importance of market forecasting which is useful for determining the needs of the customers in the US market. Demand forecasting is potent in mitigating the needs of consumers by providing them with their desired spare parts on time. The implementation of artificial intelligence (AI), blockchain and predictive data analytics play a vital role in optimising inventory management by streamlining the workflow in the supply chain management of the EV sector in the US.

Aguilar Lopez *et al.* (2022), also discussed the importance of market forecasting in developing the business of the EV industry. Apart from this, AlAlaween *et al.* (2022), opined in their study that the implementation of an artificial neural network (ANN) is essential in forecasting the demands and fluctuations in the prices of the spare parts in the EV industry. The complex market data could be simplified by the use of this technology, which would resolve the critical issues of demand forecasting in the EV industry in the US. In this way, the inventory management of the EV industry would be strengthened and achieve strong growth in the market of the US.

Furthermore, the adoption of new ideas is necessary for improving the growth of the business of the EV industry in the US. Therefore, the production of hybrid EV models is worthwhile for boosting the sales of EVs in the US market (White, 2024). This makes it easy for customers to find the spare parts for these hybrid EVs. Therefore, the pressure from the spare parts inventory management of the EV sectors in the US is reduced and the customers could get the spare parts of these cars easily. However, these hybrid models are capable of mitigating the issues of battery charging and the waiting time of customers associated with battery charging is also lowered as these vehicles are efficient in self-charging their batteries in terms of generating power from fossil fuels. This type of innovative invention is fruitful for the EV sector in the US to eliminate the issues of inventory management of spare parts.

After analysing the overall facts, it could be inferred from the above evaluation that demand forecasting is needed for the US EV industry to identify the growth factors and inhibitors of the business. The fluctuation in prices of the spare parts could also be determined by using forecasting. Specific technological innovations are potent in making proper predictions about the US market in the context of EVs. ANN is one of the most efficient technologies, which helps to determine the fluctuation in the market regarding prices and demands. Lastly, it could be said that the production of hybrid EV models is efficient in reducing the pressure on spare inventory management in the US EV sector. The reduced waiting time to receive spare parts is necessary for strengthening the positive perceptions of the customers regarding buying EVs rather than combustion engine-driven cars.

5.3 Summary

The different challenges and adopted strategies in the US EV industry have been deeply discussed in this section. Specific insights have been provided against every fact which has been elaborated in this part. However, the findings of the literature review have also been linked with the findings in the discussion portion. The real facts faced by the EV industry in the US have been thoroughly elaborated in this part of the study. The logical and critical analysis of the findings played a significant part in obtaining conclusive outcomes of the study. Possible solutions to mitigate the key challenges in the US EV sector have been suggested in the next chapter of the study.

Chapter 6: Conclusion and Recommendations

6.1 Conclusion

Electric vehicles are gradually emerging in the global market and the US market is not an exception. These vehicles are efficient in mitigating the negative impacts of greenhouse gases on the environment. Because the rate of carbon emission is almost nil in these cars. Therefore, EVs are essential in improving environmental sustainability. The market growth of the EV sector in the US is significant whereas there are some issues with the management of the inventory of spares in the US. The role of spare parts of EVs is essential in maintaining the efficiency of the vehicles. It has been found from the overall study that there is no proper infrastructure for adopting EVs in the US. The lack of charging stations is one of the most vital drawbacks. Moreover, the unavailability of spare parts is also a vital challenge faced by the EV industry in the US. Mainly the issue is associated with replaceable batteries. The major problem of EVs is associated with their excessive charging time. The need for replaceable charged batteries is required to reduce this charging time and instantly replace the charge-out batteries. On the other hand, it has been also observed that old stocks of spares are not cleared in time in the EV sector in the US, which creates issues for storing new stocks in the inventory. The waste production issues are also found high in spare inventories of the EV sector.

A “secondary qualitative data collection” method has been used to drive the study to reach a proper conclusion. The key findings of the study were specific to the objectives and research questions. It is observed that the high price of EVs restricts the Americans to buy EVs. The maintenance of these cars is also expensive as the prices of the spare parts are high in the US market. Besides, the issue of unavailability of replaceable charged batteries is also a drawback for the EV industry in the US. The main reason behind the unavailability of the spares is improper inventory management. Apart from this, unorganised inventory management also impacts the supply chain management of the EV industry in the US, which results in delays in supplying orders of spare parts to customers. These factors are responsible for negatively affecting customer satisfaction and customers in the US withdraw themselves to adopt EVs.

From the overall study, it has been found that the role of technological innovations is effective in managing the supply and demands of spares in the EV industry in the US. Proper market forecasting is necessary to understand the requirements of customers and keep stock of the spares in the inventory. The adoption of the artificial neural network (ANN) is essential in identifying the price fluctuations and demands of the spares in the market and implementing specific strategies to satisfy the requirements of the customers. On the contrary, EV companies are more focused on developing hybrid models as the availability of spare parts is good in these models with respect to the traditional EV models. Besides that, battery charging issues are not so prominent in hybrid cars because these cars have a self-charging feature which is charged by taking energy from fossil fuel used in the vehicles.

It could be concluded from the above discussion, that organised inventory management is necessary for managing the spares of EVs in the US. Organised inventory management is useful in fulfilling the demands of consumers on time in the US market within the EV industry. As a result, a good customer satisfaction level would be gained by the industry, which further helps in boosting the sales of EVs. Proper inventory management is essential in streamlining the workflow in the supply chain which in turn is crucial in mitigating the challenges faced by the EV industry in the US.

6.2 Linking with the objectives

Objective 1: ***"To identify the importance of managing inventories of spares of EVs in the US"***

The first objective of the study has been partially achieved in the literature review section and totally satisfied in the findings and discussion section.

Objective 2: ***To determine the key challenges in managing inventories of spares in the US electric vehicle sector"***

The major challenges are identified in Chapter 3 and those challenges are linked with the new information collected from different articles in the discussion section. Therefore, the second objective of the study is also achieved in a distinct way.

Objective 3: ***"To study the current inventory management practices for spare parts used in the US electric vehicle sector"***

Most of the criteria of this objective have been fulfilled in the literature review and the rest portion is achieved in Chapter 5.

Objective 4: ***"To develop effective solutions for overcoming the challenges of managing spare part inventories in the EV sector of the US"***

Some solutions have been explained in Chapter 3 and Chapter 5 and the major solutions have been provided in Chapter 6.

6.3 Recommendations

Some potential suggestions have been provided to the EV sector in the US to eliminate the key challenges. The recommendations are as follows:

- Developing more hybrid models of EVs than traditional battery-operated models will be significant in managing the inventory of spares. Because the self-charging features of the hybrid vehicles will eradicate the issues of spare inventory management in the EV industry in the US. It will resolve the issues of high waiting times for the customers regarding getting replaceable batteries.
- The use of predictive data analytics in inventory management will help in estimating the market demands of the spares and EV companies in the US could adhere to specific tactics according to that which will be necessary in resolving the demands of the customer by meeting their needs.
- Adoption of innovation like making wireless roads in most of the areas in the US would be effective in eradicating the issues of scarcity of charging stations. This will also release pressure on spare inventory management of the EV industry in the United States.

6.4 Limitations of the study

There are some limitations of the current research. Only a secondary qualitative method has been implemented in this study which did not include numerical data. The role of statistical analysis of numerical data would be effective in understanding the variables of the study in a better way. So the inclusion of a primary quantitative study would have been specific to the study. The data would have been collected by conducting an online survey. This type of data would be important to understand the real perceptions of the

customers in the US regarding the adoption of EVs. The reasons behind their dislikes of buying EVs would also be found out. However, a mixture of secondary qualitative and primary quantitative studies would be significant for the study to provide a strong foundation of knowledge to the readers.

6.5 Future scope

The current study would be beneficial for the owners and stakeholders of the EV industry in the US to understand the root causes of the challenges regarding managing the inventory of the spares. Adoption of proper strategies would make it possible for the owners of the EV companies to increase the sales of EVs in the US market by analysing the perceptions of the customers. On the contrary, the current study would be efficient to conduct similar kinds of research based on the EV sector in the US. However, this study would improve the horizon of knowledge of the readers by providing them with proper information on the US EV industry.

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Appendices

Appendix 1: Coding table

Links	Year	Theme 1	Theme 2	Theme 3
https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/a-turning-point-for-us-auto-dealers-the-unstoppable-electric-car	2021	The demands of EVs are increasing in the US market, a lack of awareness of US EV dealers in managing spare inventory, the inclusion of data analytics is essential in inventory management.		
https://www.bbc.com/worklife/article/20240311-evs-lost-their-luxury-status-symbol-reputation	2024	Reduced price of EVs increases market demands, environmental sustainability, need for high maintenance of EVs, spare		

		parts		
https://www.bbc.com/news/business-58123729	2021	Low confidence level of the customers, insufficient spare inventory management,		
https://www.bbc.com/worklife/article/20231108-three-big-reasons-americans-havent-rapidly-adopted-evs	2023		High taxes in US, high price of EVs, battery issues, absence of charging points	
https://www.bbc.com/worklife/article/20240228-are-us-ev-sales-a-disaster-or-a-booming-segment-the-answer-may-be-both	2024		Political issues, improper inventory management, lack of spare parts	
https://www.reuters.com/busin	2023		Price cuts, rising	

ess/autos-transportation/slow-selling-evs-are-auto-industrys-new-headache-2023-07-11/			inventory, increased market demands	
https://www.bbc.com/future/article/20240130-wireless-charging-the-roads-where-electric-vehicles-never-need-to-plug-in	2024			Wireless charging roads, smart roads, resolving issues with charging points
https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/going-small-to-go-big-micromarkets-in-us-auto-retail-and-aftermarket	2023			Micro and macro market, use of demand forecasting
https://www.re	2024			Hybrid EVs,

uters.com/business/autos-transportation/us-automakers-race-build-more-hybrids-ev-sales-slow-2024-03-15/				more customer satisfaction, less issues of spare parts