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Where is our delivery? The political and socio-technical roadblocks to decarbonising United Kingdom road freight

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Abstract

Road freight represents approximately 8.5% of UK carbon emissions and therefore must be abated if the UK government's objective to reach net zero carbon emissions by 2050 is to be achieved. While several technology options exist, it is commonly viewed as a hard-to-abate sector and progress to decarbonisation remains slow.

Whereas techno-economic aspects of the low carbon transition of road freight are well studied, socio-technical and political aspects are much less so. This is in contrast with substantial socio-technical literature focused on the transition of passenger vehicles. Symptomatic of this, there is little direct engagement in research with freight industry operators and participants. This study seeks to address these gaps by considering the views of these key actors through qualitative social science research.

Fifteen semi-structured interviews were undertaken with key stakeholders within the road freight industry. These revealed a range of themes and relevant issues which underline the complexity of this transition. Further analysis of the data revealed six overarching viewpoints that reflect the primary concerns of the expert interviewees. These viewpoints suggest that the challenges for the road freight transition are principally political and socio-technical, and opportunities are identified to further explore these through future research.

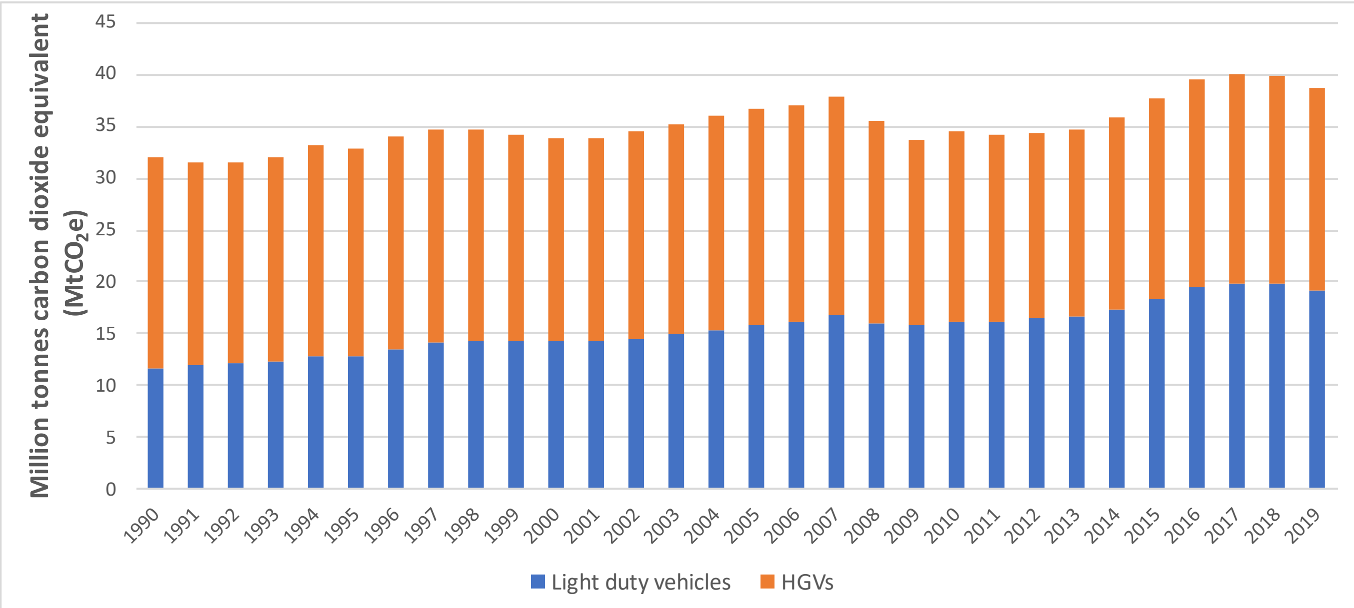
1. *Introduction*

1.1. The decarbonisation challenge

Radically reducing carbon emissions is one of the greatest challenges faced by humanity, in terms of both difficulty and severity of consequences if we fail. If low carbon transitions are not executed effectively, it is likely that a number of irreversible climatic and environmental tipping points will be passed this century [1]. The UK Government [2] has identified the serious consequences of climate change for the UK. Consequences will be worse still for countries with greater exposure to rising sea levels and extreme weather resulting in increased incidence of wildfire, drought, flooding and high temperatures.

Road freight represents approximately 8.5% of UK carbon emissions, which are split roughly equally between light vans and heavy goods vehicles (HGVs) [3,4]. Department for Business, Energy and Industrial Strategy data [3] identifies that emissions from road freight were approximately 39 million tonnes of CO_2 equivalent in 2019 (figure 1).

Figure 1: CO_2 emissions from UK road freight, per year



Source: Department for Business Energy & Industrial Strategy [3]

1.2. Features of the UK road freight sector

Road freight in the UK, as in many other countries, is highly fragmented, competitive and runs on low margins. It accounted for 77.8% of all goods moved in the UK in 2018 [4]. There were more than 44,500 road freight enterprises in the UK in 2015 with an average fleet size of 4.5 vehicles [4]. Only one operator, DHL, has a market share over 5%, and 93% of companies employ 10 or fewer people [5]. 2.54 million people work in the haulage and logistics industry, which is the UK's fifth largest employer [6]. The sector is characterised by high and increasing competition, and low barriers to entry. Retailers and wholesalers represent the largest share of a £28.6bn industry revenue [5].

Industry bodies such the Road Haulage Association [7], Logistics UK [8] and the Chartered Institute of Logistics and Transport [9] recognise that reducing emissions is a priority, and that current commitments to do this by 15% by 2025 are not sufficient.

The sector faces substantial challenges in addition to the requirement to reduce carbon emissions:

- Acute driver shortages due to EU exit, COVID restrictions, reduced test capacity and taxation changes [10]
- Longer term skills shortages and an aging workforce [11]
- Additional customs administration and border restrictions following EU exit [12]
- Urban congestion and traffic restrictions [13]
- Urban non-CO_2 emission restrictions and vehicle design regulations including Direct Vision, and resulting vehicle resale depreciation [14,15]
- Cashflow problems and the risk of business failures due to the COVID pandemic [16]

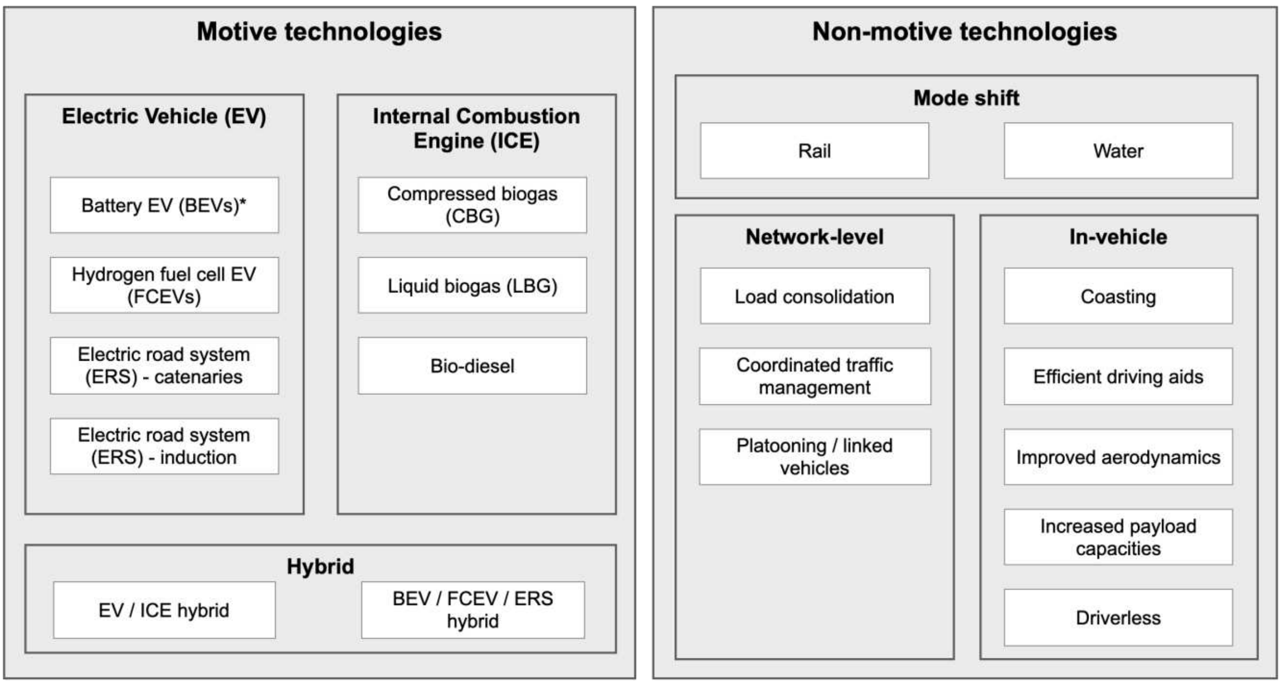
There is a popular view that growth in road freight has been driven by the increase in online shopping and home delivery. Research shows however that a greater driver is growth in the service economy and SME sectors [9], in turn driven by increased wealth and population growth.

1.3. Strategies for decarbonising road freight

The approaches for decarbonising freight can be broadly separated into motive and non-motive options (figure 2). Motive-technology decarbonisation options include battery electric vehicles (BEVs), hydrogen fuel cell electric vehicles (FCEVs), electric road systems (ERSs) and biofuels. Biofuels can be blended with fossil fuel and used in existing engines, and so present a potentially easier path to partial near-term decarbonisation. However, biofuel supply limitations mean these alone cannot deliver radical decarbonisation. Other motive technologies do provide this potential but have other dependencies and limitations (table 1).

There are also a range of non-motive solutions including mode shift, network-level technologies and in-vehicle technologies [9]. These have the potential to reduce, although not on their own eliminate, carbon emissions.

Figure 2: Opportunities to reduce carbon emissions from road freight (not exhaustive)



*: Including powered two-wheelers, freight / cargo bikes and Paxters

Sources: Authors' graphic based on [9,17,18,19]

Table 1: Motive technology options enabling full decarbonisation (not exhaustive)

Technology	Benefits	Dependencies and limitations
Battery electric vehicles	• Wide range of vehicle types, from powered 2-wheelers to trucks • High "fuel to wheel" efficiency • Zero emissions from vehicle • Public familiarity and acceptability • Relative technology maturity • Improving battery energy densities and charge times	• Range limitations – longer routes require facility to charge during rest or delivery stops • Need for grid strengthening for rapid charging of large numbers of vehicles • Need for charging infrastructure • Higher capacity batteries are large and heavy • Unanswered questions regarding battery material supply and end of life • Efficiency is temperature dependent
Hydrogen fuel cell electric vehicles	• Zero emissions from vehicle • Range and fuelling time comparable with diesel • Opportunity for zero carbon using "green" hydrogen produced from electrolysis of water • Opportunity for low carbon using "blue" hydrogen produced from natural gas with carbon capture and storage (CCS) • Opportunity for local hydrogen production, reducing distribution cost and impact	• Current high cost of fuel and vehicles • Majority of current supply is "grey" hydrogen, produced from natural gas without CCS, therefore not low carbon • Significant energy losses in production of hydrogen and (re)conversion to electricity in vehicle • Immature technology and significant engineering challenges to be resolved • High volume, low density and leak-prone – perceived fire/explosion risk • Requires major investment to build production, distribution and fuelling infrastructure
Electric road systems	• Established technology – e.g., catenaries currently used for rail • Very high "well to wheel" efficiency – minimises electricity generation requirement • Only small batteries required in vehicles for road sections not connected to ERS	• Requires major development of grid capacity • Major infrastructure investment for catenary or road induction network • Open questions on how vehicles will handle bridges, overtaking and other typical driving situations

Sources: Authors' summary based on: [4,7,9,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36]

The range of available technology solutions is both an opportunity and challenge. While providing multiple carbon reduction pathways, it also risks fragmenting resources and investment capital, and clouding policy- and decision-making. This further highlights the importance of the political and socio-technical aspects of the transition.

1.4. Research focus

This paper does not aim to add to the already substantial work considering the techno-economic benefits and limitations of different technologies. Instead, it draws on Cherp et al.'s [37] meta-theoretical framework that integrates techno-economic, political and socio-technical transition perspectives, arguing that each of these lenses is of significant importance in understanding how energy transitions proceed. Applying this framework to the case of road freight, we identify the patterning of existing literature and observe that there is limited literature which engages seriously with the socio-technical or political dimensions of the transition. A further implication of this patterning is that much of the existing work on road freight is based on quantitative modelling, with very little qualitative social science research. This paper therefore fills an important research gap by undertaking empirical research with actors who will necessarily be at the heart of the transition. The issues that emerge from the analysis reinforce that many of the challenges that may impede the transition of road freight are indeed political or socio-technical in nature.

The paper proceeds as follows: Firstly, via a literature review, it considers perspectives for understanding sustainability transitions and work focused specifically on the transition of road freight. Secondly, it provides new empirical data on how freight industry operators and participants perceive the challenges of decarbonisation. Finally, it draws conclusions and discusses opportunities for further research.

2. Literature review

2.1. Perspectives for understanding sustainability transitions.

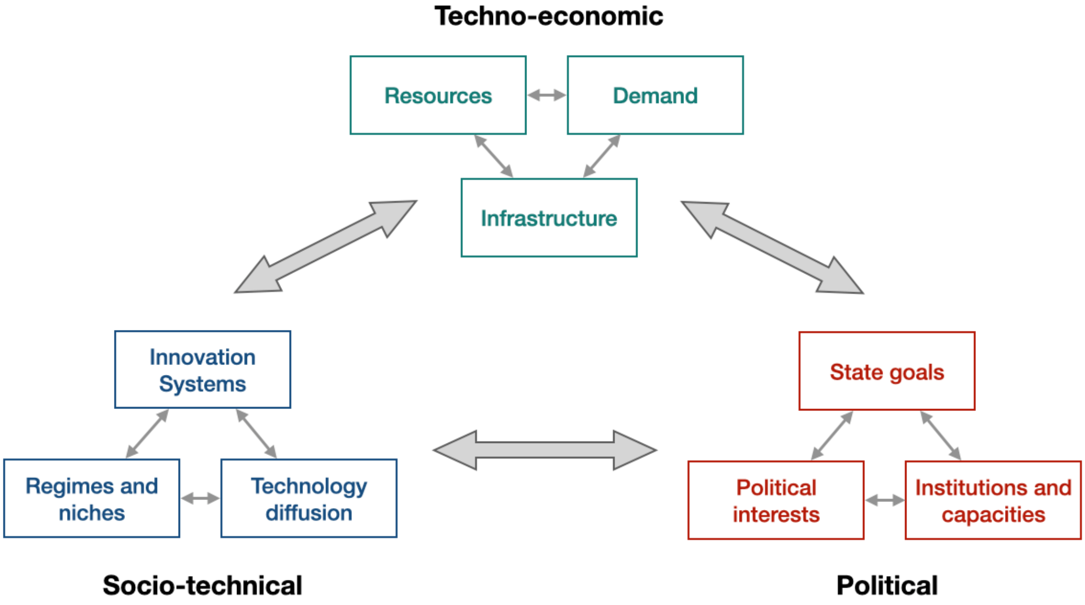
Sustainability transitions present particular challenges to policymakers and actors, and there is a rich and diverse literature that explores their dynamics. Köhler et al. [38] identify the following characteristics as key to these:

- Multi-dimensionality and co-evolution
- Multi-actor process
- Relation between stability and change
- Long-term process
- Open-endedness and uncertainty
- Values, contestation, and disagreement
- Normative directionality

The concept of carbon lock-in is central within literature. Unruh [39], Foxon [40] and Seto et al. [41] argue that co-evolution of technologies, institutions, business strategies and user practices, combined with path-dependant returns to scale, create market and policy failures that lock out carbon saving technologies and lock in carbon intensive energy systems. Foxon suggests that understanding causal relationships between these elements is necessary to define a path to a low carbon economy.

Reflecting the need to understand and address these interconnected dimensions of carbon lock-in, research into low carbon transitions spans social sciences, technology, engineering and economics. Each of these fields of knowledge provides valuable insights into the dynamics and processes of sustainability transitions. However, to some extent each strand is also partial, focusing on a particular set of issues, methods and aspects of the wider system under consideration. There are few examples in literature of these perspectives being brought together in inter-disciplinary assessments of sustainability transitions that consider the full range of factors necessary to design and execute these. An exception to this is Cherp et al. [37], who provide an integrative approach by distilling transition perspectives under three headings: techno-economic, socio-technical and political (figure 3).

Figure 3: Techno-economic, socio-technical and political perspectives



Source: Cherp et al. [37]

Each perspective is considered further below:

Socio-technical perspectives are delineated by a focus on knowledge, practices and networks associated with energy technologies [37]. Socio-technical systems literature often focuses on the role of innovation in driving transformations [42] and also considers the importance of regime change [43].

Socio-technical perspectives emphasise the co-evolutionary nature of technological innovation and the way in which new innovations emerge in relation to the incumbent, dominant socio-technical system. In the extreme, they can conclude that socio-technical change can only evolve through societal forces rather than be brought about by design. This is not the position adopted by this paper and frameworks are identified that are practically as well as conceptually helpful in envisioning and orchestrating change.

The Multi-Level Perspective (MLP) [44] is a widely-applied socio-technical transitions framework that considers regimes (the network of skills, consumer preferences, science, culture, investments and policy that has evolved alongside established technologies), niches (incubation spaces that protect new technologies from incumbent regimes) and landscape (the wider context that must destabilise the incumbent regime to create space for new technologies). MLP is intuitive and broadly applicable, but has attracted some critiques. Næss and Vogel [45] argue that it must be adapted beyond its focus on niche innovations to consider how to change the multi-segmented compositions of transport regimes. Whitmarsh [46] suggests that it must integrate natural, behavioural and political science insights, and clarify how behavioural–institutional change might occur. Svensson and Nikoleris [47] and Sorrell [48] challenge MLP from a critical realist perspective on the basis of:

- its simplified conception of social structure in terms of niches and regimes;
- the tendency to use theory as a heuristic device rather than for causal explanation;
- the ambition to develop an extremely versatile framework rather than testing competing explanations;
- the reliance upon single, historical case studies; and
- an insufficient use of comparative methods.

Other frameworks that focus on innovation niches include Technology Innovation Systems [49,50] and Strategic Niche Management [51,52].

Transition Management (TM) [38,53] takes a more directional approach that considers the requirements for successful governance of socio-technical transitions. Loorbach [53] identifies four types of necessary activity for transition governance: strategic, tactical, operational and reflexive:

1. Strategic: Vision development and the identification of potential transition pathways
2. Tactical: Specific plans for concrete routes and building of agendas and support coalitions for these routes
3. Operational: Includes innovation experiments, demonstration projects and implementation activities, aimed at learning-by-doing
4. Reflexive: Evaluation of projects and monitoring of progress leading to adjustments in visions and the articulation of best practices

By considering governance in socio-technical transitions, Loorbach implicitly assumes that these can be brought about by design. He tellingly states:

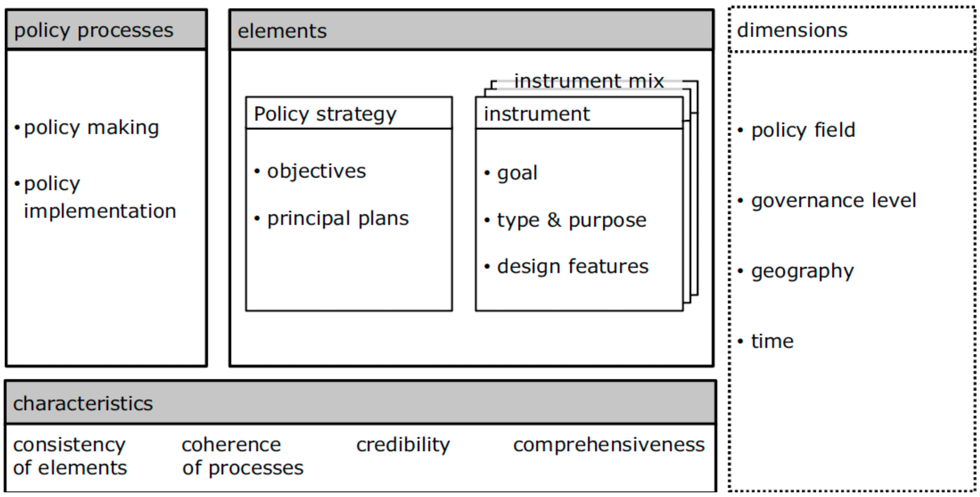
"There seems to be an increasing degree of consensus in governance research that both top-down steering by government ("the extent to which social change can be effected by government policies") and the liberal free market approach ("the extent to which social change can be brought about by market forces") are outmoded as effective management mechanisms to generate sustainable solutions at the societal level by themselves, but it is at the same time impossible to govern societal change without them."

Frantzeskaki et al. [54] observe that "Transition management includes a portfolio of tools that have a common objective to enable change in practices and structures directed towards sustainable development targets." Meadowcroft [55] describes the unavoidably political nature of the governance of sustainable development and discusses the contribution TM can make to this.

Political perspectives consider how policies affect the energy system. These include a wide variety of frameworks with different focuses.

Rogge and Reichardt [56] consider the importance of a system perspective in defining policy mixes. They identify policy mix building blocks including policy processes, elements, dimensions and characteristics (figure 4).

Figure 4: Policy mix building blocks

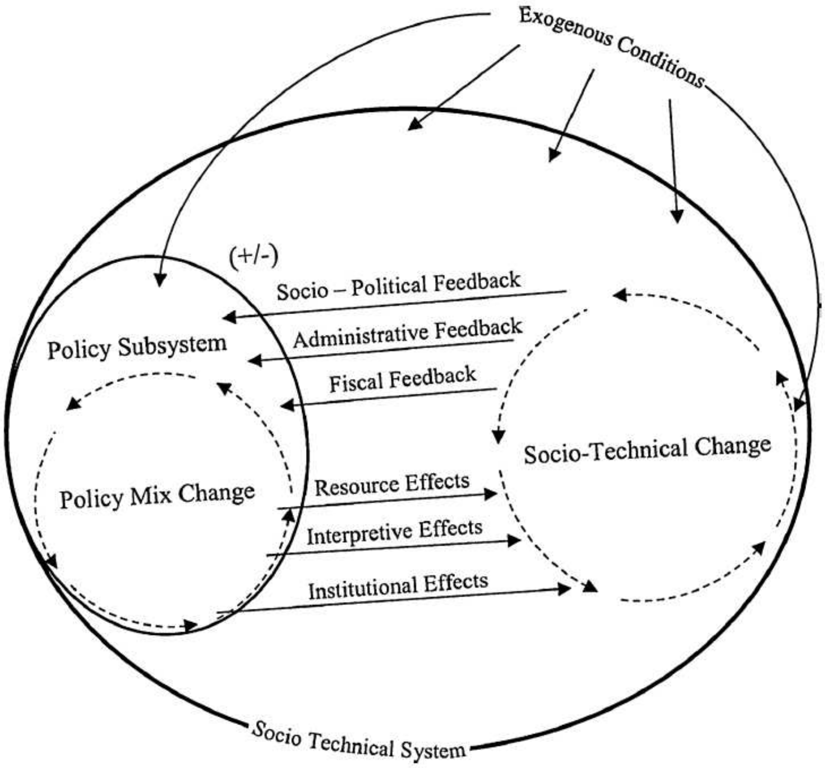


Source: Rogge and Reichardt [56]

Normann [57] contrasts case examples of securing state funding for offshore wind farm and CCS pilots in Norway. He demonstrates how different network structures facilitated different access to the policymaking process which secured very different levels of government support. Using a related rationale, Markard et al. [58] apply the concept of advocacy coalitions to map the beliefs of influencing groups in Swiss energy policy.

Edmondson et al. [59] consider the co-evolution of policy mixes and socio-technical systems, and the feedback mechanisms linking these (figure 5). They identify resource, interpretive and institutional effects of policy mix on socio-technical change; and socio-political, fiscal and administrative feedback mechanisms that in turn influence policy. These mechanisms are relevant to the transition of road freight and provide a helpful basis to consider how policy must both drive and respond to socio-technical change.

Figure 5: Interface of policy and socio-technical regimes



Source: Edmondson et al. [59]

Finally, ***Techno-economic perspectives*** consider "energy systems defined by energy flows, conversion processes and uses coordinated through energy markets" [37]. They use Integrated Assessment Models to model alternative energy scenarios and provide quantification of the economic and carbon reduction impact of different policies. They do not in general consider whether and under what conditions policymakers will implement policies.

We contend that each of these three perspectives is critical for understanding the overall dynamics of any given transition, including that of road freight, and thus we turn to review the existing work considering this particular challenge.

2.2. *Research on road freight transport transitions*

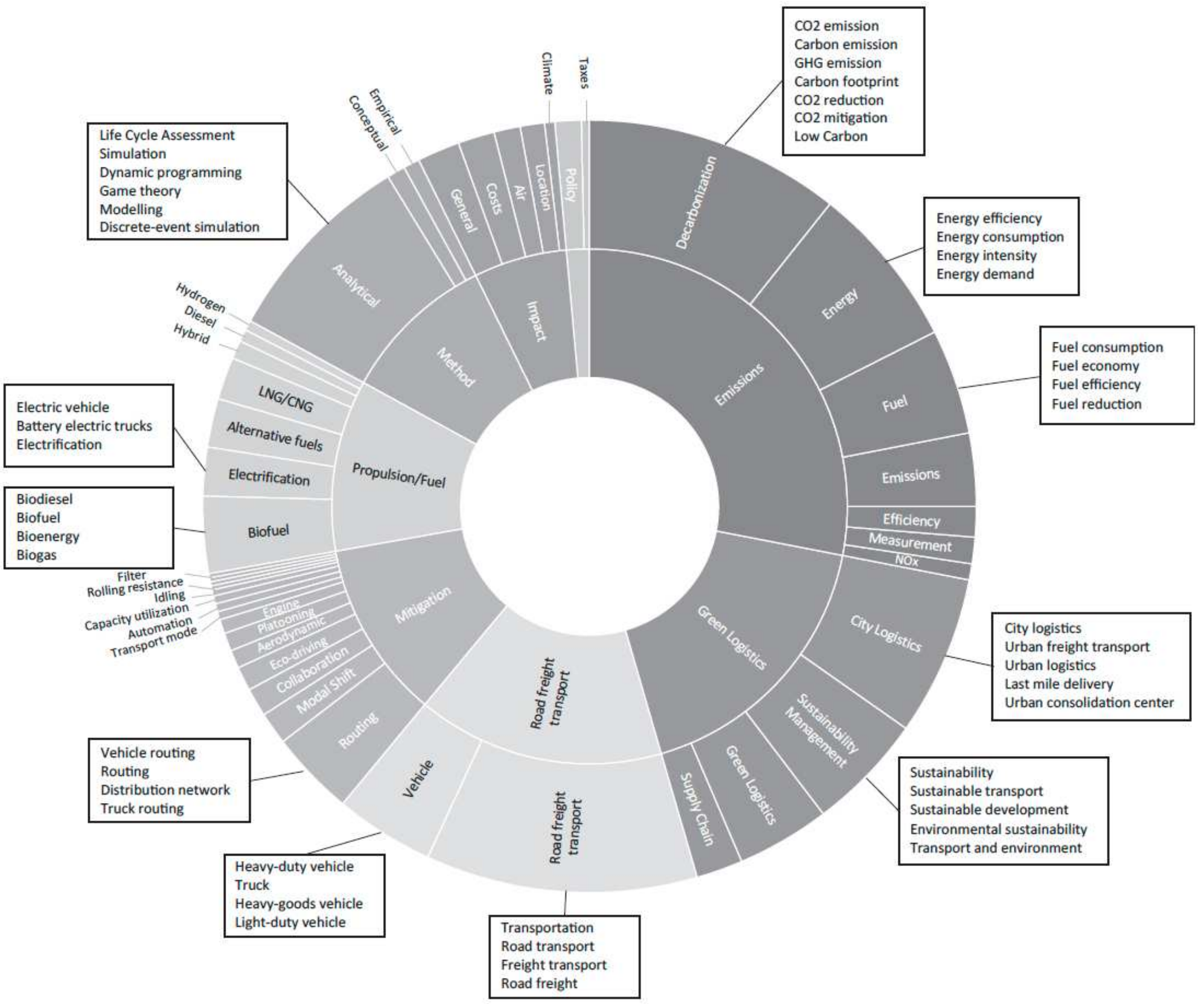
There is considerable techno-economic literature focused on the road freight transition, for example Nicolaides et al. [31], Cebon [27] and Schulte and Ny [26]. Greening et al. [19] provide a thorough analysis of different motive and non-motive technology opportunities. There is also extensive grey literature from NGO's [24,28,30,34,60], transport industry associations [7,9,25] and government advisory bodies [17,61]. The dominance of techno-economic literature is confirmed in an extensive bibliographic analysis by Meyer [62] (figure 6).

While, no examples of socio-technical or political studies of the low carbon transition of UK road freight were identified, TM theory has been adopted in studies of decarbonising Indian road freight [63,64] and MLP has been applied to the transition of passenger transport [65,66,67]. The latter concludes that, unless incumbent transportation regimes are substantially destabilised by exogenous factors, a comprehensive portfolio of governance is required to address transition barriers. Wider transportation literature also draws on socio-technical or political perspectives, including studies of UK transport policy shifts [68] and other aspects of low carbon transport transitions [69].

The dominance of techno-economic studies on this topic means that research to date has been underpinned by quantitative modelling [18, 25, 26, 30]. Socio-technical and political studies can also be based on quantitative methods [70], but are often undertaken using qualitative and interpretative methods. Examples of qualitative research can be found in international road freight literature [71], but very few focus explicitly on the low carbon transition of road freight (an exception is Björner Brauer and Khan's [72] study of the use of biogas for road freight in Sweden).

The value of qualitative approaches is the insights they can provide into important transition dynamics, including the role of key actors within the system under consideration. While they have been widely adopted in the exploration of other low carbon transportation transitions [73,74], it is notable that this is not the case for the UK road freight transition. Specifically, the perspective of road freight operators seems little considered in literature. Given that operators must ultimately make the investments and operational changes required to execute the transition, and are those most affected by it, this is a significant gap. This paper seeks to explore how UK freight operators and experts perceive the road freight transition, and the implications of this on our understanding of key challenges.

Figure 6: Road freight transition study bibliographic keyword analysis



Source: Meyer [62]

3. *Research*

3.1. Research method and design

The study targeted senior industry operators and experts to provide diverse authoritative perspectives. Interviewees were identified through a combination of purposive cross-sectional sampling and snowballing. Interviewees were targeted who provided one or more of:

- Senior operational road freight experience
- Road freight industry insight and representation
- Supply chain and logistics expertise
- Insight into transport and/or environmental policymaking

The fifteen interviewees were:

- Chief Customer Officer, major international road freight provider
- Managing Partner, private equity owner of large UK road freight provider
- Country Manager, international logistics services provider
- CEO, Chartered Institute of Logistics and Transport
- Head of Policy, Road Haulage Association (RHA)

- Acting Head of Policy, Logistics UK
- Global Head of Supply Chain, major electronic controls manufacturer
- Senior Supply Chain Partner, global consultancy
- Head of Fourth Party Logistics, major global shipping company
- Ex-Supply Chain Director, large consumer products company
- Policy Analyst, DEFRA
- Chairman, Neutral Supply Chain
- Managing Director, Neutral Supply Chain
- Ex-Supply Chain Partner, global consultancy
- Senior independent logistics and supply chain consultant

Given the focus of the study and the depth of experience and insight of participants, a qualitative research method was chosen. Qualitative research places emphasis on the study of phenomena from the perspective of insiders and recognises that research designs must be open to change during studies [75]. It also provided an opportunity to gain insights on questions that emerged during the research.

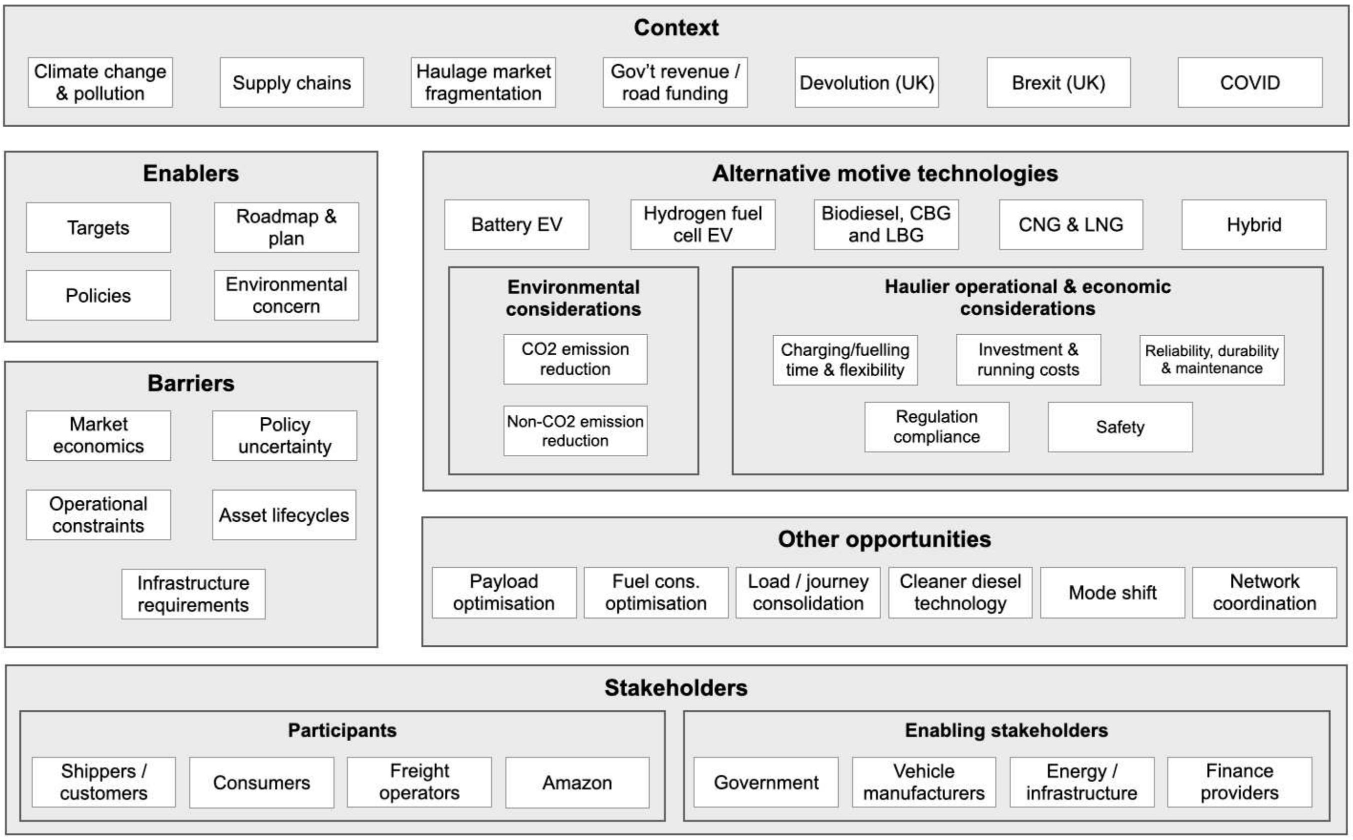
An interview guide (table 2) provided a discussion framework and defined the topic areas, but interviewees were not constrained in their replies. Questions were adapted as appropriate and useful lines of discussion were allowed to develop. Questions were also modified during the study as insight was gained into specific opportunities and challenges.

Table 2: Interview guide

Introduction	• Introduction (if required) to project and interviewer • Confirm permission for interview to be recorded • Confirm (if required) role, background and main responsibilities
Views on target to achieve net-zero carbon emissions by 2050	• Confirm if aware of government CO_2 reduction targets • Are they necessary? Why? • Are they achievable? Why? • What are the main implications for the road freight sector?
Best technology options to reduce CO_2 emissions from road freight	• Battery? In which applications? • Hydrogen fuel cells? In which applications? • Other? In which applications? • Are there any interesting initiatives they are aware of or engaged in? • What do they think road freight will look like in 2050?
Barriers to and pre-requisites for the transition of UK road freight transport	• What are the barriers to achieving government goals? • What would need to change for these barriers to be overcome? • What impacts will COVID have on progress to low / no carbon emission vehicles?
Requirements created by barriers and pre-requisites	• Who needs to do what for these changes to happen? • Of these, which are the most critical?
Wrap up	• Have we covered all the important points? • Is there anything they would like to add? • Thank you and confirm and next steps

The interviews were transcribed and then coded using NVivo software according to themes which were identified and refined during the course of the analysis. Themes were grouped within theme categories (figure 7). No starting assumption was made in interviews regarding preferred solutions. This led to discussions which covered the full range of available motive and non-motive opportunities. Views regarding transition roles and impacts were categorised by stakeholder type. Participant stakeholders were defined as operating within the value chains of the goods being transported and enabling stakeholders as operating outside of value chains but nevertheless important as transition influencers and actors. Although grounded theory was not adopted in this research, coding was, similar to grounded theory, developed during the course of the study and this process formed a key part of the synthesis of findings.

Figure 7: Interview coding themes and theme categories



Source: Synthesis of transcribed interviews

3.2. Findings

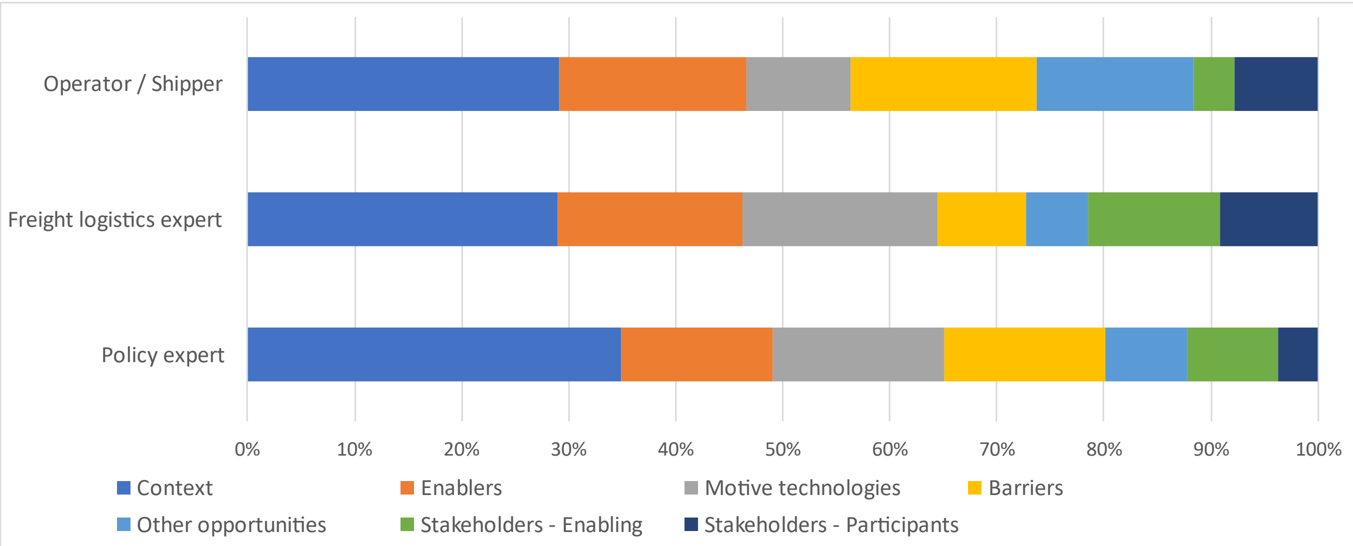
In total, 157 distinct opinions and 330 opinion-participant combinations were coded from transcribed interviews and assigned to themes. Significant observations are:

- Context was the largest theme category in terms of opinion-participant combinations. Unsurprisingly, given the timing of the study and a specific question on COVID, COVID was the context theme with the greatest number of opinion-participant combinations
- Other frequently mentioned themes within context were climate change and pollution, supply chain, UK devolution and haulage fragmentation
- Within enablers, there was consensus that targets provide a positive motivation for change. Policy was also highlighted as an important enabler, but in general with the view that existing policy was not sufficient to bring about the transition
- Four principal barriers were identified: policy uncertainty, market economics, operational constraints and asset lifecycles
- Within other opportunities, load / journey consolidation, cleaner diesel technology and fuel consumption optimisation were the most frequently mentioned
- Government was identified as by a substantial margin the most important enabling stakeholder

The 15 participants were classified as operator / shipper (5 participants), freight logistics expert (6 participants) and policy expert (4 participants). Figure 8 shows the mix of opinion-participant combinations by theme category for each of these groups. Salient observations are:

- Operator / shippers were the least focused on motive technologies and the most focused on barriers and other opportunities
- Freight logistics experts were the most focused on stakeholders and motive technologies, and the least focused on barriers and other opportunities
- Policy experts were the most focused on context

Figure 8: Theme category mix of opinion-participant combinations per participant group



Source: Coded interview transcripts

Interestingly, while there were different opinions raised by different participants, there were no examples of clearly conflicting opinions. It is possible this is in part because the interview questions did not require participants to take either-or positions (e.g., "What is the most promising motive-technology?"). It does nevertheless suggest a significant degree of common ground between participants.

Of the 157 distinct opinions coded, 61 were expressed by at least 2 interviewees. 57 of these aligned to 6 overarching viewpoints (see appendix table 1):

1. Government leadership is necessary
2. It must work economically and operationally
3. Policy uncertainty is a significant barrier
4. Non-motive technology opportunities should also be pursued
5. Hydrogen may not be viable for road freight in the near term
6. Responsibility for charging deployment and grid upgrade must be clarified

Together these 57 opinions represent 180 or 55% of the total coded 330 opinion–participant combinations and as such can be considered as the consensus findings from the study. The remainder of this section considers each of the overarching viewpoints in turn, distilling key insights from interviews for each. Illustrative interviewee quotes are provided; respecting confidentiality commitments, quotes are attributed to participant groups rather than individual participants.

3.2.1. Government leadership is necessary

There was strong consensus that government must drive the transition through regulation and economic policy, and must incentivise, or potentially directly fund, the deployment of necessary infrastructure. Government was also seen as playing a pivotal role in making technology choices and defining standards:

"It's 10 years, a huge evolution. The ability to scale at pace. I'd say a really concerted effort [is required] at a government regulatory level to drive a particular practice or code, and an infrastructure that can support it." (Operator / shipper)

An important part of government leadership was seen as the creation of a national transition roadmap, in collaboration with industry:

"If we are going to get to the 2040 deadline for HGVs, we need to understand what the steppingstones are and what the fuel is and the technologies that we need to move towards." (Policy expert)

Bold carbon reduction targets and the proposed banning of diesel vehicles were seen as necessary and helpful in driving action, but not sufficient on their own to deliver a successful transition. Both regulation and incentivisation were seen as important:

"It comes back to incentivisation, and it is bottom line business. I think there's only two ways to do that, it is grant aiding it or tax support." (Operator / shipper)

"You have got to pass regulation into the user community, the company community that they have to use that mode of transport. Otherwise, the industry just simply cannot change." (Operator / shipper)

Whilst supportive of the overall goal of a low carbon transition, interviewees expressed a lack of confidence in the achievability the UK government's target to reach net zero carbon by 2050. Underpinning this was a view that current policies to achieve carbon reduction were disconnected, did not demonstrate a good understanding of the freight sector, and would not create the conditions necessary to drive a large-scale transition:

"We have a government and policymakers who, well frankly, don't seem to be engaging in evidence-based policy. It is more like faith-based policy making." (Policy expert)

Likewise, future road funding was seen as a critical unanswered question:

"There is this big question around the funding of the roads that hasn't yet been tackled. There's quite an aversion to road charging. We think that's inevitable, and we really think there's no option but to go for that particular solution." (Policy expert)

3.2.2. It must work economically and operationally

The highly fragmented and price competitive nature of the road freight sector was seen as a key inhibitor to the low carbon transition of road freight:

"If you come along and say, you've got to make a significant capital investment, with significant depreciation costs over the next 10 years, that's really going to be strongly resisted by an industry that is so fragmented, competes significantly on price and the margins are so small." (Freight logistics expert)

“I think they [operators] will respond to legislation, but mostly to profitability. At the end of the day, because margins are so slim in that industry anyway, it’s so hard to make money, that has to be their driver first and foremost.” (Freight logistics expert)

In general, operators were supportive of the transition if it is economically and operationally feasible. Market economics and operational constraints were however identified as significant limiting factors:

“I think bluntly, and I don't think this is any great revelation, it's got to work economically because transport has the most transparent cost structure of any industry.” (Freight logistics expert)

“What the operator is interested in is, does it give me the capacity? Does it give me the load bearing that I need? Can I make my routes and plan my network and my drop offs in the same way that I always did for the same economic return?” (Operator / shipper)

The opportunity for freight operators to take action independently of shippers/customers was also seen as being heavily constrained:

“It’s very difficult for the very fragmented segment, which is haulage, to drive the change.” (Operator / shipper)

Amazon was noted as being highly influential in the setting of consumer expectations and supply chain practices:

“You cannot compete with Amazon. They're losing money on every delivery. But they will be the world's most valuable company. They've seen a phenomenal growth and they have unlimited capital.” (Operator / shipper)

There was a strong sense that freight operators in general wanted to do the right thing regarding the environment, but felt they lacked the agency to implement radical carbon reduction opportunities without wider support. In particular, shippers (freight customers) were seen as being key in driving the transition due to their more influential position in the value chain.

3.2.3. Policy uncertainty is a significant barrier

Another strong theme was that policy uncertainty is a major barrier to operators making the investment decisions necessary for a low carbon transition:

“We used to say politics worked in five-year cycles, it’s not even five years these days. But every time you think you know where you are, suddenly there’s a change in leadership, the politics changes and the goal posts then change.” (Policy expert)

The devolution of transport and environmental policymaking to local authorities was seen as a particular challenge as it has resulted in different requirements being implemented in different cities:

“The approach to [Clean Air Zones] is haphazard, and it’s left to local authorities to do their own thing ... that's ridiculous really, because most of the big vehicle operators in the UK ... operate nationally. To have different standards in a country this small is just stupid to be honest.” (Operator / shipper)

Recent policies were seen as not having sufficiently considered asset lifecycles and the impact of policies on vehicle resale values. Confidence that unforeseen policy changes will not adversely affect economic return on investments is necessary if operators are going to make the required investments in new vehicles and equipment:

“You might have a vehicle that you planned to sweat the asset for five years and now you can only get four or three years out of it, and then the residual value has dropped as well.” (Policy expert)

It was also pointed out that it is difficult, in the absence of a national roadmap, to know if investment decisions will be supported by infrastructure development and will not be undermined by future policy changes.

3.2.4. Non-motive technology opportunities should also be pursued

A range of opportunities are available that are not dependent on motive technology transition. These can be grouped under three main headings: mode shift, in-vehicle technologies and network-level technologies (figure 2). They cannot provide the radical reduction or elimination of emissions that some motive technology solutions can, but they have the potential to deliver significant incremental reductions [9]. Comments highlighted that it is not the lack of viable technologies that prevents these being more widely adopted. It is instead the need to achieve a critical mass of adoption, lack of clarity of political direction and the absence of necessary physical and information infrastructure.

Mode shift

While mode shift is attractive where the option is available, rail and water can only replace a proportion of road freight. It would also require substantial investments in cross-docking and network capacity to support a large-scale transition:

"For years rail freight frankly has not been taken up in this country in the way it should have been. Here is a form of transport with an ever-ready supply of electricity available to it, and you would think that was the best way of moving stuff around." (Freight logistics expert)

"One of the things that our ports and maritime people are talking about is the use of port facilities in urban areas where there is water access." (Policy expert)

Local planning and land development priorities were however seen as a barrier to developing the facilities required to support large scale mode shift:

"In London, if you had some land, unless London authorities actually stipulated that was purely for industrial use, any developer purchasing that land faced with the choice of putting in a concrete slab or a block of penthouse flats, they're going to go for the penthouse flats." (Policy expert)

In-vehicle technologies

In-vehicle technologies were seen as providing significant opportunities to increase fuel efficiency through route and driving style optimisation, coasting, platooning, improved aerodynamics, regenerative breaking, increased load capacity and electrification of ancillary vehicle equipment. They provide the potential for both cost and emissions reduction, and some of these can be implemented by individual operators.

If driverless technologies became technically feasible and socially acceptable, it would remove the need to coordinate fuelling stops and deliveries with driver rest periods [9]. It is however noted that current driverless technology, while possibly getting close to handling main roads and motorways, is as yet some way from being able to cope with the tight manoeuvring that is often required at the start and end of journeys.

Network-level technologies

Further opportunities still were seen if vehicle scheduling and routing could be coordinated at a network level:

"On average, every commercial vehicle on the road is only about 30 to 40% full." (Freight logistics expert)

"It requires a fundamental change in the way logistics operates and in supply chain models themselves." (Policy expert)

"We certainly believe that collaborative models will need to come to the fore to reduce empty running on vehicles and to deliver efficiencies there." (Policy expert)

Unlike in-vehicle solutions, network-level solutions require information technologies and infrastructure to be established at a national or regional level. These data hubs, or "physical internet" [76], which coordinate scheduling, loading and/or routing of vehicles could deliver substantial cost, emission and congestion reductions. These would however need to be sponsored by relevant national, regional and local authorities.

Collaboration between operators, for example using out-of-town centres to connect line haul to consolidated local delivery networks, also represents a substantial opportunity. Interviewees believed this would require changes to regulation that currently prohibits such collaboration on the basis that it is anti-competitive.

3.2.5. Hydrogen may not be viable for road freight in the near term

While recognising the theoretical benefits, interviewees were either agnostic or sceptical regarding hydrogen as a near term option to reduce emissions from freight transport. A number of reasons were cited for this, including the very large renewable electricity generation capacity required, low gas density and high propensity to leakage, current production cost and technology immaturity:

"I'm quite sceptical about hydrogen being the solution. I think it could be for some specific applications, but I think we're a long way off seeing a hydrogen fuel supply infrastructure and technology that will support what we do now with diesel." (Freight logistics expert)

"Once you get the hydrogen into the vehicle then yes, it comes out clean. It's the production which goes behind the hydrogen, the well to wheel process, which I think is the sticking point." (Policy expert)

"You do actually have to think about what the supply chain implications are of providing and generating that, because it costs an enormous amount of energy to produce the quantities of hydrogen that you'd want." (Freight logistics expert)

"The infrastructure behind hydrogen is nowhere in comparison to electric, so you would say that the electrical infrastructure is likely to get first to critical mass." (Freight logistics expert)

"Hydrogen itself is an expensive technology and a difficult one to control because hydrogen as we know is the smallest molecule in in the periodic table, which means it's very easy to leak. Secondly, it's dangerous." (Freight logistics expert)

Energy companies are seen as strong drivers of the hydrogen lobby, as they can continue to produce hydrogen from hydrocarbons pending the availability of sufficient renewable generation capacity:

"The hydrogen lobby is very strong through the oil companies. It could be because of the gas in the fields." (Policy expert)

"And you look at the oil majors and you say, if they don't invest in the future, they have no future by 2050. It's as simple as that. So, they've got an existential issue to deal with." (Freight logistics expert)

Within techno-economic literature, there is significant divergence of opinion on the viability of hydrogen as a motive technology. The National Infrastructure Commission [17] identifies hydrogen and battery electric as the most viable alternatives to diesel. The FCH [28] states: *"in transport, hydrogen is the most promising decarbonization option for trucks"; and "hydrogen refuelling infrastructure … only requires about one tenth of the space in cities and along highways compared to fast charging".* Cebon [33] however argues that that it would take approximately 18,000km^2 of wind turbines to provide enough hydrogen to fuel UK HGVs versus 5,300 km^2 if the electricity was supplied via an ERS, due to large energy losses in converting electricity (or methane with carbon capture and storage) to hydrogen and then hydrogen to electricity via on-board fuel cells.

3.2.6. Responsibility for charging deployment and grid upgrade must be clarified

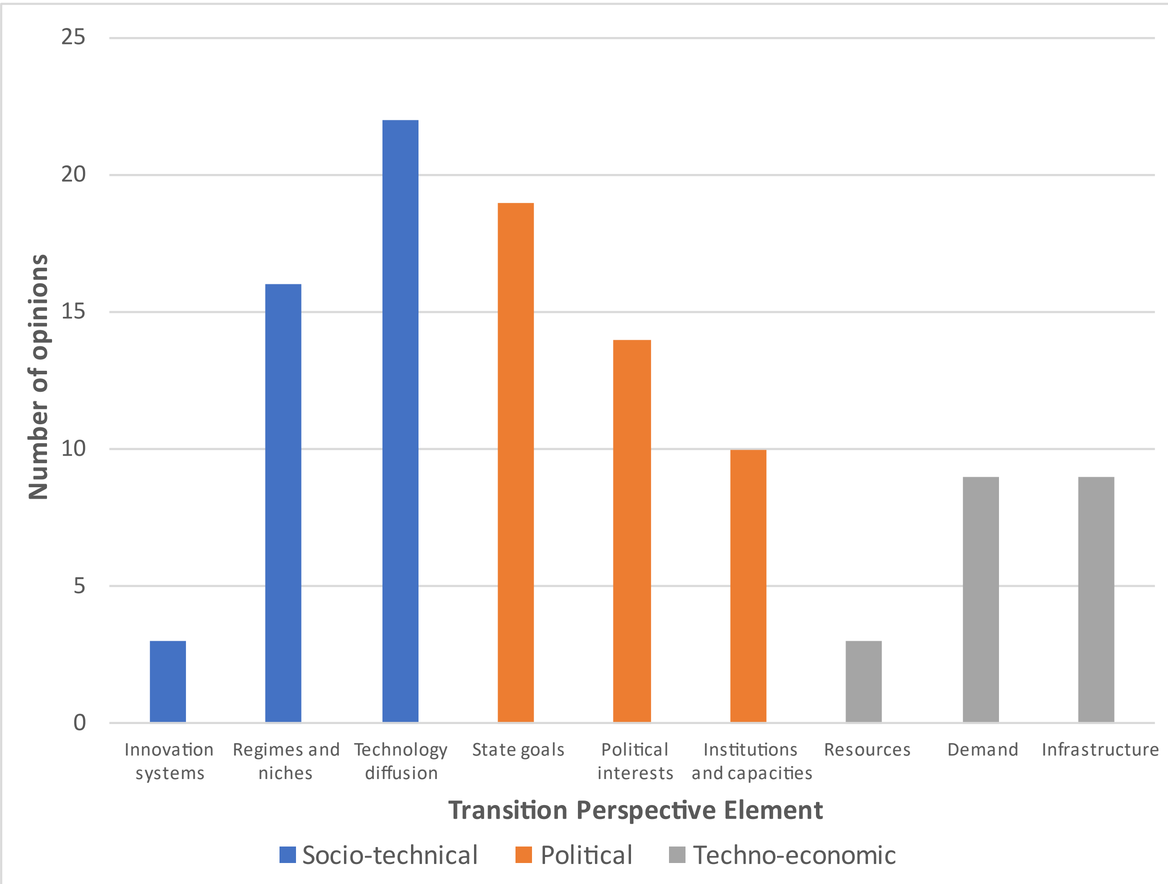
The slow progress of and lack of clarity of responsibility for charging infrastructure deployment were highlighted as key issues:

"There's a good example in the Oxford Bus Company, who have gone all electric on many of their routes. But they have then found that their electrical infrastructure supplied to their bus depot was insufficient for the charging, so they put a hybrid diesel generator solution in order to charge the buses." (Freight logistics expert)

3.3. Alignment of opinions to transition perspective elements

Each of the 57 opinions aligned to overarching viewpoints were mapped to the transition perspective elements defined by Cherp et al. [37] in figure 3. The number of opinions mapped to each element is shown in figure 9 (see appendix table 2 for full mapping). This analysis confirms that, while techno-economic factors are seen as important by interviewees, socio-technical and political factors are potentially even more so.

Figure 9: Number of opinions* mapped to each transition perspective element



*: of those aligned to overarching viewpoints and included in table 3

Source: Synthesis of coded interview transcripts (for full mapping see Appendix table 4)

4. Discussion and conclusion

This study has sought to address the lack of qualitative social science research into the low carbon transition of road freight and the lack of literature focused on socio-technical and political aspects of the transition. While qualitative social science research is well developed for consumer-centred sustainability transitions, such as that of passenger vehicles, it appears much less so for transitions where the primary actors are businesses. By engaging with industry actors and experts, a detailed understanding has been gained of transition challenges and opportunities facing the road haulage industry, including six overarching viewpoints that were shared by multiple participants in the research. Each of these viewpoints is considered as a highly important issue for which further work is required and to which a range of disciplines and methods could contribute important findings.

Further qualitative research with businesses involved in the road freight industry could provide important insights into the road freight transition, not least into the implementation of both motive and non-motive technology options. Work on public engagement in sustainability transitions has found that adoption of new technologies is rarely passive or predictable [77]; this needs to be better understood in the context of the road freight transition. Such research would result in greater engagement with firms from transition focused scholars, as advocated by Köhler et al. [38]. In addition, the explicit targeting of experts, policymakers and decision-makers seems an under-developed opportunity. Businesspeople and policymakers can both be considered as important forms of 'intermediary' within the road freight transition, who are likely to play critical roles in the way that it unfolds [78,79]. There would be substantial benefit in extending the application of social science research methods to engage with these important actors.

The breadth of the insights generated in this research also reinforces the notion that a multi-perspective approach is necessary if we are to fully comprehend the complexity of the road freight transition. There are substantial opportunities for further research adopting the different theoretical perspectives previously discussed, with some key examples outlined below.

4.1.1. Socio-technical perspective of the road freight transition

The literature review identified that a significant proportion of socio-technical literature focuses on innovation systems. The findings of this study suggest that a lack of effective innovation is not the primary socio-technical challenge for the UK road freight transition; it can in fact be argued that there is a broad established base of motive and non-motive technology innovation for road freight. However, this research highlights considerable uncertainty in how the actual dynamics of the transition will unfold, and the most important factors that will shape it. Future work using socio-technical approaches could be undertaken to explore the nature of the freight regime and the extent to which incumbency and lock-in are likely to be a barrier to the low carbon freight transition (e.g. see Klitkou et al. [80] for similar work on passenger vehicles). Similarly, work could explore transition uncertainty through the development of alternative transition pathways, including the consideration of how the dynamics of this transition interact with other aspects of the wider energy transition (e.g. Damman et al. [81]). This is of particular relevance to road freight where there are a number of competing technological options and niches.

Whilst it is important to explore the possible dynamics of the road freight transition, it is also necessary to consider how the transition might be purposively steered. TM literature considers the challenges of regime displacement and technology diffusion; and adopts a normative approach to orchestrating and governing sustainability transitions. While no applications of TM to UK road freight have been identified, there would seem to be a substantial opportunity to build on TM research conducted for other sustainability transitions and in other countries, as well as consider other approaches to the governance of socio-technical systems [82].

4.1.2. Political perspective of the road freight transition

Perhaps even more so than the socio-technical perspective, this study has identified that the political perspective is of critical importance to the decarbonisation of road freight. Government was seen by participants as playing a key role in defining technology standards and a roadmap, supporting the provision of necessary infrastructure, removing regulatory and planning obstacles, and more strongly dis-incentivising fossil fuel usage. This view concurs with Johnstone and Newell's [83] argument that the state has been somewhat under-theorised in research on sustainability transitions. Policy uncertainty was identified as a major inhibitor to the transition. Disconnected transport and environmental policymaking across devolved authorities and a historic lack of consideration of asset lifecycles were cited as significant challenges. Fiscal dependency on fossil fuels and the role of oil companies were also mentioned as important factors.

In addition, the high fragmentation of the road freight sector means that industry networks and institutions are even more influential than in other sectors. The role of these in defining and facilitating transition delivery appears yet to be explored in literature. The literature review identified the work of Normann [57] and Markard et al. [58], who consider the roles of networks and advocacy coalitions in affecting national energy transitions. There would seem to be significant value in applying this thinking to the transition of road freight. Another opportunity is to use frameworks developed by Rogge and Reichardt [56] and Edmondson et al. [59], also identified in the literature review, to evaluate the effectiveness of transition policy mixes and the interaction between these and socio-technical systems. Bearing in mind that to meet carbon targets, the road freight transition may need to be as disruptive as the passenger vehicle transition (see Brand et al. [70]), the exploration of future policy mixes seems likely to need to include instruments which destabilise the existing regime as well as supporting new technologies [43]. Again, this underlines the inherently political nature of the freight transition.

4.1.3. An integrative, directional approach

More than anything else, this study has confirmed the high degree of interconnectedness between techno-economic, socio-technical and political perspectives of sustainability transitions. While work within a single perspective can be highly valuable, policy- and decision-makers need to consider all three. Research that bridges across perspectives therefore has a greater potential to not just better understand transitions, but also to help actors bring these about. Cherp et al. [37] provide an excellent foundation for this multi-perspective approach in their work focused on national energy transitions. There is a great opportunity to extend this to other sustainability transitions including that of road freight.

One of the consequences of considering all three perspectives is accepting that the most feasible path may not be the most techno-economically efficient. A path that is economically or technically sub-optimal may be a price worth paying if it is able to gain the political and social support necessary to be executed. However, a politically expedient path that represents such a large techno-economic or socio-technical compromise that it jeopardises achieving the required environmental or human welfare outcomes should not be selected. An integrative research approach could help policy- and decision-makers evaluate these complex yet critical trade-offs.

5. *Appendix*

Table 1: Opinions expressed by at least 2 participants, aligned to overarching viewpoints

	Overarching viewpoints*					
	1	**2**	**3**	**4**	**5**	**6**
Alternative Motive Technologies						
Difficulty managing charging at driver homes		✓				✓
Open questions on charging patterns and grid loading		✓				✓
Major grid upgrades required	✓					✓
BEV not suitable for line haul due to battery size/weight and charging		✓				
Biomass supply limitations mean cannot be a large part of the solution		✓				
Hydrogen only as clean as production - now mainly from methane					✓	
Current cost of hydrogen very high		✓			✓	
Concerns regarding safety & required strength of tank					✓	
Major engineering challenges on hydrogen safe / economic dist'n		✓			✓	
Green hydrogen prod'n inefficient - very large renewable generation req'd		✓			✓	
Hydrogen provides range without payload compromise of battery		✓				
Hydrogen provides short fuelling times		✓				
Barriers						
Uncertainty within vehicle lifecycle creates investment risk	✓		✓			
History of policy introduced with insufficient notice for asset lifecycles	✓		✓			
Necessary charging infrastructure is not being developed	✓		✓			✓
Low diesel prices reduce incentive to switch	✓	✓				
Market will not accept price increases for sustainable transport	✓	✓				
Haulage market is highly efficient and very cost / price driven		✓				
Charging / fuelling must cover network and align with driver stops		✓				
Need to consider reliability and impact on maintenance cycle		✓				
Need to provide required load bearing and range		✓				
Industry hesitant to commit if policy unclear or liable to change	✓	✓	✓			
Context						
COVID recovery will reduce focus on sustainability	✓					
COVID major impact on haulier cashflows and viability		✓				
Different and incompatible approaches to Clean Air Zones	✓		✓			
Different approaches to road restrictions, e.g. cycles lanes	✓		✓			
Different vehicle standards e.g. Direct Vision	✓		✓			
Fuel tax needs replacing with road charges - gov't not addressing	✓		✓			
Usually only competitive lever is price - very thin margins		✓				
Supply chains historically optimised for cost and customer convenience				✓		
Long and complex supply chains, e.g. China				✓		
Next day deliveries add to emissions				✓		
Enablers						
Euro truck standards demonstrate regulation effectiveness	✓					
Current targets are insufficiently aggressive	✓		✓			
Targets are achievable but timing may not be	✓		✓			
Targets are necessary	✓		✓			
Other Opportunities						
Opportunities to develop platooning & coasting				✓		
Implement consolidated deliveries / nominated delivery days				✓		
Shared urban consolidation centres and deliveries				✓		
Shipper / haulier collaboration to identify emission red'n opportunities				✓		
UK rail network not close to ready for general freight	✓			✓		
Stakeholders - Enabling						
Government needs to define technology standards and roadmap	✓		✓			
Government needs to provide / drive infrastructure	✓		✓			
Government needs to remove regulatory and planning obstacles	✓		✓			
Government needs to dis-incentivise fossil fuel usage	✓		✓			
Stakeholders - Participating						
Trials with zero / low emission vehicles e.g. DHL, Waitrose		✓				
Very slim margins - will respond to profitability & legislation		✓				
Count	**21**	**20**	**15**	**8**	**5**	**4**

*: 1. Government leadership is necessary; 2. It must work economically and operationally; 3. Policy uncertainty is a significant barrier; 4. Non-motive technology opportunities should also be pursued; 5. Hydrogen may not be viable for road freight in the near term; 6. Responsibility for charging deployment and grid upgrade must be clarified

Source: Synthesis of coded interview transcripts

Table 2: Opinions (aligned to overarching viewpoints) per transition perspective element (detail)

	Socio-technical			Political			Techno-economic		
Opinions aligned to overarching viewpoints	Innovation systems	Regimes and niches	Technology diffusion	State goals	Political interests	Institutions and capacities	Resources	Demand	Infrastructure
Alternative Motive Technologies									
Difficulty managing charging at driver homes			✓						✓
Open questions on charging patterns and grid loading			✓						✓
Major grid upgrades required			✓						✓
BEV not suitable for line haul due to battery size/weight and charging								✓	
Biomass supply limitations mean cannot be a large part of the solution							✓		
Hydrogen only as clean as production - now mainly from methane		✓					✓		
Current cost of hydrogen very high							✓	✓	
Concerns regarding safety & required strength of tank			✓						
Major engineering challenges on hydrogen safe / economic dist'n	✓		✓						
Green hydrogen prod'n inefficient - very large renewable generation req'd								✓	
Hydrogen provides range without payload compromise of battery								✓	
Hydrogen provides short fuelling times								✓	
Barriers									
Uncertainty within vehicle lifecycle creates investment risk			✓	✓		✓			
History of policy introduced with insufficient notice for asset lifecycles				✓		✓			
Necessary charging infrastructure is not being developed			✓						✓
Low diesel prices reduce incentive to switch		✓	✓	✓	✓				
Market will not accept price increases for sustainable transport		✓						✓	
Haulage market is highly efficient and very cost / price driven		✓							
Charging / fuelling must cover network and align with driver stops		✓	✓						✓
Need to consider reliability and impact on maintenance cycle	✓		✓						
Need to provide required load bearing and range								✓	
Industry hesitant to commit if policy unclear or liable to change		✓	✓	✓		✓			
Context									
COVID recovery will reduce focus on sustainability				✓	✓	✓		✓	
COVID major impact on haulier cashflows and viability								✓	
Different and incompatible approaches to Clean Air Zones				✓	✓	✓			
Different approaches to road restrictions, e.g. cycles lanes				✓	✓	✓			
Different vehicle standards e.g. Direct Vision				✓	✓	✓			
Fuel tax needs replacing with road charges - gov't not addressing		✓			✓				
Usually only competitive lever is price - very thin margins		✓							
Supply chains historically optimised for cost and customer convenience		✓		✓	✓				
Long and complex supply chains, e.g. China		✓							
Next day deliveries add to emissions		✓							
Enablers									
Euro truck standards demonstrate regulation effectiveness			✓	✓					
Current targets are insufficiently aggressive			✓	✓					
Targets are achievable but timing may not be			✓	✓					
Targets are necessary			✓	✓					

Opinions aligned to overarching viewpoints	Socio-technical			Political			Techno-economic		
	Innova-tion systems	Regimes and niches	Techno-logy diffusion	State goals	Political interests	Institu-tions and capacities	Resources	Demand	Infra-structure
Other opportunities									
Opportunities to develop platooning & coasting			✓						
Implement consolidated deliveries / nominated delivery days		✓	✓		✓				✓
Shared urban consolidation centres and deliveries		✓	✓		✓				✓
Shipper / haulier collaboration to identify emission red'n opportunities	✓		✓						
UK rail network not close to ready for general freight				✓	✓				✓
Stakeholders - Enabling									
Government needs to define technology standards and roadmap			✓	✓	✓	✓			
Government needs to provide / drive infrastructure			✓	✓	✓	✓			✓
Government needs to remove regulatory and planning obstacles		✓		✓	✓	✓			
Government needs to dis-incentivise fossil fuel usage		✓		✓	✓				
Stakeholders - Participating									
Very slim margins - will respond to profitability & legislation		✓		✓					
Trials with zero / low emission vehicles e.g. DHL, Waitrose			✓						
Count	**3**	**16**	**22**	**19**	**14**	**10**	**3**	**9**	**9**

Source: Synthesis of coded interview transcripts

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