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Place-based decarbonisation for transport

CoDe ZERO

development of a Co-Designed ZERO-carbon urban freight system

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CoDe ZERO

Development of a Co-Designed ZERO-carbon urban freight system

UWE Bristol University of the West of England

Newcastle University

TRANSPORT FOR THE NORTH

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Executive Summary

Introduction

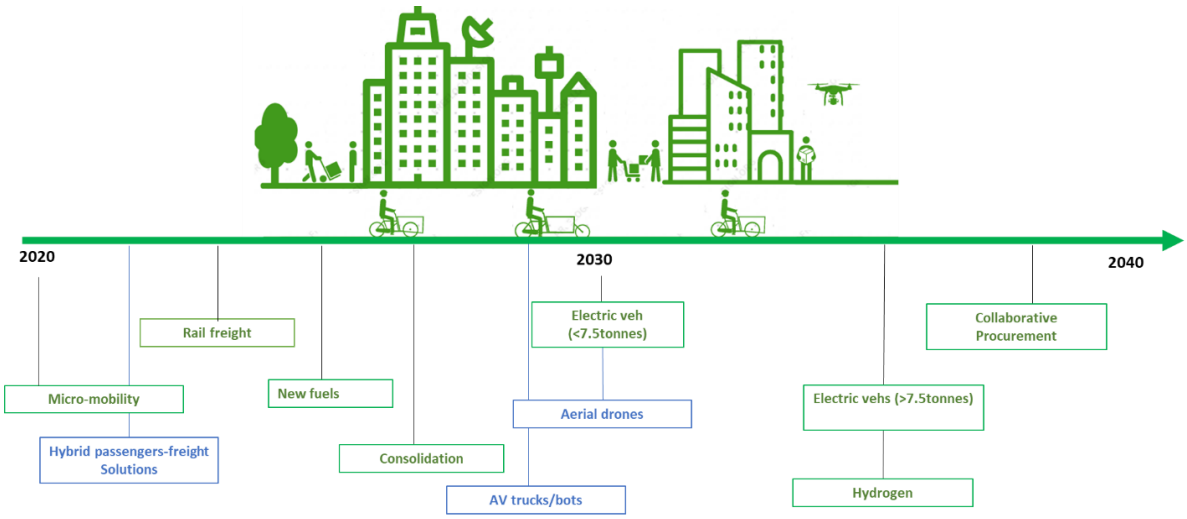
This report presents the results of CoDe ZERO, a six-month project funded by the Decarbon8 network through the Engineering and Physical Sciences Research Council (EPSRC). The aim of the project was to understand challenges and opportunities of freight decarbonisation in urban areas in the North of England, considering the perspective of key freight stakeholders based in the North.

The project was led by Dr Daniela Paddeu (Centre for Transport and Society at the University of the West of England, Bristol), who designed and ran the project in collaboration with Transport for the North (TfN) and Dr Paulus Aditjandra (University of Newcastle upon Tyne).

The main output of the project is a co-designed roadmap with a series of solutions to achieve urban freight decarbonisation by 2040. Findings show that stakeholders understand the importance of decarbonising urban freight to achieve the net zero target by 2050 (or even sooner) but believe there are a series of challenges, mainly related to the development of efficient cleaner technological solutions and to behaviour/organisational change.

Key solutions

Stakeholders co-designed the following roadmap with a range of solutions to achieve urban freight decarbonisation in the North of England by 2040.



Technical solutions such as electrification and new fuels (e.g., hydrogen) are seen as the most effective way forward to achieve urban freight decarbonisation. However, their full implementation might require time and other solutions would be needed to start reducing carbon emissions in the short term. There will not be a unique solution to solve the problem of urban freight decarbonisation, but a range of different solutions that can be integrated into a broader system-based solution. In general, it is possible to identify four main clusters of solutions, which are summarised in the table below.

Cluster	Name	Description	Main challenges
1	Micro-consolidation network	A network of micro-consolidation centres integrated to urban freight micro-mobility (e.g., e-cargo bikes) For the very last mile.	• Limited capacity of e-cargo bikes. • Extra delivery cost and time due to the consolidation hub(s). • Stakeholders might not be willing to share information and resources.
2	Rapid Rail Logistics	Moving goods between hubs (e.g., stations) by shared passenger-freight trains, using micro-mobility or e-vans for the very last-mile.	• Not suitable for the logistics of construction materials. • Investments to convert stations into consolidation hubs. • Land availability and new land use regulations.
3	Electrification and New fuels	Use of electricity and clean fuels (e.g., Liquefied Natural Gas, hydrogen) to power vans and trucks.	• Financial support from central government to freight companies. • Significant investment in recharging/refuelling infrastructure. • Insufficient availability of these energy sources in the UK. • Efficient cleaner technologies for trucks are considerably more difficult to achieve.
4	Collaborative schemes	A range of different stakeholders and competitors work together to improve efficiency and sustainability of urban freight systems.	• Freight industry not willing to share information or resources with competitors. • Bigger companies might take a greater advantage over smaller companies.

Implications for policy and research

The findings of the project offer good food for thought for future policy and research. In particular, from each of the four clusters of solutions described above, it is possible to identify the following key policy/research questions:

- Cluster 1: Big Logistics Operators already consolidate at a very optimal level. Are we sure this is going to be a commercially/operationally viable option?
- Cluster 2: Rail freight could be used as a priority/more convenient option to deliver high volumes of construction material into urban centres and would therefore represent a key solution for the logistics of construction projects/site. However, can how these materials be moved from the station to the construction sites in a sustainable way?
- Cluster 3: Is electric the only net zero solution for an urban environment? Can Compressed Natural Gas or Liquefied Natural Gas have a role given the goal is net zero not absolute zero?"
- Cluster 4: What if some players gain a greater advantage than others?

In addition, the project highlighted the need to involve end-consumers into the decarbonisation process, as they play a key role in the broader picture of urban freight decarbonisation. For this reason, other additional policy/research questions would be:

- What is the end-consumer's perception towards sustainable last-mile deliveries and what factors influence their choices in terms of consumption and deliveries?
- How can local and central governments educate end-consumers to foster awareness in order to allow businesses and citizens to play an active role in freight decarbonisation?

In general, stakeholders considered different solutions and related business models to reduce carbon emissions from urban freight, but it was not clear how these solutions should be practically adopted, and where responsibilities lie. Considering future policy and research, a strong final question from this project would be:

- Urban freight decarbonisation: how do we get there?

Place-based findings

Freight consultation in the North of England is very much market driven, with businesses playing a stronger role than authorities in shaping optimal freight operations. Business objectives are demand driven and therefore influenced by customer's behaviour, which would therefore play a key role in the broader picture of urban freight decarbonisation, as they own the power of pushing the other stakeholder to undertake more sustainable practices in order to reduce their carbon emissions. However, despite the North of England having some degree of independence, especially with Transport for the North, companies and local authorities from the North found a lack of strong governance and directions from Central Government in terms of freight decarbonisation. For example, those companies who are investing in more sustainable solutions (e.g., Liquefied Natural Gas for their fleet) feel there is a high risk of investment as it is not clear what kind of technology the Government will be supporting in the future. On the other hand, local authorities would like to implement specific measures for urban freight but feel in need of a stronger and clearer coordination from central government, who should make decisions and takes responsibilities towards decarbonisation. In addition, enforcing city level environmental policy such as low emission (or clean air) zones in the north of England (i.e., Manchester and Newcastle) has proved not as easy and straight forward as in other areas of the country. In addition to national guidelines and regulations, the North would need funding to trial new solutions and support companies to invest in cleaner delivery options.

The North is also very varied in density and topography and includes conurbation patterns, with a number of bigger urban centres, and national parks. This characteristic might be key in the design of specific solutions and measures, such as for example rapid rail freight systems among the major centres that would act as a macro-urban system, which would play a key role in the modal shift from road freight to rail, with a potential significant reduction of Heavy Goods Vehicles. However, this might require investments in the rail infrastructure, such as for example in the case of Manchester, which has got a lack of rail capacity that might be an additional challenge/uncertainty.

Finally, the specific policy structure of the North, might be responsible for an inconsistent application of policies between localities, that might generate regional variations for urban freight decarbonisation depending on local authority's priorities.

Introduction

The urban population is projected to increase by 68% worldwide by 2050 (United Nations, 2019). This will generate an increased number of people and freight movements in, between and intro urban areas, resulting in increased carbon emissions. In fact, despite being a key driver for the economy, freight transport is responsible for increased traffic congestion, reduced road safety and bad air quality, with related negative implications on the environment and public health (Korzhenevych et al., 2014; Paddeu, 2017; Iwan et al., 2016; Dablanc et al., 2017, Mckinnon, 2018). Therefore, sustainable solutions and practices for last mile solutions will play a key role in reducing carbon emissions.

The CoDe ZERO project aimed at exploring stakeholder perspective towards freight systems in order to co-design a series of scenarios to reduce carbon emissions in the North of England, while identifying uncertainties, and potential drivers and barriers to their implementation. Stakeholder engagement was a key element of the project as it maximised the effectiveness of the co-designed scenarios, as these responded to different needs and expectations of all the parties involved (e.g., logistics/freight operators, receivers, citizens). The focus on the North was important because despite only 24% of the total UK population living in the North, one third of UK road, rail, port and logistics activities happen in this area.

The freight industry in the North is mainly financially supported by the private sector, with the public sector playing a marginal role. Recently, some actions, such as the Northern Powerhouse strategy, were undertaken to foster the economic growth and skills improvement in a number of 'Core Cities' in the North of England (e.g., Manchester, Liverpool, Leeds, Sheffield, Hull, Newcastle). These initiatives aimed at improving the efficiency of the freight sector in the North, in order to support competitiveness, employment, environmental sustainability and economic growth. However, despite the willingness of central government and industry in strengthening the economic development of the North of England, and its inclusion in the broader national strategy, there is a lack of attention to carbon emissions produced by the freight sector. In particular, it is important to better understand the urban freight system, and quantify direct and indirect impacts. There is very little evidence of urban freight impacts in the North of England to date, and it is mainly related to some studies carried out in Newcastle. These studies found that the increasing volumes of Light Goods Vehicles[1] (LGVs) has a similar- environmental impact than cars, whereas Heavy Goods Vehicle[2] (HGV), mainly used in construction projects to move materials, have a more significant impact, especially in terms of carbon emissions (Aditjandra et al., 2016).

Several studies highlight the importance of communication and collaboration among stakeholders in fostering the success of a sustainable urban freight scheme (Ballantyne et al., 2013;). For this reason, the key methodological approach of the Code Zero project was 'co-production', a deep and broad participatory process to identifying, scoping and undertaking an initial assessment of future collaborative sustainable and innovative urban freight solutions, including new technologies, electrification, clean fuels, and automation. Co-production prioritises consideration of the need of the stakeholders involved to develop solutions that can be more attractive to potential providers and users because they are tailored to their needs. In turn the approach maximises the potential

[1] Light Goods Vehicles (LGVs) are more commonly known as vans.
[2] Heavy Goods Vehicles (HGVs) are more commonly known as trucks.

pool of participants and so overcome barriers related to scale and financial viability. The main output of the project is a system-level-solution to decarbonise urban freight in the North of England. The project represents a preliminary explorative study to map challenges and opportunities of freight decarbonisation and inform policy makers to define an integrated zero-carbon governance for the mobility of people and goods in urban areas in the North of England.

How the North is responding to the net-zero target

Transport is the most polluting sector in the UK, and freight transport is responsible for about 35% of the overall emissions from transport. In particular, in 2018, road freight trips accounted for about 10 million tonnes of CO2, out of a total 26 million tonnes from all trips in the North. However, similarly to other UK regions, the North has given low importance to freight when defining strategic or sustainable plans in the past. Only recently, freight has assumed a more relevant role within transport planning and strategy for the North (see for example, Zunder et al., 2014).

In line with the national commitment of the UK government to reduce greenhouse gas emissions by 100% of 1990 levels by 2050 (Climate Change Act, 2019), many Transport for the North's (TFN's) partner organisations across different sectors have defined action plans to get closer to the net zero target. At the same time, Transport for the North has developed a Decarbonisation Strategy (TfN, 2021), which draws upon detailed evidence and a comprehensive policy analysis to make a series of recommendations at both national and local levels, as well as proposing a number of regional activities to support transport decarbonisation. A significant number of these recommendations and activities relate to freight (although fewer to last mile deliveries) and these activities will dovetail with the actions flowing out of TfN's emerging Freight Strategy published later in 2021.

Some of the key activities proposed for TfN include the facilitation of large zero-emission-vehicle (ZEV) truck trials in the North; aggregating large orders of ZEV vans and trucks across the North and working with government to support regional co-ordination of measures to improve logistics efficiency, including consolidation centres, modes shift to rail and information democratisation schemes. TfN's recommendations include requiring shippers to provide consumers with information on emissions from different shipping options and encouraging the uptake of green shipping options through information and pricing.

In seeking to promote the North as a test-bed area/region for innovative clean technologies and scheme for decarbonisation, TfN joined the advisory board of Decarbon8, where it supports the definition, design and testing of solutions to decarbonise transport in the North of England through a coordinated series of actions, including research and testing.

Co-design and *co-creation* with freight stakeholders

The importance of stakeholder engagement

Stakeholder engagement represents a key driver in the acceptance and adoption of new policies and measures in urban areas (Lebeau et al., 2018; Paddeu et al., 2018). Several authors acknowledged that city logistics measures tend to be more successful if freight stakeholders are included into the decision-making process (Paddeu and Aditjandra, 2020). To this purpose, policy makers can create online forums to consult freight stakeholders towards challenges and solutions to improve the efficiency, while reducing negative impact of urban goods flows. A successful example is the Freight Partnership forum (Browne et al., 2007; Zunder et al., 2014), with Newcastle being one of the early adopters. Members of the Freight Partnership forum regularly meet three to four times a month to discuss urban freight issues. Despite the high relevance of the forum, it presents a consultative nature, and does not therefore offer freight stakeholders the opportunity to play an active role in the decision-making process. Several European cities have adopted the Multi-Actor Multi-Criteria Analysis (MAMCA) approach (Macharis, 2007), where stakeholders are asked to develop a series of tasks related to the evaluation and ranking of a series of alternative solutions for urban freight systems. These solutions are specifically designed and presented by a research team that supports policy makers to implement sustainable urban freight measures. However, even though MAMCA represents a more inclusive approach, it still does not bring stakeholders into the design process. Other efforts used focus groups, surveys and longitudinal observation to determine multi-stakeholder views (Stathopoulos et al., 2012, Gammelgaard, 2015). However, city logistics stakeholders often prefer to be involved in a more generic (e.g., easy and straight forward) form of consultation process to address urban freight issues (Ballantyne et al., 2013; Zunder et al., 2014). In addition, many of the more sophisticated models (e.g., MAMCA) require an expert team to design and deliver the workshops, making it difficult for policy makers to adopt them without an expert support (Paddeu, 2021).

Stakeholder engagement in CoDe ZERO

The methodological approach of CoDe ZERO is based on ***co-design*** and ***co-creation*** through ***stakeholder engagement***.

A series of stakeholder engagement workshops were designed and run between January and March 2021 to co-design a system-based solution for urban freight decarbonisation in the North of England: a urban freight decarbonisation roadmap.

The workshops were initially planned to run face to face in different locations in the North of England, including Leeds, Manchester/Liverpool and Sheffield, with the support of Transport for the North. However, due to the pandemic, the workshops were re-designed and delivered online on MS Teams, using MIRO.com as a digital whiteboard to visualise and collect qualitative data. Representatives from different urban groups, such as couriers, logistics operators, retailers, representatives from freight associations, and policy makers were invited to take part in the workshops.

The project team carried out a stakeholder analysis to identify and select 25 key stakeholders who play an active role in urban freight decarbonisation in the North of England. The final sample included stakeholders from the public and private sectors, policy makers, freight experts and consultants, representatives from freight associations and the energy sector. All the stakeholders were based in the North or were working on freight decarbonisation issues/projects in the North.

The project team ensured diversity in terms of expertise, geography (across the region), gender and age, in order to catch a multiple perspective of the main issues and solutions to urban freight decarbonisation in the North. Before taking part in the workshops, stakeholders gave their informed consent to participate in and contribute to the research activities. Data collected were anonymised in order to avoid any possible connections between qualitative comments and personal details. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Faculty Research Ethics Committee (Faculty of Environment and Technology) at University of the West of England, Bristol (UWE REC REF No: FET.20.10.004).

Based on the results of the stakeholder engagement workshops, the project team developed a series of recommendations for policy makers to define a specific governance model to decarbonise urban freight transport in the North of England. Recommendations were provided to understand how to integrate sustainable urban freight solutions into a broader decarbonisation transport plan that includes mobility of passengers and goods, taking into consideration a broader regional perspective within a more holistic approach.

Figure 1 shows the iterative process followed during the workshops. During the first workshop participants designed the roadmap from scratch, identifying uncertainties, solutions and drivers and barriers to their implementation. The results were then presented to a second group of stakeholders during the second workshop; they were asked to comment, critique, discuss, modify and integrate the results across the different steps. This allowed them to complement and better define a final version of the roadmap, which was then tested within a final workshop with the scope of checking transferability of the roadmap to the whole Northern region, and the opportunity to include it into a broader decarbonisation transport strategy.

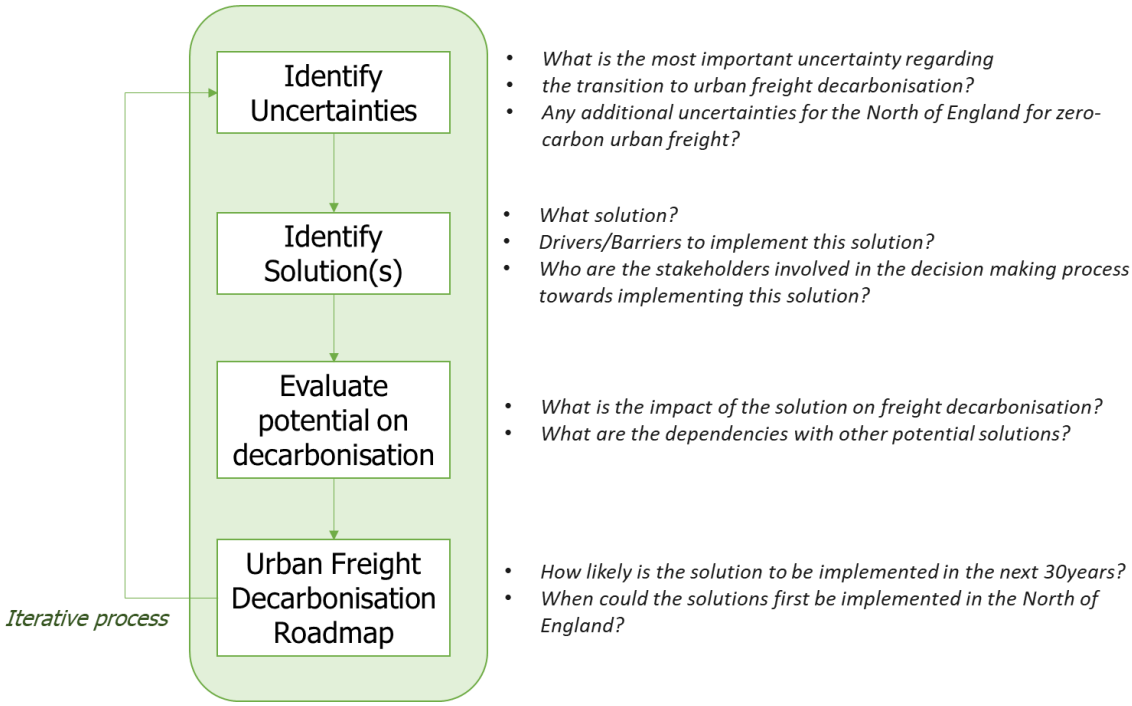


Figure 1. Methodological Framework to co-produce the urban freight decarbonisation roadmap

The use of the digital whiteboard to deliver the tasks on miro.com (see Figure 2and Figure 3) allowed participants to discuss, collaborate and co-create a series of solutions to decarbonise urban freight in the North.

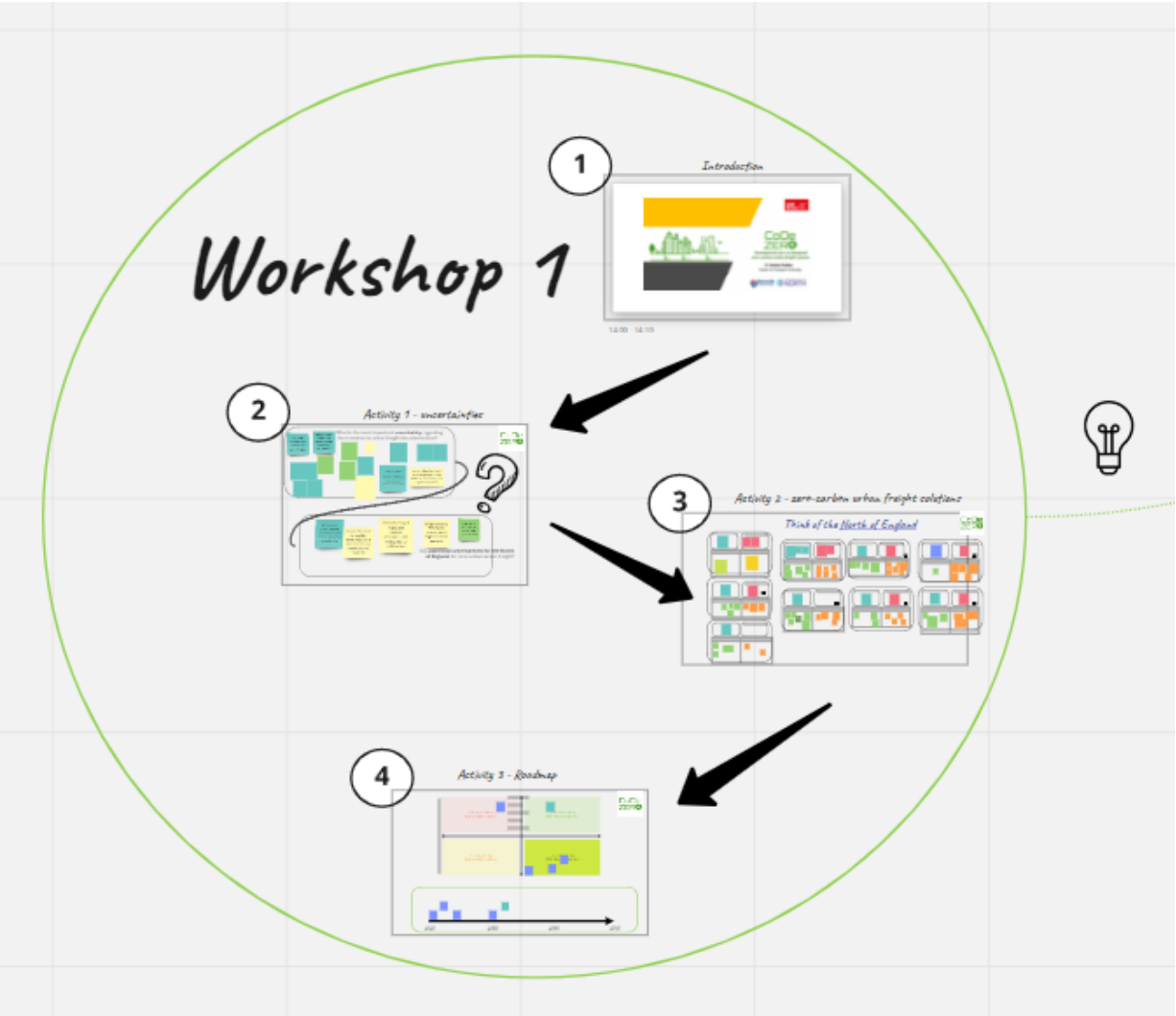


Figure 2. Example of a digital whiteboard created for workshop 1.

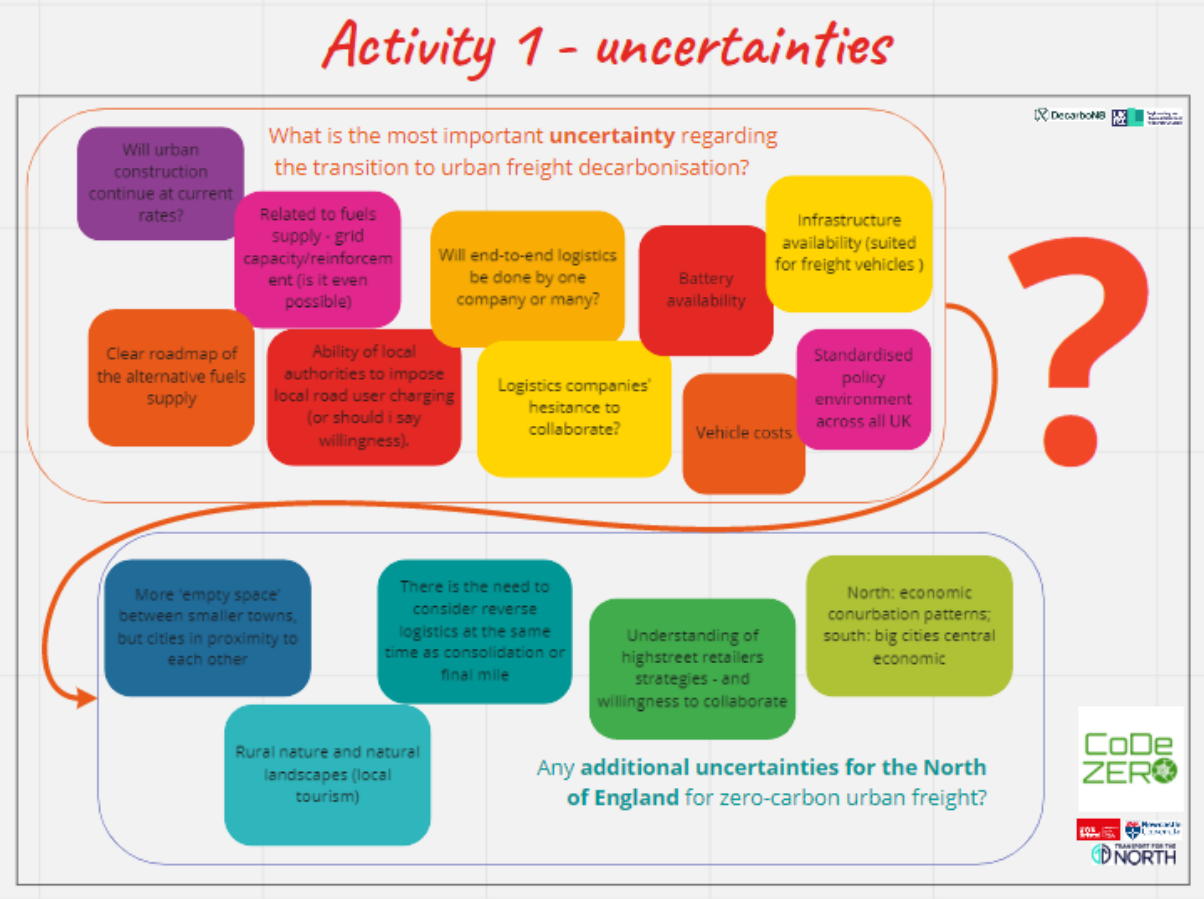


Figure 3. Example of task delivered by participants in Workshop 2

Current uncertainties towards freight decarbonisation in the North of England

The design of the roadmap has been quite complex. In fact, even though the identification of the solutions might be to some extent easier, depending on the degree of knowledge and expertise of the participants involved in the co-design activities, there is a high number of uncertainties that make it difficult to estimate when each solution can be potentially implemented. It is therefore very complex to place the decarbonisation solutions in a timeline to create a roadmap.

Stakeholders identified a number of general uncertainties (i.e., that apply to the whole country, and perhaps the whole world), and a series of uncertainties that are more specific to the North of England. They are described in the next sections.

Technical uncertainties

Stakeholders agreed on the need to decarbonise urban freight and to achieve the net zero target. However, they were not confident on what method would be most effective. They identified electrification as the most powerful solution, as it can be applied to all modes of transport, but in particular road freight (which is the major contributor to freight movements and carbon emissions). However, this would require high investments in infrastructure and the charging stations. For this reason, they believed electrification might be a solution for the medium-to-long term, and in the short-term other solutions, such as clean fuels, including biogases, Liquefied Natural Gas, hydrogen can be used to reduce carbon emissions from road freight. However, also in this case it would be required to design and create a network of refuelling stations to supply the whole fleet in the region. Also, there are currently not available technologies to produce 100% clean (e.g., zero carbon) electricity or alternative fuels. The availability of supplies would be an additional uncertainty, with the most likely scenario being to import them from abroad.

Economic uncertainties

Important uncertainties were related to the economy. In particular, it is not clear if alternative/cleaner fuels are cost-effective if compared to diesel. Also, switching to a new clean fuel would mean for logistics operators to significantly invest in new fleets of vehicles, with a related high risk.

Policy and financial uncertainties

At the moment there is a national target to reach the net zero by 2050. However, there is a lack of central directions and governance, which reflects on a need for standardise policies to be implemented across all the UK, including the North of England. Also, stakeholders expect the central government to financially support companies that decide to invest in clearer solutions to reduce carbon emissions from freight, and at the same time to provide funding locally to enable local authorities to invest in the required infrastructure.

Organisational/behavioural uncertainties

Collaboration among city stakeholders can be key to decarbonise urban freight. However, stakeholders were not sure if end-to-end logistics would be performed by one company or many

(e.g., collaborative scheme), and what kind of impact this might have on (fair) competitiveness. Another important uncertainty was related to the impact of Covid-19 on the future urban form, and whether people decide to live in a more digitally dispersed pattern rather than in central urban areas, and what impact this might have on urban freight flows.

In addition to the above uncertainties, stakeholders identified more specific uncertainties for the North of England that are described below.

Economic Geography of the North

Probably the main difference between the North and other regions is its geographical structure, which is characterised by "rural space" between smaller towns, and bigger cities in proximity to each other. The specific geographical structure of the North can be translated into a likewise specific economic framework, as the North presents metropolitan conurbation patterns driven mainly by market-led urban development (Aditjandra, 2013), whereas other regions, such as the Southern regions are characterised by a central economy related to big cities.

Policy structure in the North

The specific policy structure of the North is also an important characteristic that might have an impact on urban freight decarbonisation. Stakeholders acknowledged that there might be an inconsistent application of policies between localities, that might generate regional variations for decarbonisation depending on local authority's priorities.

Operational uncertainties in the North

Stakeholders acknowledged specific operational uncertainties related to rail freight in the Manchester area, as there is a lack of (rail) capacity that might be an additional challenge/uncertainty for freight decarbonisation in the North. Strategic (rail) freight corridors monitored by UK government in the North of England spanned between Liverpool/Manchester areas and Leeds/Sheffield areas (Aditjandra et al., 2012).

Roadmap to urban freight decarbonisation in the North of England

The results of the literature review and the stakeholder engagement workshops informed the design of the urban freight decarbonisation roadmap for the North of England (Figure 4).

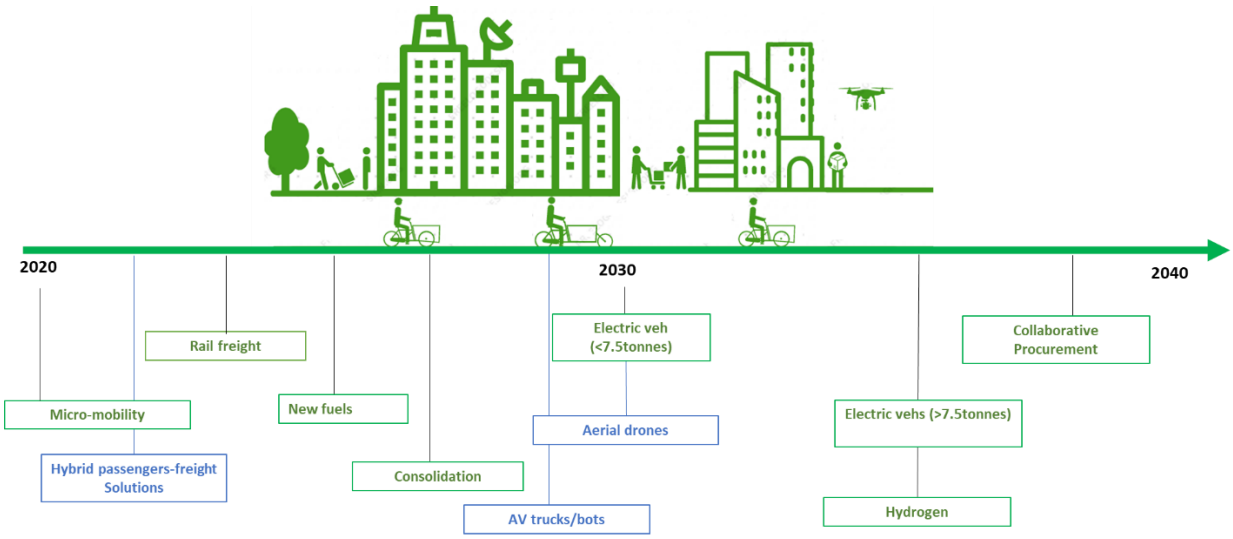


Figure 4. CoDe ZERO roadmap

Stakeholders see **micro-mobility**, which includes e-cargo bikes, as a quick win to reduce carbon emissions due to urban goods movements. This solution already exists, and it is implemented in different European cities. However, stakeholders acknowledged that the operational and cost efficiency of this solution would depend on the type of application. For example, despite working well in urban areas, e-cargo bikes might be not convenient for last-mile deliveries to rural areas, due to the limited capacity and the longer distances (compared to urban deliveries). Thus, it would be useful to understand what the ideal scenario (e.g., distance, load factor, type of goods, topography) is to make micro-mobility a competitive alternative. In addition, a large-scale implementation of this solution would require interventions on land use and urban planning, including interventions on road space design.

Stakeholders also believe that **urban freight consolidation** has the potential to reduce carbon emissions, due to a reduced number of vehicles, and can be an available option in five-to-eight years. They believe that businesses (e.g., retailers and logistics operators) might be resistant to adopt this new delivery scheme as they would need to share data and resources with their competitors, and also because it might not be suitable for all types of goods (e.g., heavy, bulky). In addition, the urban consolidation hub would add extra costs to the chain, which would reduce the attractiveness of this solution, especially because margins of last-mile deliveries are very low. Other major barriers would be “competition”, “brand protection and recognition” and “reputation”. Also, in terms of operations, freight companies might have different logistics models (e.g., return, repair, recycle) and having multiple-operators involved would increase the complexity of the system. Stakeholders are quite positive towards the idea that these barriers might be (at least partially)

overcome before 2030 with the right support from local and central governments to foster collaboration.

Another quick win identified by stakeholders was **rapid rail logistics**, especially to deliver large volumes of goods into the city centre (e.g., construction sites). Stakeholders believed this could be implemented soon, as the use of inter-city trains can be shared to move people and goods, due to the impact of the pandemic and the related increasing homeworking post-pandemic on commuting that created an opportunity in terms of increased spare capacity of trains.

In terms of clean technologies, **electrification** was considered the way forward to achieve urban freight decarbonisation. Considering that well performing electric vans are already available in the market, stakeholders believed that these could be increasingly used within the next 10 years to fully replace the current diesel fleet by 2030. However, the current technology does not offer viable efficient alternatives for bigger/heavier vehicles (e.g., heavier than 7.5 tonnes), and therefore stakeholder believed electric HGVs might be available in 10-15 years (by 2035). In the meantime, they suggested **hydrogen** might play a key role as an interim (medium-term) solution to reduce carbon emissions from HGVs. However, even in this case, more research and trials would be needed to support the development of a clean technology for production and propulsion.

New clean fuels, such as biogases, Compressed Natural Gas, Liquefied Natural Gas and similar, were considered a quicker and easier solution, as they can be immediately used as a valid alternative to diesel, until electricity and hydrogen (or zero emission fuels/energy) are available.

Finally, **collaborative procurement** between retailers, logistics operators and public bodies was seen as a good solution to optimise the overall urban flows, and reduce the demand for loading/unloading locations, kerbside loading/unloading nuisance and therefore reducing related congestion/nuisance to normal functioning of the road network. However, similarly to consolidation, this solution would imply a number of challenges, especially related to willingness to share data, resources, customers with competitors and would also represent a major barrier to new market entrants.

Interestingly, **new technologies** such as autonomous trucks and robots, or aerial drones were not identified as effective solutions to decarbonise urban freight. Stakeholders acknowledged that they could reduce costs of operations and would therefore represent an indirect solution to invest in clearer alternative delivery options. However, new technologies alone would not be a priority among the solutions to decarbonise urban freight.

Clusters of solutions to achieve urban freight decarbonisation

Considering the complexity of the urban system, the solutions identified by stakeholders and described in the previous section, should not be treated independently. In fact, the research team believe that they should be rather integrated to form part of a broader system of solutions to achieve the net zero target. For this reason, the research team identified four main clusters of solutions that are presented below.

Cluster 1. Micro-consolidation network

The first cluster includes a network of micro-consolidation centres surrounding an urban area. This network of smaller hubs would attract the freight flows destinated to receivers based in urban areas, and then micro-mobility (e.g., e-cargo bikes) would be used to deliver the very last-mile. This solution would have a direct positive impact on the reduction of congestion and carbon emissions due to urban freight movements, due to a combined effect of consolidation and use of low/zero emission solutions for the last mile. Also, due to their shape and size, e-cargo bikes might be more convenient than electric vans as can make better use of the road infrastructure, optimising occupancy of space in the road (and maximise load capacity). In addition, they would reduce the visual intrusion due to medium-big size commercial vehicles in historic centres. They would also have a lower investment cost for logistics operators who operates in urban areas. On the other hand, the limited size of e-cargo bikes might be a limitation in terms of carrying capacity and can therefore have a negative impact on cost-efficiency, which might represent a barrier when establishing a business case. Another main barrier related to urban consolidation is related to the extra costs and times it generates (e.g., added node to the supply chain) that might increase the risk of supply chain disruption. Finally, collaboration among stakeholders would be key to establish a successful implementation but might be hard to achieve as there might be retention to collaborate (see also Cluster 4).

About this cluster stakeholders wondered:

“Big Logistics Operators already consolidate at a very optimal level. Are we sure this is going to be a commercially/operationally viable option?”

Cluster 2. Rapid Rail Logistics

The second cluster presents rapid-rail logistics solutions for urban freight, with shared passenger-freight trains used to move goods between hubs and using micro-mobility or e-vans for the very last-mile. Similarly to Cluster 1, this cluster also considers hubs (i.e. UCCs in the previous cluster), but in this case these are represented by railway stations where goods arrive by train and are then delivered to the final destination by electric vans or cargo-bikes, depending on the type of goods. However, heavier/bigger-volume goods, such as construction materials would still require medium-big size transport means to reach the final destination, in case the railway station is not in proximity of the construction site. The main driver to the implementation of Cluster 2 is the significant reduction of number of Heavy Goods Vehicles and Light Goods Vehicles due to the shift to rail, and the related carbon emission reduction. The advantage of this cluster is that there is already a widespread network of railway stations in urban areas, and this would reduce the costs related to the establishment of a network of UCCs. Also, considering the impact of Covid19 on travel behaviour

and commuting, it is plausible that a good number of people will be working from home, with a related reduction of commuting trips. It would be therefore useful to re-think and re-design railway services, in order to maximise the use of the un-used capacity of trains and stations due to a reduction in the number of commuters. However, converting railway stations into urban consolidation hubs would require interventions and investments to enlarge specific areas of the stations, with consequences related to a need for bigger logistics land availability and land use regulations.

A key point from stakeholders about this cluster was:

"Rail freight could be used as a priority/more convenient option to deliver high volumes of construction material into urban centres and would therefore represent a key solution for the logistics of construction projects/site".

Cluster 3. Electrification and New fuels

The third cluster presents electrification and new fuels (including biogases, Liquefied Natural Gas–- LNG, and hydrogen) to power LGVs as an urban freight decarbonisation solution for the short, medium and long term. In fact, the number of vans had almost an exponential growth in the last 25 years (+ 106%) and it is expected to follow the current exponential growth trend in the future (DfT, 2021). This has a negative environmental impact, as 96% of vans in the UK are diesel and only 0.3% are Ultra low emission vehicles (DfT, 2021).

The implementation of this cluster of solution would not imply a reduction of the number of LGVs in urban areas, and therefore would not be effective in reducing congestion. However, due to the clearer energy source, there would be a reduction of carbon and polluting emissions and would therefore represent a plausible solution to achieve urban freight decarbonisation. This cluster would require the central government to provide financial support (e.g., incentives, subsides) to encourage logistics operators to invest in and switch to a clearer electric fleet.

On the other hand, the Government should directly (e.g., central policy/strategy) or indirectly (e.g., via local/regional authorities) put in place an investment plan to provide the required infrastructures (e.g., charging/refuelling stations) to enable the use of clean sources and at the same time guarantee energy supply/availability. Another important consideration related to this cluster is the current unavailability of technical solutions to produce clean electricity or other clean fuels. There is therefore the need to understand how to produce zero-carbon energy and fuels. This cluster mentioned applications to LGVs, as electric technology for LGVs performs quite well. On the contrary, HGVs are currently more problematic to decarbonise, as electric HGVs would require a big size battery that would reduce the load capacity of the vehicle and its overall performance, making a diesel HGV much more competitive. Electric HGVs would therefore not be a decarbonisation solution for urban freight in the short to medium term.

Working at this cluster, stakeholders wondered:

*"Is electric the only net zero solution for an urban environment? Can Compressed Natural Gas or Liquefied Natural Gas have a role given the goal is **net zero** not **absolute zero**?"*

Cluster 4. Collaborative schemes

The final cluster includes Collaborative Schemes involving all the city stakeholders. Urban freight collaborative schemes are in place when a range of different stakeholders and competitors work together to improve efficiency and sustainability of urban freight systems. The main driver to implement this solution would be an improvement in the overall performance of the system, with a reduction of demand for loading/unloading space, a more 'sized' service where it is possible to achieve economy of scale. However, even though this might sound the easiest solution, it could on the contrary be the most difficult to implement, as stakeholders are usually not willing to share information with their competitors and to collaborate. In fact, some companies/brands might take a commercial advantage at the expense of smaller/newer companies/operators, creating inequalities in the urban freight market.

A key question asked by stakeholders towards this cluster was:

"What if some players gain a greater advantage than others?"

The infographic below (Figure 5) presents a summary of the four clusters of solutions identified by the research team with the input of the CoDe ZERO stakeholders.

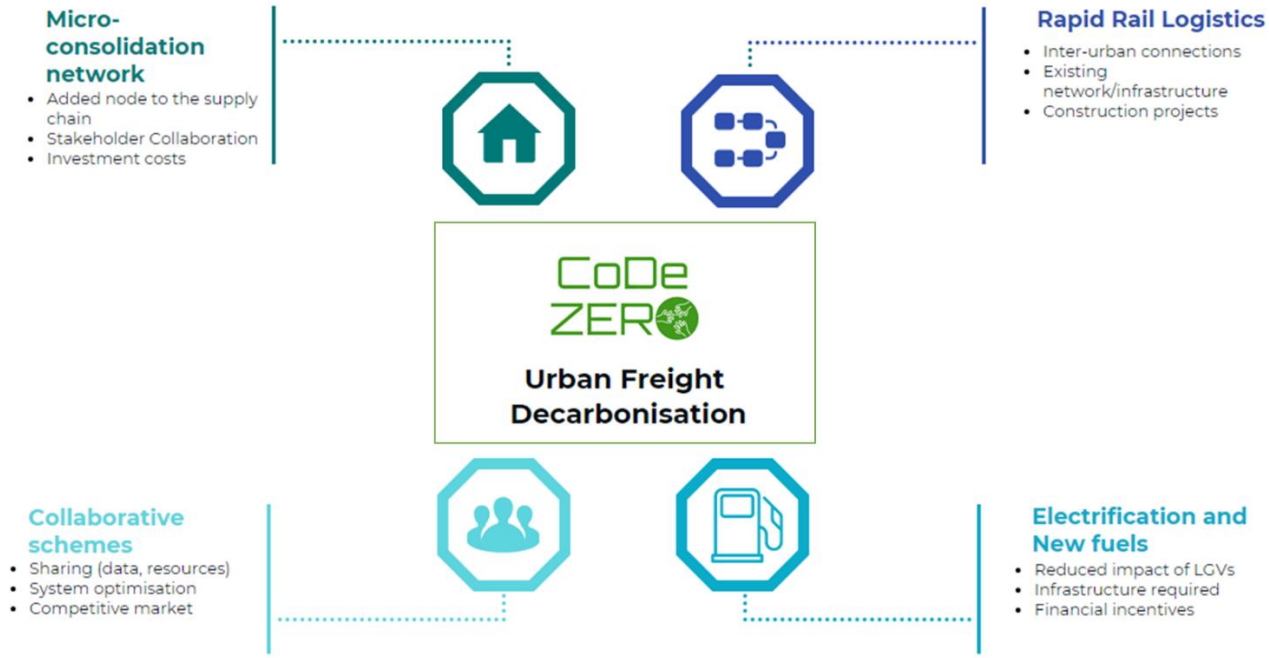


Figure 5. Solutions identified to decarbonise urban freight

Limitations and implications for future research

The short duration of the project and the limited resources did not allow the research team to go more in depth and identify priorities to shape the steps towards freight decarbonisation. Also, considering the key role of end-consumers in the broader city logistics context, the research team considered to involve end-consumers and citizens in the project. However, this would have required more time and effort and was not deliverable within the duration of the project. Considering the key role of end-consumers, it would be interesting to do more qualitative and quantitative research in the future to understand the main variables influencing end-consumer's choices and therefore understand how to drive behaviour change towards more sustainable preferences.

This report and the co-created roadmap represent a step forward in understanding challenges and opportunities for urban freight decarbonisation, and could be used by policy makers, academics and practitioners who want to learn what the expectations from stakeholders are for the next 20-30 years. A key result of the CoDe ZERO project is that all the stakeholders involved clearly recognised the importance of achieving the net zero target by 2050, the important role of freight decarbonisation, and said that "we" should do something to contribute achieving it. However, it was less clear who "we" are (e.g., who should be responsible for making decisions and taking actions) and what we should be planning and doing in the next 20-30 years to achieve the target.

All the conversations established with the different stakeholders were towards what solutions and business models we can adopt to reduce carbon emissions, but it was not clear how these solutions should be practically adopted, and where responsibilities lie. Considering future research, a strong final question from this project would be: ***Urban freight decarbonisation: how do we get there?*** - This would include qualitative and quantitative research on the impact of each solution on carbon reductions, and a list of priorities and actions to adopt the solutions and make a real contribution to decarbonisation.

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