



Managing resource dependencies in electric vehicle supply chains: a multi-tier case study

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Abstract

Purpose – To investigate dependencies that arise between companies during the ramp-up of production volume in the electric vehicle (EV) supply chain.

Design/methodology/approach – An inter-company case study method has been used. Data was collected via tours of manufacturing plants, workshops and interviews from multiple tiers in a supply chain, namely a niche EV manufacturer, as well as two of its tier one suppliers and five of its tier two suppliers.

Findings – As production volumes increased, a more relational approach was found to be necessary in inter-company relationships. Our research showed that key suppliers, in addition to providing the parts, pursued a supply chain orchestrator's role by offering direct support and guidance to the niche EV manufacturer in designing and executing its development plans.

Research limitations/implications – Resource Dependence Theory (RDT) is used to analyse and explain the changing dependencies throughout the planning and execution of production ramp-up.

Practical implications – This study will help supply chain managers to better manage resource dependencies during production ramp-up.

Originality/value – This study explores dependencies during the early stages of the production ramp-up process in the EV sector, which is in itself in the early stages of evolution. RDT is employed for the first time in this context. This study has moved beyond a simple dyadic context, by providing empirical insights into the actions taken by an EV manufacturer and its suppliers, toward a multi-tier supply chain context, to better manage resource dependencies.

Keywords – Electric Vehicle, Resource Dependence Theory, Supply Chain Management, Production Ramp-up, Case Study.

Paper type – Research paper

1. Introduction

The electrification of transportation is widely considered to be a viable strategic alternative to oil dependency and its associated harmful environmental impacts; governments in different countries have recognised this as an opportunity. For example, the US Electric Vehicle (EV) industry has had strong growth, exemplified by the California-based start-up, Tesla Motors, which has now gained a significant market share, with nearly 57,000 electric cars sold. The UK, over the last three years, has also seen a remarkable surge in demand for EVs. New registrations of plug-in cars has increased from 3,500 in 2013 to more than 166,000 by August 2018 (Lilly, 2018). It is projected that the overall number of electric vehicles could range from 9 million to 20 million by 2020 and from 40 million to 70 million by 2025 (IEA, 2017). EV manufacturers must therefore ramp up their production output to meet an increasing demand for EVs (Andersen *et al.*, 2016). Yet manufacturers face a number of supply chain challenges. For example, the supply of batteries for EVs has been identified as a potential constraint for Tesla Motors, due to the scarcity of lithium hydroxide and rare earth metals needed for the batteries (Kam, 2016).

Production ramp-up issues have received attention in the automotive industry (e.g. Almgren, 2000; Held, 2010; Surbier *et al.*, 2014), but supply chain implications specific to the emerging EV sector have received less emphasis. Therefore, there are a number of factors in the EV sector that require further exploration and explanation, especially as some of the technologies are still immature (e.g. battery systems, fuel cells, supporting infrastructure). For instance, the EV industry's new innovative products are undergoing continuous modification, while the industry's new business models are rapidly changing and often significantly vary from the business models associated with traditional internal combustion engine (ICE) vehicles (Rossini *et al.*, 2016; Klug, 2013).

Moreover, EV supply chains have not yet been fully established, as companies are often start-ups or small-to-medium sized enterprises (SMEs) with limited resources (Clegg, 2018). These start-ups and SMEs may not be currently involved in traditional ICE automotive supply chains. However, these companies may go on to become critical players in future EV supply chains (Bierau *et al.*, 2015; Rossini *et al.*, 2016). Research efforts (e.g. Terwiesch and Bohn, 2001; Niroomand *et al.*, 2012) have so far explored the implications of ‘internal production’ ramp-up on various metrics of manufacturing performance, such as quantity of product, cost, quality. But fewer researchers have highlighted the role of resource dependence connections in multi-tier case studies (e.g. Christensen and Karlsson, 2016; Filla and Klingebiel, 2014). Issues relating to resource dependency in EV supply chains will become more pressing in the future, as governments and original equipment manufacturers (OEMs) mandate, and in some cases outlaw, wholly ICE powered vehicles.

In response to the research context described above, this paper provides insights into a multi-tiered supply chain case study that focuses on a niche EV manufacturer, referred to as EV-Co (the company’s name has been changed to preserve its anonymity). This case study also encompasses the EV manufacturer’s suppliers of those drivetrain-related components that most distinguish the EV from an ICE vehicle (e.g. motor, battery, fuel cells, and electronic control units). The identity of these suppliers is also disguised to preserve their anonymity.

EV-Co plans to move from producing five units to 30,000 units within five years. As a relatively new start-up company, EV-Co will be highly dependent upon its suppliers to achieve quick volume ramp-up and all-round improved operational and supply chain performance, in order to be able to overcome their resource deficiencies and the risks associated with expansion. To compound their relatively weak position in the supply

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4 chain, EV-Co presently accounts for a very low average proportion (about 10%) of their
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6 suppliers' sales/revenue; this gives EV-Co very little relative buying power. This study,
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8 in part, adds much-needed insight into how buyer dependence on suppliers (Kähkönen *et*
9
10 *al.*, 2015) during production ramp-up can be better managed. This study explores and
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12 attempts to explain strategies to positively develop supply chain
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14 relationships/dependencies during production ramp-up activities, based on specific
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16 contingency factors. Thus, there are two specific questions that drive this research:
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22 ***Research Question 1.*** *What factors influence the level of dependence of niche*
23 *manufacturing companies on their suppliers' resources during production*
24 *ramp-up in an EV supply chain?*
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27 ***Research Question 2.*** *What strategies can be used by niche manufacturing*
28 *companies to manage their resource dependencies during the production ramp-*
29 *up in an EV supply chain?*
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32 In this study, Resource Dependence Theory (RDT) was chosen as a theoretical basis to
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34 explain research findings, because of its primary emphasis on strategic resources that are
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36 owned and controlled by companies using power, position and role differences. Other
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38 theories (e.g. Resource Based View, Transaction Cost Economics, and Relational View)
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40 would be less relevant, because of their lack of focus on asymmetric power-based
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42 strategies for resource distribution and the need to gain control over external resources.
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45 RDT was used to analyse dependencies in this multi-tier supply chain study, and
46
47 study resource dependencies, because the focal company (EV-Co) was very highly
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49 dependent on its suppliers to cope with such ambitious production ramp-up targets.
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52 The remainder of this paper proceeds as follows. The paper starts with a literature
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54 review of studies in the EV sector, in respect of production ramp-up and supply chain
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56 management. Next, RDT is presented and its key elements discussed, followed by the
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4 research methodology and the case study findings. Lastly, conclusions and further
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6 research opportunities are set out.
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11 **2. Literature review and theoretical background**

13 *2.1. Supply chain ramp-up in the emerging EV sector*

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17 In recent years, EV technology has rapidly evolved and begun to disrupt the automotive
18 industry (Weforum, 2017), as pathways towards environmentally sustainable post-ICE
19 transportation solutions (Steinhilber *et al.*, 2013) have become seen as viable.
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24 In the supply chain management literature, previous studies have focused on
25 sustainability issues (e.g. Hawkins *et al.*, 2012; Günther *et al.*, 2015; Juan *et al.*, 2016).
26 For instance, Hendrickson *et al.* (2015) investigated optimal locations for battery
27 recycling in California. By contrast, other studies have examined impacts on traditional
28 automotive supply chains, as EVs become more prolific (e.g. Klug, 2013; Rossini *et al.*,
29 2016). Challenges associated with EV adoption and use, ranging from technical issues
30 (e.g. battery technologies) to user-related concerns (e.g. range anxiety), have also been
31 explored (Li *et al.*, 2015, p. 371).
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43 In the production ramp-up literature, previous studies have explored cost, quality
44 and timeliness factors (e.g. Surbier *et al.*, 2014), as well as the impact of late engineering
45 design changes, effects of supply-chain network configuration, process and product
46 complexity, and the degree of novelty (e.g. Elstner and Krause, 2014). Glock and Grosse
47 (2015) reviewed quantitative decision support models for ramp-up planning by focusing
48 on typical planning problems, and the process characteristics of the ramp-up phase. Other
49 studies have proposed different ramp-up strategies. For example, Clark and Fujimoto
50 (1991) proposed two different strategies for ramp-up of new products in final assembly,
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4 based on the choice of ramp-up curve, the operation pattern, and the workforce policy.
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6 Schuh *et al.* (2005) also proposed three production ramp-up strategies, namely ‘slow
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8 motion’, ‘dedication’ and ‘step-by-step’; they advocated that the correct selection is
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10 dependent on specific parameters (such as utilisation, product variety, ramp-up time and
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12 decoupling level).
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16 Despite this growing body of empirical research investigations into understanding
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18 resource dependence connections, and cases of how companies choose to develop their
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20 strategies to handle the associated issues of production ramp-up, knowledge is still
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22 currently limited (Christensen and Rymaszewska, 2016).
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27 2.2. Resource dependence theory and buyer-supplier relationships

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31 RDT states that organisations are open systems, dependent on their environment ‘to
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33 obtain critical resources such as personnel, information, raw materials and technology’
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35 (Hirschheim *et al.*, 2009, p. 176). According to RDT, companies that have access to
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37 scarce resources are able to influence other companies through their relationship with
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39 them (Casciaro and Piskorski, 2005).
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43 Pfeffer and Salancik (2003) state that resource dependency levels are determined
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45 by three key factors: (i) the importance of the resource, (ii) the ease of supplier
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47 substitutability (i.e. availability of alternative suppliers and the associated switching
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49 costs), and (iii) the amount of ‘discretion’ (i.e. the ownership or ability to access and use)
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51 exerted (legislatively, geographically or politically) over the resource. Therefore, in
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53 respect to RDT, managers must strategise to minimise and overcome risky resource
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55 dependencies through either ‘buffering’ and/or ‘bridging’ strategies (Pfeffer and
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57 Salancik, 2003).
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4 Mindful of this, on the one hand, ‘buffering’ strategies are used to minimise
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6 resource dependencies on other firms by building up ‘stocks’ and reducing the uncertainty
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8 in obtaining important resources (Leonardi, 2013). On the other hand, ‘bridging’
9
10 strategies can be used to strengthen ‘flows’ between the source and sink of assets, and
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12 thus reduce the chance of crucial natural resource shortages by strengthening links
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14 through stronger strategic, operational and technical bridges between one firm and
15
16 another (Leonardi, 2013). Such bridges can be thought of as ‘boundary spanning’ objects
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18 or activities, namely physical resources, people, skills and knowledge, and/or processes
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20 (Levina and Vaast, 2005) used across a multi-tier supply chain.
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25 Several studies have applied RDT (Paulraj and Chen, 2007) to study the
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27 relationship between environmental uncertainties (demand, supply and technology) and
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29 strategic supply management, as supplier managers try to produce mutual benefits. Such
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31 collaborations should lead to accessing unique resources and minimise environmental
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33 uncertainties, as integration between companies increases. RDT has also been applied to
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35 discover factors that change buyer-supplier power dynamics, and to suggest appropriate
36
37 mitigation strategies, as both directly affect and shape relational capital (Petersen *et al.*,
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39 2008).
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44 Previous RDT studies (e.g. Kähkönen *et al.*, 2015; Kalaitzi *et al.*, 2018) in the
45
46 field of supply chain management have investigated collaboration and bargaining power
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48 in times of uncertainty, but without considering the inherent uncertainty arising from
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50 production ramp-up in EV supply chains. These previous studies have also only focused
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52 on first-tier suppliers and the focal dyad has been between OEM and the first-tier supplier.
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54 Therefore, there is a need for research in this field to go beyond simple dyadic buyer–
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56 supplier relationships (Hofmann *et al.*, 2015), and to focus on multiple tiers of a supply
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4 chain, in order to generate more valuable insights (as per Mena *et al.*, 2013; Tachizawa
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6 and Wong, 2014; Wilhelm *et al.*, 2015).
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10 11 **3. Methodology** 12

13 *3.1. Research context and approach* 14 15

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18 Given the relative infancy of research into EV supply chain dependencies, as well as the
19
20 infancy of research into buyer-supplier relationships during EV production ramp-up, an
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22 exploratory and explanatory inter-company case study was used to increase lucidity, as
23
24 used in other similar studies (e.g. Barratt *et al.*, 2011; Choudhari *et al.*, 2012; Ketokivi
25
26 and Choi, 2014; and Touboulic *et al.*, 2014). A case study approach was used instead of
27
28 a survey or quantitative approach, so that rich tacit data could be gathered to better
29
30 understand the complex relationships underlying the ramp-up of production in the EV
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32 sector (as suggested by Voss, 2009; Edmonson and Mc Manus, 2007).
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37 EV-Co was selected as the focal company in this multi-tier case study. EV-Co,
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39 founded in 2004, and based in the West Midlands in the UK, is an SME with seven full-
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41 time employees. It specialises in the design of lightweight, hydrogen fuel and battery
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43 powered vehicles, with specific capabilities in areas such as mechanical engineering, fuel
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45 cell technology, hydrogen systems, battery systems, and whole vehicle development. EV-
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47 Co produces a small hybrid fuel vehicle (i.e. a lightweight two-door, four-seater hybrid
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49 lithium ion battery vehicle intended for city use) referred to here as the ‘City-Car’, which
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51 forms the focus of this study.
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55 The City-Car is currently in Stage 2 of the three overarching product development
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57 stages; namely 1) Research, Development and Planning 2) Prototype Building 3)
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59 Low/High Volume Production (Cuffaro *et al.*, 2013). In this Prototype Building stage,
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4 supply chain management decisions become crucially important in respect of a successful
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6 product launch and production ramp-up later in the new product development life cycle,
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8 as path dependencies begin to form based on decisions about product and supply chain
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10 configurations (van Hoek and Chapman, 2007).
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14 Our study takes a multi-tier approach, and focuses on the UK-centric drivetrain
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16 components of EV-Co's City-Car. The drivetrain of the City-Car forms 55% of its overall
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18 cost (where the body forms 12%, chassis 16%, and electrical/electronic parts form 17%).
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20 The unit of analysis for this study is EV-Co and its suppliers of the drivetrain-related
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22 systems and components within its City-Car supply chain. This study focuses on the
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24 relationships between EV-Co and two of its critical tier one suppliers and five of its tier
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26 two suppliers involved in the design, build and servicing of the City-Car in the UK (as
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28 highlighted in bold in Figure 1 below). This research focus is intended to create the
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30 potential to explore, capture and explain dependencies in the EV supply chain. It is worth
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32 highlighting that the battery or fuel cell suppliers were not based in the UK (and so not
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34 included directly in the case study).
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45 46 3.2. *Data collection and analysis* 47 48 49

50 Three appropriate and complementary sources of data were used (as per Edmondson and
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52 McManus, 2007): tours of the manufacturing plants; semi structured interviews; and
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54 workshops. Multiple sources of data were used to enhance both the reliability and
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56 construct validity of this study (as per Voss *et al.*, 2002). The research was conducted
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58 from November 2016 to August 2017 in the UK (see Table 1).
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-----Insert Table 1 Approximately Here-----

Plant tours were used as an initial source of data collection, thus facilitating direct observation. In total, ten plant tours of eight separate plants were arranged and facilitated by senior management from participating companies. Exploratory visits to plants were made in teams to reduce single-rater bias during data interpretations (Eisenhardt, 1989). Observational evidence allowed for a rich understanding of complex activities and plant resources (Ketokivi and Choi, 2014). The main purpose of the observation was to determine whether a plant could potentially fill a particular role during ramp-up. For example, Chassis-Co had an under-utilised area in the factory that could be used to support the ramp-up of City-Car whereas another company, Motor-Co, had to invest in new plant and facilities to increase their capacity to fulfil large new orders in line with EV-Co's new strategy. The plant tours also created an opportunity to ask insightful informal questions about inter-company relationships, thus helping to build a systemic model. Quantitative descriptive data (e.g. lead-times, number of suppliers, or the number of goods demanded per annum) were also collected during tours to characterise participating companies and demonstrate the magnitude of change and the magnitude of risk in the ramp-up plan.

After plant tours, semi-structured interviews were used as follow-up data collection to capture the core capabilities, capacities and performance deficiencies in the supply chain. Interviewees were selected based on purposive sampling, which found and chose participants based on their specific role and knowledge of the research topic (Creswell and Plano Clark, 2007). The interview process was continued until no new information was forthcoming, and researchers reached a point of theoretical saturation (Eisenhardt,

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4 1989). Theoretical saturation was reached when fourteen interviews had been conducted
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6 in total, and one additional interview was conducted to confirm theoretical saturation and
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8 verify that no more interviews were necessary. Thus, a total of fifteen interviews were
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10 conducted with directors and managers responsible for the production and logistics
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12 functions in the eight manufacturing companies. Depending on the participant's
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14 responses, interviews lasted between one and two hours. The interviews were conducted
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16 by a two-person team, an interviewer and a transcriber, to ensure that answers were fully
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18 captured.
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23 Semi-structured interviews were based on three tools. Firstly, the 'Capability
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25 Matrix' was used for mapping companies' capabilities and supply chain capabilities.
26
27 Secondly, the Process Orientated Holonic (PrOH) Modelling Methodology (Clegg, 2006;
28
29 Clegg and Shaw, 2008) was used to visualise a high-level systemic overview of the
30
31 changing dynamics of the automotive industry in a post-ICE dominated era, as PrOH
32
33 modelling can provide the potential to understand how changes in one systemic success
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35 factor (whether it be social, economic, political or technological) can impact on other
36
37 systemic success factors in an industry, business or supply chain. Thirdly, the Global
38
39 Supply Chain Forum (GSCF) tool (Lambert, 2004) was used for analysing four specific
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41 processes, namely demand management; manufacturing flow management; supplier
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43 relationship management; product development; and commercialisation. The semi-
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45 structured interview guide was based on these tools, and included detailed questions on
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47 the company's background, main players and distribution of power among them, as well
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49 as location of customers and suppliers, production volumes from suppliers, strategic
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51 sourcing policy, existing production processes and capabilities, lead-times and relative
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53 price of each component. An outline of the semi-structured interview was sent to the
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55 managers ahead of the meeting. These structured data collection techniques were used for
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4 qualitative data collection, so that reliability and theoretical maturity of the qualitative
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6 aspects of the research study were enhanced (Yin, 2003).
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9 Two workshops were also held once an initial analysis of raw data from plant
10 tours and interviews was completed. A two-stage approach to the analysis of the data was
11 conducted (Miles and Huberman, 1994). In the first stage (Workshop 1), an intra-
12 company analysis was conducted, focusing on different dependencies in each company,
13 and coping strategies that each company followed to handle the dependencies. In the
14 second stage (Workshop 2), a cross-company analysis was conducted to identify
15 capabilities, processes and ramp-up issues across the supply chain, and capture common
16 emergent themes using RDT. Objectivity, validity and reliability of the analysis were
17 ensured by using pre-defined themes from the RDT framework (Miles and Huberman,
18 1994; King, 2004).
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32 The first workshop (January 2017) brought together eight supply chain
33 professionals: three academics, two practitioners (i.e. the directors of EV-Co and Motor-
34 Co), and two EV experts from an independent institute to discuss, refine, and extend the
35 findings from plant tours and semi-structured questionnaires. From this first workshop,
36 an initial systemic PrOH model was produced. The second workshop, held a month later,
37 involved three academics, four practitioners (i.e. the directors of EV-Co, Motor-Co,
38 Components-Co and Rotor-Co) and two experts from an independent institute to validate
39 and update the initial PrOH model, and further focus on the 'big-picture' cross-company
40 industry analysis. The next section explores the empirical findings produced by this
41 methodology.
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58 **4. Empirical findings: exploration**

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EV-Co's supply chain was analysed in respect of resource dependencies with seven of its critical suppliers for the drivetrain and its interacting sub-systems and components. Exploratory findings from the PrOH model are initially given – to set EV-Co's supply chain into a wider social, economic and political context. An explanatory narrative, based on RDT, is then given of specific coping strategies – namely 'buffering' and 'bridging' strategies to manage resource dependencies in this context. RDT uses bridging and buffering as its key coping strategies (Bode *et al.*, 2011; Meznar and Nigh, 1995). This study acknowledges that other theories can be used, but this study is focused on and restricted to RDT as an explanatory lens for its empirical findings. A template for constructing and reading a PrOH model is given in Appendix A.

4.1. The PrOH Model – the wider context for EV-Co's supply chain

-----Insert Figure 2 Approximately Here-----

The tacit systemic factors concerning EV supply chains obtained from the data collection activities are shown in the PrOH model, and further narrated below (all text is taken directly from Figure 2). By reading the core process statement from top left to bottom right in the PrOH model (Figure 2), the following dynamics are revealed.

The ICE-dominated era was influenced by socio-economic-political groups, such as consumer groups, incumbent industry groups and groups advocating on government legislation. These socio-economic-political groups are revising and reconsidering requirements for future transportation systems. These requirements include CO₂ emissions reductions, material reuse and recycling, lower weight, closed loop supply chain logistics and infrastructure. In turn, these requirements are used for the design, build

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4 and maintenance of products by organisations of the automotive industry. For example,
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6 the organisations who deliver the gearbox, interiors, body, motors, materials, electronics,
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8 manual labour, batteries, engineering skills and knowledge, small components,
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10 pneumatics, drivetrains and fuel cell providers. These organisations deliver post-ICE
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12 dominated era transport systems; for example, closed loop supply chain and logistics
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14 systems, vehicles, business / service models, EV charging stations, hydrogen stations and
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16 telematics for IoT linked systems. These are all required by end-users of post-ICE
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18 transportation systems. These users will be the commuters, drivers and passengers in the
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20 post-ICE dominated era.
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25 Systemic factors (in Figure 2) bring dramatic dynamic disruption to the
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27 automotive industry. For instance, organisations of the automotive industry will need to
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29 work in accordance with new operating characteristics; for example, more information
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31 sharing, more off-boarding, more collaborations through the supply chain, increased
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33 reliability, clearer supply chain strategy, more complete life cycle costing, more
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35 flexibility and modularity, unknowns / uncertainties, changing product complexities,
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37 more scalability of non-ICE vehicles, greater scientific bases and more globalisation.
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39 These operating characteristics are derived from the requirements for future
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41 transportation systems. The same future requirements for transportation systems are also
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43 used for the design, build and maintenance of these systems by organisations that are not
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45 traditionally part of the automotive industry; for example, off-board providers, computer
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47 manufacturers, highways agencies / toll road operators, energy companies, advanced
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49 services, civic authorities and providers of disruptive R&D, all of whom could radically
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51 change post-ICE dominated era transport systems. In addition, further dynamism is
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53 brought about by post-ICE dominated era transport systems driven by new performance
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55 metrics; such metrics include increasing supplier metrics, reducing costs, leaner
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4 inventory, increasing IoT connectivity levels, whole life cycle emissions, changing
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6 utilities and reducing lead-times. These metrics affect incumbent organisations of the
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8 automotive industry, organisations not traditionally part of the automotive industry, and
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10 end users of post-ICE transportation systems (e.g. finance / leasing companies, driverless
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12 systems, commercial operating companies, private owners and car pools / clubs). Further
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14 dynamics of the post-ICE-dominated era transport systems are governed by newly
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16 emerging regulations; for example, taxations, recycling and use, European Union
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18 changes, data security, car sharing practice, civic / road laws, insurance, and emissions /
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20 environmental legislation.
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25 All in all, these dynamic systemic factors are complex and uncertain, which makes
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27 production ramp-up of EVs a challenging undertaking, particularly for smaller companies
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29 with less resources. The interconnections between these factors are shown in the PrOH
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31 model in Figure 2. Effectively managing resource dependencies between companies in
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33 this scenario is dynamic, complex and uncertain. The next section describes coping
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35 strategies, in respect to RDT, used by companies in this multi-tier case study.
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41 *4.2. Resource dependence levels*

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45 In this section, a detailed discussion of the EV-Co's ramp-up plans is given within the
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47 wider context described in Section 4.1 (*c.f.* Figure 2). Currently, EV-Co's level of
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49 production is low. They have an assembly capability of approximately five to twenty cars
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51 per year. Thus, to achieve economies of scale for both the EV-Co and its suppliers,
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53 significant steps need to be taken.
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59 *4.2.1. Importance of the resource*

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7 Concerning the importance of the resource, prices for certain drivetrain components are
8 relatively high; components such as the hydrogen fuel system, magnets and fuel cell
9 stacks. The prices can also fluctuate considerably. Components-Co (Director 1) stressed
10 that, *'for yellow metals (i.e. a type of metal alloy that consists of 60% copper and 40%*
11 *zinc) we often observed prices going up and down'*, and that this price volatility leaves
12 EV-Co vulnerable due to current low production levels and low financial reserves.
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21 With regard to the quantities of items purchased, Motor-Co is infrequently
22 sourcing low quantities from Components-Co and Thermosensor-Co, and accounts for
23 only a small percentage of their total sales. This makes Motor-Co vulnerable during
24 production ramp-up due to its current weak buying power. By contrast, other large
25 customers who buy from Components-Co and Thermosensor-Co are more important than
26 Motor-Co, as they place regular high-volume orders. In turn, Components-Co and
27 Thermosensor-Co are dependent on their other major customers that account for the
28 majority of their sales. Any increased demand from these more significant and powerful
29 customers could have a detrimental effect on supply to Motor-Co, and therefore indirectly
30 on EV-Co, who have lower buying power and a lower priority order fulfilment rating.
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44 Another concerning issue for EV-Co is the existence of a skills deficit that can
45 lead to a dependence on human resources from other organisations. The Founder and
46 Director of EV-Co stated that, *'the workforce will need to scale-up to cope with new*
47 *production levels, but a workforce with the right skills can be hard to find, especially in*
48 *key, emerging and sought-after areas, such as fuel cells, hydrogen and EV drivetrain*
49 *technologies'*. Chassis-Co, Components-Co and Castings-Co have also indicated a lack
50 of skilled machinists who are able to make and/or modify metal parts, demonstrating an
51 overall skills shortage in this supply chain.
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4.2.2. *Supplier substitutability*

EV-Co's tier one and tier two suppliers rely on single suppliers (i.e. sole sources), who in turn have long lead-times and high risks, as components and materials are purchased from non-UK suppliers positioned around the world. For example, a three to four month lead-time is needed for Components-Co to deliver necessary quantities to Motor-Co. Likewise, delivery times for magnets to be shipped to Rotor-Co and Encoder-Co, from the Far East to the UK, are 12-14 weeks and six weeks, respectively. All eight companies in this study follow a single-sourcing strategy, which means that, *'supplier control in bargaining is high and there are limited opportunities for lowering the price'* (Founder and Director, EV-Co). Single sourcing is therefore undesirable, but unavoidable, in EV-Co's current *modus operandi* and is further exacerbated by high switching costs and risks in the wider business environment.

Another constraining factor was found to be the existing production processes and capabilities of suppliers. For example, Chassis-Co are currently, *'limited to 5000 cars per year, which is another constraint in production ramp-up'* (Founder and Director, EV-Co), and Motor-Co currently needs, *'three hours to produce one unit'* (i.e. one motor), which is too long. Hence, if Chassis-Co and Motor-Co are to enable EV-Co to produce 30,000 units, major changes need to be made to their current processes, capacities and facilities. Each of these suppliers will have to seek to minimise production lead-times and/or significantly increase their production capacity. The alternative for EV-Co is to change supplier and experience high risk and switching costs.

4.2.3. *Discretion over resources.*

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7 With respect to discretion over resources, geographical and political risk and increased
8 competition have led to resource dependence. For critical City-Car components, such as
9 magnets, fuel cells and thermo-sensors, EV-Co and Motor-Co must collaborate with
10 international partners from the USA, Canada and China, creating high asset specificity
11 dependence for their essential resources and capabilities (Espino-Rodríguez et al., 2008;
12 Lonsdale, 2001). Also, for example, Rotor-Co supplies the magnet, a critical scarce
13 natural resource that cannot be accessed easily from anywhere but China. According to
14 Rotor-Co's Assistant Sales Manager, '*Raw material costs are forecast to increase over*
15 *the coming 18 months, due to demand and legislation changes in China*'. Thermosensor-
16 Co also experience volatility when purchasing components for the temperature sensor
17 from three suppliers who are based in China. Also, companies from the EV sector
18 compete not just with other EV companies, but also with traditional incumbent
19 organisations in the automotive industry for generic components. This competition
20 creates even lower relative discretionary power for new small EV manufacturers. Some
21 empirical evidence, in the form of pertinent selected interviewee quotes, in respect to such
22 RDT factors in this EV supply chain, is given in Table 2.
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50 4.3. Strategies used to minimise/overcome resource dependency risks.

51 52 53 4.3.1. Buffering strategies

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57 Buffering strategies entail holding inventories, or altering the structure and goals of firms,
58 in order that a resource will no longer be a critical stock-out (Pfeffer and Salancik, 1978).
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4 For example, Motor-Co and Encoder-Co both keep high inventory levels of castings and
5
6 magnets, respectively. This buffering reduces the chance of running out of a product.
7
8 However, this strategy is not always possible to implement as resources such as
9
10 dysprosium have a high cost, and the price is volatile, making them too risky to stockpile.
11
12 Similarly, Rotor-Co has a transactional arms-length relationship with a Chinese supplier,
13
14 and a low inventory is kept. As the Assistant Sales Manager of Rotor-Co states, *'We keep*
15
16 *low inventory for parts to keep the cost down. Decisions regarding stock levels are based*
17
18 *only on local information ... We don't have a global forecasting system to follow spot*
19
20 *prices'*.
21
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25 In respect to buffering strategies, another practice for production ramp-up is to
26
27 increase production flexibility in terms of facilities and capabilities. The founder and
28
29 director of EV-Co stated that, *'Many of our smaller suppliers will not be able to grow*
30
31 *beyond 50-100 units per year – (e.g. bodywork) unless they decide to invest and grow*
32
33 *with us'*. For example, Chassis-Co, Components-Co and Rotor-Co are SMEs that can
34
35 currently only support production volumes of less than 1,000 units per year and cannot
36
37 support volumes above. Yet, EV-Co has a target of producing up to 30,000 units per year.
38
39 Without absolute capacity growth across the supply chain, particularly in the UK
40
41 suppliers, extreme flexibility has to be built into supply chain-based production systems.
42
43 In the short-term, tier one and tier two suppliers could implement a second production
44
45 shift and in the longer term invest in new plant facilities. However, the Founder and
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47 Director of EV-Co stated that if more volume was available, *'we should not necessarily*
48
49 *be obliged or have to fulfil all of it, but we could look to collaborate with other companies*
50
51 *such as Google and Tesla for volume to help fill it'*. This suggests that some critical supply
52
53 chain echelons may have to be buffered to encourage EV supply chains to grow.
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57 Furthermore, the Finance Director and General Manager of Rotor-Co highlighted that *'if*
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4 *there is a need for more parts, then we'll ask our parent company in India to support us*’.

5
6 This demonstrates that trust and reciprocity in supply-chain relationships is (i) worldwide;
7
8 (ii) essential but not obligatory; and (iii) that opportunism is likely to prevail over loyalty.

9
10 If buffering is to be used effectively it needs to be reciprocal, and used in trusted
11
12 partnerships, supported by wider governmental interventions.
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15
16 In this case, process technology levels, and process integration levels, were also
17
18 found to be low, because material resource planning / enterprise resource planning (MRP
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20 / ERP) systems were not used by EV-Co, Chassis-Co or Rotor-Co. Significantly, EV-Co
21
22 and Rotor-Co have plans to invest in those systems to improve the management of
23
24 dependence for the future. This investment would be via Motor-Co (sitting in the first-
25
26 tier between them), who plan to upgrade their ‘*ERP system to assist the purchasing team*
27
28 *to take ownership of the management of the motor production as we will then be able to*
29
30 *have fuller visibility of our components suppliers’ activities and act on behalf of our end*
31
32 *customer*’ (Director, Motor-Co). Without such systems, it will be more challenging to
33
34 implement innovative effective buffering strategies to aid ramp-up plans. Additional
35
36 empirical evidence, in the form of interviewee quotes, in respect to RDT buffering
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38 practice, as used by EV-Co and its suppliers, is provided in Table 3.
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50 4.3.2. Bridging strategies

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54 EV-Co’s relationships with suppliers range from arm’s length relationships for relative
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56 commodities to more co-operative relationships for more customised parts. Furthermore,
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58 purchases predominantly made by Motor-Co, Castings-Co, Components-Co and Rotor-
59
60 Co are price driven. However, in the future, EV-Co plan to pursue longer-term contracts

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4 that establish thresholds for volumes and prices over an extended period which may,
5
6 *'bring together managerial personnel from different firms and contribute to a perception*
7
8 *of common interests between the interdependent entities'* (Jaffee, 2010, p. 11).
9

10
11 Moreover, in the future, EV-Co and Motor-Co intend to involve their suppliers
12
13 earlier on in the product design process. Thus, component and material suppliers are able
14
15 to advise manufacturing companies in respect of design and production specifications,
16
17 and minimise cost without adversely affecting product quality. Specifically, Chassis-Co,
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19 Components-Co and Rotor-Co need to be increasingly involved in the conceptual
20
21 definition stage of Motor-Co's engineering design.
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25 Additional empirical evidence, in the form of interviewee quotes in respect of
26
27 RDT bridging strategies, as used by EV-Co and its suppliers, is provided in Table 3. The
28
29 above empirical exploratory narrative in Sections 4.2 and 4.3, based on RDT, is
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31 summarised into a conceptual framework in Figure 3.
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39 40 41 42 43 **5. Empirical findings: Explanation**

44 45 46 *5.1. Factors that determine the level of dependence during production ramp-up*

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49 The PrOH modelling captures socio-economic-political factors, such as taxation, car
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51 sharing practice, emissions / environmental legislation, which act upon post-ICE
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53 dominated era transportation systems. These factors are likely to bring dramatic dynamic
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55 disruption to the automotive industry, and require companies to develop new operating
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57 characteristics. These factors help to understand changes and dependencies in the EV-
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4 Co's supply chain in a wider social, economic and political context in accordance with
5
6 RDT (*c.f.* RQ1).
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8
9 This study has also identified the following operating factors that affect the level
10 of dependence between niche manufacturing companies and their suppliers' resources
11 during ramp-up activities: cost/price; quantity; skills; number of suppliers; switching
12 costs and capabilities; competition; and geographical and political risks. This study
13 confirms previous research findings (e.g. Caniëls and Gelderman, 2005) in respect of
14 cost/price, quantity, number of suppliers and switching costs. Additionally this study has
15 identified new factors, such as: (i) skills, (ii) capabilities, (iii) geographical and, (iv)
16 political risks.
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27 The failure to safeguard against critical resource volume dependencies during
28 production ramp-up can hinder large-scale production ramp-up. For example, lithium-ion
29 batteries are particularly vulnerable. In light of these issues, BMW announced the signing
30 of a ten-year contract to secure the supply of cobalt and lithium for EV batteries (Lambert,
31 2018). In this volatile business environment, small companies, such as EV-Co, must be
32 creative to build strong relationships with suppliers of cobalt (and rare earth elements)
33 and divert some supply away from traditional OEMs (Hull and Deaux, 2016; Petersen,
34 2017).
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45 *5.2. Supply chain strategies to manage resource dependencies during production ramp-* 46 *up* 47 48 49

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51 Regarding the second research question (*c.f.* RQ2), concerning strategies used by niche
52 manufacturing companies to manage their resource dependencies during production
53 ramp-up in an EV supply chain, this study found that companies apply a mix of
54 'buffering' and 'bridging' strategies.
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4 In the case of buffering strategies, safety stocks are preferred for magnets, while
5
6 they are avoided for raw material resources such as dysprosium (due to price
7
8 fluctuations). This is particularly the case for Motor-Co and Encoder-Co, both of whom
9
10 use buffering strategies in response to demand volatility and/or production ramp-up. In a
11
12 similar vein, EV-Co is beginning to use licencing agreements to manufacture with
13
14 suppliers such as Motor-Co, who are building a new 'contract production' facility, and
15
16 Chassis-Co, who have plans to increase production capacity at existing facilities to
17
18 accommodate new increased demand.
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23 Concerning bridging strategies, EV-Co originally chose its suppliers on a job-by-
24
25 job basis, however, as production volumes increase, both EV-Co and its suppliers must
26
27 work together more closely, to better manage and forecast their resource dependencies.
28
29 According to Dharmani *et al.* (2013), developing close relationship with suppliers is a
30
31 key part of capacity-change management. Bridging strategies may be particularly salient
32
33 in the case of critical resources where the discretion over any resource is relatively low.
34
35 For example, the purchase of components made from rare earth elements from China, and
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37 magnet-based resources purchased by Rotor-Co, would benefit from more effective
38
39 bridging strategies to help elevate potential production ramp-up constraints.
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46 *5.3. New insights into buyer-supplier relationships in the EV sector*

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49 A remarkable and unusual finding of this research is that EV-Co (an SME) works closely
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51 with its supplier Motor-Co (a medium-to-large organisation) based on a supplier-led
52
53 collaboration; Motor-Co orchestrates and manages EV-Co's entire supply chain, without
54
55 exploiting its high dependency (Tangpong *et al.*, 2015, p. 163). This supplier-led
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57 development initiative is in direct contrast with the traditional practice in the automotive
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59 industry, which is dominated by buyer-led collaborations and exploitation of smaller
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4 companies by the larger ones. Successful R&D collaborations like this, as highlighted by
5
6 this new empirical case, are especially critical in the early integration of suppliers and
7
8 new EV OEMs in the new product development process (Binder *et al.*, 2008; Kähkönen
9
10 *et al.*, 2015, p. 153). This is line with Mena *et al.* (2013) who found that as dependencies
11
12 shift to the upstream part of the supply chain (e.g. raw materials suppliers), upstream
13
14 companies become more powerful, and need to help develop new routes to market for
15
16 their materials and components. As this paper's original research demonstrates, this
17
18 means that upstream companies such as Motor-Co will actively help to develop and
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20 support the growth of new EV OEMs.
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25 To put it another way, EV-Co as a start-up company, which focuses on R&D of
26
27 end-user products (e.g. cars) and services (mobility services), can open up significant new
28
29 markets for its upstream (raw material) suppliers, who may be less end-user R&D focused
30
31 and more focused on high-volume production R&D. Thus, niche EV manufacturers can
32
33 help suppliers to explore and exploit new market opportunities, use resources in their
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35 supply chain more innovatively, and through effective bridging and buffering strategies,
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37 and production ramp-up plans, improve their overall supply chain's performance
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39 (Altmann and Meil, 1992).
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44 EV-Co has specific plans to partner with one or more other contract production
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46 companies, in addition to Motor-Co, through buffering strategies, as EV-Co does not plan
47
48 to set up any manufacturing capability of its own. This practice is also common in other
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50 industries, such as pharmaceuticals and electronics, where so-called 'fabless' start-up
51
52 companies focus on their core R&D competencies and outsource their production to
53
54 'foundry-like' contract-production companies, who may also be partly responsible for the
55
56 co-marketing of end products (Wagner *et al.*, 2017).
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EV-Co also has plans to mitigate high dependence on its suppliers through bridging strategies to improve relational capital and safeguard against uncertainties in the supply chain. The size of companies sought by EV-Co will be predicated by EV-Co's ramp-up ambitions. Larger ramp-up ambitions for EV-Co means bridging to larger companies with higher production capacities. These findings and plans are consistent with the empirical studies by Bode *et al.* (2011) and Su *et al.* (2014), who observed that when dependence on suppliers is high, bridging strategies are often employed.

6. Conclusions and implications

In the emerging EV sector, companies are developing new strategies and business models to respond to issues of dependence. The literature highlights the need to explore dependencies through better planning and execution of production ramp-up. Building on this, this study has examined a niche vehicle manufacturer and its suppliers of drivetrain related components, such as the motor, battery, fuel cells and electronic control units. This qualitative multi-tier supply chain study is based on RDT to gain insights into how dependencies are formed during the ramp-up of production activities, and how strategies are used to minimise resource dependencies (e.g. early supplier involvement) in respect to capabilities, supply relationships and volume flows.

6.1. Research Implications

Our findings offer a new perspective on supply chain production ramp-up in the EV sector. This research is one of the first empirical studies addressing changing dependencies, which arise during supply chain production ramp-up in the EV sector (Li *et al.*, 2014; Pazirandeh and Herlin, 2014), by applying RDT. There are three main implications stemming from this research.

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4 The first implication is that this study considers all three factors that determine
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6 dependence levels: importance of the resource; supplier substitutability; and discretion
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8 exercised over resources. This study further extends RDT by identifying sub-factors that
9
10 determine dependence levels such as: skills; capabilities; and geographical and political
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12 risks.
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16 The second implication relates to the *level of dependence and supplier*
17
18 *involvement*. Our research shows that early involvement and relationship-specific
19
20 investments by the supplier (i.e. Motor-Co), in the new-product development of City-Car,
21
22 increased buyer-supplier inter-dependence. Therefore, this study adds to the existing body
23
24 of knowledge regarding the dependence of buyers on their suppliers. For example,
25
26 Kähkönen *et al.* (2015) also found early supplier involvement increases the buyer's
27
28 dependence on its suppliers. However, Kähkönen *et al.*'s study was based on a single
29
30 company-level survey sample and did not investigate the phenomenon in-depth. Neither
31
32 did that study provide a rich understanding in a multi-tier case study.
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36
37 The third implication relates to supply chain strategies employed. This study has
38
39 found that two main supply chain strategies (i.e. buffering and bridging) can be
40
41 successfully used to manage dependencies during the production ramp-up. This is in line
42
43 with the research of Su *et al.* (2014) and partially in line with Bode *et al.* (2011), the latter
44
45 of whom advocate only bridging strategies. Common buffering strategies found in this
46
47 study are capacity sharing reciprocation, and a change towards mutually beneficial
48
49 production planning. Meanwhile, bridging strategies found through this study include the
50
51 strengthening of strategic partnerships and IT collaboration. As industry clock-speed is
52
53 expected to increase in the EV sector, due to quickening technological changes (i.e. new
54
55 fuel technology and batteries), an appropriate blend of buffering and bridging strategies
56
57 will make firms, especially SMEs, more resilient to dynamic change.
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6.2. Managerial Implications

This paper focused on resource dependencies in the production of EV vehicles, which differ from conventional vehicles. Whereas innovation in the conventional automotive industry is mainly driven only by a few large organisations, mainly OEMs and large tier one suppliers, innovation in the EV industry can come from both large and small companies. More specifically, SMEs are playing a crucial role as either suppliers and/or vehicle manufacturers. Moreover, the power is shifted upward in the supply chain away from conventional vehicle manufacturers, and away from generic automotive companies, towards specialist newcomer suppliers (Bierau et al., 2015). It is expected that around eight million EVs will be on UK roads by 2040 and a long-term transformation of the automotive industry will be needed (Fojcik, 2013). Supply chain managers should be aware of the following related findings from this study.

A lack of certain critical capabilities and capacities amongst domestic UK suppliers has been identified when put into the context of global EV supply chains. These include uncompetitive unit costs, lack of some technical capabilities, and lack of qualified suppliers with sufficient capacity (APC, 2016; Automotive Council UK, 2015).

Supply chain, logistics and purchasing managers should gain a better understanding of resource dependencies, which become set during planning and execution of production ramp-up, and which are difficult to cost-effectively diverge from later on. As stronger buyer–supplier relationships are critical for both niche and large EV OEMs, and their UK suppliers, supply chain managers must become more adept at blending bridging and buffering strategies to help the EV sector to grow.

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4 Buyers are recommended to involve their suppliers early on in EV product
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6 development, and process design, and incentivise smaller suppliers to become more
7
8 motivated and increasingly involved in production ramp-up. An additional four billion
9
10 GBP of annual component purchasing from UK suppliers has been recognised by UK car
11
12 manufacturers as necessary in order to reach a critical volume. However, OEMs are not
13
14 always able to purchase their components from local suppliers, as many report that their
15
16 plants run close to, or at, full capacity, and they have little flexibility (Henry, 2015). This
17
18 suggests that a more sophisticated blend of bridging and buffering strategies is needed.
19
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21

22
23 Lastly, the EV industry is evolving rapidly in terms of embracing new
24
25 technologies. Supply chain managers should consider commissioning new training
26
27 programmes to train purchasers and/or technicians with the skills to negotiate creatively
28
29 with suppliers of batteries, electric motors, and advanced computer and electrical system
30
31 development (Roche, 2015).
32
33

34 35 *6.3 Limitations and Future Research* 36 37

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39 This case study primarily focuses on the supply chain of a small UK-based EV
40
41 manufacturer. Therefore, results may not be directly transferable to other sectors and/or
42
43 countries.
44
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46
47 Future research could explore and compare similar production ramp-up resource
48
49 dependencies strategies in other EV companies, who have already achieved mature and
50
51 established supply chains, in a retrospective study. For example, by using RDT, a future
52
53 study could explain how Tesla made a doubly competitive move when they acquired
54
55 Grohmann Engineering (a German automation company) to positively accelerate their
56
57 own vehicle production. This was doubly competitive, because, in doing so, they may
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4 have also negatively impacted upon Mercedes and BMW, as Mercedes and BMW were
5
6 both dependent on Grohmann's equipment to build their own EVs (Miller, 2017).
7
8

9 Future research could also collect further quantitative data based on these findings
10
11 to investigate the effects of different resource dependency types and levels on bridging
12
13 and buffering strategies used during supply chain ramp-up. Such an investigation could
14
15 be achieved through the use of dynamic simulation (based on Figure 2) or structural
16
17 equation modelling approaches (based on Figure 3).
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28
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30
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33 research.
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Appendix A: Template for building and reading PrOH models.

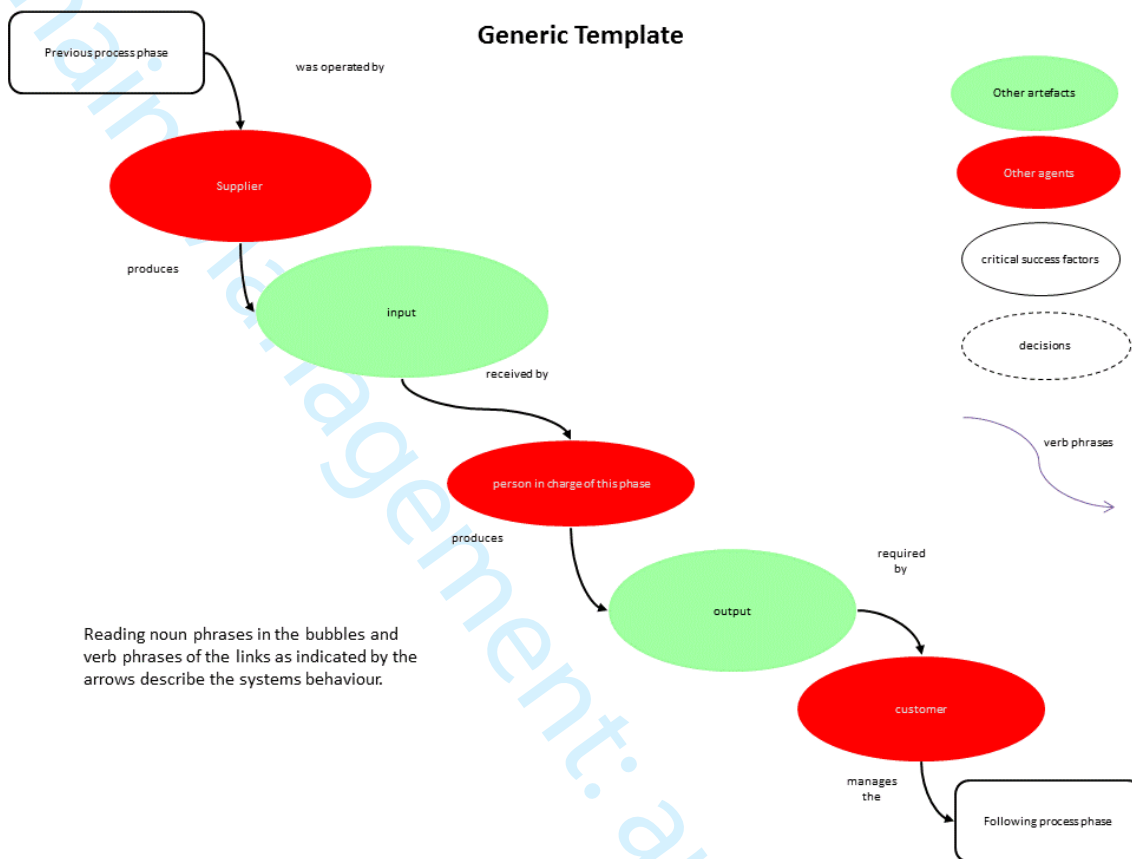


Table 1: Description of participating companies

Position in the supply chain	Company name	No. of employees	Revenues (£)	Description	No. of interviewees	Interview time and observation
OEM - focal firm	EV-Co	7	-	EV manufacturer	2 (founder & director and mechanical design engineer)	8 hours + 2 plant tours
Tier 1 suppliers	Motor-Co	70	£4.6m	Axial flux motor manufacturer	1 (director)	8 hours + 1 plant tour
	Chassis-Co	150	£3m	Chassis manufacturer	3 (chief engineer, senior engineer and logistics manager)	4 hours + 1 plant tour
Tier 2 suppliers	Castings-Co	25	£2.5m	Castings manufacturer	2 (technical director and quality assurance manager)	2 hours + 2 plant tours
	Components-Co	23	£2m	Precision components manufacturer	2 (directors)	4 hours + 1 plant tour
	Rotor-Co	18	£2.6m	Rotor manufacturer	2 (finance director and general manager, and assistant sales manager)	2 hours + 1 plant tour
	Thermosensor-Co	131,000	£32.7b	Thermosensor manufacturer	1 (senior key account manager)	2 hours + 1 plant tour
	Encoder-Co	4,000	£436.6m	Encoder manufacturer	2 (sales managers)	4 hours + 1 plant tour

Note: each plant tour lasted on average approximately two hours.

Table 2: Resource dependence level in the EV sector

RDT factors affecting dependence	EV sector "elements"	Representative quotations	Interviewee
(i) Importance of the resource	Cost/ price	<p><i>"Another potential risk identified is fluctuation on prices for some metals... we cannot afford to hedge on our purchases"</i>.</p> <p><i>"Magnets are an expensive part and we have limited option where to buy them"</i>.</p> <p><i>"There are fluctuations in the price of magnets ... we have no influence on prices"</i>.</p>	<p>Director 1, Components-Co</p> <p>Director, Motor-Co</p> <p>Sales Manager 2, Encoder-Co</p>
	Quantity	<i>"Majority of current parts manufactured are low volume high end precision, Motor-Co is looking towards larger volume work to utilise maximum machine hours... but firstly we need larger orders"</i> .	Director 2, Components-Co
	Skills	<p><i>"Managers lack specialist EV skills that are necessary, we need better people, but these cost more money"</i></p> <p><i>"There is lack of certain skills in order to hire new people... this is a national problem"</i>.</p>	<p>Founder and Director, EV-Co</p> <p>Director 1, Components-Co</p>
(ii) Supplier substitutability	Number of suppliers	<p><i>"There is a lack of (aluminium tub) chassis suppliers in the UK ... we need a broader supply base for the next generation of EVs"</i>.</p> <p><i>"There is a challenge to find other UK suppliers for castings ... this takes time ... 3rd party intervention would be useful to help broker these relationships"</i>.</p>	<p>Founder and Director, EV-Co</p> <p>Director Motor-Co</p>
	Switching costs and capabilities	<i>"We have to stay with the current supplier for the chassis due to cost and complexity of changing ... this makes it difficult to make significant product changes"</i> .	Founder and Director, EV-Co
(iii) Discretion over the resource	Competition	<p><i>"For example, recently we have bought parts from a certain supplier as they had really low inventory ... we risk using parts that become obsolete too quickly before the end product gets to market"</i>.</p> <p><i>"There was a delay in the commissioning of the batch production of the motor from one of our supplier's"</i></p>	Founder and Director, EV-Co

		<i>other customers, so our motor production was delayed ... we do not have any negotiating power in this respect”.</i>	
	Geographical and political risks	<p><i>“Our rotor includes dysprosium and China imposes export quotas for rare earth metals ... other options must be developed at a national level ... ”</i></p> <p><i>“The sourcing of magnets can be risky due to China's growing dominance in the global market for rare earth metals ... we have to deal with global supply chain, just like the big companies issues even though we are a tiny company!”</i></p>	<p>Assistant Sales Manager, Rotor-Co</p> <p>Sales Manager 1, Encoder-Co</p>

Table 3: Key Mechanisms and strategies to manage dependence levels in the EV sector

Mechanisms to manage dependence	Strategies	Representative quotations	Interviewee
Buffering	Supply chain reconfiguration (inventories, new facilities)	<p><i>“Currently we hold 10 units of finished goods ... we cannot afford to hold buffer stock due to our low scale volumes”.</i></p> <p><i>“Higher demand gives us more buying power with the factory and volumes could be managed through larger consignments to ensure healthy inventory levels ... if only we have higher orders”.</i></p> <p><i>“We want to invest to a new facility ... we have high provisional order but are waiting for them to firm up”.</i></p>	<p>Director Motor-Co</p> <p>Assistant Sales Manager, Rotor-Co</p> <p>Director Motor-Co</p>
	Product/process reconfiguration (change of production process, integration of information technology)	<p><i>“We also have the flexibility to run a second shift when required... carrying excess capacity is expensive but necessary in volatile or expanding markets”.</i></p> <p><i>“We use subcontractor designs to minimise the dependence on specific skills”.</i></p> <p><i>“We use SAP to synchronise the process ...we see cloud based systems as a great opportunity to up-scale our production with low risk and at low costs ... particularly with smaller companies”.</i></p> <p><i>“ERP planning system to plan and schedule production and manage inventory is used ... they help to bridge company to company processes”.</i></p>	<p>Senior Key Account Manager, Thermosensor-Co</p> <p>Director, Motor-Co</p> <p>Director 1, Components-Co</p> <p>Director, Motor-Co</p>
Bridging	Strategic partnership or collaboration	<i>“We plan to develop closer ties with our suppliers to engage them in the early stages of design for manufacture and to allow them to grow with us”.</i>	Founder and Director, EV-Co
	Co-operation	<i>“We try, where possible, to develop long term contracts with agreed number of units with our customers ... which allows both companies to plan for the short and medium term”.</i>	Director 2, Components-Co

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Figure 1: Supply chain tiers for EV-Co’s City-Car drive train suppliers

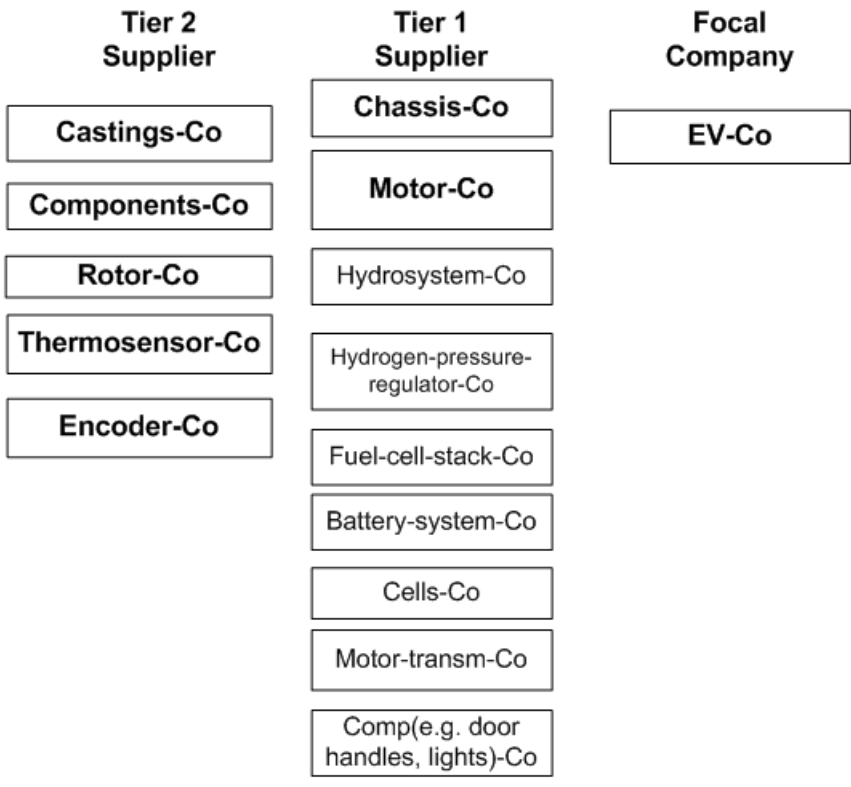


Figure 2: A ProOH model of dynamic systemic factors for forthcoming challenges in the automotive industry moving towards a post-ICE dominated era

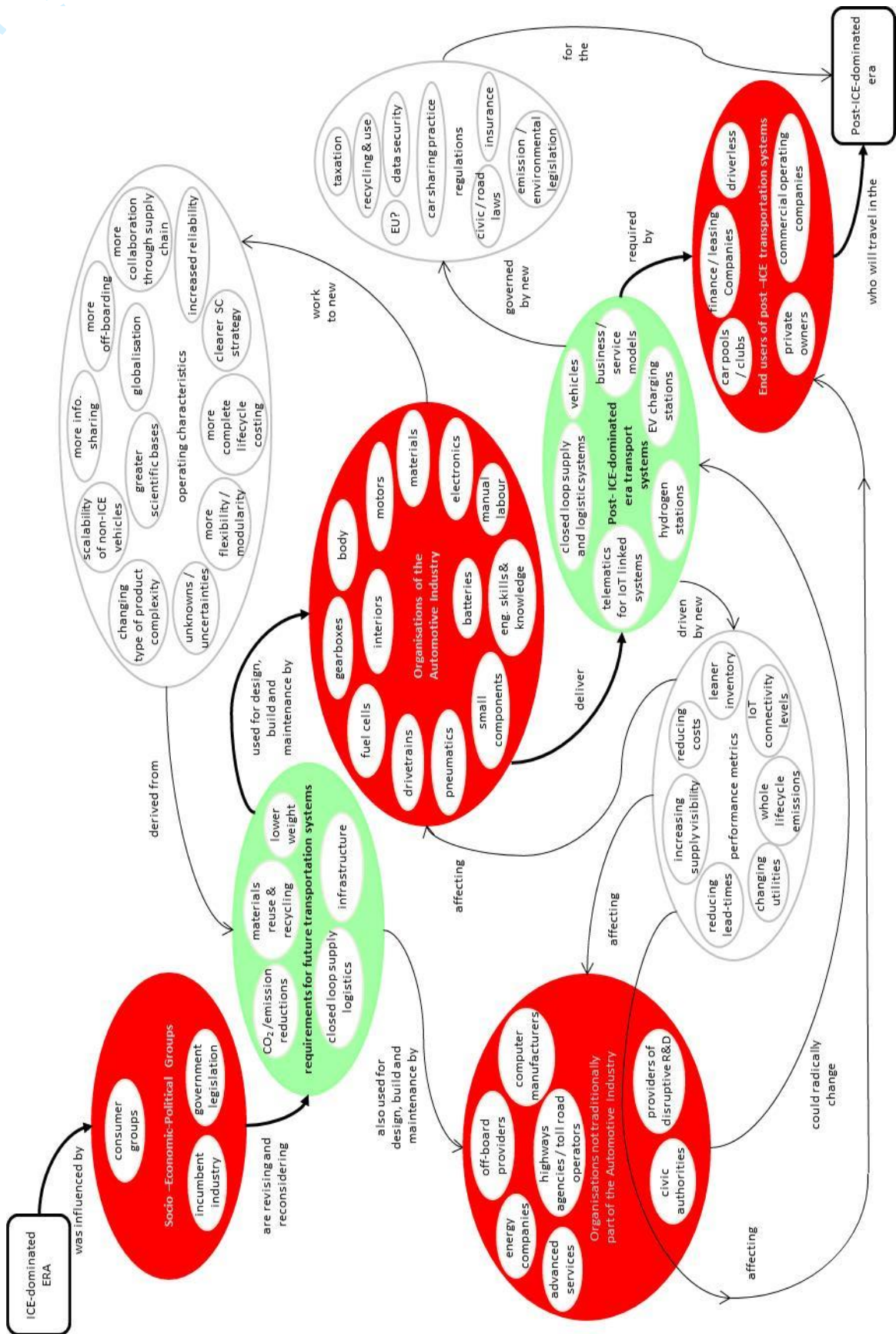


Figure 3: A summative conceptual framework for managing dependencies (as defined by RDT) in the EV Sector

