Research in Transportation Economics 104 (2024) 101424

Contents lists available at ScienceDirect

Research in Transportation Economics

journal homepage: www.elsevier.com/locate/retrec

Research paper

# Promoting sustainable urban freight through stakeholder engagement to co-create decarbonisation pathways in the UK

Daniela Paddeu [a,*], Graham Parkhurst [a], Ges Rosenberg [b], Neil Carhart [c], Colin Taylor [d]

[a] Centre for Transport & Society, University of the West of England, Bristol, UK
[b] Department of Mechanical Engineering, University of Bristol, UK
[c] Department of Civil Engineering, University of Bristol, UK
[d] University of Bristol, UK

ARTICLE INFO

*Keywords:*
Sustainable urban freight
Stakeholder engagement
Co-created solutions
Decarbonisation pathways
Technological transition
Organisational behaviour change

ABSTRACT

The contribution of greenhouse gas emissions from UK urban freight is growing in absolute terms, but the existence of alternative technology options means the urban part of the freight system has potential for relatively early decarbonisation. However, barriers are limiting the speed and extent of uptake. Indeed, freight decarbonisation is a sociotechnical challenge. Behaviour change is usually required to facilitate technological change. For this reason, stakeholders are central to processes of identifying pathways to decarbonisation. The paper reports findings from two projects undertaken in the UK in 2020–21 which examined how stakeholder engagement on freight decarbonisation could be enhanced to promote the process of identifying pathways through co-creation. The projects involved the conduct of literature reviews, stakeholder mapping exercises, and stakeholder engagement in coproduction workshops. The stakeholder mapping and engagement process led to the identification of groups of actors which were relatively easy and hard to include. Engagement and interaction were found to be promoted in some respects by the need to conduct the data collection remotely rather than in presence, and by building on established networks. In terms of the identification of pathways, stakeholders showed mixed levels of knowledge. Uncertainty about the future was generally high, with perceived risks being important. Nonetheless, short, medium and long-term pathway features were identified, with electrification playing a key role in the long term. However, the need for strong multilevel governance providing a clear regulatory framework and incentives for change was perceived by stakeholders overall to be more significant than a particular technology. The paper concludes with an agenda for further research.

## 1. Introduction

Freight transport is responsible for more than a third of UK transport greenhouse gas emissions (Department for Transport - DfT, 2023), and the contribution of last-mile deliveries is growing rapidly. Light goods vehicles (LGVs) (used for all purposes) are responsible for 15% of motorised vehicle miles in British urban areas, rising to 25% in the largest urban areas. LGVs are responsible for 30% of all oxides of nitrogen and particulate emissions from road transport (Cairns & Sloman, 2019). Despite the need for decarbonisation, in most countries freight transport has only recently attracted the attention of Governments, in stark contrast with sustainable *personal* mobility having been a salient topic within transport policy for many years (Hammond et al., 2020; McCollum & Yang, 2009; Paddeu & Aditjandra, 2020).

Freight transport is a difficult industry to decarbonise, due to the intensive use of fossil fuels by the modes of transport involved – mainly road (Meyer, 2020). In addition, compared to personal mobility freight transport is already operationally relatively efficient, and there are structural constraints on change, such as sunk investments terminal infrastructure. In this context urban freight presents as having higher potential for early decarbonisation than the sector a whole. Fourteen percent of urban transport emissions (globally) are from freight (ITF, 2019), with quantities expected to significantly increase due to increasing demand for goods and freight transport's reliance on fossil fuels (McKinnon, 2023). As in the case of decarbonisation in general, emissions reductions will involve to some extent both technological change and behavioural change.

Technology substitution offers to reduce carbon emissions whilst

* Corresponding author.
*E-mail address:* daniela.paddeu@uwe.ac.uk (D. Paddeu).

https://doi.org/10.1016/j.retrec.2024.101424
Received 31 March 2023; Received in revised form 25 January 2024; Accepted 29 February 2024
Available online 21 March 2024

minimising the need for changing business practices, or more radical industrial reorganisation, for example spatial redistribution. Electrification and new fuels (in particular hydrogen) have been identified as the most likely and effective technologies for substitution in all modes of freight sector (Greening et al., 2019). However, the production of low-carbon hydrogen at sufficient scale and the supply infrastructure. The performance of electric Heavy Goods Vehicles (HGV) remains too limited for widespread commercial adoption (Haugen et al., 2021). However, away from the long-haul, electric and human-powered technologies are much more applicable to the typical duty cycles of urban delivery vehicles. Cargo bikes offer a low-impact micro-mobility solution for the last mile, and a transition is underway. In the UK, for example, the number of new registrations of LGVs with zero or 'ultra-low' (defined as emitting fewer than 75 g/km $CO_2$) increased from fewer than 2000 in 2018 to over 14,000 in 2021 (Department for Transport, 2023). Statistics about modern cargo bike sales are less precise, but media estimates indicate UK sales of 4000 in 2020, with one manufacturer experiencing 75% growth in a year. However, this progress needs qualifying. Not all of the low emission vans are for freight service, although replacement of diesel van fleets with electric vans by the major logistics companies has made an important contribution to the increase. It remains the case that less than 1% of the approximately 4 million vans registered in the UK in 2021 were ultra-low emissions vehicles (DfT, 2023). In the case of cargo bikes, round half of purchases are for deliveries by businesses (Bike Europe, undated), but the UK lags far behind the European market leaders in adoption. Government financial incentives have supported adoption in several countries, to overcome barriers related to relatively high cost of a new niche technologies compared to established ones, psychological factors such as perceived risk and uncertainty, and the need to change business practices to adapt to the characteristics of the new technologies.

If on the one hand cleaner technologies can help reducing carbon emissions from urban freight, on the other hand decarbonisation variously requires organisational change within organisations and between them. Horizontal collaboration (HC) or 'coopetition' (Mangan and McKinnon, 2019; Ferrell et al., 2020), and more general collaborative schemes (Paddeu et al., 2018) can result in optimised freight movements and therefore greater system efficiency and lower GHG emissions. An example of a collaborative scheme relevant for sustainable urban freight is the urban freight consolidation centre (UFCC). If applied effectively an UFCC can reduce congestion and emissions whilst improving the quality of life in urban areas through reduced presence of heavy vehicles. However, UFCCs require the sharing of resources (e.g., HGVs/LGVs, depots) among stakeholders. This means that competitors must be willing to collaborate and coordinate their activities, potentially sharing information about their businesses, and losing brand visibility on the urban street (McLeod et al., 2020). For this reason, despite the greater collective benefits achievable through collaboration, collaborative schemes, such as UFCCs, are often difficult to establish, as sharing information and resources with other actors can be seen to contradict the interests of achieving success in a competitive marketplace (Hribernik et al., 2020; Mason & Harris, 2019). Also, if not well regulated, a collaborative scheme might favour the larger and established players, to the detriment of new and smaller players, generating inequalities in the market (Paddeu et al., 2018). It is worth noting that some successful examples of collaborative schemes in urban logistics exist, such as the "logistics hotels" established in dense areas in Paris, to consolidate parcels from suburban centres, renting space at favourable rates in exchange for using low-emission transport. This initiative has proved to be successful in reducing emissions and enhancing delivery efficiency, ultimately aiming to reduce heavy vehicle use and its negative effects (Dablanc, 2023).

Urban freight decarbonisation therefore presents a sociotechnical research problem.

- subsidies can go only so far in persuading actors to adopt technologies and practices which would otherwise be seen as 'second choice';
- practices such as collaboration between businesses tend not to emerge spontaneously and at large scale without active policy intervention; and
- priorities such as protection of market share and brand are not readily tradeable for a simple subsidy.

Instead, knowledge and trust need to be built amongst networks of stakeholders around a process which develops decarbonisation as a collective responsibility, through a process of stakeholder engagement. Several studies demonstrated that stakeholder engagement and collaboration can be key drivers for the success of a sustainable urban freight scheme (Fancello et al., 2017; Morganti & Gonzalez-Feliu, 2015). Measures that aim at improving sustainability of transport in urban areas are usually more difficult to implement, as public and stakeholder acceptance is usually more difficult to achieve, due to a need for behaviour/organisational change (Tagliapietra et al., 2019). It becomes therefore important to understand how to best engage stakeholders to design appropriate policies and interventions to achieve urban freight decarbonisation and meet net zero. For this reason, the research presented in this paper aimed at engaging stakeholders to understand their perspective towards urban freight challenges and opportunities for decarbonisation. The research was carried out within two coordinated projects following similar objectives and methods CRAFTeD and CoDe ZERO. CRAFTeD took a whole-freight system perspective, including a focus on urban freight, whose results are considered in the current paper, whilst CoDe ZERO was exclusively focussed on urban freight (a more detailed description of the projects is provided in Section 3).

The projects sought to enhance stakeholder action on the topic of freight decarbonisation through addressing the following questions.

- How can diverse freight stakeholders best be collaboratively engaged towards decarbonising the freight system?
- What dependencies, barriers and trade-offs exist in the domain of freight decarbonisation from a stakeholder perspective and how might they be managed?
- What kind of solutions can be implemented in the short, medium, and long-term to decarbonise urban freight in the UK?

A fuller explanation of this approach is provided in the following sections. Section 2 presents a literature review on stakeholder engagement within the urban freight policy context. Section 3 explains the methods used to engage stakeholders towards urban freight decarbonisation. Section 4 presents the main findings from the projects relating to sustainable urban freight, leading to a discussion in Section 5 of the main challenges and opportunities for identifying decarbonisation pathways, including the role of stakeholders in driving the change. Finally, the paper ends with some concluding remarks, and offers recommendations for a future research agenda.

## 2. Stakeholder engagement within the urban freight policy context

Freight stakeholder engagement has emerged as a critical factor in recent studies considering the design and implementation of sustainable freight measures (Lebeau et al., 2018; Paddeu et al., 2018), with greater success claimed for those change processes in which stakeholders are closely involved in the decision-making (Paddeu & Aditjandra, 2020). For this reason, online forums to consult freight actors have become increasingly popular among policy makers (Zunder et al., 2014). When local authorities want to implement a new policy, they need to have deep knowledge of the broader policy framework (Marsden & Reardon, 2017), and understand where the specific policy fits toward the broader policy goals (Howlett, 2018), which are defined by politicians. However, politicians usually make short-term decisions to meet public acceptance (and favour) rather than long-term policy goals (Christiansen, 2018; Shaw & Docherty, 2019). Urban freight is usually a lower priority policy area, which is driven by financial and human resources (Akgün & Monios, 2018). In general, National and European goals influence the design of urban freight policies at local level. These goals are usually very broad, and include (i) improved air quality, reduced congestion, and increased road safety (Fossheim & Andersen, 2017). Urban freight strategic planning can therefore include policies to address these goals, such as traffic restrictions (Quak, 2008), time windows (Dablanc, 2008), low emission zones (Ellison et al., 2013), freight consolidation (Zunder et al., 2016). However, these measures do often find opposition from the general public and stakeholders, mainly due to a lack of communication between local authorities and stakeholders (e.g., retailers, manufacturers, logistics operators) (Zunder et al., 2016), which makes the implementation of most measures unsuccessful (Akgün et al., 2019). Furthermore, the lack of capabilities on urban freight policy among local authorities, and their inability to integrate it to the broader urban transport planning (mainly focused on personal mobility), are responsible for a general inefficient urban freight system in most cities (Paddeu & Aditjandra, 2020; Witkowski & Kiba-Janiak, 2014). Decisions are therefore made not considering the needs and expectations of the different stakeholders involved in the urban freight system (Paddeu et al., 2018). This might be a big issue in terms of likelihood of success for specific measures. Indeed, despite the expected benefits due to innovative and sustainable solutions, their successful implementation strongly depends on to what extent users are prepared to shift from a more traditional, well-known system, to a new one (Paddeu & Aditjandra, 2020). Stakeholder engagement and increased awareness can be therefore key drivers to implement sustainable urban freight policy and planning, as they can be used as a way of emphasized participation or engagement as empowerment, equity, trust, and learning process (Reed, 2008).

The literature provides a series of methods used to engage stakeholders and bring them closer to the decision-making process. Probably the most common tool used by policy-makers to involve stakeholders in city logistics decision-making is the use of online forums, where stakeholders can express their interests and discuss problems and solutions (Quak et al., 2016). In some UK cities, these forums come in the form of Freight Partnerships (Browne et al., 2007), where city freight stakeholders are engaged in consultations and regularly meet with local authorities to discuss issues related to city businesses' operations. However, these do not exist in many cities, as logistics is not perceived as a priority issue from an urban policy and planning perspective. A famous method to design and evaluate urban freight measures is the Multi-Actor Multi-Criteria Analysis (MAMCA) (Macharis, 2007), which has been used across different European projects. With MAMCA, stakeholders are asked to evaluate and rank a series of pre-designed alternative solutions (or scenarios). However, despite the effective inclusiveness of the approach, stakeholders do not own the power of co-designing possible solutions of plausible future scenarios, which are, in fact, designed by academics (Paddeu & Aditjandra, 2020). Other common stakeholder engagement methods include focus groups, surveys, and longitudinal observation to explore multi-stakeholder views towards freight (Gammelgaard, 2015; Stathopoulos et al., 2012). However, usually stakeholders find it easier and prefer to be engaged in a consultation process (Ballantyne et al., 2013; Zunder et al., 2014), as methods such as MAMCA would require the intervention of an expert team to support policy makers, who would often not be able to use these kinds of methods autonomously (Paddeu, 2021).

However, stakeholder engagement can sometimes have a narrow and instrumental meaning when it refers to how an organisation seeks to manage how it is perceived and to influence its external audiences to share its vision and mission. In the context of collaboration over wide societal objectives, instead, stakeholder engagement is a process for sharing understandings of the world, and co-designing solutions that can command wide consensus. Taking a critical realist perspective (Bhaskar, 1975), whilst we may accept that we share the same world, in this case the one that is experiencing global heating due to anthropogenic climate change, we do not directly observe that world. Each stakeholder perceives the world somewhat differently, according to his or her experiences, based on observing only a part of the reality indirectly, mediated by a framework of explanation, such as normative theories underpinned by science, or perhaps more popular understandings. Following this perspective, the aim of CRAFTeD and CoDe ZERO was to explore stakeholder engagement with the purposes of furthering a co-produced, and therefore shared, understanding of freight decarbonisation by aligning individual stakeholder perceptions so they could give rise to common purposeful action.

## 3. Methods

The methods used for the research presented in this paper were.

- Stakeholder analysis and mapping (Freeman, 1984; Mitchell et al., 1997), to identify the right stakeholder groups to engage, with different interest and power. Our approach was influenced by Flood and Jackson (1991 – see "The 12 Critically Heuristic Boundary questions", Table 1, p.297) in understanding who holds the power and knowledge necessary for effective change;
- Participatory approaches to engage stakeholders across a series of different activities within online workshops and using a digital whiteboard (e.g., Miro.com); and
- Knowledge co-creation, i.e., a deep and broad participatory process for identifying, scoping, and undertaking an initial assessment of solutions to decarbonise urban freight. Co-production prioritises consideration of the needs of the stakeholders involved to develop solutions that can be more attractive to potential providers and users, because they are tailored to their needs (Paddeu & Aditjandra, 2020).

The research was undertaken within two research projects: CRAFTeD, which run between November 2020 and May 2021 and explored stakeholder perspective towards freight transport decarbonisation in the UK, using a regional approach, and exploring urban freight as a quick win towards decarbonisation. CoDe Zero, which run between October 2020 and March 2021 and explore stakeholder perspective towards urban freight decarbonisation in the North of England.

The process was initiated with international literature reviews to identify broad and realistic prospect areas for decarbonisation interventions (technologies, new business models and behaviour changes) and indicative timescales. This provided evidence for a first critical reflection, exploring the boundary of the UK urban freight system, and the potential for decarbonisation including salient system dependencies and stakeholder viewpoints. It was therefore possible to explore a diverse range of perspectives towards urban freight decarbonisation and to identify specific challenges.

The stakeholder-mapping exercise emphasising equity, diversity, and inclusion in order to identify shortcomings in comprehensiveness and hence representation and learning, and the evaluation of conceptual approaches and their related methods for facilitating co-productive stakeholder engagement that navigates the complexity of their decision-making over demand and freight-technology futures.

The review and mapping tasks underpinned the primary data collection through an iterative series of stakeholder engagement workshops with key freight stakeholders. These included policy makers, academics, professionals, freight operators, and experts, involving a total of 45 participants (see Table 1). Stakeholders were invited to different engagement events, including small discussion groups on specific themes, and larger group model building workshops with breakout groups. Hence the method followed an approach starting with a core stakeholder group, and then organically growing the network of participant stakeholders (Bryson, 2004) until adequately identifying

**Table 1**
Stakeholders engaged across the two projects.

| Workshop | Project | When | n. Of stakeholders | Gender (M - male; F - female) | Stakeholder group |
|---|---|---|---|---|---|
| 1 | 2 | Jan 2021 | 8 | 5 M, 3 F | academia:1; association:1; business:4; consultancy:1; public:1. |
| 2 | 2 | Jan 2021 | 6 | 2 M, 4 F | academia:1; association:2; business2; consultancy:0; public: 1. |
| 3 | 1 | Mar 2021 | 11 | 8 M, 3 F | academia:0; association:0; business:7; consultancy:3; public:1. |
| 4 | 1 | Mar 2021 | 11 | 11 M, 0 F | academia:1; association:1; business:5; consultancy:1; public:3. |
| Advisory Board | 1 | Feb 2021 Mar 2021 | 9 | 7 M, 2 F | academia:4; association:0; business:2; consultancy:2; public:1. |

potential solutions and related drivers/barriers to implementation.

An innovative methodological feature was the convening of an expert panel to guide and reflect upon the process. Following presentation of the initial findings at the meeting, feedback from individual members was sought after the meeting. The panel was subsequently reconvened with the group reflecting collectively on its earlier feedback as individuals.

The results from the literature review and stakeholder mapping exercise were used to inform the design of the stakeholder engagement workshops and the advisory panel workshops. Each workshop was carefully designed following a specific protocol, with guidelines about time and description of the tasks that were developed during the session. These protocols support the research team to ensure that the workshop run smoothly, participants were effectively engaged, and the expected outcomes were achieved. Each workshop included: (i) agenda and objectives of the workshop, to outline the scope and expected outcome(s) of the workshop; (ii) brief introductory presentation to set the scene and to ensure a base level of common knowledge; (iii) icebreaker activities, to help participants get to know each other and create a positive and inclusive environment; (iv) participation rules, about participant behaviour to ensure a respectful and safe environment; (v) description of the tasks, for each task with an explanation of the purpose and contribution to the overall outcome. The protocol also included instructions for the facilitator(s) regarding the facilitation of discussions, time management, fostering participation, and addressing potential challenges. At the end of each workshop, participants were asked to provide feedback on the format and content of the workshop, in order to improve the design and the delivery of the next workshops.

A summary of the methodological flow is presented in Fig. 1 and a description of the stakeholders involved in each workshop across the two projects is provided in Table 1.

The information presented to stakeholders was framed around the production of a prototype roadmap, identify barriers to change, map assets and explore a wide set of opportunities to decarbonise urban freight. The decarbonisation targets set out for the freight sector in the UK's Sixth Carbon Budget (Climate Change Committee, 2020) were used as an impelling proposition to drive the roadmapping process. However,

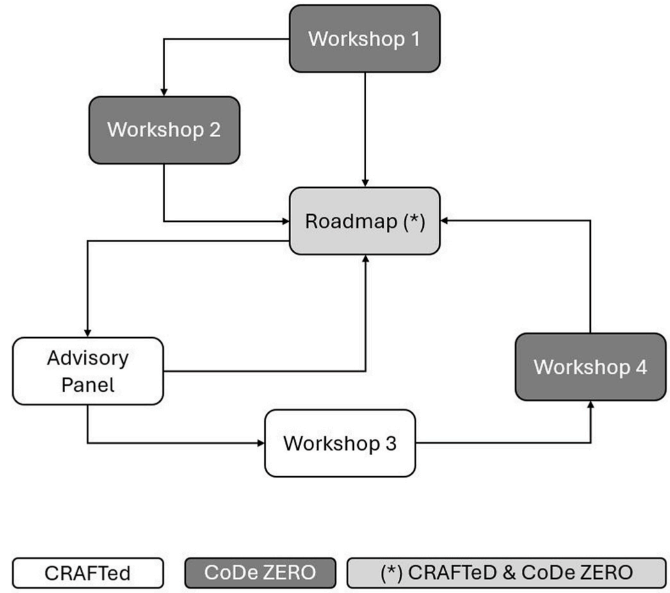


**Fig. 1.** Methodological flow (the roadmap was co-created with stakeholders across the two projects).

given the significant uncertainty around timescales for the development and investment in new decarbonisation technologies and changing stakeholder behaviours, the research process emphasized the sequencing of transition processes, rather than identifying strictly time-bounded outputs.

Workshops were video recorded. Participants used sticky notes to record their ideas and thoughts towards specific questions across the different tasks developed within each workshop. These, together with the research team's notes, were analysed to identify key themes to highlight the stakeholders' perspective towards potential challenges and opportunities for urban freight decarbonisation.

## 4. Findings

### *4.1. Collaborative engagement of stakeholders towards decarbonisation*

Based on the stakeholder mapping exercise and the response to contacts made with potential participants of the research, engagement with freight decarbonisation as a priority can be characterised as being best amongst: (i) large organisations, likely due to the greater specificity of management roles and overall capacity to engage; (ii) individual professionals, including some policymakers, with a particular personal concern; (iii) freight-oriented professionals due to their elite expertise and freight being 'core business' for them; and similarly (iv) environmental and efficiency managers, for whom transport looms large in their organisation's indicators.

Conversely, but with some important exceptions, those with low engagement were: (i) smaller organisations; (ii) whole organisations, including third sector as well as businesses, suggesting that decarbonisation does not yet permeate all their activities in the way it will need to if the mission is to be achieved; (iii) stakeholders without an explicit decarbonisation remit within their roles, perhaps because they did not want to impinge on the responsibilities of colleagues; (iv) those transport professionals with a passenger rather than freight orientation, for a combination of expertise, experience, and perceived remit barriers; (v) those in the Energy sector, for whom transport remains just one end-user sector, and where the dependencies of transport sector success on infrastructure delivery have not yet been fully realised; (vi) financial/strategic planning roles; and (vii) freight users, including citizens and business-to-business customers, for whom the responsibilities for decarbonisation are still seen to lie solely with the shipper.

A principle which emerged from the discussions around effective engagement was that it is an ongoing process that has formal and informal aspects and requires maintenance. Relationships are bounded by practical constraints and opportunities, such as already being in regular contact for purposes other than decarbonisation, and the spatial scale of which it is possible to have regular face-to-face meetings within the working day. This networking potential – both within large organisations as well as between organisations of different size – is important given that behavioural-organisational change requires horizontal collaboration amongst stakeholders and depends on trust relationships: a form of social capital which needs building and maintaining over time.

Considering the more formal aspects, governance was seen as important at different levels. Even at the level of the individual urban area, stakeholder relations need to take place over a wider level of governance for a range of reasons: larger companies make policies at a regional or national level, and decisions in one urban area may influence another. At the time of study, England was experiencing a re-emergence of a subregional level of transport governance in the form of Subnational Transport Bodies (following the abolition of regional institutions in the 2000s). These new institutions were to bring forward Transport Decarbonisation Strategies and Freight Strategies, linked to national priorities. These arrangements were identified as more advanced in the north of England, where there had for some time been a successful example of Freight Partnership Forum (FPF) (Browne et al., 2007; Zunder et al., 2014), involving regular meetings to discuss freight issues in the region. However, even this forum was identified as consultative, without decision-making powers.

Other opportunities exist through institutions with wider remits. For example, in the case of South West England, the work of an Infrastructure Partnership included decarbonisation within its remit alongside enhancing connectivity, and provided a source of existing semi-formal or formal stakeholder networks ready to engage on the topic.

### 4.2. Dependencies, barriers, and trade-offs

Stakeholders expressed a high level of uncertainty towards future solutions, in particular related to their technological development and also the governance (e.g., policy, planning and regulations) that would need to be in place to enable their implementation at local and national level. Their successful implementation might depend on a series of key factors that would be important influencers on the pathway for decarbonisation. These could be classified into tangible uncertainties and less-tangible uncertainties.

*Tangible uncertainties* include those where the factor is identified as relevant, and in principle the policy makers have control over the decision-making process, but there is uncertainty as to how the issue will be addressed. An important example is the energy infrastructure (Martins-Turner et al., 2020), where it is known that massive infrastructure investments are needed, and the broad technology options are probably narrowed to battery-electric or hydrogen fuel cells (potentially using compounds such as methane or methanol as feedstocks), but uncertainties remain around which of these pathways, or in which combination, they will be followed and the actual cost-efficiency of new (clean) fuels, including electricity and hydrogen, compared to diesel. Other uncertainties are related to main responsibilities in terms of costs (e.g., who will pay for the new vehicles or infrastructure) and regulations (e.g., what measures will be in place by when).

*Less-tangible uncertainties* include those in which there is uncertainty about whether the factor will be influential on urban freight decarbonisation, or the factor emerges from an international context over which a single country has low influence. For example, population evolution and distribution are perhaps more predictable than the political-economic environment, but also subject to uncertainties, and, with the exception of some forms of migration, not easily open to policy influence. From a city logistics perspective (e.g., urban freight), it is worth considering potentially significant changes in the urban form in a post-COVID scenario, and whether people decide to live in a more digitally dispersed pattern rather than in central urban areas, with a related impact on urban freight flows.

Depending on the level of uncertainty and the effort required to implement them, stakeholders identified solutions that could be implemented now, others that are most likely to be implemented in the future, as the infrastructure is already in place, and other solutions that would be more difficult to implement, as they would require a drastic change.

### 4.3. Solutions

#### 4.3.1. Short-term

Following the logic of the methodology, the findings about solutions have been grouped into: (i) what should happen now (short term); (ii) what is most likely to happen in the future (medium-term); (iii) what is most difficult to happen, as it would require a drastic change (long-term).

Solutions that could be implemented soon (or now) are related to a new design of the network, to reduce the number of HGVs and LGVs in urban areas. The most popular solution among stakeholders to respond to this need, was freight consolidation through the establishment of a network of micro-consolidation centres located in the proximity of the surroundings of the urban area. In this scenario, HGVs and LGVs currently delivering to an urban area, would need to do their deliveries through the consolidation centre(s), where goods would be received, handled, and delivered to the destination by full load electric vans (e.g., bigger size/weight products) or e-cargo bikes or by portering managed as a delivery practice rather than ad hoc workaround to congested streets and limited parking (Martinez-Sykora et al., 2020). This would have a significant positive impact on the reduction of commercial vehicles in the area, with a related impact on improved air quality, carbon emissions, congestion and road safety, while providing for potentially quicker last-mile deliveries.

Stakeholders also acknowledged that this would allow a better use of the road infrastructure, as smaller delivery vehicles would be used for the final mile. However, despite the positive impact these solutions might have to decarbonise last-mile deliveries in the short term, a series of significant challenges were identified. As in the case of larger consolidation centres discussed in the introduction, specific barriers related to competition included the need for brand protection and recognition. If companies were not to use their own vehicles to make the deliveries, they would lose the value of being recognised by consumers. In addition, there might be some resistance from receiving businesses to the use of a new delivery approach, and the micro-consolidation hubs would imply increased operational costs and supply chain disruption. Additional challenges included the limited capacity of cargo-bikes (compared to HGVs and LGVs), vehicle licensing issues, and road safety, due to a lack of proper infrastructure. Finally, there was a general concern about the effectiveness of the introduction of consolidation hubs for last mile deliveries, as one participant said: "*Big logistics operators already consolidate at a very optimal level. Are we sure this is going to be a commercially/operationally viable option?*"

In addition to micro-consolidation, stakeholder suggested hybrid transport solutions as being achievable now and enabling better use of existing vehicles and infrastructures. Public transport (e.g., buses and trains) could be used to transport both goods and people during off-peak passenger hours. A secondary benefit of this approach would be a positive impact on the financial viability of public transport services, which were being affected at the time of research by the related effects of restrictions on travel and an increase in remote working. This solution was very popular in the North of England, where it was suggested to use the railway system to connect multiple-urban hubs (e.g., Manchester, Liverpool, Sheffield, Leeds) and serve an interlinked network of urban systems. This would then need to be integrated to proximate mobility options (e.g., cargo-bikes) for the very last mile, and railway stations could be adapted to serve as consolidation hubs.

The main advantage of this solution, in addition to the existing network of stations in urban areas, which would maximise sustainable urban accessibility to goods, would be a maximisation of the use of the resources and the spare capacity of trains and stations during out of peak hours. However, development to this extent would require a change in land use (e.g., lack of logistics land availability and new land use regulations), and the current capacity of railway stations would not be enough to held and manage large volumes of freight, which would tend to push the approach into the medium-term.

#### 4.3.2. Medium-term

Despite being already available in the market, electric vans were considered a solution that could be available in 8–10 years, due to a current lack of infrastructure and a lack of supply to be able to electrify the whole UK fleet. Urban planning and policy will be required to electrify the whole network (e.g., refuelling stations) to enable electric vans to be used at large scale. This solution can help reducing carbon emissions from last-mile deliveries (but not to completely avoid them) but would not reduce congestion. Another issue might be related to potential issues with the availability of spares and parts in the short-to-medium term, and also issues related to affordability of these vehicles. This would have a direct impact on market inequalities, as smaller operators might be forced to switch to an electric van (e.g., traffic restrictions in urban areas), but not able to afford it. For this reason, stakeholder believed that appropriate funding schemes and subsides should be provided to operators to offset the extra costs in order to encourage companies to invest in a new fleet. New fuels, such as hydrogen, was also indicated as a medium-term solution for bigger delivery vehicles, such as HGVs. Stakeholders believed that electric HGVs might be a more challenging solution to be available in the short to medium term, and in the meantime, hydrogen could be used as an alternative clearer alternative to traditional fuels. However, this would require significant advancements in the technology of the vehicles, as well as investments in the existing infrastructure (e.g., refuelling stations) in order to create the appropriate conditions for hydrogen HGVs to be an available and convenient alternative.

In addition to electric vans, stakeholders identified automated transport systems, such as aerial drones and autonomous delivery robots as solutions that might be integrated to existing delivery solutions in the medium term. They believed that even though these technologies would not be key in terms of decarbonisation, as electrification should be the main focus, by being electric and operationally efficient, these technologies can add extra value to an urban freight decarbonisation strategy. However, the implementation of these technologies would face a series of issues, mainly related to public acceptance and co-existence of automated systems in a mixed-traffic environment (e.g., human driven vehicles and autonomous vehicles). This would therefore require specific regulations, planning and policy to make them a safe and operationally viable option.

#### 4.3.3. Long-term

Other solutions were considered more challenging to implement, as they would require a more drastic change, and were therefore indicated as potential solutions to decarbonise urban freight in the long term (e.g., 15–20 years). These include, for example, electric HGVs (e.g., greater than 7.5 tonnes). Despite the clear indication from stakeholders to switch to smaller vehicles for deliveries in urban areas, they also recognised that bigger vehicles (e.g., HGVs) would still be needed for larger volume (e.g., bigger/heavier products) deliveries, such as supermarkets or similar. This implies that cleaner solutions would be needed to decarbonise HGVs. This would include electric HGVs or cleaner fuels, such as Hydrogen. The former, would face a series of challenges related to the inadequacy of current technologies to appropriately perform and therefore being operationally (e.g., duration of the battery, lack of infrastructure, recharging stations) and financially (e.g., reduced load capacity due to big size batteries) viable. The latter would require significant advancements in terms of vehicle technology, but also significant interventions in the infrastructure. Also, in both cases, there are a series of additional uncertainties due to the availability of supply, future costs, and appropriate planning requirements to enable these technologies to be successfully implemented. Currently, the UK does not produce enough electricity to supply the whole national fleet and would potentially be dependent on other countries.

Even though decarbonising bigger delivery vehicles was considered key for long term urban freight decarbonisation, while at the same time challenging, stakeholders acknowledged that an even more powerful and challenging solution would be collective and collaborative procurement. This would require strong collaboration among stakeholders, which might be difficult due to commercially sensitiveness of the information that would need to be shared in such kind of schemes, and also resistance to change and share resources and facilities with competitors. In addition, with already well-established partnerships, it might be difficult for new market entrants to join, and this might therefore generate market inequalities. On the other hand, this solution might significantly reduce the number of delivery vehicles in an urban area, and their related negative externalities (e.g., congestion, pollution, road safety issues), as well as reduce the inappropriate use of the kerbside for loading unloading operations (e.g., irregular parking due to congested loading/unloading areas). The main concern about this solution was related to the potential for some stakeholder to gain a greater advantage than others, suggesting that local and national authorities might need to manage these schemes in order to ensure fairness.

## 5. Discussion

### 5.1. Technology vs organisational change

Technological and operational solutions, such as modal shift, increased vehicle load and energy efficiency, as well as reducing the carbon content of energy used, have been suggested by previous studies, such as McKinnon's (2018), as the way forward for freight decarbonisation. However, the study presented in this paper points out the fact that stakeholders were explicitly placing behaviour change solutions ahead of 'technical fixes', which may reflect growing perceptions of the failure of technology-led solutions to date to solve environmental problems. In general, stakeholders believed that technology alone could not provide sufficient response to the challenge of decarbonisation, and that technological solutions would need to be augmented by or secondary to demand-side behaviour changes. This would include, for example, private-public partnerships and collaborative schemes, which several studies (Gatta et al., 2019; Marcucci et al., 2017; Paddeu & Aditjandra, 2020; Paddeu et al., 2018) highlighted as being potentially sufficiently powerful to drive decarbonisation of urban freight. However, operational and behavioural change, such as the one required to establish collaborative schemes, would require stakeholders with competing interests to trust each other and also the collaborative scheme itself, with a number of challenges related to willingness to share information and resources with competitors (e.g., Paddeu et al., 2018).

For others, however, typically in the private sector, there was optimism that technical fixes could provide a primary part, or the whole response, to the freight decarbonisation challenge. Concerning specific technological potentials, the key debate featured electrification as the more realistic long-run decarbonisation pathway for last-mile deliveries (and road freight in general), with solutions for e-cargo bikes and e-vans being technically viable for many niches. This is in line with a number of previous studies (McKinnon, 2018; McKinnon et al., 2011) that support the electrification pathway to decarbonise urban freight. It is too early to say whether the increase acquisition of e-vans identified in Fig. 1 represents the first stage in a transformation of the national fleet, but for many potential users the barriers to overcome are significant. The market offer of electric van options remains limited (Teoh, 2022), in terms of acquisition cost, concerns about the risk of expensive battery replacements where the vehicle is not leased, and poor operational performance (e.g., limited range and reduced payload capacity). These factors come in addition to general limitations on road transport electrification for consumers, including the limited development to date of the charging infrastructure and the availability of EV-specific maintenance services. An additional factor that could affect business decision-making about vehicles investments now is the global rise in energy costs, which had a higher proportionate impact in the UK on electricity prices than diesel prices. The relatively high increase for electricity could reduce or eliminate the energy cost per km advantage of EVs, depending on the source of electricity for charging (Parkhurst & Clayton, 2022, chap. 12), although would be expected to benefit energy-efficient micro-mobility solutions.

### 5.2. Who can afford and embrace the urban freight decarbonisation pathway?

Stakeholders were positive towards the principle that companies (e.g., retailers and logistics operators) should adopt sustainable practices to decarbonise their operations and services. However, according to Martins-Turner et al. (2020), freight transport costs might increase by up to 17% when switching to an electric van. The ability of businesses to be able to afford to switch to a more sustainable option, such as cleaner delivery vehicles, emerged in the stakeholder engagement as related both to size of business and business model. In short, it would depend on some mechanism to pay for the extra cost of electrification.

If companies have to finance the extra costs from profits, that would limit companies with smaller profit margins, from being able to switch. Considering the very small profit margins of last-mile delivery (Aktas et al., 2021), that would not be a viable business model, and a company pursuing it might be forced to exit from the market, unless cross-subsidised from another area of a businesses' activity for its social impact value. Another option would be to seek to pass the cost on to end-consumers or retailers through the delivery price. However, unless able to exploit a market niche with consumers willing to pay extra for a lower-impact delivery, competition from operators not using cleaner technology would again tend to exclude them from the market. A third option would be for national and local authorities to 'level-up' the playing field to ensure businesses embrace the decarbonisation pathway, either through strong incentives (e.g., more significant subsides to invest in cleaner vehicles than currently exist), or through firmer regulation (bringing forward the phase-out of internal combustion engine vehicles in some way), or GHG emissions-related pricing (such as through road fuel taxation). History suggests the politics around these propositions would be controversial (Parkhurst, 2002).

Nonetheless, it would in principle be important in designing an appropriate strategy to take into consideration a holistic view of urban freight decarbonisation, looking into short, medium, and long-term implementation steps, as some measures might be more effective in the long term. For example, the study carried out by Arroyo et al. (2020) demonstrated that carbon pricing is not effective when daily distance operated is low, as it is likely to be levied per km. Its effectiveness increases as distance increases, but EVs tend to have restricted operating ranges, so might not be seen as effective alternatives to paying the levy. Carbon pricing has therefore been considered a poor tool for promoting electric vehicles in the short term, suggesting that it should be included in long-term plans and actions.

Another issue relates to embracing the 'wrong' decarbonisation pathway. For example, some companies might decide to invest in fossil fuels with modest decarbonisation benefits in the short run, such as Liquefied Natural Gas (LNG) in order to improve their sustainability performance in the short-to-medium term, whereas the government's policy measures might prioritise electrification as the way forward towards decarbonisation, in effect creating penalties for companies that adopt fuels such as LNG. This would punish companies that are willing to act early to reduce the carbon footprint of their operations, despite the risks created due to uncertainty about the evolution of national and local policy. Therefore, in line with Churchman and Longhurst (2022), this paper highlights that policy uncertainty is a significant barrier to urban freight decarbonisation. More needs to be communicated about the relative benefits of making such investments to avoid the risks of either unrealistic self-attributions of decarbonisation contributions, or stranded assets.

### 5.3. The role of stakeholders in driving change

The freight sector is very fragmented, with a number of actors with different needs and expectations. This fragmentation has been recognised as a significant barrier to urban freight decarbonisation (Churchman & Longhurst, 2022). For this reason, it is important to engage urban freight stakeholders in the design of specific solutions and policies in order to maximise acceptance and adoption (Lebeau et al., 2018; Paddeu and Aditjandra., 2020; Paddeu et al., 2018). Local government has been identified as playing an important stakeholder coordinating role (Witkowski and Kiba-Janiak (2014), and in the present research the regional tier and the role of professional institutions was also found to be important.

Considering the high fragmentation, strong competition and low margins of the urban freight sector, not all organisations necessarily want to 'be in the same room', let alone actively collaborate (Paddeu et al., 2018). However, those that did engage could do so enthusiastically and with commitment, although engagement was not necessarily by those individuals that undertake the relevant critical decision making, and in some cases, they were looking to build a decarbonisation coalition to help them influence the decision-making of those holding the necessary power. A study carried out by Bjørgen et al. (2021) suggests that collaboration, negotiation, and consensus building are potential viable strategies to overcome the complexity and often conflicting interests within urban freight. In addition, stakeholders from the private sector should be included into the urban freight planning process in order to design solutions that respond to different needs. Overall, a key finding from the projects presented in this paper was that there is a massive task to communicate the importance of and broad responsibilities for freight decarbonisation and the implications of individual and organisational action.

## 6. Conclusion, policy implications and research agenda

Stakeholders generally identified changes of regulation, governance, and organisation as more significant for successful decarbonisation than a particular 'breakthrough' technology. Hence, there was a call for strong governance. Nationally coordinated infrastructure prioritisation and investment are essential, whatever the balance of finance from the public or private sectors. National-led targets, incentives and regulations will be essential if decarbonisation is to be prioritised above the other demands the organisations face in delivering their primary outputs efficiently in either a competitive business or public sector environment. Considering this same issue from a commercial perspective, a value-creating mechanism that delivers decarbonisation is needed. This might require a top-down policy approach, due to the complex nature of the stakeholders involved, which make the freight sector a market driven system (Ghisolfi et al., 2022). The diversity of stakeholders involved in the urban freight system, with different interests, needs and preferences, strongly influences the potential impact of urban freight decarbonisation policy in different environments. Stakeholder engagement is therefore a potential tool to maximise policy acceptance and reduce resistance, while maximising the potential success for implementation of specific measures and solutions. Despite identifying a series of solutions that could lead to urban freight decarbonisation, stakeholders recognised the high uncertainty, especially towards technology readiness and behaviour/organisational change (e.g., collaborative schemes).

There are several areas in which future research is necessary. In terms of stakeholder engagement methods, there needs to be: (i) a review of the decarbonisation focus and potential of existing professional networks, to determine their sufficiency; (ii) establishment of local/urban living labs to understand the specific needs and potentials of particular local/urban areas; and (iii) engagement with end-consumers to develop the wider 'carbon literacy' needed to both influence consumer behaviour and make the actions of public and private bodies transparent and explicable.

Concerning the development of the decarbonisation pathways, there is a need to integrate the freight decarbonisation map with those of the sub-sectors, individual major actors, and the macro-economy and to integrate across sectors to include the energy, construction, retail and finance sectors. Related to the expansion and integration of existing networks and the development of living labs there is a research challenge around how these networks can be resilient to the extent necessary for them to be capable of addressing decarbonisation up to 2050 and beyond. With respect to finance and investment, more needs to be understood about the networks that influence decisions, and the extent to freight operators are free agents in respect of these choices.

Finally, a series of more specific research questions relating to both future stakeholder engagement and details of decarbonisation actions were identified.

- How can actors who hold power and influence on the freight system but who perceive themselves to be outside of it be encouraged to engage with freight decarbonisation?
- How can urban freight stakeholders be motivated to collaborate on decarbonisation efforts despite the challenges posed by fragmented interests and decision-making power within organisations?
- What is the optimal mix of in-presence and remote stakeholder engagement opportunities in order to maximise both participation and depth of interaction?
- What are the sequences and dependencies of delivering specific pathways?
- How can effective carbon data-reporting from commercial actors be achieved?
- What is the potential for short-run greater efficiency and optimisation within the current urban freight system (ahead of more radical change)?
- What is the nature of the package of regulatory and incentive measures that could achieve a rapid shift in values within business models to incentivise low-carbon investment and operating practices for last-mile deliveries and city logistics?

## CRediT authorship contribution statement

**Daniela Paddeu:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Graham Parkhurst:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Ges Rosenberg:** Conceptualization, Investigation, Methodology, Funding acquisition. **Neil Carhart:** Conceptualization, Investigation, Methodology, Funding acquisition. **Colin Taylor:** Conceptualization, Investigation, Methodology, Funding acquisition.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The authors do not have permission to share data.

## Acknowledgments

The authors acknowledge grant funding from the UK Engineering & Physical Sciences Research Council in respect of the projects "CRAFTeD - Co-produced Route-mapping to Accelerate Freight Decarbonisation: A Transdisciplinary Learning and Decision Framework" and "CoDe ZERO - Development of a Co-Designed Zero-carbon Urban Freight System".

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