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User Experience and Operating Performance in Cargo Bike Selection for Sustainable Urban Delivery

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Abstract

Cities increasingly promote cargo bikes as environmentally friendly alternatives to conventional delivery vans, yet the success of these vehicles in everyday operations depends not only on their technical specifications but also on the experiences and preferences of the riders who use them. This paper develops and applies an integrated framework for cargo bike selection that combines detailed operational modelling with a systematic assessment of user experience. The goal is to support logistics operators and public authorities in choosing cargo bike models that are both operationally efficient and acceptable for riders engaged in intensive last-mile delivery. The framework links three components. First, a network and demand model describes realistic delivery patterns based on data from a major logistics operator. Second, a routing model based on the Capacitated Vehicle Routing Problem is used to simulate last-mile delivery operations performed by seven widely used cargo bike models. From these simulations we derive indicators of efficiency, including freight work per unit of battery capacity and the number of required routes and recharges. Third, a survey of forty-eight professional cargo bike riders captures the perceived importance of operational parameters such as carrying capacity, distance achievable on one battery charge, vehicle weight, number of gears, and number of wheels. Statistical tests confirm a high level of agreement among riders and allow the derivation of attribute weights that reflect user priorities. Operational and behavioural evaluations are then combined into a single integrated indicator of cargo bike suitability. This indicator ranks the seven models and reveals how trade-offs between capacity, range, weight, and handling shape both simulated performance and rider acceptance. A regression model links the integrated indicator to key operational parameters \, enabling the estimation of suitability scores for new cargo bike designs without the need to repeat the full simulation and survey process. Results show that carrying capacity and distance per battery charge are decisive for both efficiency and user satisfaction, while weight and gearing mainly influence longer or more demanding delivery cycles. The study demonstrates that ignoring rider experience can lead to the selection of operationally strong but behaviourally weak cargo bikes, limiting the potential of sustainable urban freight initiatives. By embedding user perspectives in a quantitative selection tool, the proposed framework offers a transferable approach for planning human-centred, low-emission delivery fleets.

Keywords: Sustainable Urban Freight Transport; Cargo Bike Selection; Last Mile Delivery; Driver Experience and Behaviour; Human Centred Logistics Design; Decision Support Modelling;

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1 Introduction

Cities are under growing pressure to decarbonise urban freight while maintaining reliable last-mile delivery under rising demand. This challenge is becoming more acute as urbanisation continues: about 55% of the world's population already lives in urban areas, and this share is projected to reach 68% by 2050 (United Nations, 2018). At the same time, the transport sector produces nearly 8 Gt of CO_2 emissions, while freight transport contributes substantially to overall greenhouse-gas emissions and local externalities such as congestion, noise, and road-space competition (IEA, 2023; OECD, 2024). In this context, cargo bikes have emerged as a promising low-emission alternative for urban delivery because they can reduce pollution, improve access in dense areas, and help build more livable cities. Recent analytical evidence suggests that even existing cycling infrastructure can support the substitution of a meaningful share of parcel deliveries by cargo bikes, with further gains possible through targeted network improvements (Yang & Lee, 2024). These developments have made cargo bikes an increasingly important element of sustainable urban freight strategies, but they have also raised a more specific question: which cargo bike is the most suitable for a given delivery context, and for whom?

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The current state of the art shows substantial progress in understanding the technical and organisational feasibility of cargo-bike logistics. Recent reviews and empirical studies have examined operational typologies, policy and infrastructure requirements, network suitability, route optimisation, and the spatial conditions under which cargo bikes can complement or replace vans (Narayanan & Antoniou, 2022; Carracedo & Mostofi, 2022; Ding et al., 2024; Galkin et al., 2025). Other work has shown that cargo-bike operations are sensitive to infrastructure design, parking conditions, weather, and route characteristics, while vehicle geometry, loading configuration, and stability can materially affect safety and rideability (Dalla Chiara et al., 2023; Malik et al., 2023; Paudel & Yap, 2024). However, this literature remains fragmented. Operational studies typically evaluate performance in terms of distance, cost, emissions, or routing efficiency, whereas human-centred studies tend to discuss acceptance, ergonomics, or occupational risks without integrating these factors into model-based fleet selection. As a result, logistics operators and public authorities still lack a decision-support tool that jointly considers operating performance and user experience when choosing among cargo bike models for intensive urban delivery.

This paper addresses that gap by developing an integrated framework for cargo bike selection that combines detailed operational modelling with a systematic assessment of rider priorities. The study links three components. First, it uses network and demand data from a major logistics operator to represent realistic last-mile delivery patterns. Second, it applies a Capacitated Vehicle Routing Problem (CVRP) model to simulate the performance of seven widely used cargo bike models and to derive indicators such as freight work per unit of battery capacity, number of routes, and recharging requirements. Third, it incorporates the results of a survey of 48 professional cargo-bike riders to identify the relative importance of key vehicle attributes, including carrying capacity, achievable distance per charge, weight, gearing, and wheel configuration. These operational and behavioural evaluations are then merged into a single integrated suitability indicator, and a regression model is estimated to predict suitability scores for new bike designs. In doing so, the paper advances the literature by moving beyond purely technical or purely behavioural approaches and proposing a human-centred, quantitatively operationalised method for selecting cargo bikes in sustainable urban delivery systems.

The remainder of the paper is organised as follows. Section 2 reviews the literature on sustainable urban freight, cargo-bike deployment, and the role of user experience in vehicle choice and delivery performance. Section 3 presents the methodological framework, including the demand and network model, the CVRP-based simulation procedure, the rider survey, and the construction of the integrated suitability indicator. Section 4 reports the empirical results of the case study and the ranking of the evaluated cargo bike models, while Section 5 discusses the implications for logistics operators, manufacturers, and urban policymakers. Finally, Section 6 concludes by summarising the main findings, highlighting the contribution of integrating user experience into cargo-bike selection, and outlining directions for future research.

2 Literature review

Cargo bikes have become an increasingly important option in the transition toward sustainable urban freight transport, particularly in dense urban areas where short delivery distances, curb-space pressure, congestion, and environmental constraints reduce the relative efficiency of conventional vans. Recent reviews show that research on electric cargo cycles has expanded substantially, covering operational typologies, environmental benefits, policy support, and practical barriers to wider deployment. Empirical and simulation-based studies further indicate that cargo bikes can perform effectively in last-mile distribution when supported by favourable operating conditions, such as short delivery tours, access to consolidation or micro-depots, and suitable cycling infrastructure (Narayanan & Antoniou, 2022; Llorca & Moeckel, 2021; Melo & Baptista, 2017). At the same time, comparisons with conventional delivery vehicles suggest that cargo bikes can reduce emissions, lower traffic impacts, and in some contexts achieve competitive operating costs, especially in dense central districts and on routes with advantageous stop patterns (Conway et al., 2017; Sheth et al., 2019). However, the literature also makes clear that these benefits are highly context dependent and shaped by local urban form, delivery density, and network conditions rather than guaranteed in all settings (Dalla Chiara et al., 2023).

Within this broader field, a more focused stream of research has examined how cargo-bike design affects operational performance. Studies consistently identify a set of key technical attributes that influence delivery feasibility, including carrying capacity, battery range, vehicle weight, wheel configuration, and geometry. These characteristics affect route length, payload feasibility, recharge frequency, maneuverability, and the ability to perform reliably under real operational constraints. Operational research contributions have addressed these questions through routing and simulation models, including vehicle-routing formulations tailored to cargo bicycles and assessments of how electrification and vehicle design alter productivity in parcel delivery (Fontaine, 2022; Llorca & Moeckel, 2021; Narayanan & Antoniou, 2022). This literature has been instrumental in translating vehicle specifications into measurable logistics outcomes such as energy use, distance, costs, and route productivity. Nevertheless, most existing approaches remain predominantly techno-operational: they are effective at assessing whether a cargo bike can complete a task efficiently, but less effective at evaluating whether that bike is acceptable or manageable from the rider's perspective.

Cargo bike choice in urban logistics is shaped by a combination of technical, operational, and human-related factors. The literature consistently identifies carrying capacity, battery range, and vehicle weight as the primary technical determinants because they directly influence route feasibility, charging frequency, and the ability to transport multiple deliveries within a single tour (Elbert & Friedrich, 2020; Fontaine, 2022). Operational conditions such as delivery density, route structure, and access to micro-depots also affect the suitability of cargo bikes relative to conventional vehicles (Melo & Baptista, 2017; Conway et al., 2017). At the same time, studies increasingly emphasize the importance of human and behavioural factors, including rider comfort, perceived safety, maneuverability, and physical workload, which can strongly influence whether cargo bikes are accepted and used efficiently in practice (Thoma & Gruber, 2020; Malik et al., 2023; van Duin et al., 2022). Additional contextual elements such as infrastructure quality, traffic stress, and weather conditions further shape rider preferences and operational performance (Giordano et al., 2022). Taken together, these findings suggest that cargo bike selection should not rely solely on technical specifications but must also incorporate rider experience and operational context to ensure effective and sustainable last-mile delivery systems.

Taken together, the literature points to a clear unresolved gap. Although there is now substantial knowledge on what cargo bikes can achieve operationally and growing insight into how riders perceive and use them, these two strands are rarely integrated into a single decision-support framework for cargo-bike selection. This study addresses that gap by combining network-based operational modelling with survey-based rider preferences to evaluate cargo-bike suitability in a more realistic and human-centred way. The review leads to three conclusions that motivate the proposed methodology: first, cargo bikes are a credible and increasingly important component of sustainable urban freight systems, but their success depends strongly on operational context; second, model-specific vehicle characteristics have measurable effects on delivery performance and should therefore be evaluated systematically rather than treated as interchangeable; and third, rider experience is not a secondary issue, but a core determinant of whether technically feasible cargo-bike operations can be sustained in practice. These conclusions justify the integrated approach adopted in this paper, in which simulation-based measures of operational efficiency are combined with empirically derived rider preferences to produce a unified cargo-bike suitability indicator

3 Methodology

3.1 Multi-level policy context and decision levels

Cargo-bike deployment is shaped by multi-level governance, where higher-level policy frameworks define targets and constraints, and lower-level actors implement operational choices. At the supra-national level, the EU Urban Mobility Framework explicitly calls for coordinated action with public and private stakeholders to optimise urban logistics and last-mile delivery, and links this agenda to decarbonisation and innovation measures. The European Declaration on Cycling also recognises cycling's expanding role in urban goods transport, explicitly mentioning cargo bikes and the need for enabling conditions. At the same level, the EU's urban freight pages position last-mile logistics as a priority area for zero-emission solutions, providing a policy umbrella for local measures that support cargo-bike operations.

At the city/regional level, the relevant policy instrument is increasingly the Sustainable Urban Logistics Plan (SULP), which frames freight interventions (e.g., consolidation, curb management, low-emission delivery, access rules) as part of a strategic package rather than isolated pilots. A key implementation mechanism is the creation of microhubs, small urban consolidation points where goods are transferred from larger vehicles to low-emission modes such as cargo bikes; these hubs can also enable charging, parking, and operational coordination. Together, these instruments imply that cargo-bike performance is not only a vehicle question: it depends on how local policy shapes infrastructure quality, consolidation opportunities, and charging access.

At the operator level, policy becomes a set of internal rules that translate city conditions into fleet decisions: (i) procurement and fleet composition (which models are bought and in what mix), (ii) routing and dispatch policies (how demand is batched into tours and how bikes are assigned), and (iii) workforce and training policies (which riders operate which bikes, and how comfort, workload and safety are managed). These operator policies implicitly define trade-offs between energy productivity, service reliability, and rider burden—trade-offs that standard "tech-only" selection tools often do not make explicit.

At the rider level, the key mechanism is the efficiency–comfort trade-off: riders differ in how they value capacity, range, stability, and handling relative to physical effort and fatigue management. This heterogeneity matters because the same cargo bike can be "optimal" for one rider profile and unacceptable for another. The present paper, therefore treats rider priorities as an explicit, modelled input and operationalises three rider profiles (Efficiency-Oriented, Comfort-Oriented, Balanced) as scenario levers in evaluation.

3.2 Overview of the integrated evaluation framework

To reflect these multi-level realities, we adopt a dual-path framework that evaluates cargo bikes through (1) a technical/operational lens and (2) a user-experience lens, then merges both into a single suitability indicator, presented in fig. 1. The technical path uses routing simulation (CVRP) to measure operating performance and energy productivity; the behavioural path uses rider-derived attribute weights to score how well each bike aligns with user priorities. The final indicator penalises bikes that perform well on only one dimension, making trade-offs transparent and decision-relevant.

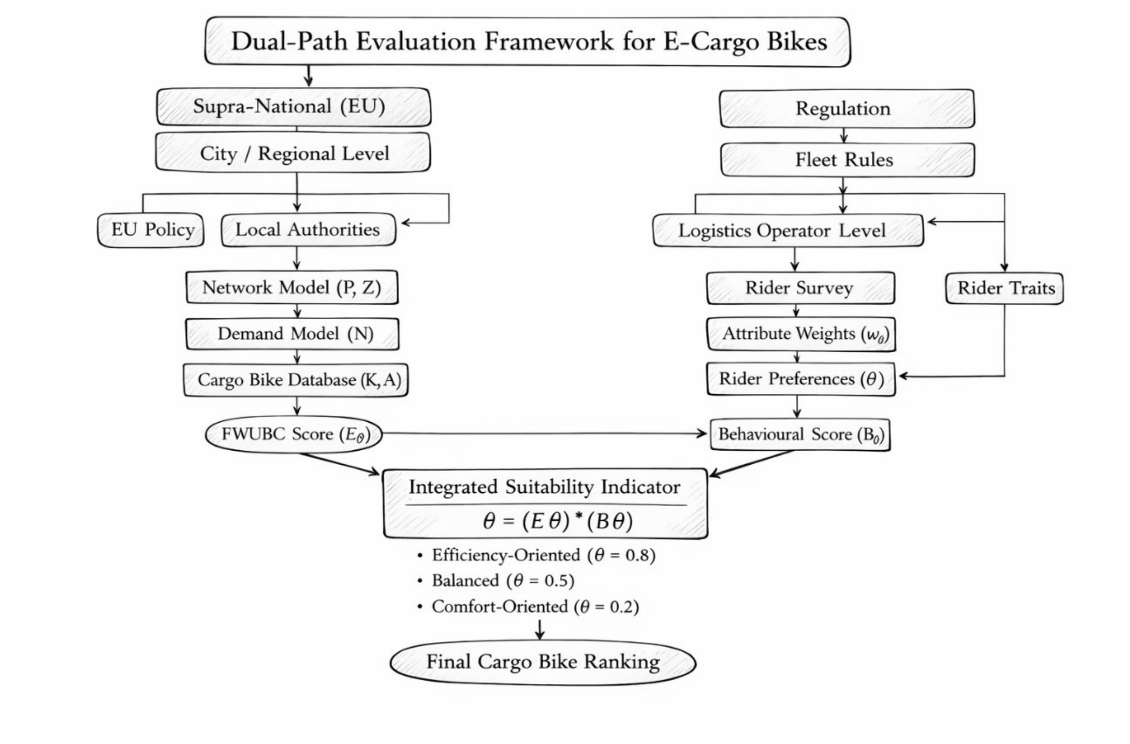

Figure 1. A dual-path evaluation framework for E-cargo bikes

3.3 Data inputs

Four datasets feed the framework. First, a network model represents the street system used for deliveries (including realistic travel distances between stops). Second, a demand model captures delivery locations and shipment patterns based on operator data, enabling realistic tour generation. Third, a cargo-bike database specifies the technical attributes of candidate models (e.g., capacity, range, mass, gearing, wheels). Fourth, a rider survey captures the perceived importance of operational attributes and the rider's stated split between efficiency and comfort, which is later used both for weighting and for rider-type scenarios. (In the operationalisation used in the underlying study design, the integrated indicator combines efficiency and behavioural scores using a tunable weight parameter, and explicitly recalculates results for rider typologies.)

3.4 Operational modelling and efficiency indicator

Operational performance is evaluated through a CVRP formulation, used to simulate last-mile tours for each cargo-bike model under the same demand and network conditions. The simulation yields core operational outputs such as total driven distance, number of routes, and freight work (e.g., tonne-kilometres). Following the study's logic, efficiency is summarised via an energy-productivity indicator, Freight Work per Unit of Battery Capacity (FWUBC), so that bikes are compared on how much freight work they deliver per unit of stored energy rather than on distance alone. The resulting FWUBC-based ranking constitutes the "technical path" score used later in integration.

3.5 User-experience modelling and behavioural indicator

The behavioural path begins with eliciting which cargo-bike attributes riders consider relevant, followed by importance ranking. Survey data are first tested for internal consistency using Kendall's coefficient of concordance, and attribute ranks are converted into weights that reflect user priorities. In line with the method described in the study draft, the behavioural score is computed as a weighted product (geometric-mean) index: attributes valued most by riders receive larger exponents, and "deal-breaker" weaknesses (e.g., insufficient range or excessive weight) reduce the score disproportionately rather than being fully compensated by strengths elsewhere. This produces a behavioural ranking of cargo-bike models grounded in rider experience.

3.6 Integrated suitability indicator and rider-profile scenarios

The technical and behavioural scores are combined into a single integrated suitability indicator using a geometric-mean structure with an explicit weighting parameter that represents the decision-maker's stance on the efficiency–comfort trade-off. This indicator acts "like a slider": when the weight on efficiency is high, the ranking is driven mainly by FWUBC; when it is low, the ranking is driven mainly by rider priorities—yet very low performance on either side remains penalised. To represent heterogeneous workforces and policy priorities, we recalculate the integrated indicator for three rider profiles: Efficiency-Oriented (x=0.8), Comfort-Oriented (x=0.2), and Balanced (x=0.5), allowing scenario-dependent procurement and assignment decisions.

3.7 Regression-based shortcut for rapid screening

Finally, to support practical decision-making under limited time or when evaluating new designs, the framework includes a regression-based shortcut that approximates the integrated indicator as a function of key cargo-bike attributes. This step is intended for rapid screening within the observed design space, reducing the need to repeat the full simulation and survey workflow for every new candidate model:

$$\max\ S_i = E_i^{\alpha}\, U_i^{1-\alpha}, \tag{1}$$

where: S_i is the overall suitability score of the cargo bike i; E_i is the normalized operational efficiency score derived from the routing simulation; U_i is the normalized user-experience score derived from rider preferences; $\alpha \in [0,1]$ is the weighting parameter reflecting the relative importance of operational efficiency versus user experience.

This objective function identifies the cargo bike that provides the best combined balance between technical-operational performance and rider acceptability. The preferred alternative is therefore the one with the highest value of S_i. Thus, the selection problem is formulated as the maximization of an integrated suitability score that combines operational efficiency and user experience in a multiplicative form, ensuring that weak performance in one dimension cannot be fully compensated by strong performance in the other.

4 Results

4.1 Comparative results of the evaluated cargo bike models

Table 1 presents the core empirical results of the dual-path framework for the seven evaluated cargo-bike models. The table combines the outputs of the CVRP simulation, the rider-based behavioural index, and the integrated suitability indicator under three preference scenarios: balanced $(x = 0.5, z = 0.5)$, efficiency-oriented $(x = 0.8, z = 0.2)$, and comfort-oriented $(x = 0.2, z = 0.8)$. The case study uses real delivery operations from Pardubice, a medium-sized Czech transport hub, which makes it a relevant context for urban last-mile analysis.

Table 1. Core comparative results for the seven evaluated E-CB models

ID	Model	FWUBC (tkm/Wh)	Technical rank	User-centric index (*Ki*)	User rank	Integrated score (balanced)	Balanced rank	Integrated score (efficiency-oriented)	Efficiency rank	Integrated score (comfort-oriented)	Comfort rank
1	Clamber Carbat 24	0.0070	7	0.470	7	0.0033	7	0.0045	7	0.0022	7
2	TERN HSD P9	0.0320	5	0.650	3	0.0208	4	0.0280	3	0.0155	4
3	TERN GSD S10	0.0560	6	0.740	2	0.0414	1	0.0474	1	0.0362	2
4	GEPIDA Cargo	0.0630	1	0.641	4	0.0404	2	0.0453	2	0.0368	1
5	Urban Arrow Shorty Cargo LINE	0.0142	3	0.513	6	0.0073	6	0.0093	6	0.0058	6
6	MAXPRO Parcel Mate	0.0260	4	0.820	1	0.0213	3	0.0237	4	0.0191	3
7	Urban Arrow Cargo XL LINE	0.0141	2	0.566	5	0.0080	5	0.0103	5	0.0062	5

The table shows that the ranking depends strongly on whether one looks at technical efficiency alone, user preferences alone, or the combined indicator. The best technical performer is E-CB 4 (GEPIDA Cargo) with a FWUBC of 0.063 tkm/Wh, followed by E-CB 7 with 0.0141–0.0142? No — the actual second-best technical score is E-CB 3? The observed technical ranking in the dataset is: E-CB 4 = 1st, E-CB 7 = 2nd, E-CB 5 = 3rd, E-CB 6 = 4th, E-CB 2 = 5th, E-CB 3 = 6th, and E-CB 1 = 7th. This is an important empirical result because it shows that operational efficiency is not determined by payload alone: E-CB 4, with a moderate payload of 200 kg, outperforms the heavier 250–275 kg bikes because its 170 km range and relatively low 32 kg kerb weight reduce the charging burden and improve energy productivity.

4.2 Behavioural results and rider priorities

The user-experience path produces a different pattern. The strongest behavioural score is achieved by E-CB 6 (MAXPRO Parcel Mate) with a user-centric index of 0.82, followed by E-CB 3 (0.74) and E-CB 2 (0.65). By contrast, the technically best model, E-CB 4, is only 4th in the behavioural ranking with a score of 0.641. This divergence is explained by the rider-derived attribute weights. The survey identified carrying capacity as the dominant criterion with a weight of 0.423, followed by distance per battery charge (0.218), number of wheels (0.131), bike weight (0.121), and number of speeds (0.107). In other words, users systematically valued payload and operational flexibility more than marginal gains in battery-normalised freight efficiency.

This pattern is statistically robust. The agreement among respondents is strong, with Kendall's coefficient of concordance $W = 0.79$, and the associated Pearson $\chi^2 = 126.17$exceeds the tabular value, confirming that the differences in attribute importance are not random. Empirically, this means the behavioural ranking is not an anecdotal supplement to the operational model; it is a stable second evaluation axis supported by consistent rider judgments. Substantively, it explains why E-CB 6, despite only moderate technical efficiency (0.026 tkm/Wh), emerges as the most preferred option from the user perspective: its 250 kg payload and preferred wheel configuration compensate for its mass penalty in the behavioural index.

4.3 Integrated ranking: where technical and behavioural evidence converge

The balanced integrated indicator provides the clearest summary of the dual-path framework. Under equal weighting of efficiency and comfort ($x = 0.5, z = 0.5$), the final ranking is led by E-CB 3 (TERN GSD S10) with an integrated score of 0.0414, followed closely by E-CB 4 (0.0404), then E-CB 6 (0.0213) and E-CB 2 (0.0208). The lowest-ranked model is E-CB 1, with a score of only 0.0033. This ranking is analytically important because E-CB 3 does not top either single dimension: it is 6th technically, but 2nd behaviourally, and its final first-place position reflects a stronger balance between the two than any competitor. Put differently, the integrated indicator rewards bikes that are good enough on both axes, rather than exceptional on one axis and weak on the other.

The score differentials are also meaningful. The gap between the top-ranked balanced model (0.0414) and the bottom-ranked one (0.0033) is more than 12-fold, indicating substantial heterogeneity in overall suitability across the seven tested bikes. Even among the better-performing models, the distinction is non-trivial: E-CB 3 exceeds E-CB 6 by roughly 94% on the balanced score ($0.0414 vs. 0.0213$), despite E-CB 6 being the riders' favourite. This is precisely the type of evidence the integrated framework is designed to reveal: a bike can be highly preferred, but still not be the best all-round option once energy productivity and route performance are introduced into the decision.

4.4 Preference scenarios and rider typologies

The scenario analysis further clarifies how rankings shift when the decision-maker gives more weight to either operational efficiency or rider comfort. Under the efficiency-oriented scenario, E-CB 3 remains 1st (0.0474)and E-CB 4 remains 2nd (0.0453), while E-CB 2 moves to 3rd and E-CB 6 falls to 4th. Under the comfort-oriented scenario, the order changes slightly: E-CB 4 becomes 1st (0.0368), E-CB 3 becomes 2nd (0.0362), and E-CB 6 remains 3rd (0.0191). The fact that the top two models swap places while the rest of the order stays relatively stable suggests that the system is sensitive but not unstable: preference heterogeneity matters, but it does not fully overturn the empirical ranking structure.

These scenario shifts align with the observed rider typologies. In the survey, approximately 30% of respondents were efficiency-oriented, 73 were comfort-oriented, and 66 formed a balanced group, confirming a trimodal preference structure rather than a single homogeneous rider population. This justifies the use of scenario-specific rankings and suggests that a one-bike-fits-all procurement strategy is unlikely to be optimal. Instead, the results support a portfolio approach in which different E-CB models are assigned to different operational contexts or rider profiles.

5 Discusion

The results add value to the cargo-bike literature in two main ways. First, they provide evidence that technical efficiency and rider acceptance can diverge, and that this divergence is large enough to change selection outcomes. While earlier work has quantified operational feasibility and impacts of cargo cycles through simulations and real-world pilots (Melo & Baptista, 2017; Conway et al., 2017; Llorca & Moeckel, 2021) and OR-oriented routing formulations have advanced performance modelling for cargo bicycles (Fontaine, 2022), the present study shows that a model that is operationally strong is not necessarily behaviourally strong. This finding complements recent research demonstrating that infrastructure use and operational interaction differ by cargo-cycle design and conditions (Dalla Chiara et al., 2023) and aligns with evidence that adoption and sustained use depend on user-side constraints and preferences (Narayanan & Antoniou, 2022; Malik et al., 2023). The empirical contribution is the integrated, data-driven indicator that formalises this duality and reveals "balanced winners" that may not top either single dimension—bridging the gap between predominantly techno-operational selection approaches and more qualitative human-factor insights (Gruber & Thoma, 2019; Thoma & Gruber, 2020; Ivanisević et al., 2021).

From a practice perspective, the results offer a concrete decision-support implication: fleet selection and assignment should be treated as a portfolio and matching problem, not a one-model procurement choice. The integrated ranking shows that rider-favoured options can be penalised by energy productivity and charging burden, while technically efficient options can be penalised by usability-related attributes—meaning that ignoring either side risks underperformance, poor uptake, or operational friction. This is directly relevant to operators considering cargo bikes as substitutes for vans in dense areas, where earlier evidence already shows trade-offs in cost and route structure (Sheth et al., 2019) and differences in operational behaviour in real cities (Conway et al., 2017). For public authorities, the implication is that cargo-bike promotion policies (e.g., microhubs, cycling infrastructure, curb management) should support not only feasibility but also rider-usable system design, since rider experience is a measurable determinant of system effectiveness (Malik et al., 2023; Dalla Chiara et al., 2023). Overall, the study operationalises a “human-centred logistics” principle into a replicable tool: it helps choose bikes that deliver both workable performance and rider acceptability, increasing the likelihood that sustainable delivery initiatives achieve durable real-world impact (Narayanan & Antoniou, 2022; Melo & Baptista, 2017).

Conclusions

This study developed and tested a dual-path framework for cargo-bike selection that integrates operating performance and user experience into a single decision-support tool for sustainable urban delivery. Using real delivery data, CVRP-based simulation, and survey evidence from professional riders, the study demonstrated that cargo-bike suitability cannot be assessed adequately through technical specifications alone. The results showed that carrying capacity and distance per battery charge are the most influential factors for both operational efficiency and rider acceptance, while weight, number of wheels, and gearing shape secondary but still meaningful trade-offs. The findings therefore confirm that cargo-bike selection is a techno-human problem, where vehicle productivity and rider usability jointly determine practical success.

From a broader governance and sustainability perspective, the findings suggest that cargo-bike selection should be viewed not only as a fleet-management task, but as part of a multi-level transition in urban freight systems. At the firm level, the results support portfolio-based procurement and rider–vehicle matching; at the city level, they inform infrastructure, microhub, and curb-management decisions; and at the policy level, they contribute to the wider shift toward low-emission, human-centred urban logistics. In this sense, the study speaks directly to SDG 11 (Sustainable Cities and Communities) through more liveable and less congested urban transport systems, SDG 12 (Responsible Consumption and Production) through more resource-efficient delivery operations, and SDG 13 (Climate Action) through support for low-carbon freight substitution pathways. The broader relevance of sustainable transport as an enabler across multiple SDGs is explicitly recognised by the United Nations, which frames transport as a cross-cutting mechanism for achieving the 2030 Agenda, while the 2030 Agenda itself links sustainable consumption, resilient cities, and climate action as mutually reinforcing goals

The study contributes to the literature by extending existing operational and environmental assessments of cargo bikes with an explicit and quantified user-experience dimension. In doing so, it moves beyond approaches that treat cargo-bike selection as either a purely technical optimisation problem or a largely qualitative adoption issue. The proposed integrated suitability indicator provides a transferable way to compare different cargo-bike models under realistic urban delivery conditions and to estimate the likely suitability of new designs within a comparable operating environment. From a practical perspective, the framework supports more informed procurement, assignment, and policy decisions, helping align fleet design with both delivery efficiency and rider acceptability.

At the same time, the study has some limitations. The empirical application is based on a single case study and a specific set of cargo-bike models, which means that the numerical rankings should not be generalised mechanically to all cities or operators. In addition, the behavioural component focuses on stated rider priorities and does not yet include observed physiological workload, long-term fatigue, or seasonal effects such as weather variability. Future research could therefore expand the framework by testing it in different urban contexts, incorporating economic indicators more explicitly, and combining rider preferences with objective ergonomic or biometric measures. Such developments would further strengthen the use of human-centred decision-support tools in sustainable urban freight planning.

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References

Azad, A., Al-Husseini, A., Awasthi, A., & Arboleda, C. (2023). Environmental impact and cost price analysis of electric cargo bikes and electric vans for freight transport. Journal of Cleaner Production, 321, 129023.

Bošković, S., Švadlenka, L., Dobrodolac, M., Jovčić, S., & Zanne, M. (2023). An Extended AROMAN Method for Cargo Bike Delivery Concept Selection. Decision Making: Applications in Management and Engineering, 1, 1-9

Carracedo, D., & Mostofi, H. (2022). Electric cargo bikes in urban areas: A new mobility option for private transportation. Transportation Research Interdisciplinary Perspectives, 16, 100705. doi:10.1016/j.trip.2022.100705.

Conway, A., Cheng, J., Kamga, C., & Wan, D. (2017). Cargo cycles for local delivery in New York City: Performance and impacts. Research in Transportation Business & Management, 24, 90–100. doi:10.1016/j.rtbm.2017.07.001.

Ding, Y., Wang, X. C., Pérez-Guzmán, S., Wojtowicz, J., & Conway, A. (2024). Multi-criteria assessment and ranking framework for the potential of cargo cycle operation: Using New York city as an example. Transportation Research Part A: Policy and Practice 179, 103898. https://doi.org/10.1016/j.tra.2023.103898

Dalla Chiara, G., Donnelly, G., Gunes, S., & Goodchild, A. (2023). How cargo cycle drivers use the urban transport infrastructure. Transportation Research Part A: Policy and Practice, 167, 103562. doi:10.1016/j.tra.2022.103562.

Fontaine, P. (2022). The vehicle routing problem with load-dependent travel times for cargo bicycles. European Journal of Operational Research, 300(3), 1005–1016. doi:10.1016/j.ejor.2021.09.009.

Gruber, J., & Thoma, L. (2019). Perception of drivers and barriers in the adoption of cargo cycles by private and public organizations in Germany. Transportation Research Procedia, 41, 395–397. doi:10.1016/j.trpro.2019.09.063.

Galkin, A., Švadlenka, L., Vrba, R., & Kijewska, K. (2025a). Navigating the future of urban logistics: Conceptual framework for Dynamic Freight Management. Transportation Research Part D: Transport and Environment, 147, 104956. https://doi.org/10.1016/j.trd.2025.104956

International Energy Agency. (2023). Transport (Tracking Clean Energy Progress). IEA.

Ivanišević, T., Trifunović, A., Čičević, S., Pešić, D., Simović, S., Zunjic, A., ... & Manojlovic, U. (2023). Analysis and determination of the lateral distance parameters of vehicles when overtaking an electric bicycle from the point of view of road safety. Applied Sciences, 13(3), 1621.

Llorca, C., & Moeckel, R. (2021). Assesment of the potential of cargo bikes and electrification for last-mile parcel delivery by means of simulation of urban freight flows. European Transport Research Review, 13, 33. doi:10.1186/s12544-021-00491-5.

Koning, M., & Conway, A. (2016). The good impacts of biking for goods: Lessons from Paris city. Case studies on transport policy, 4(4), 259-268.

Malik, F. A., Egan, R., Dowling, C. M., & Caulfield, B. (2023). Factors influencing e-cargo bike mode choice for small businesses. Renewable and Sustainable Energy Reviews, 178, 113253. doi:10.1016/j.rser.2023.113253.

Melo, S., & Baptista, P. (2017). Evaluating the impacts of using cargo cycles on urban logistics: Integrating traffic, environmental and operational boundaries. European Transport Research Review, 9, 30. doi:10.1007/s12544-017-0246-8.

Narayanan, S., & Antoniou, C. (2022). Electric cargo cycles: A comprehensive review. Transport Policy, 116, 278–303. doi:10.1016/j.tranpol.2021.12.011.

OECD. (2024). Urban Logistics Hubs (ITF Roundtable Reports, No. 195). OECD Publishing. doi:10.1787/da4dee9f-en.

Paudel, M., & Yap, F. F. (2024). Analyzing the impact of bicycle geometry and cargo loading on the rideability and safety of cargo bikes: An investigative study. Heliyon, 10(8).

Sheth, M., Butrina, P., Goodchild, A., & McCormack, E. (2019). Measuring delivery route cost trade-offs between electric-assist cargo bicycles and delivery trucks in dense urban areas. European Transport Research Review, 11, 11. doi:10.1186/s12544-019-0349-5.

Sonar, H. C., & Kulkarni, S. D. (2021). An integrated AHP-MABAC approach for electric vehicle selection. Research in Transportation Business & Management, 41, 100665.

Thoma, L., & Gruber, J. (2020). Drivers and barriers for the adoption of cargo cycles: An exploratory factor analysis. Transportation Research Procedia, 46, 197–203. doi:10.1016/j.trpro.2020.03.181.

United Nations, Department of Economic and Social Affairs, Population Division. (2019). World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420). United Nations.

Yang, S. C., & Lee, Y. J. (2024). Optimizing E-bike controls for human-bike interaction to enhance riding experience and efficiency. *International Journal of Industrial Ergonomics*, *104*, 103651.