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Turning a spotlight on construction logistics for a sustainable urban environment—a review of current policy concepts and literature

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Construction logistics is an influential participant in the overall urban freight network and a bottle neck for an efficient construction process. Especially in the urban area professionalization of its management may reduce negative impacts on the environment from which stakeholders, like construction companies, policymakers and residents, do profit. In order to shed light on construction logistics in the urban environment in particular, a two-step methodological approach was pursued, which reconciles scientific findings with consideration in policies for the first time. Therefore, the current state of research was investigated by performing a systematic literature review and applying bibliometric keyword co-occurrence analyses in the first place. Moreover, policy papers (grey literature) on urban freight transportation of the 20 biggest cities in the DACH-region (Germany, Austria, Switzerland) were analyzed for their consideration of construction logistics in an initial case study. The results demonstrate limited consideration with only four cities paying deliberate attention within their overall logistics policy concepts and just one city providing construction logistics-specific policy recommendations. This is in line with the findings that although construction logistics in the urban environment is an emerging topic in academia, it is currently underrepresented in the context of urban logistics research. Therefore, combined results suggest insufficient translation of research findings into actionable policies despite existing literature providing possible ways to design future policies, e.g., by supporting decision-making. In conclusion, strategic management of construction logistics in the urban environment should be paid more attention to from both policy and academia in proportion to its environmental and socio-economic effects as well as its impact on the whole construction process. In that regard, predominately robust empirical data is needed in order to legitimate effective and sustainable concepts for urban construction logistics for both public and private actors.

KEYWORDS

construction logistics, city logistics, urban area, sustainability, policy concepts, literature review

1 Introduction

Urban construction sites are particularly challenging for construction management and especially its logistics. Traffic-related delays in deliveries and damaging of stored material on-site due to on-going construction activities may interfere with a coordinated construction process (Lundesjo, 2015). Due to limited storage options on construction sites, just-in-time

deliveries are pursued to avoid material storage by adaptation to punctual needs (Sommer, 2016). Consequently, most individual transports do not utilize their full capacity. Studies have shown that the occupancy of construction-related inner-city transports was below 50% on average (Vrijhoef, 2018). In addition, the multitude of transportation vehicles are estimated to constitute to around 20%–35% of the overall urban freight traffic (Brusselaers et al., 2020), to 38% of CO_2 emissions of overall urban freight transportation (Leerkamp et al., 2020) as well as to noise pollution, congestion and other environmental and socio-economic impacts (Fredriksson et al., 2022). Although these numbers by estimation still need further specification, the significant impact of construction logistics on the urban environment is evident (Vrijhoef, 2018; Janné, 2020; Brusselaers et al., 2021).

Looking at the bigger picture, freight transportation in urban areas in general cause around 25% of overall transport emissions and more than 69% of inner-city accidents (European Commission, 2011; Rizet et al., 2016). These impacts on the sustainability of a city have created awareness in public (Leerkamp et al., 2020), an on-going trend of logistics initiatives from various stakeholders in urban areas in order to professionalize urban logistics management and reduce its implications (Kin et al., 2017) as well as an increase in scientific research (Hu et al., 2019; Arvianto et al., 2021). Today, there is a broad base of scientific studies available especially in the field of city logistics. To name a few examples, there are systematic literature reviews on urban logistics research giving insights into the *status quo* and trends of research (Lagorio et al., 2016) and thematic reviews from the governmental perspective providing ideas for a better measurement and monitoring of the performance of city logistics (Lindholm, 2013). Moreover, there are reviews with the aim of comparing city logistics challenges and solutions for more and less developed economies (Arvianto et al., 2021) or reviews providing scientometric analyses by visualizing current research clusters, collaborations and connecting keywords (Hu et al., 2019).

However, given the impact construction logistics has both on the construction process and the urban environment, research that investigates and discusses the relevance of urban construction logistics from different perspectives is still rare. The few scientific literature reviews available focus on specialized topics within the construction logistics field. First of all, Janné (2020) analyzed articles within the research topics of Supply Chain Management (SCM), logistics and third-party logistics (TPL) for construction sites and highlighted the increased importance of supply chain orientation and cooperation within the logistics context, especially with third-party logistics. Moreover, Tetik et al. (2022) compared industrial logistics practices with construction logistics based on literature and provided ways for construction industry and research on how to gradually improve logistics practices. In addition, digital perspectives for construction logistics and construction SCM are recurring motifs in literature reviews. This includes Whitlock et al. (2018), who linked Building Information Modelling (BIM) with construction logistics based on literature thereby providing knowledge on the synergies of BIM and the management of construction site logistics as well as directions for future research. Furthermore, Chen et al. (2021) conducted a literature review to identify enabling criteria for construction supply chain coordination and *inter alia* focused on digital technologies like linked databases or automated monitoring technologies.

However, all of these reviews focusing construction logistics do only scratch the surface of urban construction logistics and its special challenges. To bridge this gap, this paper performs a scientific literature review specifically targeting construction logistics in the urban environment. In addition, not only the perspective of research on construction logistics management, but also the perspective of policy and governance is presented. For this, policy papers on city logistics of the 20 biggest cities in Germany, Austria and Switzerland (DACH-region) were investigated towards their consideration of construction logistics as an initial case study. By performing this two-part approach, the paper aims at providing insights into the current representation of construction logistics in research and policy on the one hand, but also at finding common denominators to establish sustainable urban construction logistics in the future. Therefore, the following research questions (RQ) were addressed.

1) What is the current relevance of construction logistics and construction transportation in policy?
2) What is the current state of research regarding construction logistics in urban areas and is it adequately researched in light of the current challenges?
3) What are the current innovations that need to be (further) addressed, both scientifically as well as from policy and decision makers that can lead towards a more sustainable management of construction logistics in the urban environment?

2 Methodology

To answer these research questions and for analyzing the role that construction logistics play in the environment of urban policy and governance as well as in academic research, two literature-based approaches were utilized, namely, the analysis of strategy and policy papers of public authorities on the one hand and the analysis of scientific publications on the other.

2.1 Analysis of strategy and policy papers of public authorities

To acquire knowledge on the role that construction logistics play in urban policy and governance (RQ1), policy concepts, strategy papers and guidelines (also referred to as grey literature) on the topics ‘construction logistics’, ‘city logistics’, ‘freight transportation’ and ‘urban mobility’ of the 20 most populous cities of the DACH-region (Germany, Austria and Switzerland) were qualitatively reviewed.

Since these types of documents are not listed in scientific databases and had to be acquired individually, the completeness of the set of documents was ensured by corresponding with the responsible departments of the examined cities. In addition, the documents needed to meet formal inclusion criteria in order to gather a comparable dataset. First of all, documents had to be officially written, commissioned and published by the local authorities of the examined cities. Nevertheless, documents co-authored, authorized and/or funded by the related public institution were considered as well. Beyond that, the documents

needed to be publicly available. Finally, the specific focus on the topics mentioned above was fundamental.

After the acquisition of the grey literature, these documents were qualitatively reviewed and systematized into categories representing the level of consideration of construction logistics within the respective concept of each city respectively in order to map its current relevance to the policy making institutions. Apart from the categorization, the content of these concepts, in which construction logistics was considered, was described in detail.

2.2 Analysis of scientific publications: Qualitative systematic literature review in combination with selected scientometric tools

In order to shed light on the current state of research regarding construction logistics in the urban environment (RQ2) and, building on that, to be able to discuss whether or how research is addressing the challenges that cities are facing, existing scientific literature was reviewed systematically.

Methodically, Systematic Literature Reviews (SLR) have been used in previous literature-based studies, for example, to elucidate challenges and innovative solutions (Arvianto et al., 2021) or trends (Hu et al., 2019) in city logistics research. SLR are tools to answer defined research questions based on a clear and structured process of searching for literature regarding a topic of interest (Snyder, 2019). However, given the diversity of the logistics research disciplines under investigation that feature a variety of different types of studies and study designs, the low level of comparability was a limiting factor. Therefore, a SLR process seemed to be not fully applicable for this very study. Instead, a qualitative SLR was conducted, in which a strict systematic process was applied to collect all literature essential to the topic of interest while a qualitative approach was used to assess it (Snyder, 2019). In addition, meaningful tools of scientometric analyses were utilized to systematically extract information of the research field on the meta level. These scientometric tools are capable of analyzing literature based on publication metrics like keywords (Leydesdorff and Milojević, 2012).

The operative research framework of the qualitative SLR process included four main phases following the framework of Cerchione and Esposito (2016). First of all, a search strategy with suitable keywords was formulated that addressed the underlying issue and research questions adequately. Then, a systematic search for literature was performed and the obtained publications were processed towards generating the literature dataset for further investigations. Diverse scientometric analyses were performed on the final dataset next in order to gather a generous overview of the research field. In the end, a qualitative full-text review of specifically selected publications was conducted in order to elaborate on the research findings comprehensively. In the following, these four main phases are described further in detail.

2.2.1 Search strategy

The overall study aimed at reviewing the current state of research on construction logistics in the urban environment and its affiliated policy measures. Therefore, the keywords "construction logistics", "city/urban logistics" and "policy/governance" were chosen to represent the necessary research fields that relevant literature needs to be acquired on to answer RQ2 and RQ3 as well as to be able to refer back to RQ1 in the discussion. Furthermore, using these keywords alone and in combination was expected to give valuable insights into interdependencies and topics of mutual interest across the disciplines.

2.2.2 Systematic literature acquisition and processing of the dataset

The set of literature for the literature review was acquired from a total of two different journal databases, namely, the databases 'Web of Science', 'SCOPUS' and 'EBSCO Host' in order to increase the likelihood to identify and include all relevant scientific publications related to the topic of interest. For literature acquisition, a search in the bibliometric tags 'title', 'abstract' and 'keywords' was performed for the relevant search terms 1) 'Construction Logistics', 2) 'City Logistics' and 'Urban Logistics' and 3) 'Policy' and 'Governance' alone and in all combinations possible. The seven resulting search strings are depicted in Table 1.

For processing, the obtained literature of the individual searches was exported search string-wise into the reference management software Zotero and duplicates were removed. After that, publications for the final survey were selected by eliminating all publications from the data sets that met conventional exclusion criteria (Vilela et al., 2017; Hu et al., 2019; Salim et al., 2019) depicted in Table 2.

To summarize, an overview of the acquisition and processing procedure following the PRISMA principles (PRISMA, 2023) as well as an exemplary presentation for one of the seven search strings are displayed in Figure 1. For practical reasons, the literature base for the 'policy/governance' section was obtained from only one database and not processed using the exclusion criteria due to its large number of results. The obtained seven datasets of publications allowed for selected scientometric analyses and the qualitative literature review next.

2.2.3 Scientometric analysis

For this study, an overlap analysis of the three selected research topics and a co-occurrence analysis based on keywords were adequate to facilitate answering research questions RQ2 and RQ3.

By means of the search strategy, publications being affiliated to more than one research field, indicating an overlap of research interest across the disciplines, were identified at first. The findings were illustrated using a Venn diagram that shows the logical relation between the datasets (Figure 1A).

For further insights into the literature of the overall topics and of the overlapping section, the dataset of literature was then further analyzed using the VOSviewer program for bibliometric mapping (van Eck and Waltman, 2010). By displaying co-occurrences of individual keywords, interrelated topics become visible and research clusters can be identified as studies like those of Hu et al. (2019) have shown. Therefore, the keyword co-occurrence analysis can also act as a valuable reference point for the subsequent qualitative in-depth literature review.

2.2.4 Qualitative literature review of selected publications

Apart from the quantitative scientometric analysis of the scientific publications, literature on the intersections of the 'construction logistics' field with the other two research fields

TABLE 1 Search strings utilized for the systematic acquisition of literature on the three research disciplines under investigation.

Disciplines involved	No.	Search string
One	1	"Construction Logistics"
	2	"City Logistics" OR "Urban Logistics"
	3	"Policy" OR "Governance"
Two	4	("Construction Logistics") AND ("Urban Logistics" OR "City Logistics" OR "City" OR "Urban")
	5	("City Logistics" OR "Urban Logistics") AND ("Policy" OR "Governance")
	6	("Construction Logistics") AND ("Policy" OR "Governance")
Three	7	("Construction Logistics") AND ("Urban Logistics" OR "City Logistics" OR "Urban" OR "City") AND ("Policy" OR "Governance")

TABLE 2 Exclusion criteria for literature selection.

Exclusion criteria for construction logistic related search terms
Language other than English
Published previous the year 2000
Less than 5 pages
Non-peer reviewed
Repeated articles (e.g., conferences Procedia and Journal article, the latest of these publications in chosen)
Articles that do not directly relate to the keywords (e.g., construction processes in space)

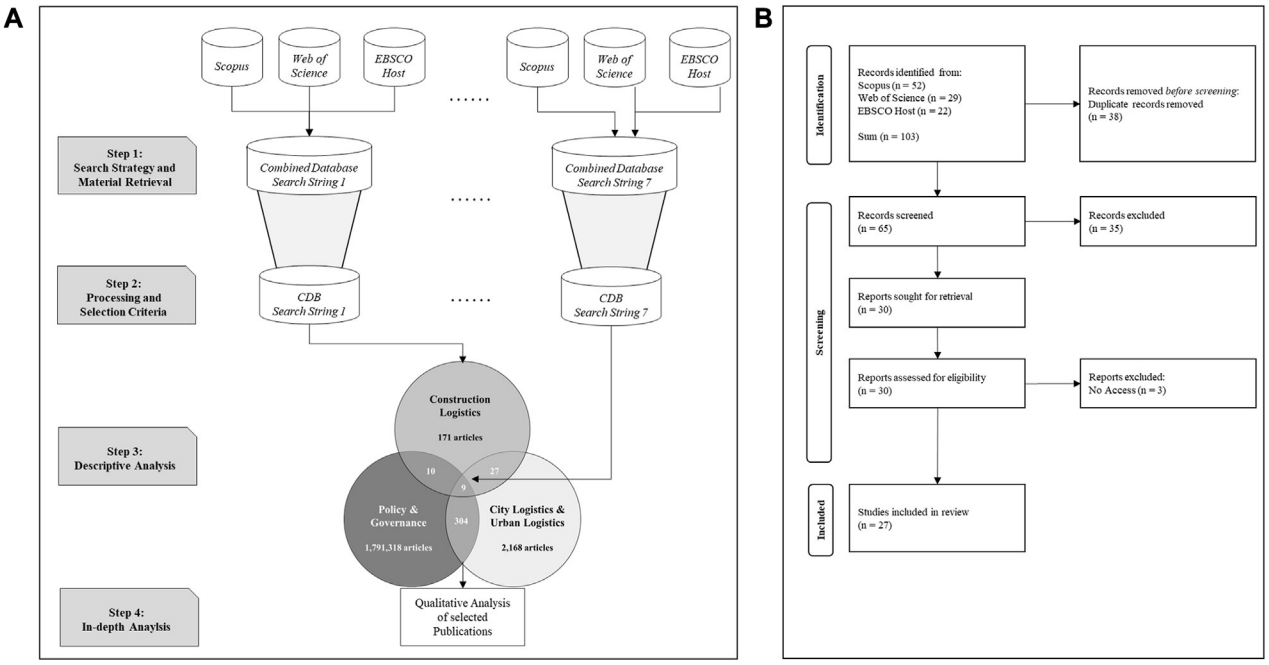


FIGURE 1
Overview of the acquisition and processing procedure following the PRISMA principles (PRISMA, 2023) **(A)** and exemplary presentation for the search string 4 "("Construction Logistics") AND ("Urban Logistics" OR "City Logistics" OR "City" OR "Urban") **(B)**.

'city/urban logistics' and 'policy/governance' was qualitatively reviewed. For synthesizing an in-depth understanding of literature within the specific subfields, publications were read and clustered content-wise in an iterative process aiming to provide an overview of current findings and concepts and map down research gaps and perspectives for future research.

3 Results

3.1 Analysis of policy and governance concepts of the 20 most populous cities of the DACH-region

Strategic concepts on logistics in the urban environment of the 20 most populous cities within the DACH-region were analyzed towards the level of consideration of construction logistics to map its relevance to policy making institutions. In addition, the concepts, in which solid consideration was given, were outlined to give an insight on current ideas of municipalities meeting the grand challenges of construction logistics in their respective city.

In 16 out of 20 cities examined (80%), considerations on construction logistics were completely absent (Figure 2, no consideration) or the term was mentioned but without further specification (low consideration). Three cities, corresponding to a share of 15%, provided specific ideas on construction logistics within their overall concept on logistics (medium consideration), focusing, for example, on possibilities of using transportation modalities other than trucks (Berlin/Germany), restricted time slots for entering the city and considerations regarding the consolidation of material flows by utilizing central logistics strategies (Stuttgart/Germany) or the use of electric vehicles (Dresden/Germany). The only city providing concepts concentrating on construction logistics itself (high consideration) was Vienna (Austria).

In general, there was no trend observed between the construction activity within the cities represented by the number of construction permits per 100.000 inhabitants, highlighting that there is no significant correlation between the construction volume in a city and the level of considering construction-related logistics within a cities' strategy. Those cities providing concepts with medium and high consideration of construction logistics offer the following ideas in detail.

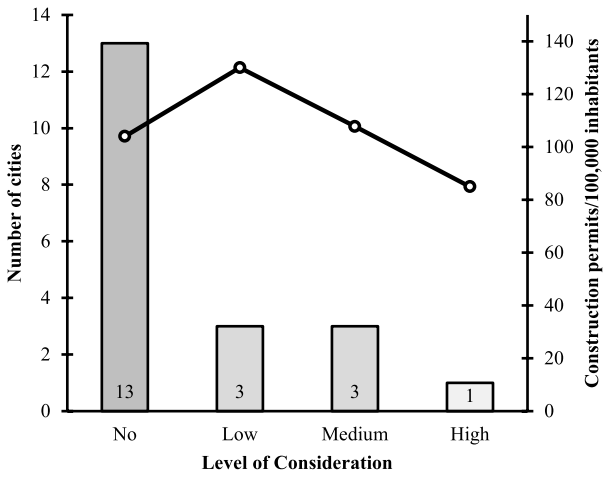


FIGURE 2
Categorization of the 20 most populous cities of the DACH-region according to their level of consideration (no, low, medium, high) of the topic "construction logistics" within the cities' overall logistics and urban mobility concepts (bar chart, left y-axis). Average construction activity within the cities of one category, represented by the average number of construction permits issued over 4 years (2016–2020) per 100,000 inhabitants (line chart, right y-axis).

In the concept provided by the City of Berlin in Germany (Senatsverwaltung für Umwelt, 2021) three major courses of action regarding construction logistics in the urban environment were presented. First of all, especially the inland waterway transport using the river Spree was taken into consideration for managing logistics in the construction sector. Apart from using different modalities of transportation, the estimated amount of traffic caused by a construction project was mentioned to prospectively be considered more strongly during the process of issuing building permits. The additional submission of sustainable logistics concepts for the respective construction site was suggested as well. Finally, collaborative decision making integrating all participating stakeholders for creating innovative delivery systems in the urban area were proposed including the construction industry by mentioning Construction Consolidation Centres (CCC) as an example for pooling different material flows together for inner-city deliveries. Despite these first attempts of advocating construction logistics management and solutions, the City of Berlin reported awareness that there is still no sufficient picture of where construction logistics activities reside geographically within the city and stated that further (statistical) information is needed. Therefore, the city acknowledged that including all stakeholders is necessary in order to optimize inner-city transportation processes. The suggested ideas for construction logistics management in Berlin would require mutual comprehension of construction and construction logistics processes from both public and private stakeholders.

Historically, a first pilot project using the river Spree and the railway infrastructure for transportation already took place for building the 'Potsdamer Platz' around the turn of the millennium and had proven successful in terms of decreasing the number of trucks and emissions. However, this kind of logistics solution has not made it into the city's construction logistics practice yet.

For reducing the negative impacts of construction logistics on the urban environment, the City of Stuttgart (Germany) proposed the development of integrative construction logistics concepts in close coordination and collaboration of developers and the municipality (IHK Stuttgart, 2012). Exemplarily mentioned were both the introduction of CCC for integrating large numbers of autonomous material flows and restricted time slots for construction transportation vehicles entering the city. Especially the latter was seen as fundamentally important since the majority of construction-related logistics activities in Stuttgart has been shown to operate within the peak of the cities' rush-hour traffic especially adding to congestion and risk of accidents. Apart from proposing solutions for managing construction logistics activities in the concept, the City of Stuttgart additionally presented the action of distributing leaflets for interested developers comprising relevant information, for example, about recommended routing, congestion times and specific authorization procedures. Although the City of Stuttgart sees the need for action, none of the innovative concept ideas, except for the information leaflets, have been put into practice yet.

Similar to the City of Stuttgart, the City of Dresden (Germany) deemed solutions like consolidation centers for the construction industry important to investigate (Landeshauptstadt Dresden, 2015). Moreover, the city's concept suggested investigating the utilization of electric vehicles for construction transportation.

All in all, for the cities Berlin, Stuttgart and Dresden that mentioned construction logistics within their overall concept on logistics in the urban area (medium consideration), construction activities were perceived as a disruptive factor within the planning of overall inner-city transportation. Consequently, mitigation strategies for reducing the impacts of construction logistics within the respective city were called for.

In that respect, out of all cities investigated Vienna (Austria) was the city where construction logistics has been considered most within the urban logistics environment by providing two strategy concepts concentrating on construction logistics itself (high consideration).

The first concept was a guideline for the environmentally sustainable realization of a construction project specifically focusing on construction logistics, giving input to developers on how to reduce its environmental impact, for example, by decreasing the construction traffic volume (Stadt Wien, 2004).

The guideline proposed measures and concepts in the course of different types of construction sites and for different phases of the construction process. These measures included, for example, the recommendation of preparing a transportation concept pointing out the possibilities of using modalities of transportation other than trucks like train and ship, time management of material deliveries or utilizing a CCC. In addition, specific measures, for example, for sorting, recycling and disposal of waste on-site but also for protecting the surrounding neighborhood from noise and dust emissions were addressed. By illustrating the measures in certain case studies, the City of Vienna demonstrated both the reduction of CO_2 emissions by up to 91% using trains for the transportation of pre-fabricated concrete elements (Mischek, 2004) and the prevention of 35% of waste transports when sorting materials correctly and using adequate landfills (ÖKOTECHNA, 2003). Furthermore, particular attention was paid to CCC's. In comparison to the other cities' concepts, Vienna gave specific ideas on CCC setups and provided feasibility assessment indicators for the location of a CCC. Importantly, the city of Vienna also recognized that ways for financial compensation of the external costs for realizing a CCC need to be investigated in the future.

The second concept published by the city of Vienna concerning construction logistics management was a guideline that addresses the procurement procedure of both public and private actors by providing standardized tendering text modules for sustainable construction logistics practices (Wien and Brezansky, 2017). Furthermore, checklists to monitor the specific measures in the realization phase of construction projects are provided. The guideline presents measures for reducing both transport pollutant and noise emissions and for optimizing waste management by assessing multimodal transportation or the possibility of material consolidation, coordinating transportation via delivery-planning tools or providing concepts for minimizing the burden placed on residents. Similar to the first concept, the measures proposed were specifically allocated to different types of construction projects such as building construction, underground or road construction.

All in all, the analysis showed that considerations on construction logistics played a minor to non-existent role in policy and governance on logistics of the majority of the 20 most populous cities of the DACH-region. First considerations regarding construction logistics in the urban environment were given by a couple of cities, focusing mainly on solutions like CCC's and trimodal transportation. However, ideas on how to operatively implement innovative construction logistics solutions were lacking. In addition, most of the recommendations are not implemented yet.

Especially given the impact that construction logistics have environmentally and socio-economically, the current state of scientific literature was analyzed next to get insights into construction logistics in the urban environment from a research-based point of view.

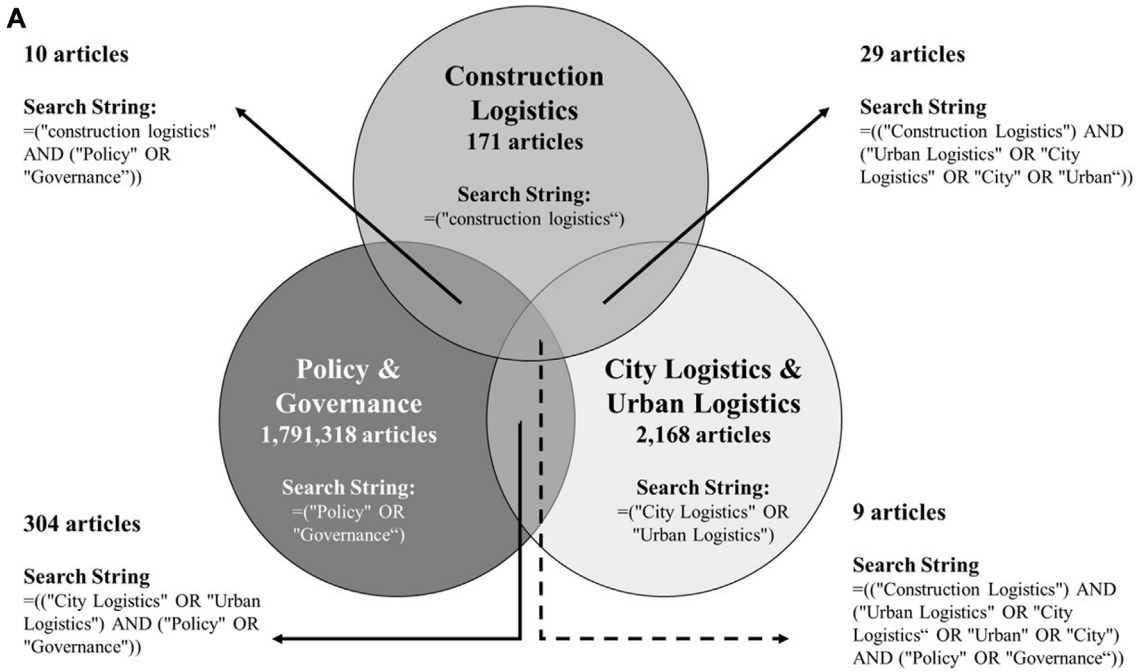
3.2 Analysis of scientific literature on construction logistics in the urban environment

A quantitative search for scientific literature on the keywords "Construction Logistics", "City/Urban Logistics" and "Policy/Governance" alone and in combination was performed in order to identify publications on construction logistics and especially those that are cross-linked with the other selected topics of interest. Figure 3 shows the results of the overlap analysis. Both a quantitative and a qualitative in-depth analysis of the obtained scientific literature were conducted.

3.2.1 Overlap analysis of mutual literature across research disciplines

With 171 articles in comparison to 2,168 articles identified, the research base on construction logistics is almost 13 times smaller than that of city logistics, classifying it as a niche topic. Within research on construction logistics, 16.9% of articles were shown to have a connection with city logistics proving that the urban environment is one of the predominant topics that research on construction logistics is dealing with. This indicates that the research field of construction logistics recognizes the need to pay attention to the urban environment. However, from the perspective of city logistics only every 100th (1.3%) research paper was referencing construction logistics. Given the impacts that construction logistics have on the urban environment, e.g., accounting for more than a third of all carbon emissions caused by urban logistics transportation (Leerkamp et al., 2020), there is an imbalance between its relevancy on the city and its scientific attention from an urban point of view.

When comparing the scientific literature bases of the two investigated logistics fields in terms of their respective consideration of policy and governance aspects, research on city logistics seems to pay more attention to it (304 out of 2,168 articles corresponding to 14%) than research on construction logistics (10 out of 171 articles corresponding to 5.8%) in general. However, when focusing on the share of literature on construction logistics that specifically overlaps with city logistics and hence construction logistics in the urban environment (29 articles), policy aspects were considered in 9 out of 29 articles (corresponding to 31%), which is more than twice as much as in comparison to city logistics itself. Given the relatively small data set of publications on construction logistics research, this analysis does not claim to fully bring quantitative evidence, but the



B

	Construction Logistics	City Logistics & Urban Logistics	Policy & Governance
Construction Logistics	100 %	16.9 %	5.8 %
City Logistics & Urban Logistics	1.3 %	100 %	14.0 %
Policy & Governance	< 0.1 %	< 0.1 %	100 %

FIGURE 3
Overlap analysis of the results of a quantitative literature search on depicted keywords using the three scientific databases 'Web of Science', 'Scopus' and 'EBSCO Host' **(A)** and the corresponding matrix showing the percentages of overlap **(B)**.

relative trend is readily apparent that policy and governance play an important role in research on construction logistics in the urban context. Nonetheless, the scientific literature basis on construction logistics, especially in a city logistics context, is small in terms of absolute numbers and is hardly noticed as part of it.

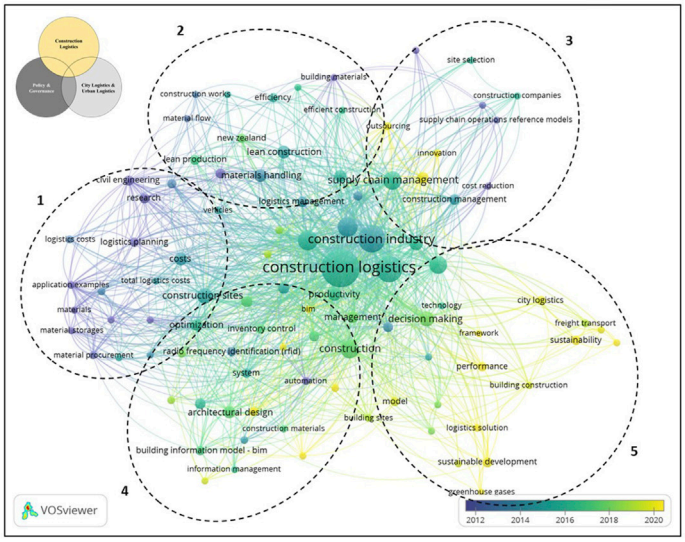
3.2.2 Keyword co-occurrence analysis

Adopting scientometric methods, like keyword co-occurrence analyses, has given valuable insights into, for example, the city logistics research field on a meta level in recent years (de Carvalho et al., 2019; Hu et al., 2019). To gather a better understanding, identify research clusters and unveil emerging topics of the scientific literature in the construction logistics field and at the interplay of urban/city logistics and policy/governance, a co-occurrence analysis of the indicated keywords in the set of publications was conducted using the VOSviewer program for bibliometric mapping (van Eck and Waltman, 2010).

Figure 4 and Figure 6 display the resulting keyword co-occurrence networks of the whole construction logistics literature dataset and the partial literature dataset of publications at the overlap with city/urban logistics and policy/governance, respectively. Keywords with a threshold higher than three (whole construction logistics literature) or two (partial literature of the overlaps) *occurrences* within the datasets are displayed as a *node* in the network which becomes larger in size, the more often the keyword is used. Moreover, keywords appearing together in one publication are connected via a *link*. The more often two individual keywords occur together in one publication, the higher the *link-strength*, indicated by increased line thickness, is. Eventually, the sum of all links multiplied by the individual link-strength results in the *total link strength* of a keyword.

As shown in Figure 4B, the keyword *construction logistics* presents itself with an occurrence of 96 and a total link strength of 447. Around this core keyword representing the research field, five research sub-clusters were identified based on the keyword co-occurrence analysis. These clusters are focusing on logistics management on site (cluster 1) with keywords like *material storage* or *site layout*, lean construction management (cluster 2)

A



B

Keyword	Occurence	Total link strength
construction logistics	96	477
construction industry	90	473
logistics	82	351
project management	66	299
construction projects	34	171
supply chain management	33	180
construction	31	169
supply chains	29	157
construction sites	28	144
...		
city logistics	5	22
...		
Construction consolidation centre	3	9

FIGURE 4
Co-occurrence analysis of the indicated keywords within the 171 publications in the research field of 'construction logistics' **(A)** (see appendix for a full-scale version) and an overview of the most relevant keywords ranked by number of occurrence **(B)**. The colour scale indicates year of publishing of the underlying publication that the keywords are affiliated to.

(*lean production, efficient construction*), supply chain management (cluster 3) (*supply chain operation reference models, construction companies*), digitalization (cluster 4) (*building information modelling, information management*) and last but not least sustainability and logistics in the urban environment (cluster 5) (*city logistics, sustainable development*). What is striking is that the keywords in cluster 5 were utilized most recently in terms of publication year of the respective publication according to the bright coloration of nodes and links. Therefore, addressing aspects of sustainability and the urban environment are currently the latest and emerging topics under investigation in the field of construction logistics.

This finding coincidences with a quite rapid increase in publication activity for research on construction logistics starting in 2017 as depicted in Figure 5 (dark grey line). Around half of all publications (54%) in the field that were published between 2000 and 2021 have been released specifically in the past 4 years. In comparison, the onset of the increase of publication activity in the research field of city logistics was around 5 years earlier, namely, in 2012 (bright grey line), albeit the increase was not as rapid. When specifically analyzing the publication activity of literature targeting the overlap of construction logistics and city/urban logistics, there is a significant increase apparent starting around 2018. More than 60% of the publications in this dataset were published in the 3 years until 2021, underlining the clear trend of construction logistics in the urban field being an emerging topic derived by the keyword co-occurrence analysis.

According to Figure 6 illustrating the keyword co-occurrence analysis for the literature dataset of the overlapping topics, there are three thematic clusters observed. First of all, cluster 1 addresses decision making regarding construction logistics setup's (CLS) in the urban area, like CCC. Apart from that, the impact assessment of construction logistics in the urban environment (cluster 2), like the assessment of, for example, greenhouse gas emissions, and approaches for optimization (cluster 3), e.g., construction logistics schedules, are in the focus of research according to the keywords.

All in all, research on construction logistics, especially at the interface of city/urban logistics, is gaining importance and is coming to the fore, relatively. However, the construction logistics field is lagging behind city logistics research. To get a better understanding of the existing literature and further contribute to answering RQ2 and RQ3, an in-depth qualitative analysis of the literature was performed next.

3.2.3 In-depth content analysis of literature

The literature search has identified a set of scientific publications in the research field of construction logistics and has especially identified those 37 that specifically address construction logistics in regard to either policy/governance (10), city/urban logistics (27) or both (9). These publications were qualitatively reviewed next.

Although three individual intersections were identified upon keyword relations, the in-depth content analysis of the literature at these overlaps revealed that the content of the publications is closely positioned in general. Roughly differentiating, publications at the intersection of construction logistics and city logistics were paying attention to sustainable practices for construction logistics in the urban environment as well as its IT-based optimization, while those publications on the triple overlap of construction logistics, city/urban logistics and policy/governance were especially focusing on tools and methods for decision making and stakeholder involvement. Apart from that, the one publication that was found at the intersection of construction logistics and policy/governance was focusing on the greenhouse gas (GHG) footprint of transports of construction sites. All in all, the three data sets of literature on the search term overlaps were generally small in terms

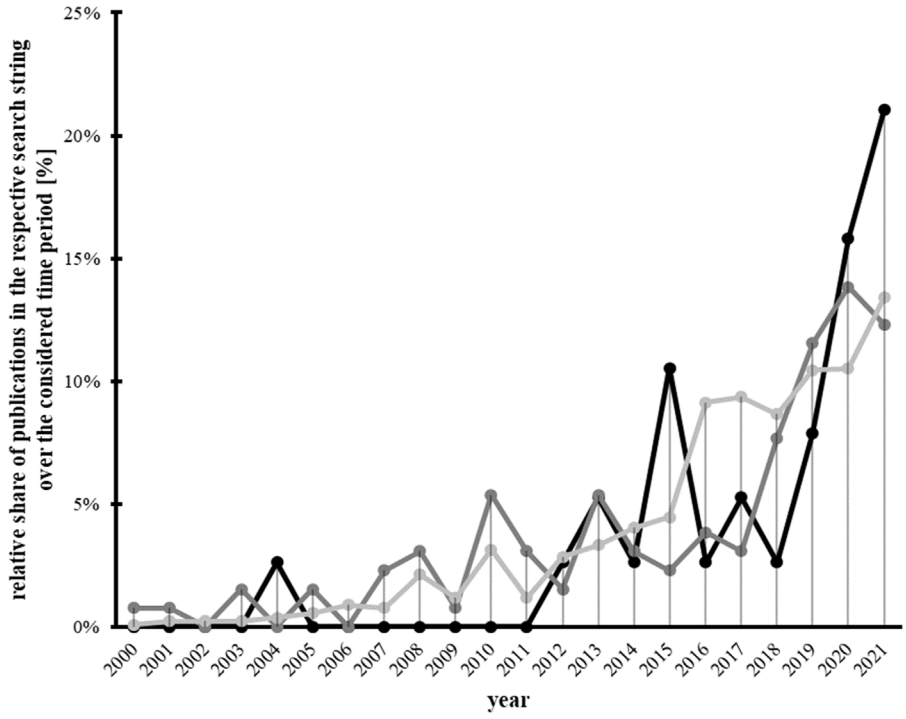
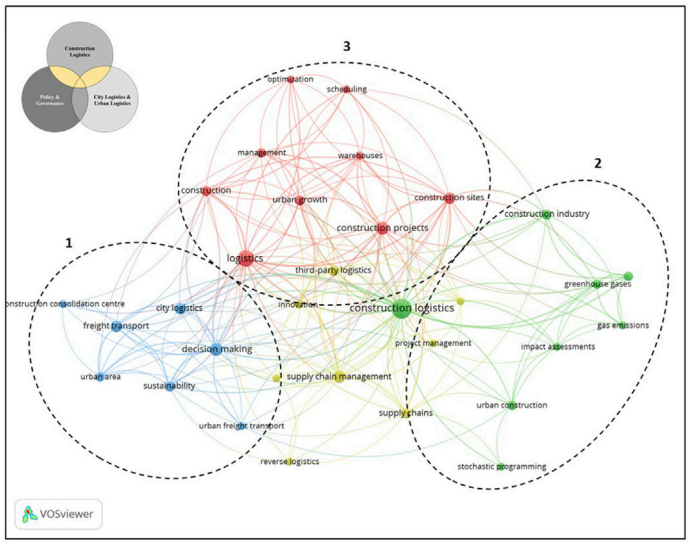


FIGURE 5
Relative share of publications published per year in the research field of "construction logistics" (dark grey line), "city logistics" (light grey line) or at the overlap (black line) in the time period between 2000 and 2021.

A



B

Keyword	Occurence	Total link strength
Construction logistics	18	79
Logistics	11	54
Decision making	7	38
Construction projects	7	36
Supply chain management	6	33
Construction sites	5	34
City logistics	5	22
Freight transport	5	22
Construction	4	26
Sustainability	4	25
...	...	...
Stochastic programming	2	5

FIGURE 6
Co-occurrence analysis of the indicated keywords within the 29 publications at the overlap of the research fields of 'construction logistics' and 'city/urban logistics' **(A)** (see Appendix for the full-scale version) and an overview of the most relevant keywords ranked by number of occurrence **(B)**.

of absolute numbers. Therefore, it was concluded that a segregated content evaluation making generous assumptions on predominant topics at the overlaps would not be tenable given the obtained dataset and would in general fall too short to reflect the state of research. For this reason, the following literature review will incorporate all identified publications on the intersections without further contextualizing the affiliation to a certain overlapping section.

Construction logistics itself can be divided into four process areas. These include procurement logistics, on-site logistics and

disposal logistics as well as the cross-sectional process of coordinating and controlling logistical information (German Lean Construction Institute, 2022). In that regard, the examined literature mainly focused on the process of procurement logistics, the transportation of supplies to the construction site and the resulting interactions with the urban environment.

First, there is evidence that the execution of construction logistics presents itself with particular characteristics, for example, in comparison to city logistics. By collecting data of transport activities related to construction on four construction sites in Luxembourg City (Luxembourg), Paris (France), Valencia (Spain) and Verona (Italy) over 8 months respectively, Guerlain et al. (2019a) showed that there are significant differences in construction-related logistics patterns in comparison to generic urban freight transportation of, for example, retail, food and services. For instance, the supply chain validity appeared to be temporary, not permanent, the vehicle sizes were heavy goods vehicles (HGV) instead of large goods vehicles (LGV), or the digitalization of the delivery process was low. In addition, construction logistics activities do not only adversely affect the environment but also the budget of the construction project from a management perspective if not handled appropriately (Brusselaers et al., 2021). Last but not least, construction logistics processes and strategies do not only include, but also affect a vast number of stakeholders, ranging from municipalities and developers, over (sub) contractors and logistics providers to local citizens nearby (Fredriksson et al., 2021). Thus, managing construction logistics is facing a special challenge to bring together different interests and needs (Fredriksson and Huge-Brodin, 2022).

For addressing these issues, there is common consensus in the literature that the professionalization of construction logistics management and the utilization of innovative construction logistics setup's (CLS) is a key to reducing transport-associated negative socio-economic and environmental impacts of construction logistics in the urban environment. These can be differentiated between asset-based, like electric vehicles, and non-asset-based CLS, which are purely organizational and used to coordinate logistics, like a checkpoint (Janné and Fredriksson, 2019).

The CLS mentioned and investigated most frequently is the Construction Consolidation Center (CCC), also referred to as Construction Logistics Center (CLC), that allows for storage of materials and consolidation of transports on the last mile thus attempting to reduce the number of deliveries to one or multiple construction sites and enables for well utilized just-in-time deliveries (Allen et al., 2012; Guerlain et al., 2019a; Dhawan et al., 2020; Janné, 2020; Moussaoui et al., 2021; El Moussaoui et al., 2022). The possible reduction of the number of freight vehicles and emissions, when potentially introducing a CCC in the logistics supply chain, had already been demonstrated artificially by computational simulation (Dell'Amico and Novellani, 2017; Guerlain et al., 2019a; El Moussaoui et al., 2022). Furthermore, especially for urban development projects, the implementation of a CCC has proven to facilitate the construction process (Janné and Fredriksson, 2019) and a comparison case study from a residential project showed, that there are also benefits in reducing environmental emissions (El Moussaoui et al., 2022). All in all, integrating a CCC as a CLS was attributed great attention and great potential to address the challenges of construction logistics especially in the urban environment.

However, the identified literature was found not to focus on respective innovative CLS's per sé but especially on understanding motivations, objectives and expectations of different stakeholders towards urban CLS's and providing methods and tools for decision support to find adequate CLS's for specific construction projects in the urban environment.

Concerning this matter, the lack of knowledge within public decision making institutions towards requiring CLS's (Brusselaers et al., 2021) on the one hand and the lack of research on governance mechanisms for these CLS's (Janné and Fredriksson, 2019; Morel et al., 2019) on the other hand were seen as critical for a sustainable management of urban construction logistics. That is why developing tools and methods for evidence-based decision making are at the forefront of current studies.

For instance, based on pilot construction sites in four European cities that were utilizing CCC's respectively, Guerlain et al. (2019b) have developed and tested a set of Decision Support Systems (DSS) addressing public and private actors. These proposed systems allow, for example, for the specific assessment of construction logistics-related impacts based on combining defined policy measures, namely, vehicle sizes, requirements for vehicle emission standards and the introduction of a CCC, in a participatory approach that provides immediate results for each scenario possible. Moreover, cost-benefit analyses for introducing a CCC or the possibility to find its most beneficial location within the city are offered.

Interestingly, amongst other results, it was discovered that implementing a CCC solely does not guarantee improvements regarding environmental and health impacts (Muerza and Guerlain, 2021). Consistent with that, other studies conducted on a CCC for a construction project in Stockholm revealed that there were cases in which the mandatory and sweeping execution of construction logistics via a CCC even led to an increase in transportation activity (Janné and Fredriksson, 2019). Thus, finding appropriate and beneficial CLS's depend on a variety of external conditions. In case of a CCC, especially the specific logistics profile and the complexity of both the construction site and the respective urban area are seen as crucial factors to determine the need and adequacy of this type of CLS (Guerlain et al., 2019b).

Simultaneously, stakeholder awareness and involvement are perceived as central aspects for developing and achieving sustainable construction logistics due to the variety of different interests and needs.

For this purpose, a better understanding of the interdependencies of urban planning and construction logistics planning is necessary (Morel et al., 2019) and can be gained via conceptually modelling the interdependencies between the different actors (Fredriksson and Huge-Brodin, 2022). Especially when thinking about the different sources of information for sustainable logistics planning and coordination in the urban environment, knowledge about the roles and stakeholders are necessary (Fredriksson and Huge-Brodin, 2022). Amongst others, especially the separation between public policy making and practice as well as the insufficient knowledge of the other function are hindering the process towards sustainable construction logistics (Morel et al., 2019). Therefore, it is of importance to integrate all stakeholders in early planning stages of construction projects

already (Fredriksson et al., 2021) and in the course of planning an appropriate CLS (Muerza and Guerlain, 2021).

For this purpose, one recurring methodology in literature is the multi-actor multi-criteria analysis (MAMCA) that facilitates collaborative decision making of all stakeholders by systematically structuring the complex process. Since its development (Macharis, 2007), its adaptation to the context of construction logistics in the urban environment (Macharis et al., 2016) and its on-going refinement via conducting case studies (Brusselaers et al., 2021; Fredriksson et al., 2021) took place. Foremost the complexity of decision making due to the multi-actor field with diverging interests and often limited knowledge about construction logistics processes have been demonstrated by utilization of the MAMCA. However, especially for governance and local authorities collaborative and multi-criteria decision making play a vital role in supporting the still fragmented decision making process towards sustainable construction logistics and might help to overcome financial, organizational or policy barriers (Brusselaers et al., 2021).

Although DSS tools or the MAMCA method have proven to be able to identify appropriate CLS for specific construction projects in favor of sustainable urban construction logistics, the initiation of such CLS still represents a serious obstacle due to resistance of stakeholders within the construction logistics supply chain (Janné, 2020). Reasons for that are seen in formal barriers, like, for example, the lack of political attention and consequently the lack of direction from a strategic level that would foster innovation as well as informal barriers, like the lack of sense of urgency and missing knowledge about possible benefits of innovative logistics management (Morel et al., 2019). In case of CCC's, studies have shown that there is a discrepancy between the drivers for the implementation of a CCC and drivers for its utilization (Morel et al., 2019; Brusselaers et al., 2021; Janné and Fredriksson, 2021). While the implementation of CCC's is currently mainly society-focused and stimulated by the aim of reducing the impacts on citizens, environment and traffic as well as to elevate the attractiveness of the city, the utilization of CCC's is driven by possible economic advantages for the end-users such as the reduction of the number of deliveries to or storage of material on the construction site as well as the improvement of just-in-time call offs that translate into an efficient and undisturbed production process. Therefore, viable business models, the cost of utilization and benefit balance between initiator, service provider and end-user were seen as critical factors for acceptance and utilization especially by private actors (Janné and Fredriksson, 2021).

In current CLS projects, this lack of acceptance is enhanced by an indirectly created "forced costumer role" of construction companies (Eriksson et al., 2021). The obligation to use the CLS especially originates from the interest of public institutions, like a sustainable logistics process, diverging from the ones of the construction companies, like an increase in productivity as well as an obligation for the construction companies to use and pay for the CLS when tendering for the construction project (Eriksson et al., 2021).

By now, one key element that is missing in research though, is the availability of broad and robust empirical data and accurate methods for predictive simulation of effective costs and benefits of sustainable CLS's, especially on an urban-wide level. For logistics patterns in the construction industry, the lack of data and poor data quality was recognized (Guerlain et al., 2019b; Sezer and Fredriksson, 2020) and the need for data collection (Brusselaers et al., 2020) as well as data sharing (Morel et al., 2019) was given high priority for future research and practice. Acquisition of data is thereby facing particular difficulties, since data on transportation and construction logistics processes are spread among various stakeholders due to the fragmented nature of the construction industry and are yet not fully digitalized (McKinsey, 2016; Schnell et al., 2022). Furthermore, data collection over time is intrinsically not required these days and available documentations are missing essential information, e.g., on the suppliers locations or the routing of the delivery vehicle (Brusselaers et al., 2020). As a consequence, applying estimations becomes necessary when calculating, for example, associated transport emissions (Sezer and Fredriksson, 2020). However, lacking the capability to evaluate the economic, environmental, and social impacts of transport solutions evidently is a primary concern for creating an effective transport strategy, measures or tools (Guerlain et al., 2019b; Sezer and Fredriksson, 2020).

In favor of being able to calculate implications of construction logistics and innovative CLS in the urban environment accurately, data collection methods, which do not interfere with the on-going construction activity and thereby cause additional effort for participants, are seen as vital (Sezer and Fredriksson, 2020). To derive real-world costs and benefits of CLS's within the construction process and urban environment, more real-world pilot projects need to be initiated and evaluated (Morel et al., 2019).

Brusselaers et al. (2022) proposed an approach for a sustainability assessment framework based on external cost calculations, like congestion or accident costs, as well as Life Cycle Assessment of the on- and off-site activities of urban construction logistics and therewith compared different transport modes and vehicle types in Brussels (Beglium) (Brusselaers et al., 2022). To create a data base, on-board units, a GPS tracker within heavy goods vehicles, were used. Furthermore, the researchers used the same data source to run an in-depth environmental impact assessment for the HGV driving through the territory of Belgium and displayed that more than one-fourth of the HGV's traffic in Belgium is generated by construction activity, resulting in over a million euros of environmental and other external costs per month (Brusselaers et al., 2023). Another method to gain a better understanding of the implications of construction logistics is provided by Rönnberg et al. (2022) who recorded noise and particle pollution data on-site with low-cost sensors to give planners and decision makers for construction sites and logistics a better understanding of these external factors.

For initiating innovative CLS, public authorities can be assigned a special responsibility, e.g., by including requirements for sustainable construction logistics in the tendering process or in policy documents or strategy papers of the corresponding urban area and thereby foster innovative practice from private construction or logistics companies (Guerlain et al., 2019a; Morel et al., 2019; Brusselaers et al., 2021). However, detailed information on how these sustainable public procurement processes could be implemented are not readily available for public authorities and adequate policy recommendations which integrate the characteristics of diverse municipalities, e.g., different

infrastructural prerequisites (Venås et al., 2020; Fredriksson and Huge-Brodin, 2022).

Diverging from the procurement logistics, the solutions for the challenges associated with urban construction logistics are sought for from the on-site perspective in some papers. In these scenarios, the interior and exterior storage spaces on-site are also a limiting factor for material procurement and need to be taken into consideration when calculating an optimal trade-off between minimal logistics cost and minimal schedule criticality (Said and El-Rayes, 2013). From the perspective of construction companies or construction sites, methods like stochastic programming or simulations to increase the safety of logistics transportation (Olia et al., 2013) or to optimize logistics processes for prefabricated materials (Hsu et al., 2020), but also to optimize delivery schedules (Nolz, 2021) and logistics cost (Son et al., 2021) could provide information about favorable transport solutions in the urban area and facilitate the enhancement of sustainable construction logistics practice.

4 Discussion

According to the analysis of the policy concepts from the 20 biggest cities in the DACH-region, strategic thoughts on construction logistics are currently underrepresented or not present in most cities. At the same time research on construction logistics in the urban environment clearly is an emerging topic when taking the results of the literature review into account. To this point, research primarily focused on the supply of building materials to the construction site and its induced impacts on the urban environment as well as on the general sustainability assessment, especially of CLS. However, in the majority of cases, decision making in favor of the latter, is not yet based on quantitative metrics and hitherto on reliable data on construction logistics due to its unavailability.

Therefore, the results point out that data acquisition and data collection of various construction logistics processes is one important aspect to further progress the in-depth evaluation and optimization of urban construction logistics. While there are current approaches for measuring and predicting implications of construction logistics in the urban environment (Janné and Fredriksson, 2021; Brusselaers et al., 2023) as well as the induced effects of CLS (Guerlain et al., 2019b; Berroir et al., 2021; Brusselaers et al., 2021; Muerza and Guerlain, 2021; El Moussaoui et al., 2022), more data on the construction logistics process, e.g., loading rates of the vehicles (Brusselaers et al., 2022), would help to reduce the need of assumptions and deviations. Setting up concepts for standardized data acquisition could be a way to guide construction companies and providers of logistics services towards recording data in a reasonable manner for all parties involved. Since data sets from various project types and locations would become comparable then, this would allow for a better assessment of the construction logistics and effects of CLS with wide-spread implications for both companies and policymakers. In addition, introducing standardized technical terms for building materials would enable a better comparability of, e.g., delivery management systems and would therefore facilitate the predictability of construction logistics activity. Moreover, the exchange of logistics data, which is currently spread among various stakeholders of the construction logistics process, needs to be achieved (Fredriksson and Huge-Brodin, 2022). For this purpose, integrating the perspectives of all stakeholders and thereby information along the construction supply chain, like, e.g., construction material specialized dealers, is necessary (Vidalakis et al., 2011). In urban retail logistics, data exchange has already proven to improve especially the ecological behavior of the predominant stakeholders and build a basis for public institutions to determine subsidy (Maggi and Vallino, 2016). In regards to the construction industry, this collaborative and interdisciplinary work is also aimed for by using building information modelling (BIM). For construction logistics, BIM could provide a platform not only for interdisciplinary and standardised data exchange, but also for a stronger link of the different construction logistics processes, e.g., on-site and off-site logistics (Magill et al., 2020; Whitlock et al., 2021; Placzek et al., 2022).

Therefore, broad and robust empirical data sets on construction logistics could pave the way for a better assessment of CLS in terms of economic and environmental potential and could lead to an enhanced decision making method for clients, construction companies or logistics service providers as well as policymakers.

For clients, construction companies or logistics service providers, data will create the basis to establish new business models for sustainable CLS with economic profitability as well as reduced risk and uncertainties. Besides calculating the dimensions of a CCC for one or multiple construction sites more accurately, the costs and benefits for initiators, like clients, and users, like construction companies, could be more evenly distributed. A more cost-causative allocation of the total costs, which is also recommended by policy papers (Senatsverwaltung für Umwelt, 2021) and construction logistics research (Eriksson et al., 2021; Ekeskär et al., 2022) as well as a company-specific quantification of benefits is especially necessary due to the high deviation of logistical services needed for different construction tasks. Since the CLS is also used to improve the construction process on the construction site, considering the contractors' perspective and benefits could strengthen the contractors' identification with the CLS (Ekeskär et al., 2022). One example of successful cost allocation is shown in city logistics by Ciardiello et al. (2021), who developed an approach to allocate costs of urban consolidation centers among participating stakeholders and thereby achieve financial sustainability.

While business models might be less risk averse and flexible in terms of implementation, empirical data needs to confirm the beneficial effects for decision making of cities or municipalities. Therefore, a sound database and the consequent sustainability assessment could provide a valid basis to enact targeted policy measures, like using multi-modal transportation (Mommens and Macharis, 2014; Hu et al., 2019; Brusselaers and Mommens, 2022). Furthermore, a better understanding of construction logistics could lead to a higher importance of logistics processes in building certification schemes (Sezer and Fredriksson, 2021).

However, construction, construction logistics and especially policy often strongly depend on regional factors (Brusselaers et al., 2022). Construction logistics policymakers act in a multidisciplinary field and need to consider multiple levels of construction logistics prerequisites, like the available infrastructure and interests from various stakeholder groups in addition to the already fragmented industry landscape

(Fredriksson and Huge-Brodin, 2022). Especially in the urban environment, elements like urban density, traffic, stakeholders or the existing infrastructure can limit or broaden the possibilities in policy decision making. These constraints force the need for an individual assessment of construction logistics on a regional level (Fossheim and Andersen, 2017) and to develop policies fitting the circumstances of the area of interest (Belfadel et al., 2021). In contrast, working inductively and translating results back to more comprehensive models or standardized approaches for urban areas with similar circumstances as well as the transferability of concepts and models are an essential part, especially in research, and also needed in urban logistics (Lindholm, 2013).

Last but not least, limited attention is currently paid to foresight research to intertwine future trends of urban development, logistics innovation but also upcoming trends in construction processes, like adaptive manufacturing or an increasing level of prefabrication. These challenges could heavily interrelate and change the way to design a sustainable urban construction logistics in the future and need to be stronger addressed by research.

Since only policy concepts from the DACH-region were analyzed in this first case study, results have to be put in further context in the future. National research from other countries than DACH could provide valuable additional insights on construction logistics schemes. Studying policy concepts from other geographical regions would allow to identify possible regional-specific issues and adaptations of policy concepts. It is also important to point out that the analysis was based on existing literature on construction logistics in the urban environment by using the qualitative literature review as a first approach for collecting and structuring the existing knowledge basis. Further studies should focus on giving greater insights into construction logistics research that could be adapted for the urban environment. Nonetheless, the literature review highlighted the relevance of construction logistics in the urban environment and opportunities to enhance the current research base.

5 Conclusion

This study provides evidence that strategic management of construction logistics in urban environments should be paid more attention to from both policy and academia in proportion to its impact on the whole construction process as well as its environmental and socio-economic effects. Besides a small level of recognition of construction logistics as part of the urban environment that could be improved, the current lack of data could be one explanation for missing policy measures regarding construction logistics since a potential empirical proof and legitimation is absent. While innovative concepts for construction logistics hold great potential for an optimized and sustainable urban environment, broad and robust empirical data and research is still needed in order to find ways into the policy concepts of cities and municipalities. Lastly, the multi-actor field requires enhanced multidisciplinary effort for efficient and sustainable urban construction logistics that has the potential to align cities with sustainability goals and the needs of modern societies.

Author contributions

PH and HJ contributed to conception and design of the study. PH organized the database, performed the analysis and wrote the first draft of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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Appendix A

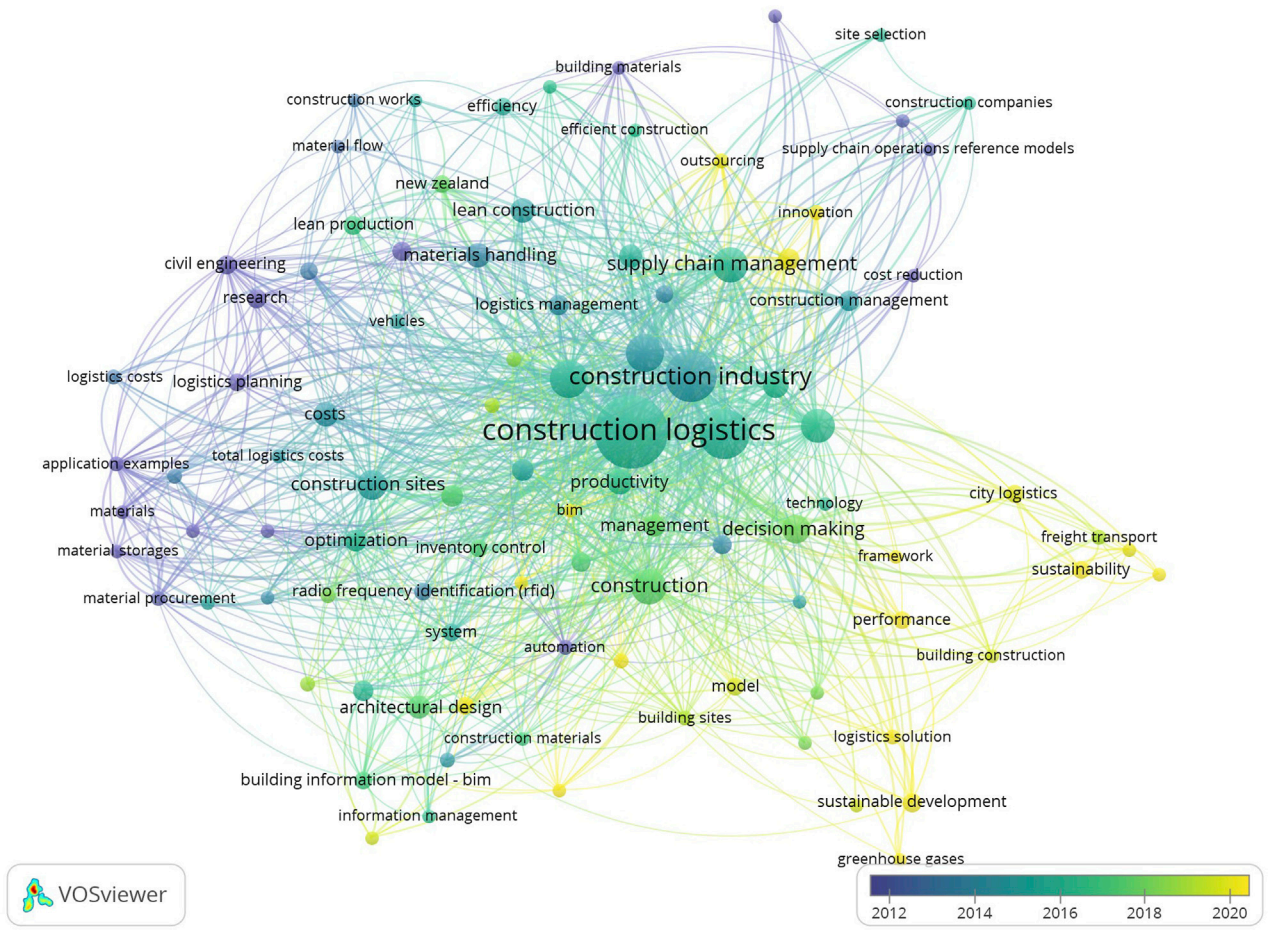

FIGURE A1

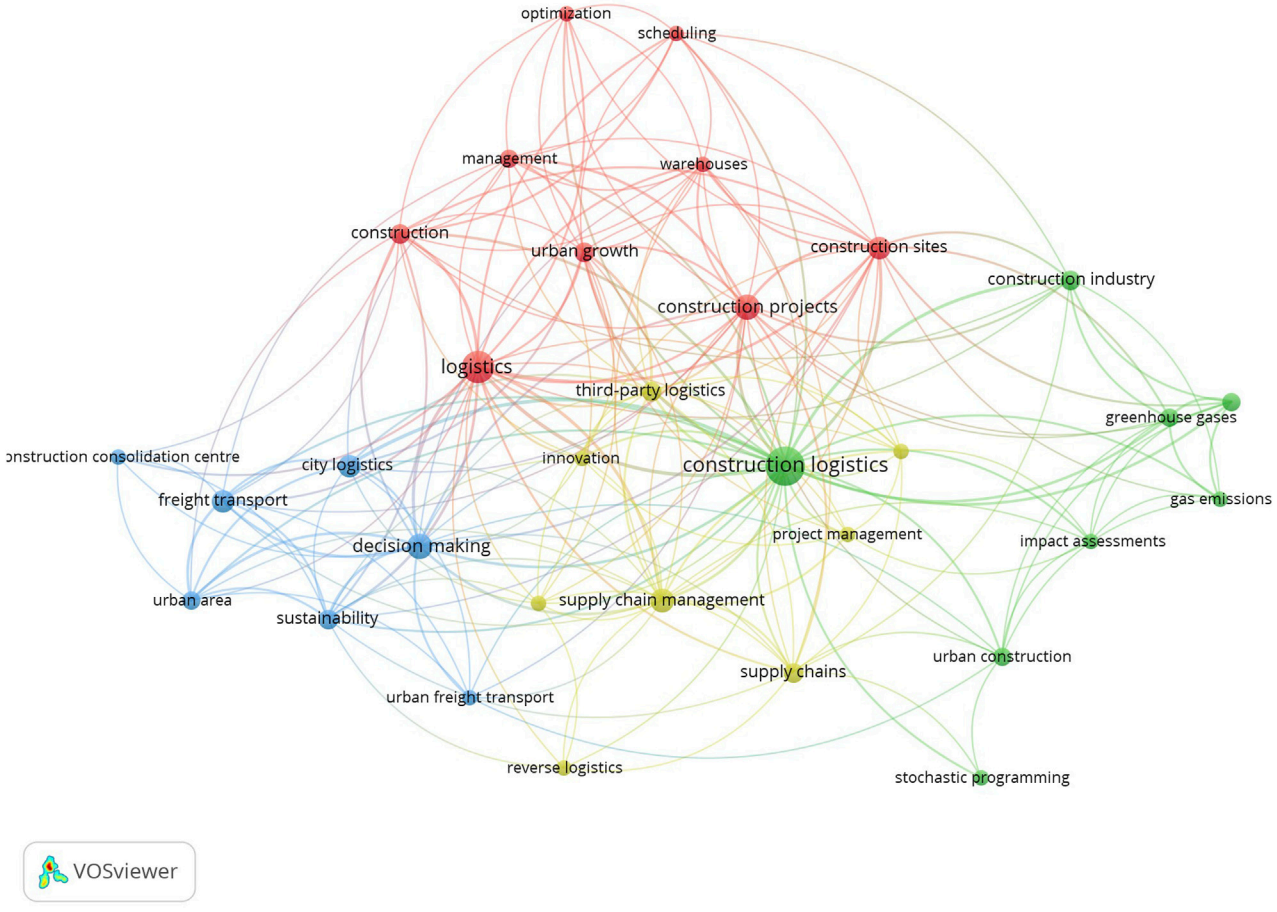
optimization
scheduling
management
warehouses
construction
urban growth
construction sites
construction industry
construction projects
logistics
third-party logistics
greenhouse gases
onstruction consolidation centre
city logistics
innovation
construction logistics
freight transport
gas emissions
project management
impact assessments
decision making
urban area
supply chain management
sustainability
urban construction
supply chains
urban freight transport
reverse logistics
stochastic programming
VOSviewer

FIGURE A2