When Urban Policy Meets Technological Niche: MLP-Informed Lessons from Multi-City FCCP Initiatives

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Abstract

European municipalities play a vital role in decarbonizing urban freight. This study explores the potential of Fuel Cell Cargo Pedelecs (FCCPs) as a more sustainable alternative to diesel-based and battery-powered logistics. Using the Multi-Level Perspective (MLP) framework, it examines how FCCPs can transition from niche pilots into mainstream adoption, aided by supportive policy measures. An Interreg North-West Europe project trialed 35 FCCPs, generating data analyzed through mixed methods and Multi-Actor Multi-Criteria Analysis. Findings highlight FCCPs' operational advantages—such as efficiency and positive public perception—alongside barriers like high costs, limited hydrogen infrastructure, and fragmented regulation. Coordinated efforts are required across all MLP levels: expanding refueling networks, streamlining certification, and incentivizing early adoption. By addressing these systemic challenges, municipalities can fully integrate FCCPs into urban logistics, contributing to cleaner, more resilient transport systems.

Keywords: sustainable urban logistics, fuel cell technology, cargo bikes, Multi-Level Perspective, transport policy, cycling infrastructure, innovation diffusion

1 Introduction

European city administrations are currently undergoing a major transformation of transportation systems. This change is being driven by the urgent need to address environmental concerns and the evolving logistical requirements of modern urban areas (Schippl et al. 2016). Traditional modes of transportation are increasingly seen as unsustainable due to their environmental footprint, particularly in terms of greenhouse gas emissions and air pollution. The challenge is to develop innovations in the transport sector to meet these new demands while striving for environmental sustainability (Zawieska and Pieriegud 2018).

Among these innovations, fuel cell cargo pedelecs (FCCPs), i.e. the energy supply of cargo bikes with the help of fuel cells, have emerged as a promising solution. This technology not only aligns with the growing environmental consciousness but with political strategies aimed at managing urban development more effectively. Despite considerable advancements in fuel cell technology, there is still a noticeable gap in their practical application and testing, particularly in cargo bike applications and among novice users (Glover et al. 2021). While recent research has shown significant progress in fuel cell efficiency and integration into vehicles (van Biert et al. 2016; Giddey et al. 2012), the success of these technologies in real-world scenarios hinges on addressing practical considerations such as infrastructure development and user training (Cui et al. 2018).

Furthermore, there is a clear gap in the literature regarding the operational and policy dimensions that influence the adoption of FCCPs. Previous research has addressed both the technical development and the environmental benefits of FCCPs but has largely overlooked the complexities of integrating these vehicles into urban environments. This oversight underscores the need for a comprehensive analysis that takes into account both on-the-ground operational realities and the overarching policy efforts shaping the adoption of FCCPs in European cities.

In this study, we apply the Multi-Level Perspective (MLP) framework to situate FCCPs within the broader socio-technical system of urban logistics. The MLP examines transitions by analyzing interactions across three levels: (1) niche innovations (where FCCPs are developed and tested in protected spaces like pilot programs), (2) regime structures (e.g., entrenched diesel-based logistics systems), and (3) landscape pressures (e.g., European climate goals and societal demand for sustainability). This approach provides a systemic lens through which to explore the adoption and integration of FCCPs.

This study aims to bridge the gap in understanding the operational realities and policy dimensions surrounding the adoption of FCCPs. Specifically, it addresses two core research questions:

What conditions are required for FCCPs to transition from pilot projects to widespread use in urban logistics systems?

How can policy measures address barriers to FCCP adoption while supporting innovation in urban transport?

The paper is structured as follows: The next chapter presents the background and context of the research, including an overview of FCCP trial use in an Interreg project, and the applied research methods. The subsequent analysis evaluates the experiences of the case study cities, their motivations for FCCP adoption, and an initial assessment of policy measures by both city representatives and logistics service providers. This is followed by a re-evaluation of those policy measures in light of actual usage experiences, highlighting operational realities, key drivers and barriers to adoption, and transferable strategies for FCCP-supportive policies. Finally, the paper concludes by discussing future perspectives and summarizing the key findings.

2 Background & methodology

2.1 Trialing of 35 fuel cell cargo pedelecs within Interreg project

Within the Interreg North-West Europe project FCCP (FCCP - Fuel Cell Cargo Pedelecs, 2023), 35 bikes were technically developed and tested in selected cities (Aberdeen, Issy les Moulineaux, and Stuttgart, among others). The design of the initial vehicles corresponds to so-called „heavy-duty" cargo bikes. These vehicles have three or four wheels and the cargo box for loading approximately one pallet is positioned behind the rider. Available models from cargo bike manufacturers were used as the starting point for the FCCP development (see Figure 1). The project – running from 2018 to 2023 – allowed to identify the key drivers that promote their uptake and the barriers to their widespread adoption. Throughout the project's duration, the deployment and utilization of FCCPs varied across the partner cities, both in terms of how they were used and the duration of their use.

Figure 1: Three examples of the trialled fuel cell cargo pedelecs: Bring S by Bayk, UM CargoBike by Urban Mobility, Amadillo by Velove (photo: DLR)

The 35 FCCPs developed during the project were tested in various environments and applications. The usage scenarios can be categorized along two dimensions: by type of user (private vs. public organizations) and by type of use (freight trips, service trips, or on-site trips). Private companies such as the cycle logistics enterprise VeloCarrier employ FCCPs in multiple cities, as do other messengers like TL in Berlin and delivery services such as Norco Energy and Royal Mail in Aberdeen. Unicorn in Schwäbisch Gmünd provides an example of service-sector usage of FCCPs for on-site transport.

Public and non-profit uses are equally diverse. For instance, Issy-les-Moulineaux transports equipment via FCCPs, Stuttgart's municipal departments and Aberdeen's city council use them for park maintenance, and both the German Aerospace Center (DLR) and Aberdeen employ them for on-site technical equipment transport. Educational and healthcare facilities in Aberdeen also confirm FCCPs' adaptability to various institutional settings.

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For on-site trips and internal transport, entities like the German Aerospace Center and Stuttgart's sewage plant utilize FCCPs, as do educational and healthcare facilities in Aberdeen, confirming FCCPs' adaptability across various institutional settings.

2.2 Methodology

The research combined desk research, interviews, surveys, and focus groups. An initial catalogue identified 18 potential measures for promoting FCCPs, addressing urban planning, regulation, bicycle promotion, and hydrogen-specific steps. Interviews with municipal representatives and logistics providers clarified perceived barriers, feasibility, and real-world experiences. A Multi-Actor Multi-Criteria Analysis (MAMCA) with 33 logistics professionals and four city representatives helped rank policy measures by effectiveness, cost-benefit, implementation timeframe, and political acceptance (Brans and Vincke 1985). A follow-up survey with 18 participants offered further insights on policy and stakeholder motivations.

3 Ex-ante evaluation of policy measures to promote fuel cell cargo pedelecs

3.1 Case study cities

The participating case study cities are cities that have engaged in both the qualitative interviews and the re-assessment process, as well as collected practical experience with the FCCPs. This allows them to provide both an ex-ante and an ex-post evaluation of the political measures from experience. The case studies cities, Issy-les-Moulineaux, Stuttgart and Aberdeen, each present distinctive approach to urban development, mobility, and environmental sustainability, reflecting their unique geographical and economic contexts.

Their experiences highlight dynamics at all three MLP levels, while aligning with environmentally, company, and vehicle-specific factors affecting adoption.

Aberdeen, Issy-les-Moulineaux, and Stuttgart participated in interviews, policy assessments, and pilot trials, allowing both ex-ante and ex-post perspectives. Each city’s unique context—Aberdeen’s pivot from oil to hydrogen, Issy-les-Moulineaux’s dense urban form and digital-economy hub, and Stuttgart’s automotive heritage—frames their approaches to sustainable mobility.

3.2 Motivations for FCCP promotion from a municipal perspective

The different characteristics of the cities are reflected in the motivations for participating and trialing the bikes, as identified in the interviews and in a survey conducted for the application (with 18 participants). Even though the survey revealed that environmental protection was the dominant motivation, with 12 out of 18 respondents citing this as the main reason for trialing hydrogen freight bikes. But there are other factors in addition to environmental protection that are motivating the municipalities. This is exemplified by Aberdeen's strategy on establishing itself as a leading European region for early deployment of hydrogen fuel cell vehicles and becoming a hub for hydrogen technologies in Scotland. Their hydrogen strategy, primarily cantered on vehicles like cars, vans, and buses rather than cargo bikes, aims to position Aberdeen as a pioneer in hydrogen propulsion technology. This includes ambitious projects like the first offshore hydrogen farm, set to be operational by 2025 with support from EU and UK funding.

These motivations are driven by landscape-level pressures (e.g., EU climate policies) and regime-level ambitions (e.g., air quality improvements).

3.3 Degree of implementation of policy measures

Interviews with municipal representatives indicated varying levels of policy implementation. Most commonly, city governments had already introduced restrictions on conventional vehicles—such as speed limits or low-emission zones—and had invested in expanding or improving cycling infrastructure. Public outreach campaigns were also popular, reflecting the consensus that shifts in public behavior and opinion are vital for a sustained transition. Although many local administrations have begun funding cargo bike projects or offering training sessions, only a few had taken significant steps to develop local hydrogen refueling infrastructure. Some form of financial subsidy existed in most places, but direct support for commercially used cargo cycles remained scarce, hindering the business case for operators. A municipal micro-depot was present in only one city, indicating that broader integration of FCCPs into urban logistics remains a challenge.

3.4 Evaluation of policy measures by municipalities and logistics service providers

A MAMCA-based assessment involving city officials and logistics providers highlighted the nuanced perspectives on policy measures. Cities tended to prioritize political acceptance and relevance or effectiveness, while logistics providers placed more emphasis on cost-benefit considerations. Both groups, however, valued investments in high-quality bicycle infrastructure, disincentives for conventional vehicles (such as congestion fees or low-emission zones), and expanded hydrogen fueling networks. Public awareness campaigns about hydrogen and cargo bikes were also generally seen as beneficial.

Measures such as municipal micro-depots, local subsidies for hydrogen infrastructure, and testing programs enjoyed moderate support, reflecting a shared interest in practical experimentation with FCCPs. Overall, the findings indicate consensus on the importance of robust infrastructure investments and complementary policy levers, even if actual implementation pathways differ across municipal contexts.

Applying the PROMETHEE method to combine these weights with each measure's scores yielded a ranking. Highlights include:

High Scores:

- Developing high-quality bike infrastructure
- Restricting motorized vehicles (congestion fees, low-emission zones)
- Expanding hydrogen fueling networks
- Public relations for hydrogen and cargo bike usage

Moderate Scores:

- Municipal use of cargo bikes
- Testing programs and campaigns
- Local funding for hydrogen infrastructure

Lower Scores:

- Urban planning measures like municipal micro-depots or subsidized land use

These results suggest a shared view that infrastructure—both for cycling and hydrogen—plus strategic disincentives for conventional vehicles are critical levers for fostering cargo bike adoption.

4 Re-evaluation of policy-measures in light of user experience

Following the initial evaluation, a second round of qualitative interviews and a focus group discussion were conducted with city representatives after the FCCPs had been deployed. Additional interviews were also carried out with FCCP users. The goal was to re-assess the preliminary evaluations in light of actual user experiences and to adjust the evaluations as necessary.

4.1 Observed drivers and barriers during FCCP usage

Niche-Level Dynamics:

- Drivers: The pilot deployment improved public perception of hydrogen technology, especially in cities like Issy-les-Moulineaux, where hydrogen initiatives extended beyond transportation. The visibility of FCCPs reduced skepticism and fears, empowering employees—particularly those without driving licenses—to participate in urban logistics. The health benefits and enjoyment of cycling, coupled with FCCP efficiency in delivering up to 150 parcels daily, were notable advantages.
- Barriers: Technical limitations, such as inadequate payload capacity and insufficient suspension, constrained adoption. Safety concerns during reverse maneuvers and discomfort for shorter operators further hindered usability. Limited funding and fragmented certification processes for FCCPs added to the challenges, slowing progress in scaling up their use.

Regime-Level Resistance:

- Drivers: FCCPs offered significant operational advantages, such as easier navigation in restricted urban areas and reduced parking challenges, which logistics service providers like VeloCarrier found crucial. These align with broader urban initiatives to transition away from diesel-based logistics systems.
- Barriers: Entrenched diesel logistics systems remain dominant, with economic structures favoring fossil-fuel-dependent transport. High initial costs for hydrogen vehicles and infrastructure deterred adoption. Interoperability challenges, such as the incompatibility of German-built FCCPs with French hydrogen refueling standards, further highlighted systemic barriers. Regulatory frameworks often lagged behind the technical requirements of hydrogen technologies, complicating widespread integration.

Landscape-Level Pressures:

- Drivers: Societal demand for sustainable urban transport and EU climate policies provided a supportive environment for FCCP adoption. Cities like Stuttgart and Aberdeen leveraged these pressures to align hydrogen technologies with long-term sustainability goals.

- Barriers: High hydrogen refueling costs, limited specialized insurance options, and inadequate public awareness campaigns weakened societal support. Public concerns about hydrogen safety persisted in some areas, emphasizing the need for more robust engagement strategies.

4.2 Recommendable and Transferable Measures

Based on the above findings, three interconnected sets of measures, informed by the MLP framework and diffusion theory, are proposed:

1. **Niche-Level Measures**: Expand pilot programs to refine FCCP designs and address operational challenges related to safety and payload capacity.
2. **Regime-Level Measures**: Standardize hydrogen refueling systems and simplify certification procedures to accelerate FCCP uptake among logistics providers. Provide targeted subsidies or low-interest loans to lower economic hurdles and align incentives with sustainability targets.
3. **Landscape-Level Measures**: Launch more proactive public awareness campaigns and make broader investments in hydrogen infrastructure. These initiatives would help reinforce positive attitudes toward hydrogen safety and demonstrate strong commitments to decarbonizing urban logistics.

5 Outlook: what needs to happen to improve chances for market uptake of FCCPs?

It's evident that while local policy measures are undoubtedly beneficial or even necessary basis to support fuel cell powered cycle logistics, the progression of fuel cell technology in small vehicles is far from being self-sustaining. The challenges are multifaceted, encompassing technological hurdles, economic constraints, and human factors, all within the complex framework of political and regulatory environments. Scaling up FCCPs effectively requires significant progress across multiple dimensions:

Technological Advancements: Ongoing R&D can improve FCCP performance, durability, and cost-effectiveness. Modular fuel cell systems tailored to specific power demands, combined with scaling up production, can lower unit costs. Analysis at DLR suggests that manufacturing 1,000 or 10,000 units significantly reduces costs, particularly for the fuel cell stack.

Table 1: Cost development of the DLR stacks depending on unit numbers

Units	10	100	1,000	10,000	100,000
Cost per unit	24,468 €	8,198 €	4,482 €	2,555 €	2,419 €

- **Infrastructure Development**: A robust hydrogen refueling infrastructure is vital. National and EU hydrogen strategies could drive the establishment of an extensive refueling network designed to accommodate small vehicles like FCCPs, ensuring seamless and efficient urban transport.
- **Exploiting Regulatory Opportunities**: Municipalities play a pivotal role by leveraging existing regulatory frameworks or creating new ones to foster FCCP adoption. Tailored regulations and incentives would encourage FCCP use and help integrate them more deeply into urban transport systems.
- **Stakeholder Education**: Informing and training stakeholders about FCCPs' potential and benefits is critical. Well-informed policymakers, businesses, and the general public are more likely to support and adopt FCCPs, thereby broadening their market acceptance.
- **Collaboration and Partnerships**: Cooperation across national borders among industries, research institutions, and governments can expedite innovation, knowledge-sharing, and address common barriers. Such partnerships create the groundwork for widespread adoption of FCCPs as a sustainable urban mobility solution.

6 Conclusion

Integrating the MLP framework with innovation diffusion theory shows that FCCP adoption requires interventions across all systemic levels. Niche-level experimentation must be bolstered by regime-level disruptions of existing logistics norms, in tandem with landscape-level societal and policy pressures. Addressing these interlinked dynamics can move FCCPs from pilot-stage innovations to mainstream solutions, substantially contributing to the decarbonization and modernization of urban transport systems.

By highlighting the intersection between operational realities and policy efforts in FCCP adoption, this study provides valuable insights for academics, policymakers, urban planners, and environmental advocates. The pilot deployments of FCCPs in the participating cities afford a practical appraisal of this technology within the context of urban life, reinforcing the important role that cities play in testing new mobility solutions and promoting sustainable urban transport.

The findings emphasize the necessity of locally tailored strategies that cater to each city's specific conditions. By engaging with a wide range of stakeholders, the study identifies policy measures to promote FCCP integration while exposing both the benefits and challenges encountered in real-world applications. Ultimately, a coordinated strategy encompassing technological innovation, infrastructure expansion, regulatory support, and stakeholder education can create a conducive environment for FCCPs—one that enables them to become an integral component of greener, more efficient, and more sustainable city logistics.

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