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A SWOT Analysis of the UK EV Battery Supply Chain

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Abstract: The aim of this research is to identify and explore the UK electric vehicle (EV) battery industry's supply chain strengths, weaknesses, opportunities and threats (SWOT) by taking a leading UK EV battery company as an exploratory case study. Our research addresses the gap in knowledge surrounding the UK EV battery supply chain, as the current literature is limited whilst demands for EVs are surging. There are significant opportunities awaiting the EV battery industry, though it is crucial that companies are aware of the threats facing them. To address the gap, this research followed an exploratory qualitative research design using semi-structured interviews with experienced interviewees in the industry. By applying the SWOT analysis framework and the theory lens of Resource Based View (RBV), we suggest that the UK EV battery industry should diversify its supply base into multiple regions such as India, Africa, and the US, which would reduce the reliance on sourcing from China whilst maintaining good supplier relationships and continuous innovation.

Keywords: electric vehicle; battery; supply chain management; SWOT analysis

1. Introduction

Electric vehicle (EV), one form of Alternative Fuelled Vehicle (AFV), has become a hot topic in the global automotive industry. The global EV industry is currently worth USD 129,671 million, with an annual predicted growth rate of 15.69% to USD 359,854 million by the end of 2025 [1]. In the UK, AFV registrations are rising rapidly from 1,690 units in 2001 to 141,270 units in 2018, which account for around 6% of the UK market [2]. The UK National Grid predicts that the stock of EVs in the UK will reach between 2.7 and 10.6 million units by 2030 and could rise as high as 36 million units by 2040 according to the House of Commons [3]. Accenture in April 2019 forecasted that EV sales would grow exponentially, and that over half of all UK vehicles sales would be EVs by 2040 [3]. This statistic highlights EVs as a promising and fast-growing industry.

Electric batteries are a critical component of EVs which are taking over the role of major technology differentiator in the automotive industry, in place of the traditional powertrain [4]. Currently, 40–50% of the cost of an EV stems from its battery, with another 20% stemming from other components in the electric powertrain such as electronics and motors [5]. The cost of battery manufacturing can be further broken down into cell production, which holds around two-thirds of the value, and module and pack assembly [6]. The current industry trend in battery manufacturing is to source battery cells externally from the supply chain but maintain module and pack assembly in-house [7].

Currently, there are no major battery producers in the EU or US [8], while China currently holds over 70% of global EV battery production [9], including the major battery manufacturers such as BYD and CATL [5]. There are other notable EV battery manufacturers, namely the Japanese companies SKI and Panasonic. Furthermore, China is currently the largest EV consumer in the world due to

its rising middle class and an increasing awareness of air pollution [10]. Whilst this can be seen as a huge market opportunity for UK-based companies to capitalise on [11], it is also a hugely competitive market which is dominated by cash-rich technology giants and, therefore, a difficult market to disrupt and compete in.

The opportunities and threats of the UK automobile industry are driving further research. However, it has received less attention, with only a handful of academic papers addressing the topic, and with obvious gaps in terms of research, especially relating to the EV battery industry [2,12–15]. The UK is no longer home to any significant British-owned original equipment manufacturers (OEMs); only Morgan, Caterham and McLaren remain, none of whom produce affordable cars, and OEMs with a manufacturing presence in the UK such as Nissan, JLR and MINI are all foreign-owned.

Nonetheless, there are enormous supply chain networks across the country that cater to the global industry giants and home-grown technology focused companies as demonstrated by Kalaitzi et al. [14]. Furthermore, the UK government policies are encouraging and nurturing the growth of highly advanced automotive companies, and the UK follows an ambitious agenda in support of not only Research and Development (R&D), but also the manufacturing of EVs [12]. As a result, there are remarkable opportunities for small and medium enterprises (SMEs) in the electric mobility market–although it is worth noting that this is more applicable within the supply chains such as EV battery suppliers, rather than competing with existing OEMs such as Volkswagen and Toyota [12]. This provides a growth opportunity for UK-based companies to develop technical expertise and a competitive advantage in electric battery technology, which can be sold to OEM. It is believed that the UK is in a strong position to become a global leader in developing the next generation of electric batteries [2].

Crucially, it is argued that "the most important determinant of the future health of the automotive industry [in the UK] will be whether batteries are manufactured in the UK" [15] (p. 2). This means that battery manufacturers based in the UK, and their supply chains, must remain competitive in order to promote the development of the UK automotive industry's sustainability. This supply chain presence indicates a need for further research into the topic. Thus, in this research we aim to answer the following research questions: What are the opportunities and threats for UK's EV battery supply chain? How can UK EV battery companies take such opportunities and mitigate the threats according to their strengths and weaknesses?

We aim to identify and explore the UK EV battery industry's supply chain Strengths, Weaknesses, Opportunities and Threats (SWOT analysis) by taking a leading UK EV company as an example. We adopt the theory lens of resource-based view (RBV) to provide recommendations to both the company and the industry on how best to mitigate the threats whilst capitalising on the opportunities. RBV suggests that distinctive resources and capabilities that are valuable, rare, inimitable and non-substitutable can sustain a firm's competitive advantage [16], which aligns with our research focus. Semi-structured interviews were conducted as the data collection method. The results were analysed through thematic analysis along with current literature to draw similarities, compare differences and identify the key areas for further examination. We identified and addressed the gap in the literature regarding the strengths, weaknesses, opportunities and threats in the UK EV battery supply chain.

The paper is composed of six sections: Section 2 provides a literature review on the EV supply chain, EV battery development and the applied analysis framework and theory. Section 3 presents the research methodology. Section 4 carries out the case analysis. Section 5 furthers the discussion. Finally, Section 6 concludes the whole research.

2. Literature Review

This section begins with an overview of EV supply chain management (SCM), then EV battery development and finally the SWOT analysis framework and the RBV theory.

2.1. EV Supply Chain Management

Lambert [17] (p. 2) defined supply chain management as "the management of relationships in the network of organisations, from end customers through original suppliers, using key cross-functional business processes to create value for customers and other stakeholders". Christopher [18] put forward the famous quote that "Supply chain competes, not companies". This is particularly evident in the automotive industry as all elements of the supply chain must interact and collaborate to achieve the desired end product.

The natural environment is viewed as a major competitive issue for the automotive industry today due to increasing global and social awareness regarding climate change and vehicle emissions [19]. Furthermore, it was found by the European Environment Agency that EVs benefit local air quality due to their lack of street-level exhaust emissions [3]. Therefore, the ever-quickening and developing need for EVs has created various opportunities for automotive companies and their multiple tiers of suppliers, but also, interestingly, for new players and companies to enter the EV market and supply chains [12,14].

Steinweg [20] breaks down of the "cradle-to-grave" EV battery supply chain processes into four stages: 1st extraction of raw materials (Tier 3 suppliers); 2nd production which further includes 2.1 cell production (Tier 2 suppliers), 2.2 battery production (Tier 1 suppliers), 2.3 vehicle assembly; 3rd consumption; 4th disposal. Major OEMs such as Tesla and Aston Martin Lagonda operate at stage 2.3, where they assemble the vehicles for sale to consumers. Their supply chain consists of three major tiers: Tier 3 suppliers usually extract raw materials such as Lithium and Cobalt from mines and sell them to Tier 2 suppliers. At stage 2.1, key EV battery sub-components such as cells, busbars and electrical wiring are manufactured by Tier 2 suppliers using the raw materials procured from Tier 3's. These parts are then sold to Tier 1 suppliers who source and assemble the sub-components into an entire battery unit (stage 2.2), which is then sold to OEMs. Stage 3 is arguably the longest part of the supply chain process as this is where the EVs batteries are consumed or used, by the final consumers. The process ends at stage 4, where the EV battery is disassembled and parts are either recycled or disposed of.

EVs have existed for over 100 years [21], but have only become economically viable and popular in the last 10–20 years [22], making it an exciting and growing potential market for companies to capitalise on. The industry's movement towards the adoption of EVs was supposed to, in theory, lower the barriers to entry to the market due to having fewer moving parts within the car and increased ease of assembly [23]. There has been an increasing trend in OEMs outsourcing noncore manufacturing activities upstream to Tier 1 suppliers in recent years [24]. Therefore, there are huge opportunities for Tier 1 battery suppliers to capitalise on the increased demand for their products and services.

2.2. EV Battery Development

The cost of EV batteries have reduced significantly over recent years from around $1200/kWh in 2010 to a predicted figure of $94/kWh by the year 2024 [25]. The rapid fall in costs indicates an increase in the viability of mass market EV batteries. Lithium-Ion batteries are currently considered the most promising technology for the future of EV batteries, which have a long lifespan, high energy density and high efficiency, alongside potential for further improvements [26]. However, currently they are known to raise safety concerns such as fires [27] and the energy density is still below market requirements [28]. Crucially from a supply chain perspective, there are concerns about raw material availability [29].

Lithium-Ion batteries consist of an anode and cathode, a liquid electrolyte, current collectors and casing and packing materials. Although Olivetti et al. [30] argue that this type of battery is unlikely to be constrained by resource limitations, other literature has identified the threat of Lithium resource depletion [31]. Rapidly increasing demands for EVs will put further strains on the availability of the raw material, Lithium, and consequently will increase prices [28]. This has already been observed as the price of Cobalt and Lithium has more than doubled since 2015 [5]. Another risk that Lithium

presents as a raw material is its geographical location; Europe holds no significant deposits [32], whereas 74% of the world's known resources are from South America. However, a significant amount of these reserves are owned by Chinese companies [5]. This can be considered a significant geopolitical risk for EV battery manufacturers in that they need to heavily rely on this region due to its political, economic and social instability [33]. However, Evans [34,35] concluded that any concerns regarding Lithium resource depletion are unfounded, meaning that academic consensus on this issue is somewhat divided. A common conclusion appears to be that global stores of Lithium will suffice for the next few decades [36]. However, this depends on the adoption rate of EVs and consequential increase in demand for Lithium. Therefore, it could be prudent for EV battery manufacturers to reduce the amount of Lithium used in each battery and to promote the development of battery recycling [37]. It is also worth noting that the use of Lithium is not purely limited to the EV industry; batteries now represent 65% of global end-use markets in comparison to 23% in 2010 and this category also includes batteries used in mobile phones and computers [38]. Some analysts estimate that three-fourths of all global Lithium production will focus on EV batteries by the year 2025 [39].

Chinese suppliers have also been identified as playing a significant role in the Lithium-Ion battery supply chain [40], suggesting a potential reliance and control issue for electric battery manufacturers. There are further potential major supply chain issues regarding electric battery production that can be identified from the literature. Curry [41] highlighted an upcoming shortage of production capacity for battery components, such as separators, as the growth in EV sales in China is beginning to create supply bottlenecks.

Curry [41] suggested a potential strategy for battery manufacturers, highlighting the need for companies to: (1) Improve profit margins to attract new investment; (2) Improve technology to reduce production costs; (3) Enter the stationary storage market to increase market share. Stages 1 and 2 are most applicable to this research as its main focus is on automotive applications. Profit margins could be increased by engaging with lower-cost suppliers, and technology could be improved by investing further in R&D by developing technical partnerships. Recent developments in Lithium-Ion battery technology has involved light-weighting and improving energy density [30], but there is still further progress to be made.

2.3. Analysis Frameworks

The SWOT analysis framework is a well-known key strategic tool used to address complex business decisions in order to streamline information and support the decision-making process [42]. This framework allows for a better understanding of how to leverage strengths in order to capitalise on new opportunities, whilst identifying weaknesses that potentially magnify threats to the company [43]. Of the four aspects, strengths and weaknesses belong to organizational internal factors and the opportunities and threats are external factors [44]. The strengths are tangible and intangible positive factors which can support organizational success; weaknesses are negative attributes which hinder the achievement of desired outcomes; opportunities are external factors which can nurture organizational success and threats are externalities which can compromise desired outcomes [44].

Whilst there is no academic consensus on the origins of the SWOT analysis [45], it has been present in management literature for at least half a century [42]. SWOT analysis has also been applied in EV studies, such as in the analysis of the strengths, weaknesses, opportunities and threats inherent in EV in general [46], and the factors affecting the diffusion of EVs in Brazil [47].

This research adopts the framework to identify supply chain strengths, weaknesses, opportunities and threats regarding the EV battery supply chain and provides recommendations to mitigate the risks and capitalise on the opportunities. In response to Haberberg [48] who is a critic of the SWOT framework without prioritizing the factors, this research seeks to improve the traditional framework by ranking each code under the appropriate category from highest to lowest priority.

Literature argues that the competitiveness of a company is now better measured by the competitiveness of its supply chain than other more traditional measures [18,49]. This highlights

the requirement for more research into SCM and the threats and opportunities that it faces in the twenty-first century. RBV has been applied in this research, which has attracted increasing amounts of attention over the years [50,51]. It proposes that organisations need valuable and irreplaceable resources and capabilities to gain competitive advantages, which are also difficult for others to imitate [52]. Moreover, Bharadwaj [52] proposed that RBV is more useful in explaining how enterprises transform unique resources into capabilities and integrate and reconfigure resources to achieve competitive advantage. Therefore, it is considered one of the best methods to depict a company's gain of competitive advantage through a focus on resources. A company's internal strengths and weaknesses are considered controllable, whereas its external opportunities and threats are not [53]. Therefore, the RBV of firms argues that a company should focus on its controllable internal strengths and weaknesses in order to exploit its external opportunities [53,54]. However, Rothaermel [55] argues that the best approach to sustainable competitive advantages through the RBV is to consider both internal and external factors equally and combine both views in order to achieve and sustain competitive advantages. Thus, RBV can be applied which complement the SWOT analysis framework.

Barney [16] categorises resources as human capital, physical capital and organisational capital. Grant [53] expanded this further to include technological capital, financial capital and reputational capital. Resources can also be broken down into tangible groups, such as infrastructure, and intangible groups, such as information sharing [56]. Butner [57] argues that the major challenges facing SCM include visibility, cost management, risk management, increasing demand from customers and globalisation. The automotive supply chain is far more complex than the more traditional methods as it tends to be larger in size and features several network levels. However, on the global stage it is seen to be lagging behind other supply chains such as consumer goods and pharmaceuticals and in measurables such as integration, responsiveness and visibility [58]. Furthermore, the issue of "sustainability" is becoming more critical in the modern automotive industry [59,60].

3. Methodology

Given the limited empirical research on UK EV battery supply chain, this research adopts an explorative case study in order to answer our research questions. Yin [61] (p. 13) suggests that "A case study is an empirical enquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident". A case study method is appropriate in this research to explore the UK EV battery supply chain. This section provides the research design through sampling techniques, data collection and analysis. Research quality has also been considered.

3.1. Case Selection and Sampling

Company X is a UK-based advanced engineering company, with a particular focus on and expertise in the manufacture of batteries for EVs. This research uses Company X as a case study for the industry due to the high level of expertise and knowledge held by its employees. Although there have been no new OEMs entering the UK market, Company X is a strong example of the market opportunities available in the supply chain, particularly in electric battery production.

A non-probability method was used for this research as it allows for participants to be selected based on their characteristics. The sampling characteristics required were employees working at Company X who had experience working in or managing EV battery supply chains. These characteristics allowed the employees to discuss their knowledge and understanding of EV battery supply chains and to answer our research questions based on its strengths, weaknesses, opportunities and threats.

3.2. Data Collection and Interview Design

The data was collected by using semi-structured interviews and was stored as voice recordings and interview notes. Interviews were chosen as the primary data collection method because they allow for a more in-depth discussion and exploration of a particular issue or research area [62]. Tracy [63] (p. 132)

identified that interviews "provide opportunities for mutual discovery, understanding, reflection and explanation". The semi-structured design was selected because having pre-designed questions allowed the participants to prepare some thoughts on the research topic beforehand, whilst also allowing for further questions to be asked and elaborated upon during the interviews.

Initially, three participants at Company X were approached and interviewed for this research. A further two participants were approached, however, due to the COVID-19 pandemic, they were unable to be interviewed. Participant D was approached through one of the researchers' personal network, and although he never worked for Company X, he was interviewed via phone due to his experience in the EV battery industry through working for competitors to Company X. Participant D's participation in this research has strengthened its validity and representativeness as he provided insights from a different company setting whilst highlighting many of the same points as the participants employed by Company X. Given the fact that the manufacturing of batteries for EVs is in its infancy in the UK, only a small sampling size for interviews was applied.

The interviews took place on-site at Company X in order to maximise convenience for the employees taking part. The interviews took place on February 25th, 2020 during normal working hours. A list of pre-constructed questions (As in Appendix A) was sent to the participants ahead of time to allow them to prepare their answers. However, it was made clear that some additional questions relating to the subject would be asked on the day of the interview in order to enhance the research. Table 1 below shows key details of each participant and interview. Participant C provided answers in word format and also provided further explanations over the interview; thus the length was shorter than the others.

Table 1. Breakdown of Participant Details.

Participant ID	Job Title	Employer	Date	Length
Participant A	Procurement Officer	Company X	25/02/2020	30 min
Participant B	Procurement Manager	Company X	25/02/2020	35 min
Participant C	Project Manager	Company X	25/02/2020	14 min
Participant D	Battery Manufacturing Engineer	Competitor to Company X	10/02/2020	45 min

3.3. Data Analysis

After data collection, we conducted the data analysis. The data was analysed through developing transcripts and subsequently coding and identifying key themes and groups. As used by Fereday and Muir-Cochrane [64], this research adopted a hybrid process of inductive and deductive reasoning. It followed a data-driven inductive approach of exploratory codes and themes whilst also incorporating existing theory and literature through deductive reasoning.

A thematic approach was followed for data analysis due to its flexibility. Also, it supported the exploratory nature of the research and allowed for developing a variety of codes and themes through the analysis [65]. Braun and Clarke's [66] six-phase approach to thematic data analysis was followed: transcribing interviews, creating codes, collating the codes into themes, reviewing the themes, defining the themes and finally analysing them in line with the literature. Its breakdown allows for a more structured approach to data analysis and ensures that the codes and themes created are reviewed and defined [66].

The codes were established by first reviewing the transcripts in their entirety before slowly going back through them again and pulling out some initial key sentences or phrases. This research follows an iterative approach, which means each code has been changed, renamed or broken down into further codes at least twice. Table 2 illustrates how the codes were developed through thematic analysis from the interviews by linking them to the direct quotes taken from each participant.

Table 2. Example codes linked to direct quotes taken from participants.

CODE	QUOTATION
QUA+ (Good quality of parts)	"With the busbars, we have gone to British Supplier A on these last six packs … you know when you receive the parts, they will function, they will work, they will be beautiful" "The quality of parts produced is improving dramatically from various different places around the world"
SRM+/ SRM- (supplier relationship management)	"1% [of suppliers] are smart enough to know what they're doing and have the market knowledge and awareness [of] various other investors who are going 'this is what you should be doing'" "The buy-in of the supply chain to get them to understand what we're trying to do [is the biggest supply chain threat]. There are not many people who understand what we're trying to do and it's the suppliers who do that [who] can really thrust a programme forward"
CSC (Chinese supply chain)	"As the global supply chain becomes more reliant on China … the speed and efficiency of doing something outside the box becomes more difficult"
DIS (Disruptive technology)	"We do a lot of first-to-market technologies and in that we absolutely get issues and challenges because you've never done it before, you don't actually know what the consequences are, there's a lot of calculated risk and you're dealing with a supply base that's never actually done it either"
USC (UK supply chain)	"There's not enough emphasis on trying to onshore strategic parts such as batteries and electric motors. We should be trying to keep knowledge and experience of EVs in the UK, but our country's new battery plants are basically five years [too] late. The supply chain to support just isn't there"
MAT (Supplier maturity)	"I would say that suppliers being mature in the field of developing batteries, because it's still relatively new technology there's not an abundance of suppliers out there and it's quite specialised at the moment"
SCL (Supply chain locations)	"We would always like more time to be able to branch out to more global supply chains such as India"
COS- (cost of supply)	"We need to work on reducing the cost because in order for the world [to go fully electric], we've got to make it affordable"
INF (Improvements in infrastructure)	"The infrastructure has to be improved and developed. There is currently disparity regarding the types of charging points available—there are lots of different ones and they're not all offered at each electric charging point. It's not just about having charging points, but it's also about having the correct types of charging points"
COR (COVID-19)	"Coronavirus is a major issue for our supply chain at the moment … At this moment in time there are 6 suppliers affected by this but that's going to increase, especially with the way [the virus] has extended and now the fact that Italy is now affected"
DEM+ (Increase in demand for batteries)	"The world has to electrify, so quantities required will increase, but it's about trying to make the technology smart enough, it's about trying to make the technology cost-effective, because everything is massive at the moment"
RAW/ ETH/ WOR (Raw materials/Ethical issues/Workers' rights)	"The [supply chain] issues will be surrounding Cobalt and magnets as well. We want to make sure that they're ethically sourced because sometimes it's a little bit fraught. Regarding magnets, most of them come out of China … there's high demand for such a small commodity coming out of one area, so you haven't got a wide source—and if you do go elsewhere, again, you're at risk of whether it's ethical, safe, sustainable, are the workers being looked after etc."

3.4. Research Quality

The lack of standardisation in semi-structured interviews can potentially cause concerns about the reliability and dependability of the data [67]. Interviewer bias was possible due to potential variance in their tone, non-verbal behaviour and interpretations; interviewee bias was also possible with the risk of their perceptions of the interviewer, dislike of probing questions and wanting to cast themselves in a favourable light [68]. To reduce respondents' bias, multiple interviewees with differing job roles, experience and insights were interviewed to provide multiple perspectives. The primary data collected from these interviews, along with secondary data collected from the literature review, were applied as a form of triangulation [69]. Furthermore, two members of the research team examined the transcripts and agreed upon the codes, whilst the other two members compared their meaning with literature. We followed the processes recommended in SCM literature to ensure rigor when conducting case study research [69].

The findings from this research are not expected to be repeatable due to the time period in which they were collected and the nature of the changing environment. The circumstances being explored in this research are dynamic and complex. The quality of this research is expected to be reliable because many of the main arguments from the data are supported by both the participants at Company X and Participant D who has never worked there. This can be seen as a form of risk mitigation as their response supports those of the participants from Company X. The sampling method and data collection method also ensure reliability, and therefore value, in the findings of the research.

4. Results and Analysis

This section presents the research findings from conducting the semi-structured interviews and analysing them through the development and allocation of codes and themes. A thematic analysis was undertaken in this research, which was chosen as it is considered to be a foundational approach to qualitative data analysis supported by Braun and Clarke [66]. A SWOT analysis framework was used to categorise the selected themes in order to identify UK EV battery industry's internal supply chain strengths and weaknesses, before exploring the external opportunities and threats and developing potential suitable paths for the industry to follow [70].

As a result of coding the transcribed interviews, the following patterns and trends became evident in the data, namely: locations of key suppliers, cost, ethics and sustainability, infrastructure, external events, technology, supply, demand, lead times and timescales. Codes relating to design issues and supplier maturity related more to internal factors, hence their classification as Weaknesses. Codes relating to supply chain locations and increases in the quantity of parts available can be seen as external factors, which is why they have been categorised as Opportunities. This is the same for Strengths, which are deemed internal, and Threats which are considered external issues.

Table 3 below shows how the most relevant codes have been grouped into themes and formed into a SWOT analysis framework, where each code is ranked according to importance within its corresponding theme. Some codes appear in multiple themes, for example DEM+ can be seen under Strengths and Threats. This is due to the complicated and multi-faceted nature of the EV automotive supply chain, where an event or a situation can act as both a benefit and a risk to a company. An overarching theme that unites this analysis appears to be the locations of Company X's suppliers. The countries from which they source EV battery parts have been identified by all participants as strengths, weaknesses, opportunities and threats to the supply chain, particularly when linked themes such as costings, supply and external disasters are considered.

Table 3. SWOT Analysis of Key Codes constructed from the Semi-Structured Interviews.

INTERNAL FACTORS					
RANK	**CODE**	**STRENGTHS (+)**	**RANK**	**CODE**	**WEAKNESSES (-)**
1.	SRM+	Good supplier relationship management	1.	USC	UK supply chain
2.	USC	UK supply chain	2.	CSC	Chinese supply chain
3.	QUA+	Good quality of parts	3.	DIS	Disruptive technology
4.	COL	Collaboration within supply chain	4.	DES	Design issues
5.	DEM+	Increase in demand for batteries	5.	IMP	Issues with critical parts
6.	ESC	European supply chain	6.	MAT	Supplier maturity
EXTERNAL FACTORS					
RANK	**CODE**	**OPPORTUNITIES (+)**	**RANK**	**CODE**	**THREATS (-)**
1.	SCL	Expand supply chain locations	1.	COR	COVID-19
2.	CSC	Chinese supply chain	2.	COS+	Increase in cost of parts
3.	COS-	Decrease in cost of parts	3.	RAW	Raw materials
4.	SUP+	Increase in supply of parts	4.	ETH	Ethical issues
5.	INF	Improvements in infrastructure	5.	DEM+	Increase in demand for parts
6.	ISC	Indian supply chain	6.	LLT	Long lead times
7.	TIM+	Increase in timescale availability	7.	WOR	Workers' rights
8.	AFSC	African supply chain	8.	SRM-	Bad supplier relationship management
9.	ASC	American supply chain	9.	SUP-	Decrease in supply of parts
			10.	TEC	Technology

Supply Chain Strengths: Good supplier relationship management (SRM+) was the highest ranked strength of Company X's EV battery supply chain, as identified by the participants. The company maintains strong relationships with its existing supply base, allowing it to develop new technologies and negotiate prices. Participants identified the UK supply chain (USC) as a strength due to its expertise in advanced manufacturing and close proximity to Company X. However, this code was also identified as a weakness because it is not price competitive in comparison to other supply chains such as China (CSC) and India (ISC). Superior quality parts (QUA+) can also be seen as a strength of Company X's supply chain as parts sourced from China continue to improve and meet the required specifications. Furthermore, almost all parts sourced from European and UK suppliers continue to maintain high standards of quality (QUA+).

Supply Chain Weaknesses: the Chinese supply chain (CSC) was interestingly identified as a weakness of Company X's EV battery supply chain. This is in part due to the country's increasing cost of labour and long lead times but also due to Company X's overreliance on Chinese suppliers, making them vulnerable to price increases or disasters such as the COVID-19 pandemic. Supplier maturity (MAT) was also highlighted as a weakness of Company X as EV batteries are still considered an emerging technology, meaning many parts suppliers are still in their infancy and suppliers are therefore showing their inexperience in producing high volumes of high quality, highly complicated parts.

Supply Chain Opportunities: The ability to expand their supply chain locations (SCL) was highlighted as a key opportunity for Company X's EV battery supply chain as well as the need for the industry to continue to develop. India (ISC), Africa (AFSC) and the US (ASC) are examples of emerging manufacturing locations that Company X could capitalise on. Despite participants considering China to be a weakness of Company X's supply chain, it was also mentioned as an opportunity. This is because of the country's increasing demand for EV's [71], making it a growing market opportunity, and its manufacturing expertise paired with its still relatively low cost of labour (although this is increasing). The continuing decrease in the cost of parts (COS-) paired with an increase in supply (SUP+) has created a strong opportunity for Company X to save on costs and increase profit margins whilst increasing the supply of their EV batteries to OEMs.

Supply Chain Threats: The biggest threat to Company X's EV battery supply chain, as identified by participants, is the current "COVID-19 (COR) pandemic". As the pandemic was largely unanticipated and has had a truly global reach and impact, Company X and its supply chain were unable to sufficiently prepare for its effects. Parts from China have been delayed since February 2020 and there are ongoing disruptions to manufacturing in Europe and in the UK. Furthermore, there are ongoing threats to Company X's supply chain due to raw materials concerns (RAW) and ethical (ETH) issues linked to EV battery components. Participants discussed concerns around the continuing availability of raw materials such as Lithium and Cobalt due to the rapidly increasing demand for EVs, as well as the ethical issues surrounding these materials such as working conditions (WOR), extraction methods and sustainability. Finally, a global increase in demand of EV battery parts (DEM+) has caused price increases (COS+), making the manufacture of EV batteries more expensive for Company X. This was identified as a threat by participants as it has the potential to decrease Company's X's international competitiveness.

5. Discussion

The data transcribed from the interviews was broken down and categorised using the SWOT analysis framework. By applying the RBV, this section conducts an in-depth discussion combining Company X's internal strengths with its external opportunities and internal weaknesses with external threats [16,46,47].

5.1. Internal Strengths and External Opportunities

Company X's key internal strengths can be paired with its key potential supply chain opportunities according to Table 3 in order to illustrate how the former can support the exploitation of the latter.

Strengths in good supplier relationship management (SRM+) have been paired with opportunities in Chinese, Indian, African and American supply chains (CSC, ISC, AFSC, and ASC), because the data analysis has shown Company X to have strong supplier relationship management, meaning it has the opportunity to expand its supply chain globally to countries and companies with higher technical abilities and lower costs, therefore improving its competitive advantage. Perdontis [72] argues that the EV industry's strong and fast-growing global supply chain network is one of its key strengths, meaning that Company X must use this resource further in order to develop its competitive advantage. Overall, the findings suggest company X should diversify its supply base from China into multiple regions.

Strengths in collaboration within supply chain (COL) can be linked to Opportunities to expand supply chain locations (SCL) as Company X's ability to collaborate with multiple suppliers within its supply chain provides an opportunity to expand its supply chain locations further afield. This is supported by Kalaitzi et al. [14] who highlighted supplier-led collaborations as an opportunity for EV battery companies. Considering that Company X has already capitalised on this (as it is a strength rather than an opportunity), this suggests that the company holds some competitive advantage over other companies within the industry.

Strengths in the UK and European supply chain (USC and ESC) and opportunities to increase in timescale availability (TIM+) are also linked because, in general, parts ordered from European and UK suppliers have a much shorter lead time than those from Asia. Therefore, Company X has the opportunity to decrease lead times on various parts and increase timescale availability for production.

Through a review of the literature, it was highlighted that an existing strength of the EV industry is the rapidly increasing demand (DEM+) for EV batteries, as forecasts suggested [1,3]. This was confirmed during the interviews conducted for this research. Furthermore, Andwari et al. [28] identified an opportunity on cost reduction in battery parts and manufacturing, which also supports the findings of this research. A strengths increase in demand for batteries (DEM+) has been linked to an opportunities decrease in the cost of parts (COS-) and an increase in the supply of parts (SUP+) because through an increase in demand for EV batteries, Company X has the opportunity to place larger orders with suppliers which in turn encourages lower costs per unit and increases the supply of parts to the market.

5.2. Internal Weaknesses and External Threats

Table 3 also identifies the relationship between the internal weaknesses of Company X and the threats it is facing or may face in the future and how these can be mitigated.

Heavy reliance on the Chinese supply chain (CSC) can be interpreted as a weakness and means there are ongoing ethical (ETH) and workers' rights (WOR) threats in Company X's supply chain, which it does hold some accountability for through due diligence. Furthermore, at the time of the interview when the COVID-19 pandemic had not yet reached the UK, this reliance on the Chinese supply chain (CSC) meant that COVID-19 (COR) was a huge threat to the supply chain in the form of late or cancelled orders. Participant D highlighted in his interview that the UK supply chain (USC) was a weakness to many EV battery supply chains because the technology and factory infrastructure is not present. This has consequentially created a threat because Chinese suppliers can no longer operate. Having a stronger and more used UK supply chain (USC) may have prevented this situation. Furthermore, Participant B highlighted that because the EV industry as a whole has a heavy dependency on the Chinese supply chain (CSC), the country has control over vast amounts of valuable raw materials (RAW), which can drive threats such as price inflation and lack of supply. There are also primary resource depletion threats for some elements of the battery such as Lithium and Cobalt, which are predominately sourced from China [28]. This point is supported by Egbue and Long [73] concerning the critical issues in raw material supply of Lithium for EV batteries.

The fact that Company X is manufacturing such cutting-edge parts and using disruptive technologies (DIS) can be seen as a weakness (not mentioned as a strength by interviewees) due to the lack of supporting infrastructure and government policy to develop and mature the supply chain. Furthermore, there is a shortage of production capacity in China for EV battery components [41].

This therefore presents threats to Company X's EV battery supply chain such as long lead times (LLT) due to the manufactured parts being overly complicated, and a decrease in the supply of parts (SUP-). The reason for this is because there are limited companies able to produce these parts, yet demand for them is rapidly increasing. Furthermore, suppliers don't actually own the technology or have the expertise needed in order to be able to produce the parts required for an EV battery. There is still currently high uncertainty regarding technology and potential markets in the EV industry [72].

As highlighted by all participants, a weakness of Company X is the ongoing design issues (DES) that are currently being faced regarding EV batteries. Designs are often changed at the last minute, and issues are sometimes only realised when the part has been delivered ready for assembly to the battery. This is paired with the lack of supplier maturity (MAT) Company X is facing within its supply chain which can result in suppliers delivering poor quality or incorrect parts as they are unable to meet Company X's requirements. Advanced battery manufacturing is still very much in its infancy [72], along with its corresponding supply chain. This means that the threat of increases in the cost of parts (COS+) is very much present within their supply chain. This is supported by the literature as Khan and Kushler [74] argue that high cost and performance limitations of EV batteries pose a real threat to the industry.

Finally, poor supplier relationship management (SRM-) due to lack of supplier buy-in into Company X's projects is a threat linked to weaknesses in critical parts. As shown in Participant D's interview, companies across the EV industry are struggling to source critical battery parts, which is strongly linked to the threat of Company X's supply chain being unable (or unwilling) to invest in new technology and materials in order to produce the required parts.

5.3. Further Discussion

Critically, the literature does not discuss natural disasters or pandemics as a threat to the EV battery industry; perhaps because there have not been many since its fruition. However, COVID-19 is without doubt a significant and ongoing threat to Company X and others like it as it is bringing the entire global supply chain to a halt. It is crucial for companies to develop risk mitigation procedures in order to mitigate the negative effects COVID-19 will inevitably have on supply chains. In order to potentially reduce the widespread effects pandemics and disasters such as COVID-19 inflict, Company X could develop more UK/European-based supplier relationships rather than global ones. Although this may have some cost implications, it would mean that parts are more likely to be delivered due to the close proximity between company and supplier; this may be particularly prudent for strategically important parts. Considering that there are EV battery manufacturers located globally, supporting home-grown suppliers could create benefits for more than just the manufacturers in times of crisis such as this.

From the data analysis, what can be identified is that the codes often present themselves as both opportunities and threats – they have tremendous potential to improve the EV battery supply chain, but also offer varying levels of risk. For example, the Chinese supply chain is an opportunity for Company X as it is at the forefront of EV battery technology and offers lower costs than the majority of European and UK supply chains. However, as China continues to grow, labour costs are increasing and companies are growing in size, providing fewer opportunities for cost savings and technological development. Furthermore, there are ongoing ethical issues in China relating to workers' rights and raw materials sourcing.

An element that the literature examined which was not touched upon by the participant interviews was the threat of international competition [72]. This should certainly be considered a threat to Company X as the EV battery technology becomes more widespread and more companies begin to manufacture them [1]. It is therefore crucial for Company X to develop its competitive advantage using the RBV in order to remain at the forefront of the market. However, Chung et al. [75] identified that OEMs require high performance, safety, reliability, quality and financial stability in their suppliers and therefore favour established relationships, which may threaten Company X's competitiveness. To mitigate this potential risk, it could look to exploit new market entrant suppliers offering new technology that OEMs

and their current suppliers are not aware of or able to access [75]. This capitalises on the agility of Company X's supply chain and allows it to be expanded further globally. Another opportunity to consider, as identified by Tahil [33], would be to explore South America as a potential strategic supply chain location given its reserve of lithium. However, it is not uncommon for this area to experience significant civil unrest and corruption which could hinder the development of a sustainable and reliable supply chain.

6. Conclusions

The research aimed to identify and explore the UK EV battery supply chain's strengths, weaknesses, opportunities and threats in the form of a SWOT analysis by taking a leading company as an example, with a view toward providing recommendations to both the company and the industry on how to mitigate the threats whilst capitalising on the opportunities. RBV was adopted in order to support the exploitation of Company X's opportunities and convert them into competitive advantages.

Company X has a broad range of strengths and weaknesses regarding its EV battery supply chain. It has strong supplier relationship management and uses the UK and European supply chains given their close proximity. However, Company X could develop its UK supply chain more than it currently does, which is largely due to its heavy reliance on the Chinese supply chain. Overall, the company is finding that the quality of parts from its supply chain is increasing and there is more demand for EV batteries. However, there are still ongoing problems with sourcing critical elements of the battery given its nature as a disruptive and new technology, and the supply chain is still struggling to mature in time to meet Company X's needs.

There are several external opportunities available for Company X to exploit in order to improve its competitive advantage in the EV industry. It has the potential to diversify its supply bases in order to expand its supply chain locations into countries such as India, Africa and the US, as well as significantly reduce the cost of parts. However, the most significant current threat of Company X is COVID-19, the impact of which is still very much unknown – not only within Company X but throughout the entire world. There are also risks involving the sourcing of raw materials and ethical issues that stem from expanding supply chains into emerging and developing markets such as China and India. Opportunities also lie in the improvement of EV infrastructure and the increase in saturation of EV battery parts. However, as nations, particularly China, are developing from the increasing demand for battery components, labour and manufacturing costs will inevitably rise.

This research has explored and addressed a gap in the existing literature regarding the strengths, weaknesses, opportunities and threats within the UK EV battery supply chain [2,12–15]. This study also allowed for a deeper understanding of the current landscape of the UK EV battery supply chain, and what can be done to improve its performance and stability. It has explained why certain opportunities and threats exist and has developed a framework to support EV battery companies in improving their competitive advantage through the theory lens of RBV.

On a practical level, this research has confirmed and expanded the previously understood strengths, weaknesses, opportunities and threats within the EV battery supply chain. It has also reinforced the link between internal strengths and external opportunities, and internal weaknesses and external threats companies can use in order to develop their competitiveness. The core recommendations to the UK EV battery industry are as follows:

6.1. Explore Further Use of the UK and European Supply Chains

Close geographical and cultural proximity to suppliers is largely beneficial and can vastly reduce lead times. The UK EV battery industry should engage suppliers in cost reduction negotiations to ensure prices are competitive with other manufacturers.

6.2. Explore Manufacturing Opportunities in Countries Such as India, Africa and the US

This offers the UK EV battery industry a first-mover advantage and the opportunity to reduce manufacturing costs significantly due to lower labour costs in these countries or access to latest technology. Furthermore, it diversifies the supply base in order to reduce the overreliance on sourcing from China. However, UK EV battery companies should be mindful of the sustainability of these countries' manufacturing capabilities due to economic and political instability, as well as ethical compliance.

6.3. Continue Collaborating with the Supply Chain on the Design of Parts and Manufacturing Processes

It is crucial for the UK EV battery industry to maintain and develop its current competitive advantage in this area to play a critical role in the global EV market.

6.4. Reduce Reliance on Chinese Supply Chain

Whilst China is no doubt a major player within the EV battery industry and should therefore still be used, the UK EV battery industry should reduce its exposure to the country's cost increases and disasters such as COVID-19.

6.5. Use COVID-19 as an Exercise to Develop Resilience Capability

Although this pandemic has affected the vast majority of companies globally, the UK EV battery industry should use it as an opportunity to improve its disaster planning and risk mitigation, to be more resilient in future.

6.6. Continue to Engage with New Suppliers that Are Able to Meet the Technical, Quality, Cost and Lead-Time Requirements

The EV battery industry is still in an emerging market with rapidly developing technologies and innovations, and the UK EV battery industry should continue to search for new suppliers that are entering the market in order to maintain their position at the forefront of the industry.

In terms of limitations, this research only included one case company with limited numbers of interviews, with some additional input from an individual who had previously worked at a competing company. This does leave the data open to some bias; however, it is important to understand that we conducted the interviews with senior managers; the context of Company X, which is an industry-leader in EV batteries; and the data therefore provided us a well-rounded and holistic understanding of not only its supply chain but broader issues as a whole.

Interviewing a larger number of participants both from Company X and other EV battery companies, or even suppliers in China would strengthen this research. In addition, the context of the UK is also somewhat limited as EV battery manufacturers exist globally and have different factors affecting their supply chains. This enables the possibility for future research and investigation.

Further research should conduct similar studies on competitors to Company X and then compare the findings in order to show, through the RBV, which company is most able to develop their competitive advantage through exploitation of their external opportunities. The SWOT analysis framework can also be applied and rated with rankings from a wide range of experts and practitioners via a survey approach. Finally, and interestingly, our interviewees didn't mention the impact of Brexit which may have had little impact compared to COVID-19. This comparison is also worth further research and investigation.

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Appendix A Semi-Structured Interview Protocol

1. What is your role within the company?
2. What strengths does Company X have in its EV battery supply chain?
3. What weaknesses does it have?
4. What changes would you like to see made?
5. What opportunities for the future does Company X have in its EV battery supply chain?
6. What threats does Company X face?
7. How does Company X engage its suppliers in innovation?
8. What is Company X's relationship like with its suppliers on EV battery projects?
9. Is Company X engaged in any activities to help develop its EV battery suppliers?
10. How does Company X juggle influence from its suppliers?

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