GREEN CITIES
GREEN LOGISTICS FOR GREENER CITIES

7th International Conference Green Cities 2026 – Green Logistics for Greener Cities, 15-17 April 2026, Szczecin, Poland

# Application of digital technology for micro-hubs development: Literature review

Tomáš Malčic [a], Maja Kiba-Janiak [b], Natalia Szozda [b], Radim Lenort [a,1], Pavel Wicher [a], Laura Palacios-Argüello[c], Robert Frischer [a], Ondřej Krejcar [a]

[a] *Škoda Auto University, Na Karmeli 1457, Mladá Boleslav 293 01, Czech Republic*
[b] *Wroclaw University of Economics and Business, Komandorska 118/120, 53-345 Wroclaw, Poland*
[b] *University of Luxembourg, 6, rue Richard Coudenhove-Kalergi, Luxembourg L-1359, Luxembourg*

**Abstract**

Urban freight transport is undergoing structural transformation driven by e-commerce growth, climate-neutrality targets, and increasing spatial constraints in city centres. Among the most discussed instruments for reorganising last-mile logistics are urban micro-hubs, including emerging concepts of mobile and temporary facilities. This paper presents a PRISMA 2020-guided systematic literature review aimed at consolidating current knowledge on application of digital technology for micro-hubs development. Based on a structured Web of Science search protocol, 35 peer-reviewed studies were identified and coded across nine indicators aligned with three research domains: digitalization status and outcome measurement, micro-hub location and evaluation including flexible concepts, and utilization of selected digital technologies. The results reveal a methodologically mature and strongly KPI-oriented field: most studies employ optimisation or simulation models and report quantified environmental and operational impacts, while two-thirds apply explicit location methods and structured evaluation frameworks. However, flexible or mobile micro-hubs remain underrepresented, Digital Twin applications appear only marginally, validation in real or pilot settings is limited, and extended-reality support is entirely absent. The review demonstrates that no study to date integrates Digital Twin–enabled orchestration, mobile micro-hub design, and immersive operational support within a validated framework. The paper concludes by outlining a research agenda towards instrumented, adaptable, and human-centred last-mile systems capable of supporting climate-neutral urban logistics.

Keywords: Urban logistics; micro-hubs; last-mile logistics; digitalization

## 1 Introduction

Cities face mounting pressure to reconcile rapid e-commerce growth with climate targets, air-quality standards, and curbside constraints (Jaller & Pahwa, 2020). Within this context, urban micro-hubs reconfigure the last mile into shorter, cleaner, and more space-efficient legs operated by cargo bikes, light electric vehicles, or parcel lockers (De Bok et al., 2024; Gunes, Fried, & Goodchild, 2024). As a result, micro-hubs have become a focal instrument in the governance and planning of sustainable urban freight. At the same time, policy-makers and operators increasingly require digitalized planning that is auditable and KPI-rich, and instrumented with operational technologies such as Digital Twins (Liu et al., 2023; Liu, Pan, & Ballot, 2025) and human-in-the-loop training or support through extended reality. These expectations shape both the research agenda and the evaluation standards applied to micro-hub initiatives.

Despite this strategic salience, the published evidence is uneven in three respects: how micro-hubs are conceptualized and measured within digitalized planning frameworks; how location decisions and operational designs are evaluated; and the degree of operational instrumentation and validation achieved in real or quasi-real settings (for example, Digital Twins, extended reality support, and field-grade pilots). This review responds to that gap by consolidating and diagnosing the literature in a manner that is method-transparent and results-oriented.

The study aims to establish a consolidated, PRISMA-guided systematic literature review aimed at current knowledge on application of digital technology for micro-hubs development. The review adopts three analytical domains that provide a clear structure for the research questions each disaggregated into operational sub-question used for coding and synthesis:

**RQ1 – Digitalization status and outcomes.** What is the current state of digitalization in the field of last-mile logistics (RQ1.1)? Which data-driven approaches and enabling technologies are reported (RQ1.2)? What outcomes are commonly measured (RQ1.3)?

[1] Radim Lenort. tel.: +420-730-803-165; e-mail address: radim.lenort@savs.cz

**RQ2 – Location, evaluation, and flexibility.** Which methods are used to locate micro-hubs (RQ2.1)? What evaluation frameworks are applied (RQ2.2)? Are there concepts or cases of flexible, mobile, or temporary hubs (RQ2.3)?

**RQ3 – Digital twin, e-cargo, and extended reality.** Does the literature apply Digital Twin technology to micro-hub-based systems (RQ3.1)? Are there validated e-cargo implementations (RQ3.2)? Are VR/AR applications used for training or operational support (RQ3.3)?

## 2 Research Methodology: PRISMA protocol and bibliometric analysis

This study employs a systematic literature review (SLR) guided by the PRISMA 2020 protocol (Page et al., 2021), designed to examine the application of digital solutions for micro-hubs development in last-mile logistics, location, design, evaluation and operation. The methodological design mirrors the staged structure of PRISMA (identification, screening, eligibility, inclusion) while applying a reproducible Web of Science (Clarivate) search strategy developed specifically for this domain.

### *2.1 Identification and screening*

The identification phase of this review was carried out exclusively within the Web of Science Core Collection (Clarivate), which was selected for its comprehensive coverage of research streams directly relevant to urban freight, transportation systems, operations research, engineering, and urban studies. The search strategy and coding scheme were subsequently aligned with the three domains that emerged during the scoping phase, namely the digitalization of last-mile logistics, the location and evaluation of urban micro-hubs, and the emerging operational use of selected digital technology. By restricting the review to a single, well-indexed database and a fully pre-specified protocol, the identification process ensured methodological reproducibility and conceptual coherence.

The search parameters were intentionally narrow in scope yet broad enough to encompass the conceptual diversity of micro-hub research. Records were limited to English-language publications between 2011 and 2026, and the admissible document types included peer-reviewed journal articles, review articles, early-access items, and proceedings papers. These platform-level restrictions were applied uniformly prior to running any queries. The topic string itself enumerated the central terminology associated with micro-hubs and last-mile logistics through following keywords: “Microhub”, “Micro-depot”, “Micro-consolidation”, “Micro-logistics hub” “Urban Micro-consolidation”, “Urban Consolidation Center”, “Proximity Logistics”, “Mobile Access Hub”, “Mobile Depot”, “Urban logistics”, “Micro-fulfillment Center”, “City logistics” and “Last-mile”.

Because digitalization constitutes a core pillar of this review, the topic string was expanded with an inclusion set that comprised descriptors of digital and data-driven decision-support practices, including “Urban Freight”, “Digital Twin”, “Simulation”, “Agent-based”, and “Discrete Event”. At the same time, a corresponding exclusion set was introduced to minimise retrieval of structurally unrelated literature most notably energy-systems research making use of visually similar vocabulary such as “Microgrid”, “Energy Hub”, and “Power System”. These exclusions were necessary to avoid common false positives identified during preliminary scoping.

To maintain conceptual relevance without compromising interdisciplinary depth, the protocol applied a second layer of refinement based on Web of Science Categories, retaining only those directly aligned with logistics, transport, modelling, optimization, urban governance, sustainability, and digital technologies. Categories in engineering, environmental sciences, management, operations research, computer science, geography, sustainable technologies, transportation, and urban studies were therefore included. In contrast, categories unrelated to micro-hub research such as water resources, thermodynamics, oceanography, aerospace engineering, and several fields in physics, chemistry, and applied optics were excluded. Parallel exclusion cuts were implemented at the level of Citation Topics (meso and micro) and Research Areas, eliminating peripheral domains such as geochemistry, antenna design, software testing, maritime safety, and microwave photonics.

Once the full query had been executed, all retrieved records were exported and deduplicated. Screening proceeded in two stages. First, titles and abstracts were examined independently by two reviewers according to the pre-registered inclusion and exclusion criteria. This initial screening removed records lacking a substantive connection to micro-hubs, last-mile logistics, or digitalization in any meaningful sense. In the second stage, full-text articles passing the abstract screening were retrieved and assessed independently by both reviewers. Differences of interpretation were resolved through discussion, adhering strictly to the eligibility logic defined in the protocol. No automation tools or machine-learning methods were used at any point in the screening process.

The entire identification, screening, eligibility assessment, and inclusion process is documented in the PRISMA 2020 flow diagram (see Figure 1), which presents the sequential reduction of the record set, starting from the initial number of identified records through duplicate removal and manual screening, concluding with the 35 studies included in the final synthesis (Page et al., 2021; Snyder, 2019; Xiao & Watson, 2019).

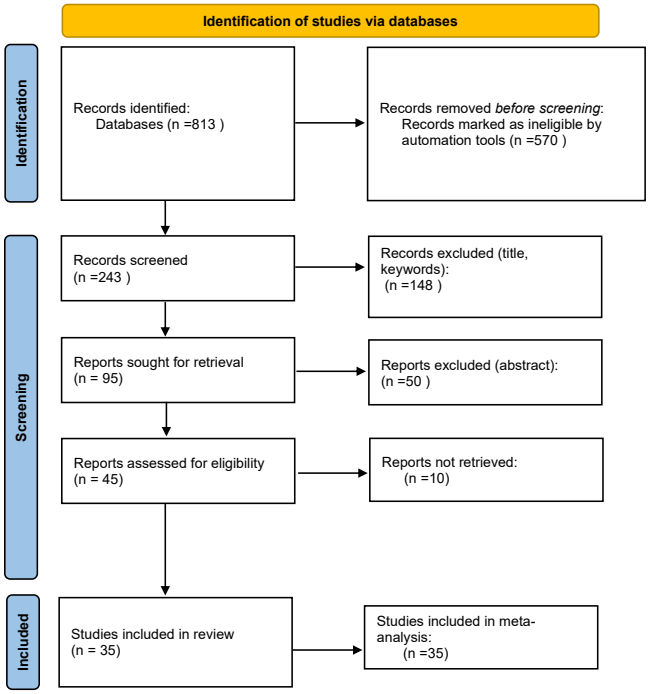


Fig. 1. PRISMA diagram of study inclusions and exclusions for the SLR

## 2.2 *Eligibility criteria and study inclusion*

The eligibility criteria for this review were established prior to screening and applied consistently during both the title-and-abstract phase and the full-text assessment. Studies were considered eligible when they demonstrated a substantive connection to urban or last-mile logistics and offered an explicit treatment of a micro-hub or a functionally comparable urban logistics node, such as micro-depots, mobile access hubs, or micro-consolidation facilities. In addition, included works were required to engage meaningfully with at least one dimension of digitalization, whether through data-driven planning tools, simulation or optimization approaches, Digital Twin implementations, or through evaluation frameworks capable of producing quantifiable outcomes such as cost, time, vehicle-kilometres, or emissions. Eligibility further required that all records satisfied the Web of Science platform filters defined in the search protocol, including publication language, year range, and document-type constraints.

Exclusions occurred when retrieved records deviated from the conceptual or thematic scope of the review. Articles were removed when they fell outside the topic-string logic most notably in cases where literature appeared due to lexical similarity yet bore no relevance to urban logistics. Ineligible records were also filtered out when they matched one or more of the EXCLUDE conditions specified in the protocol, including keyword collisions, Web of Science Category mismatches, Citation Topic misalignment, or Research Area classifications known to generate irrelevant results. Finally, studies were excluded when, despite superficial proximity to logistics or infrastructure, they did not provide substantive analytical, methodological, or evaluative relevance to the review's three domains: the digitalization of last-mile logistics, the location and evaluation of micro-hubs, or the operational use of selected digital technologies. All exclusions were documented systematically to preserve auditability and to maintain full traceability within the PRISMA workflow.

## 2.3 *Bibliometric analysis*

A bibliometric analysis was conducted to complement the systematic review and to reveal how the included studies collectively shape the conceptual landscape of micro-hubs and digitalized last-mile logistics. Using established mapping tools, two basic visualisations were generated—a word cloud and a thematic map. Together, they provide a structured view of dominant themes, methodological tendencies, and conceptual absences within the corpus.

The word cloud highlights the most salient terms used across the included studies (Aria & Cuccurullo, 2017). Delivery, logistics, city, transport, management, model and sustainability appear most prominently, reflecting a literature anchored in operational performance, urban context, and model-based decision-making (see Figure 2). The prominence of terms linked to routing and system modelling mirrors the strong prevalence of measured outcomes in the corpus and confirms the KPI-oriented character of contemporary micro-hub research.


Fig. 2. Word cloud of 35 included studies

The thematic map provides a final layer of insight by positioning clusters according to their relevance and maturity (Aria & Cuccurullo, 2017). Motor themes include delivery, city and areas as well as models, depot and goods, signalling that urban-delivery models and facility-routing interactions form the conceptual core of the field (see Figure 3). A basic but still developing theme emerges around logistics, management and urban context, reflecting work on governance and organisational considerations that has yet to consolidate conceptually. Methodological topics such as neighbourhood search and other optimisation heuristics appear in emerging or declining positions, underscoring their role as technical supports rather than stand-alone subjects.

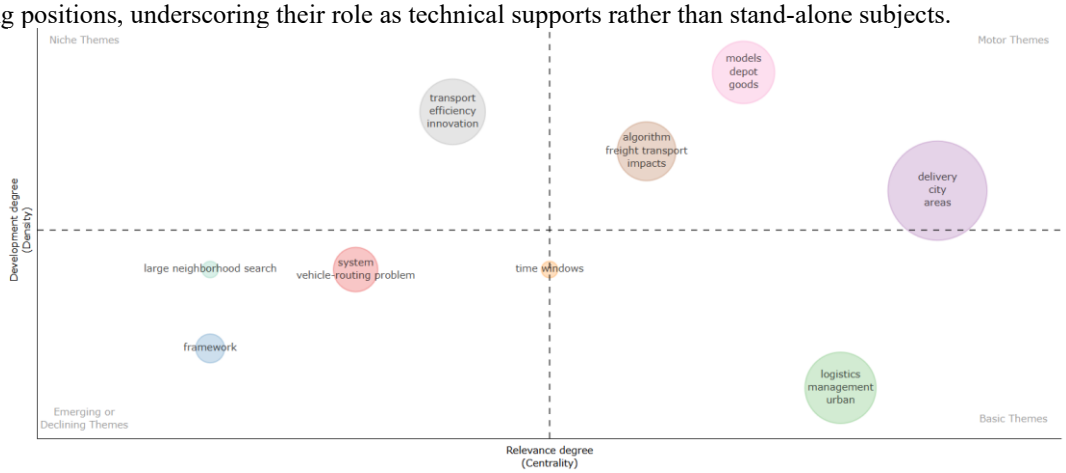


Fig. 3. Thematic map of 35 included studies

Taken together, the bibliometric outputs depict a field that is operationally mature and strongly centred on delivery modelling, performance metrics and optimisation-driven location and routing. At the same time, the absence of consolidated clusters related to Digital Twin technology, extended reality or mobile micro-hub concepts reveals a significant conceptual and technological gap. These patterns align directly with the systematic review findings and frame the need for research that bridges established modelling traditions with instrumented, flexible and human-centred operational systems.

## 3 Results

This chapter synthesizes the empirical results of the systematic review by combining the PRISMA-derived corpus of 35 studies with the structured research-question matrix developed in the methodological stage. While the bibliometric analysis in the previous chapter revealed the conceptual structure of the field, the matrix presented here provides a more granular view of how individual studies engage with digitalization, location and evaluation, operational flexibility, Digital Twin use, e-cargo, and extended-reality support. Each article was coded across nine indicators corresponding to RQ1.1–RQ3.3, enabling a comparative assessment of the thematic strengths and gaps across the evidence base (see Table 1).

Table 1. Research question relevancy matrix

| Study reference/Research question | RQ 1.1 | RQ 1.2 | RQ 1.3 | RQ 2.1 | RQ 2.2 | RQ 2.3 | RQ 3.1 | RQ 3.2 | RQ 3.3 | Total % |
|---|---|---|---|---|---|---|---|---|---|---|
| (De Bok et al., 2024) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 66.7 |
| (Bloemer & Minner, 2025) | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 44.4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (Hribernik et al., 2020) | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22.2 |
| (Savchenko et al., 2022) | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 22.2 |
| (Katsela et al., 2022) | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 55.6 |
| (Kahalimoghadam, Thompson, & Rajabifard, 2024) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 55.6 |
| (Ackva & Ulmer, 2024) | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 55.6 |
| (Kaspi, Raviv, & Ulmer, 2022) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 33.3 |
| (Janjevic & Ndiaye, 2014) | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 44.4 |
| (Tadić et al., 2022) | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 55.6 |
| (Liu et al., 2025) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 88.9 |
| (Bilgili et al., 2024) | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 22.2 |
| (Rosenberg et al., 2021) | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 33.3 |
| (Ceccato, 2023) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 66.7 |
| (Huang, Huang, & Guo, 2020) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 55.6 |
| (Rudolph et al., 2022) | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 44.4 |
| (Bullock et al., 2025) | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 33.3 |
| (Xiao, Du, & Sakai, 2025) | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 22.2 |
| (Novotná et al., 2022) | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 33.3 |
| (Faugère, White, & Montreuil, 2020) | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 55.6 |
| (Arrieta-Prieto et al., 2022) | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 44.4 |
| (Oliveira et al., 2025) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 66.7 |
| (Danach, Raad, & Nasser, 2025) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 55.6 |
| (Montero-Vega & Estrada, 2025) | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 55.6 |
| (Stokkink & Geroliminis, 2025) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 55.6 |
| (Andar, Huskova, & Dyntar, 2024) | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 44.4 |
| (Sawik, 2024) | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 44.4 |
| (Guo et al., 2024) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 55.6 |
| (Gunes et al., 2024) | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 44.4 |
| (Lee, Kim, & Low, 2025) | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 33.3 |
| (de Oliveira & de Oliveira, 2025) | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 44.4 |
| (Golinska-Dawson & Sethanan, 2023) | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 55.6 |
| (Liu et al., 2023) | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 66.7 |
| (Rave & Fontaine, 2025) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 55.6 |
| (Castillo et al., 2024) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 55.6 |
| **Total % per RQ** | 51.4 | 80.0 | 88.6 | 65.7 | 91.4 | 28.6 | 5.7 | 22.9 | 0.0 | 48.3 |

### *3.1 Digitalization status and outcomes.*

The coding reveals a field that is consistent and methodologically mature in its use of digital techniques. Half of the included studies explicitly examine digitalization within micro-hub-based last-mile systems, with 18 of 35 articles (51.4%) addressing digital components directly. A stronger signal emerges for data-driven methods, which appear in 28 of 35 studies (80.0%). Most contributions apply some combination of optimisation models, simulation frameworks or geospatial decision techniques. These tendencies are also reflected in the bibliometric figures, where modelling and routing dominate the conceptual core. Almost the entire corpus 31 of 35 studies (88.9%) reports quantified outcomes, including vehicle-kilometres, emissions, travel times, operational costs and related performance metrics. This preference for KPI-oriented evaluation echoes both the dense co-occurrence links between delivery, logistics and model in the network visualisation and the motor-theme placement of delivery, city and areas in the thematic map. Together, these patterns confirm that the evidence base is digitally enabled, analytically rich and strongly outcome-driven.

### *3.2 Location, evaluation, and flexibility*

A complementary strength lies in location and evaluation practices. Twenty-three studies (65.7%) deploy a concrete location method such as facility-location modelling, location–routing integration or GIS-driven shortlisting. The presence of these techniques is consistent with the thematic map, where location-related concepts occupy central, well-developed positions. Framework-based evaluations are even more common, appearing in 32 studies (91.4%). These frameworks include scenario comparison, multi-criteria evaluation and social-cost or environmental impact assessments. In contrast, flexible, mobile or temporary micro-hub concepts remain comparatively rare, appearing in only 10 studies (28.6%). This mirrors the peripheral position of mobility-related terms in the bibliometric network and their absence as consolidated thematic entities. While the literature excels at modelling fixed-site micro-hubs, it has not yet developed an equivalently rich evidence base for deployable or

dynamic hub infrastructure an increasingly relevant requirement for real city environments dealing with volatile demand, construction constraints or variable curb-space access.

### *3.3 Digital twin, e-cargo, and extended reality.*

The sharpest gaps appear in the form of sparse operational digitalisation. Only two studies (5.7%) employ Digital Twin technology in a substantive manner. These works represent isolated efforts and do not yet form a discernible thematic cluster in the bibliometric results. Validation of e-cargo systems is limited to eight studies (22.9%), typically through simulation-based comparisons or pilot deployments. Most strikingly, no study in the corpus uses extended-reality approaches such as virtual or augmented reality for training, operational support or human–technology interaction. This absence is reflected visually in the bibliometric maps, where such terms either do not appear. The field remains overwhelmingly rooted in modelling and conceptual evaluation rather than instrumented, operator-centred digital systems.

## 4 Discussion and conclusion

Across all indicators, the evidence base reveals a field with a dual character. On one hand, the literature is mature, data-driven, and quantitatively rich, with digitalization present in half of all studies, data-driven methods in more than three quarters, and measurable KPIs reported in nearly ninety percent of the corpus. Likewise, location and evaluation practices are well established, with two thirds of studies applying explicit location methods and more than ninety percent employing structured evaluation frameworks. These strengths dominate the conceptual core seen in the bibliometric analysis and underpin the consistency observed in RQ1 and RQ2. On the other hand, clear technological and methodological gaps persist: flexible or mobile micro-hubs are examined in only a minority of studies, Digital Twins appear in fewer than six percent, validation is limited to a small subset, and extended-reality applications are entirely absent. These missing elements form the conceptual periphery in the bibliometric figures and emerge in RQ3 not as marginal omissions but as structural limitations in the current evidence base. Against this background, the studies highlighted below are those that most directly and comprehensively address the research questions by combining concrete digitalization practices, transparent location and evaluation approaches, and, where available, operational validation. They represent the strongest exemplars within the corpus and provide the foundation for articulating the research gap and future agenda for instrumented, flexible, and human-centred last-mile micro-hub systems.

Liu, Pan, & Ballot (2025) demonstrate a rare, fully articulated use of a Digital Twin to coordinate physical assets (for example micro-hubs, bicycle fleets, and charging and parking infrastructure) and to test operational rules through synchronized virtual representations. They do not only specify the knowledge layer that enables orchestration but also report quantitative improvements in operating costs, distance travelled, and emissions under different city governance regimes, thereby addressing both the digitalization question and the demand for rigorous, outcome-based evaluation. Liu et al. (2023) advance the architectural foundations of digitalized city logistics by defining how Digital Twins and semantic technologies can expose and query resources destinations, modalities, and transshipment points to design responsive configurations of the last mile. While primarily conceptual and model-oriented, they clarify how interoperable data and formal ontologies can underpin planning decisions, complementing empirical works by supplying a generalizable blueprint for digital orchestration. De Bok et al. (2024), through a city-scale simulation that compares van-based distribution with micro-hub systems employing low-emission vehicles, document substantial reductions in vehicle-kilometres within the zero-emission zone alongside changes in tour composition and distance patterns. They thus offer clear, decision-ready evidence on the environmental and operational consequences of shifting to micro-hubs in a real urban context. Ceccato (2023) combines route optimization with discrete-event simulation and quantifies differences between cargo-bike and van operations across a set of practical outcomes, including costs, travel time, distance, emissions, and other externalities, and explicitly explores the sensitivity of site selection. The result is a transparent demonstration of how modelling and evaluation can be joined to steer micro-hub location decisions under uncertainty. Oliveira et al. (2025) integrate facility location design with real operational signals, including a reported halving of delivery time after activation of the crowdshipping leg, while proposing a compact micro-hub network that covers almost the entire urban population. They thereby contribute validation evidence and governance insight at once a combination that is comparatively rare in the literature.

Despite the breadth of contributions advancing digitalization in micro-hubs, the consolidated evidence base reveals a clear and consequential gap. Only two of the 35 studies employ a Digital Twin in an operationally meaningful way, and only 8 studies demonstrate systematic validation of micro-hub-based e-cargo systems. Flexible or mobile hub designs appear in just 11 studies, and extended-reality applications are entirely absent. Taken together, these omissions indicate that the field has not yet progressed from modelling and evaluation to fully instrumented, real-time, human-centred operations. No study succeeds in integrating three elements: Digital Twin–enabled orchestration, mobile micro-hub design, and XR support for operational practice. Addressing this missing conjunction offers a substantial opportunity for high-impact research, opening a pathway toward last-mile

logistics that is not only sustainable and analytically robust but also operationally synchronised, adaptable and centred on the needs of both cities and couriers.

**Acknowledgements**

The research leading to these results/this publication has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101238585.

**References**

Ackva, C., & Ulmer, M. W. (2024). Consistent routing for local same-day delivery via micro-hubs. *OR Spectrum*, *46*(2), 375–409. https://doi.org/10.1007/s00291-023-00735-x

Andar, J., Huskova, K., & Dyntar, J. (2024). Navigating urban logistics challenges: An optimized approach to parcel distribution in the Prague city center. *E+M Ekonomie a Management*, *27*(3), 1–14. https://doi.org/10.15240/tul/001/2024-5-005

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Arrieta-Prieto, M., Ismael, A., Rivera-Gonzalez, C., & Mitchell, J. E. (2022). Location of urban micro-consolidation centers to reduce the social cost of last-mile deliveries of cargo: A heuristic approach. *Networks*, *79*(3), 292–313. https://doi.org/10.1002/net.22076

Bilgili, F., Yılmaz, Ş. F., Zaralı, F., & Demirel, N. (2024). Evaluation of integrated sustainable last-mile delivery methods in an intuitionistic fuzzy environment. *Environment, Development and Sustainability*, *26*. https://doi.org/10.1007/s10668-024-05461-0

Bloemer, A., & Minner, S. (2025). An economic and environmental framework for assessing urban last-mile logistics. *International Journal of Logistics Research and Applications*, *29*(1), 1–33. https://doi.org/10.1080/13675567.2025.2575085

Bullock, A., McLeod, F., Grote, M., Ouelhadj, D., Crabb, J., Cherrett, T., Wall, G., & Fletcher, G. (2025). Locating urban freight micro-consolidation centres: A practical methodology. *Transportation Planning and Technology*, *49*(1), 53–72. https://doi.org/10.1080/03081060.2025.2603525

Castillo, C., Panadero, J., Alvarez-Palau, E. J., & Juan, A. A. (2024). Towards greener city logistics: An application of agile routing algorithms to optimize the distribution of micro-hubs in Barcelona. *European Transport Research Review*, *16*(1), 44. https://doi.org/10.1186/s12544-024-00669-7

Ceccato, R. (2023). Last mile distribution using cargo bikes: A simulation study in Padova. *European Transport/Trasporti Europei*, (90), 1–11. https://doi.org/10.48295/ET.2023.90.3

Danach, K., Raad, A., & Nasser, A. (2025). Multi-Modal Last-Mile Delivery Optimization With Smart Micro-Hubs: A Branch-and-Price Approach With Valid Inequalities. *IEEE Open Journal of Intelligent Transportation Systems*, *6*, 1596–1611. https://doi.org/10.1109/OJITS.2025.3638659

De Bok, M., Giasoumi, S., Tavasszy, L., Thoen, S., Nadi, A., & Streng, J. (2024). A simulation study of the impacts of micro-hub scenarios for city logistics in Rotterdam. *Research in Transportation Business & Management*, *56*, 101186. https://doi.org/10.1016/j.rtbm.2024.101186

de Oliveira, I. K., & de Oliveira, L. K. (2025). Sustainable evaluation of last-mile delivery alternatives by using microhubs in public transportation stations. *Revista Transportes e Território*, (33). https://doi.org/10.34096/rtt.i33.14332

Faugère, L., White, C., & Montreuil, B. (2020). Mobile Access Hub Deployment for Urban Parcel Logistics. *Sustainability*, *12*(17), 7213. https://doi.org/10.3390/su12177213

Golinska-Dawson, P., & Sethanan, K. (2023). Sustainable Urban Freight for Energy-Efficient Smart Cities—Systematic Literature Review. *Energies*, *16*(6), 2617. https://doi.org/10.3390/en16062617

Gunes, S., Fried, T., & Goodchild, A. (2024). Seattle microhub delivery pilot: Evaluating emission impacts and stakeholder engagement. *Case Studies on Transport Policy*, *15*, 101119. https://doi.org/10.1016/j.cstp.2023.101119

Guo, F., Wang, Z., Huang, Z., & Ma, X. (2024). Robust optimization of microhub network and mixed service strategy for a multidepot location-routing problem. *Computers & Industrial Engineering*, *190*, 110070. https://doi.org/10.1016/j.cie.2024.110070

Hribernik, M., Zero, K., Kummer, S., & Herold, D. M. (2020). City logistics: Towards a blockchain decision framework for collaborative parcel deliveries in micro-hubs. *Transportation Research Interdisciplinary Perspectives*, *8*, 100274. https://doi.org/10.1016/j.trip.2020.100274

Huang, Z., Huang, W., & Guo, F. (2020). Integrated sustainable planning of micro-hub network with mixed routing strategy. *Computers & Industrial Engineering*, *149*, 106872. https://doi.org/10.1016/j.cie.2020.106872

Jaller, M., & Pahwa, A. (2020). Evaluating the environmental impacts of online shopping: A behavioral and transportation approach. *Transportation Research Part D: Transport and Environment*, *80*, 102223. https://doi.org/10.1016/j.trd.2020.102223

Janjevic, M., & Ndiaye, A. B. (2014). Development and Application of a Transferability Framework for Micro-consolidation Schemes in Urban Freight Transport. *Procedia - Social and Behavioral Sciences*, *125*, 284–296. https://doi.org/10.1016/j.sbspro.2014.01.1474

Kahalimoghadam, M., Thompson, R. G., & Rajabifard, A. (2024). Determining the number and location of micro-consolidation centres as a solution to growing e-commerce demand. *Journal of Transport Geography*, *117*, 103875. https://doi.org/10.1016/j.jtrangeo.2024.103875

Kaspi, M., Raviv, T., & Ulmer, M. W. (2022). Directions for future research on urban mobility and city logistics. *Networks*, *79*(3), 253–263. https://doi.org/10.1002/net.22092

Katsela, K., Güneş, Ş., Fried, T., Goodchild, A., & Browne, M. (2022). Defining Urban Freight Microhubs: A Case Study Analysis. *Sustainability*, *14*(1), 532. https://doi.org/10.3390/su14010532

Lee, B. K., Kim, Y. J., & Low, J. M. W. (2025). Performances in Last-Mile Deliveries involving Cyclic Services of Shuttles and Cargo Bikes. *Transportation Research Record: Journal of the Transportation Research Board*, *2679*(10), 1174–1191. https://doi.org/10.1177/03611981251346182

Liu, X., Jiang, D., Tao, B., Xiang, F., Jiang, G., Sun, Y., Kong, J., & Li, G. (2023). A systematic review of digital twin about physical entities, virtual models, twin data, and applications. *Advanced Engineering Informatics*, *55*, 101876. https://doi.org/10.1016/j.aei.2023.101876

Liu, Y., Pan, S., & Ballot, E. (2025). Federated digital twins platform for smart city logistics: A knowledge-driven approach. *International Journal of Production Economics*, *290*, 109772. https://doi.org/10.1016/j.ijpe.2025.109772

Montero-Vega, M., & Estrada, M. (2025). Moving-micro hubs: Redefining last-mile logistics with autonomous hub vehicles (AHVs) and delivery robots (ADRs). *Transportation Research Part E: Logistics and Transportation Review*, *203*, 104229. https://doi.org/10.1016/j.tre.2025.104229

Novotná, M., Švadlenka, L., Jovčić, S., & Simić, V. (2022). Micro-hub location selection for sustainable last-mile delivery. *PLOS ONE*, *17*(7), e0270926. https://doi.org/10.1371/journal.pone.0270926

Oliveira, L. K., Oliveira, I. K., Nascimento, C. D. O. L., Marcucci, E., & Gatta, V. (2025). Mobility as a service for freight and passenger transport: Identifying a microhubs network to promote crowdshipping service. *Case Studies on Transport Policy*, *19*, 101356. https://doi.org/10.1016/j.cstp.2024.101356

Page, M. J. et al. (2021). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ*, n160. https://doi.org/10.1136/bmj.n160

Rave, A., & Fontaine, P. (2025). The location routing problem with time windows and load-dependent travel times for cargo bikes. *European Journal of Operational Research*, *323*(1), 97–107. https://doi.org/10.1016/j.ejor.2024.11.040

Rosenberg, L. N. et al. (2021). Introducing the Shared Micro-Depot Network for Last-Mile Logistics. *Sustainability*, *13*(4), 2067. https://doi.org/10.3390/su13042067

Rudolph, C., Nsamzinshuti, A., Bonsu, S., Ndiaye, A. B., & Rigo, N. (2022). Localization of Relevant Urban Micro-Consolidation Centers for Last-Mile Cargo Bike Delivery Based on Real Demand Data and City Characteristics. *Transportation Research Record: Journal of the Transportation Research Board*, *2676*(1), 365–375. https://doi.org/10.1177/03611981211036351

Savchenko, L., Grygorak, M., Polishchuk, V., Vovk, Y., Lyashuk, O., Vovk, I., & Khudobei, R. (2022). Complex evaluation of the efficiency of urban consolidation centers at the micro level. *Scientific Journal of Silesian University of Technology. Series Transport*, *115*, 135–159. https://doi.org/10.20858/sjsutst.2022.115.10

Sawik, B. (2024). Optimizing Last-Mile Delivery: A Multi-Criteria Approach with Automated Smart Lockers, Capillary Distribution and Crowdshipping. *Logistics*, *8*(2), 52. https://doi.org/10.3390/logistics8020052

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Stokkink, P., & Geroliminis, N. (2025). On the optimal micro-hub locations in a multi-modal last-mile delivery system. *Transportation Research Part E: Logistics and Transportation Review*, *203*, 104344. https://doi.org/10.1016/j.tre.2025.104344

Tadić, S., Krstić, M., Kovač, M., & Brnjac, N. (2022). Evaluation of Smart City Logistics Solutions. *Promet - Traffic&Transportation*, *34*(5), 725–738. https://doi.org/10.7307/ptt.v34i5.4122

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Xiao, Y., & Watson, M. (2019). Guidance on Conducting a Systematic Literature Review. *Journal of Planning Education and Research*, *39*(1), 93–112. https://doi.org/10.1177/0739456X17723971

Xiao, Z., Du, X., & Sakai, T. (2025). Locating in informally-developed spaces: Disentangling the spatial preferences of e-commerce logistics microhubs. *Journal of Transport Geography*, *127*, 104287. https://doi.org/10.1016/j.jtrangeo.2025.104287