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A systematic literature mapping of current academic research linking warehouse management systems to the third-party logistics context

Daria Minashkina
LUT University, LUT School of Engineering Science, Yliopistonkatu 34, 53850 Lappeenranta, Finland, EU, ORCID 0000-0002-3606-0721, daria.minashkina@lut.fi
Ari Happonen
LUT University, LUT School of Engineering Science, Yliopistonkatu 34, 53850 Lappeenranta, Finland, EU, ORCID 0000-0003-0744-1776, ari.happonen@lut.fi (corresponding author)

Keywords: WMS, warehouse management systems, third-party logistics operator, systematic literature review.
Abstract: Academic research on third-party logistics operators selecting warehouse management systems is scarce at best, based on found 86 area-specific studies written in English. Only 17 studies had mentions of 3PL and WMS but did not directly reference 3PL using WMS. Eighty-six studies covering four main categories contributed to understanding ongoing research in WMS characteristics and the 3PL context. One category is warehouse characteristics relevant to WMS, and the others concern the warehouse management system as its taxonomy, functions, features, and deployment considerations. Within these four categories, 17 subtopic areas were identified. WMS deployment considerations had the highest number of subtopics (ten), being the most focused area for WMS selection considerations for the system's successful implementation and operation usage. WMS functions and features category contained only a subtopic, indicating a need for additional research on operational functions in management systems and 3PL operations context. Award-winning 3PL validated our findings, utilizing their extensive industry experience. Based on the 3PLs validation review, fast-developing and technology areas, such as digitalization and the newest warehouse management technologies, were the only areas missing from the academic literature. Research is carried out to map the missing specific digitalization, technology-based research, development, innovation possibilities, and WMS sustainability-related knowledge gaps. By addressing the knowledge gap in existing literature, the study significantly contributes to understanding WMS utilization in the 3PL context, providing new insights into WMS characteristics overview, advancing research in 3PL logistics selecting WMS, and defining future research venues of WMS aspects.

1 Introduction

The increasing demand for faster and more efficient supply chain operations has forced companies to ensure excellence in the supply and logistics-related business operations by adhering to the supply chain (SC) paradigm to be as strong as its weakest link [1]. Since the 1950s [2], as a general practice, companies have hired a third party to perform some of their non-core business activities [3,4] to be able to focus on their core business functions and outsource non-essential tasks [5,6]. Thus, a company can move from a make to a buy [7], employing value creation models offered by an outsourced company [8]. The top four reasons for outsourcing are decreasing costs, accessing unavailable in-house information technology (IT) resources, enhancing business processes, and freeing internal resources and time to focus on customers [9]. Furthermore, 3PLs have recently transformed from "just asset providers" to strategic SC decision-making partners [10,11]. What makes the selection of the right 3PL one of the strategic decisions for leading companies/vendors and main contractors in SCs [12] is the need for proper trust-building models [13].

The global third-party logistics providers (3PL) market is projected to reach $1.3 trillion by 2028, with a growing number of companies recognizing the benefits of outsourcing logistics and supply chain management activities [14]. Most companies confirm that warehousing and transportation are one of the most commonly outsourced activities [15,16]. As [17] has shown, warehousing is currently among the most outsourced service. Interestingly, a warehouse is also widely recognized as a crucial node in the total performance of the whole SC [18-21].

Considering the high importance of warehousing to SC performance and the vast competitiveness of outsourcing markets, 3PLs need to maintain the best knowledge [22] and understand their role in SC [23]. Likewise, 3PLs should comply with their customer's current and future demands and concerns and keep up with fast technology development cycles as technology advancements impact SC performance [24]. In this context, 3PLs explore novel, new, and more sustainable services for their customers and search for new systems and technology solutions to enhance outsourcing [25]. Advanced data information systems and ICT systems play center stage in sharing crucial operations information across all SC actors [26-31]. Digital technologies and information systems integration significantly transform and advance information value for SC operations [32-34]. Over the past decade, research has constantly reported a positive correlation between the implementation of advanced technologies in warehousing and a company's bottom-line growth as reduced costs and lead times, previously unavailable information access, and operations transparency [35-39]. The main trends in previous years' literature are related to the concept of Logistic 4.0 in warehousing development, such as robotization, simulation and optimization, radio-frequency identification (RFID), big data and warehouse data, automated guided vehicles (AGV), Internet of Things (IoT), and multi-agent systems [36]. [40] demonstrate the effectiveness of using simulation techniques to identify bottlenecks and solve complex problems in the operational environment. In the paradigm of Logistics 4.0, a warehouse management system (WMS from now on) is one of the innovative technologies to transform warehouse operations significantly [35] and impact SC operations [39].

WMS is among the four technologies to manage SC (such as barcoding, just-in-time, and material requirements planning) to implement in warehouses [41]. WMS is a software-based management system supporting warehouse operations recording [42] and managing all warehouse resources, such as inventory, storage space, personnel, and equipment [43]. A WMS aims to enhance and achieve efficiency in all warehousing activities [20]. The primary warehouse operations encompass receiving, storage, order picking, and shipping [21,44,45]. Nowadays, a WMS is among the trustworthy SC technologies for companies to enhance business performance to enhance companies' business performance [43]. For example, in the shipping industry, a WMS is frequently demanded technology by shippers from 3PLs, to whom they outsource logistics activities [46]. In food SCs, the top 3PL cold storage providers utilize WMSs heavily, too [43]. Reviewing best practices for 3PLs, a WMS is accounted as a critical technical component to make SC functions more transparent [39] Gupta et al. (2019). For 3PLs, WMSs increase management abilities and operational excellence as a part of advancements in the field of information systems. The goals of this study are to 1) map the current topic-specific literature focus area publications, 2) investigate topic-related research focus categories, and 3) add specific understanding related to current research gaps. To achieve these goals, the authors identified three main research questions (RQs):

RQ1: What are the WMS characteristics discussed in the literature relevant for 3PL warehousing activities involved in selecting WMS activities?

RQ2: What is the current focus of 3PL logistics selecting WMS?

RQ3: Are any relevant WMS aspects that need to be added to academic research on 3PL warehousing operators selecting WMSs?

The current study provides a valuable contribution to the literature on the topic of WMS selection and implementation by 3PLs. By synthesizing existing WMS-related literature, this research provides a comprehensive overview of the critical parameters that 3PL providers should consider selecting a WMS. Moreover, this study will identify potential avenues for future research to advance the understanding of WMS characteristics further.

2 Methodology

2.1 Research design

A systematic literature review (SLR) was used as a research methodology to reduce biases from authors' subjectivity [47,48]. Additionally, the nature of SLR should make it easier for other researchers to continue this work and replicate the results [49]. SLR is a well-known research method allowing transparent and reproducible literature analysis with predefined process steps [50], helping to identify, evaluate, and interpret all available research relevant to a particular research question, topic area, or phenomenon of interest [51]. Moreover, SLR is also considered at the top of the hierarchy of research evidence [52-54], providing academic evidence for the selected study field and focus area, with a rigorous process of theoretical synthesis of already published evidence in literature materials on the topic [51]. SLR lies at the heart of pragmatic management research" and can offer advancement for both the academic and practitioner communities [55]. The SLR approach and methodology applied in this research follow the PRISMA 2009 model (Preferred Reporting items for systematic reviews and meta-analyses) that offers a way to improve the quality of reporting systematic reviews [56]. A systematic mapping process [57] was selected to add depth to SLR findings based on SLR. In this extended analysis, we seek to demonstrate the distinctive warehouse logistics operating characteristics and what a 3PL should consider selecting WMS and system features. The mapping continued with a comprehensive analysis of area-specific publications in SLR to pinpoint specific research gaps and well-covered knowledge areas [58].

2.2 Research data collection

Figure 1 illustrates Prisma 2009 methods flow diagram implementation for the SLR applied in this study. In this research, we used the academic scientific library research portal tool, with access to nearly 100 databases (such as ABI/INFORM, Scopus, Web of Science, EBSCO, Emerald, and ProQuest, among others), to collect the research articles from online databases and extract academic literature. Any time frames did not limit the literature collection. The final round of data collection was performed on the 15th of July, 2021). The literature was collected with four keyword combination sets to maximize efficiency and widen the data collection phase. According to systematic mapping guidance [57], searching keywords were selected in such a way to address the RQs and find answers. Consequently, the keywords were defined to provide sufficient research material for the follow-up analysis. For comprehensiveness of keyword selection, in addition to academic knowledge, empirical experts from the context of the 3PL operations (including, but not limited to, the logistics operations company CEOs, members of the board, key account managers, and operations team development members) were also interviewed to reveal most current terminology in use in this study area. These experts contributed to the keyword definition. In addition to the academics, the authors consulted on the research keyword definition phase. Having collected academics' and 3PL operators' opinions and additions to the keywords list, we continued interviewing WMS software solution providers for possible additions to cover all views on WMS and 3PL expertise-related matters.

Defining the possible keywords to be utilized in the academic literature collection phase, we found that using just the abbreviation "wms" alone, without its complete form, tended to produce a massive number of non-related publications due to its use in multiple research fields with numerous meanings. To overcome the overload utilization of "wms," we decided to use this three-letter abbreviation "wms" with its long-form "warehouse management system" with the Boolean operator AND. However, parentheses used together with "warehouse management system" significantly limited results leaving only a small sample of studies for further analysis. To address this issue, a complete spelling of "warehouse management system" was utilized instead of using parentheses to establish a connection between warehouse management and other systems within the warehouse.

To solve the issue, a complete word form of warehouse management system without parenthesis was used to include a connection to warehouse management and other systems in a warehouse. To cover the academic research on the 3PL operations, synonymous and interchangeable terms keywords were utilized too, namely, "3PL, "logistic service operator," and "third-party logistics". Furthermore, the search terms "selection" and "characteristics" were selected as additional keywords to focus on literature devoted to 3PLs selecting WMSs.

After keyword searches, publications type and metadata-based automated filters were applied to concentrate mainly on peer-reviewed journals, which were available for online search tools and written in English. Then, in the screening phase, all found duplicates (352 studies) were removed by utilizing and double-checking with Excel Zotero tools. After that, we excluded 1,589 studies based on their titles and abstracts that did not contribute to 3PL's selection process of WMS, e.g., algorithms application in a warehouse, risk management, order-picking strategy, inventory positioning, or general SC views. After filtering out the non-contributing studies and publications, a full-text evaluation was continued with the 115 studies, which were accessed as potentially eligible for contributing to this research work. The full-text review of the potential 115 studies ended with 86 studies, contributing to our SLR studies analysis phase.

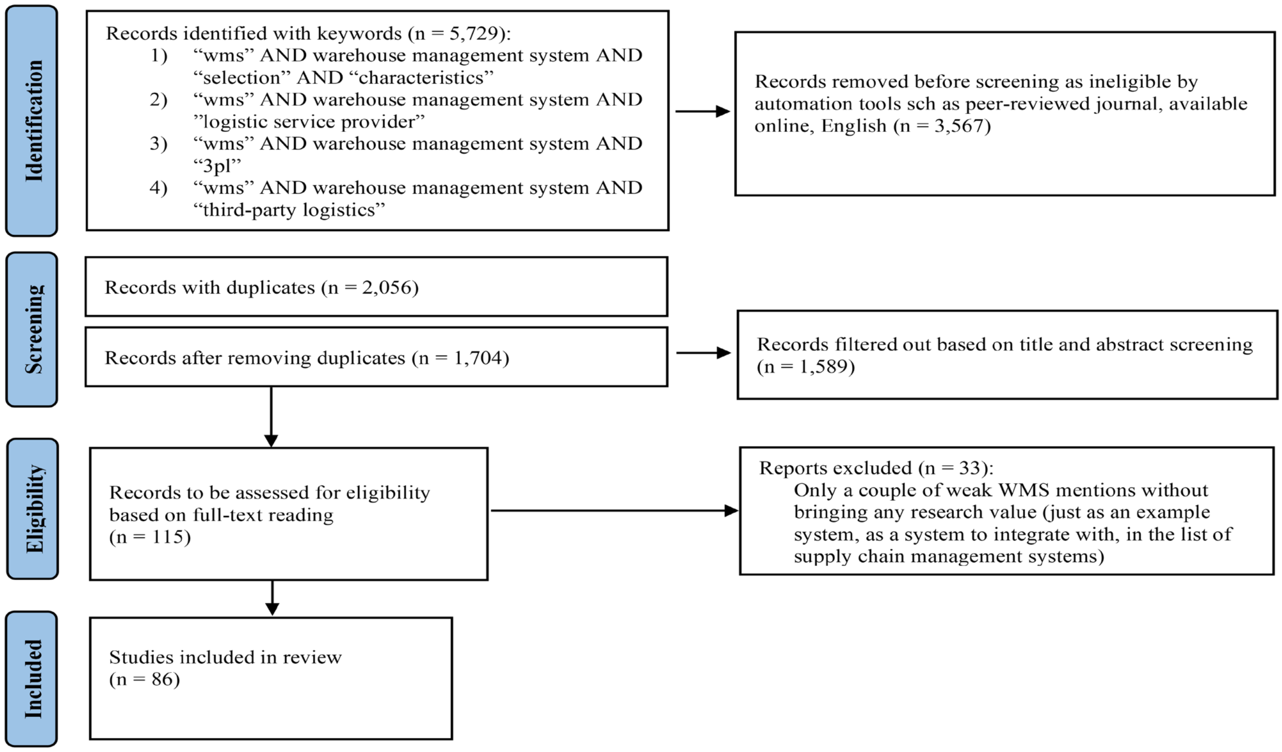

Figure 1 The utilized SLR process steps in the study, adapted from [54,56,59]

3 Literature review and analysis

The presentation of SLR analysis is started through a summary in Table 1 illustrating detailed specific areas of research contributions the found 86 sources.

Table 1 Comprehensive SLR results in summary table format

YEAR	ID/REFERENCE	Reference to 3PL operators and WMS	WAREHOUSE CHARACTERISTICS FOR WMS FUNCTIONALITY				WMS TAXONOMY		WMS FUNCTIONS AND FEATURES	WMS DEPLOYMENT CONSIDERATIONS										*Number of aspects mentions (X) in topics in each study*					
			Warehouse type	Warehouse operational specifications (performance, processes, SKUs characteristics, order lines and etc.)	Warehouse physical parameters (size, layout and etc.)	Warehouse automation systems description	WMS definition	WMS types	WMS functions and features	WMS fitness to business, scalability & modularity	Integration with logistics automation & communication systems	Warehouse database integration	WMS user interface	WMS replacement	WMS implementation time	WMS costs aspects	WMS vendor support service	Quality verification	Vendor's reputation	*Reference to 3PL operators and WMS*	*Warehouse characeristics for WMS functionality*	*WMS taxonomy*	*WMS functions and features*	*WMS deployment considerations*	*Overall study significance among five topics*
1996	[113]						X				X				X	X				0	0	1	0	3	**4**
1997	[95]				X	X			X											0	2	0	1	0	**3**
	[96]					X	X		X						X	X			X	0	1	1	1	3	**6**
1998	[114]						X		X	X						X				0	0	1	1	2	**4**
	[140]															X	X		X	0	0	0	0	3	**3**
	[100]					X		X			X	X					X			0	1	1	0	3	**5**
1999	[108]					X														0	1	0	0	0	**1**
2000	[60]	X						X	X		X				X	X				1	0	1	1	3	**6**
	[103]						X			X										0	0	1	0	1	**2**
	[85]			X	X	X														0	3	0	0	0	**3**
2001	[119]								X											0	0	0	1	0	**1**
	[120]								X											0	0	0	1	0	**1**
2002	[132]									X	X			X						0	0	0	0	3	**3**
	[82]		X	X	X	X	X	X	X	X	X				X	X	X			0	4	2	1	5	**12**
	[67]	X						X		X		X								1	0	1	0	2	**4**
2003	[130]									X	X	X	X		X	X			X	0	0	0	0	7	**7**
2004	[61]	X																		1	0	0	0	0	**1**
	[62]	X																		1	0	0	0	0	**1**
	[91]			X		X			X		X									0	2	0	1	1	**4**
	[125]								X											0	0	0	1	0	**1**
	[99]	X						X			X		X							1	0	1	0	2	**4**
2005	[44]					X					X									0	1	0	0	1	**2**
2006	[133]										X									0	0	0	0	1	**1**
	[80]		X					X	X	X	X	X	X		X	X	X	X	X	0	1	1	1	9	**12**
	[92]			X			X			X										0	1	1	0	1	**3**
2007	[94]			X			X		X		X									0	1	1	1	1	**4**
	[81]		X				X									X				0	1	1	0	1	**3**
	[65]	X						X	X							X				1	0	1	1	1	**4**
	[86]			X		X	X	X	X	X	X	X	X	X	X	X	X		X	0	2	2	1	9	**14**
2009	[118]							X	X											0	0	1	1	0	**2**
2010	[104]						X	X	X		X					X				0	0	2	1	2	**5**
	[45]				X		X													0	1	1	0	0	**2**
	[110]						X		X	X										0	0	1	1	1	**3**
2011	[101]					X														0	1	0	0	0	**1**
2012	[131]						X			X			X		X	X	X	X	X	0	0	1	0	7	**8**
	[138]											X								0	0	0	0	1	**1**
	[20]		X		`			X							X	X				0	1	1	0	2	**4**
2013	[21]	§		X	X				X	X										0	2	0	1	1	**4**
	[134]										X									0	0	0	0	1	**1**
2014	[117]			X			X	X	X											0	1	2	1	0	**4**
	[97]					X	X		X		X									0	1	1	1	1	**4**
	[90]			X	X	X	X	X	X	X	X					X		X		0	3	2	1	4	**10**
	[63]		X			X	X	X		X	X		X	X	X	X	X	X	X	0	2	2	0	9	**13**
	[128]						X					X								0	0	1	0	1	**2**
2015	[84]			X	X	X														0	3	0	0	0	**3**
	[105]						X	X	X	X	X				X	X				0	0	2	1	4	**7**
	[98]					X			X	X										0	1	0	1	1	**3**
	[121]								X											0	0	0	1	0	**1**
	[116]							X												0	0	1	0	0	**1**
	[93]			X				X												0	1	1	0	0	**2**
	[89]			X	X				X		X									0	2	0	1	1	**4**
	[107]						X				X									0	0	1	0	1	**2**
	[87]			X		X	X													0	2	1	0	0	**3**
	[88]			X	X	X			X											0	3	0	1	0	**4**
2016	[139]											X								0	0	0	0	1	**1**
	[102]					X			X		X			X						0	1	0	1	2	**4**
	[64]	X						X							X					1	0	1	0	1	**3**
	[112]						X				X									0	0	1	0	1	**2**
	[122]								X		X									0	0	0	1	1	**2**
	[126]								X		X									0	0	0	1	1	**2**
	[28]						X		X											0	0	1	1	0	**2**
2017	[68]	X					X													1	0	1	0	0	**2**
	[115]						X							X		X				0	0	1	0	2	**3**
	[109]						X				X									0	0	1	0	1	**2**
2018	[127]								X											0	0	0	1	0	**1**
	[83]		X				X													0	1	1	0	0	**2**
	[6]								X											0	0	0	1	0	**1**
	[136]										X									0	0	0	0	1	**1**
2019	[69]	X			X															1	1	0	0	0	**2**
	[70]	X		X		X			X		X									1	2	0	1	1	**5**
	[71]	X					X	X	X											1	0	2	1	0	**4**
	[123]								X		X									0	0	0	1	1	**2**
	[106]						X		X		X									0	0	1	1	1	**3**
	[129]								X											0	0	0	1	0	**1**
	[135]										X									0	0	0	0	1	**1**
	[137]										X									0	0	0	0	1	**1**
	[72]	X							X		X									1	0	0	1	1	**3**
	[73]	X					X				X									1	0	1	0	1	**3**
2020	[79]	X				X			X											1	1	0	1	0	**3**
	[124]								X											0	0	0	1	0	**1**
	[77]	X																		1	0	0	0	0	**1**
	[74]																			0	0	0	0	0	**0**
	[75]	X																		1	0	0	0	0	**1**
	[76]	X				X	X													1	1	1	0	0	**3**
2021	[78]	X																		1	0	0	0	0	**1**
		18	**6**	**15**	**10**	**21**	**31**	**19**	**39**	**16**	**34**	**8**	**6**	**5**	**12**	**18**	**7**	**4**	**7**						
		18	**52**				**50**		**39**	**117**															

The reference details for all 86 publications can be found in the table with the corresponding reference ID. The third column shows which publications referenced 3PL operators and WMSs research together, and the following columns reveal different research areas to which the specific publication contributes. In the following parts, we explain the deeper details in Table 1. In short, the table visualizes the categories of subtopics and four main topics of the 86 publications. The first main topic connects WMS to warehouse characteristics, and the other three are devoted to WMS taxonomy, functions and features, and deployment issues. Each main WMS area contains area-specific subtopics with the number of contributed publications. All discussed subtopic areas in these 86 publications were put into similar groups and topics. Counted connections in studies show the significance of the work and its contribution to the 3PLs and WMS context.

Table 1 can be interpreted in several ways. Firstly, 86 sources were grouped according to publication years, and there are clear historical trends in publications. Especially researchers have demonstrated more interest in WMS-associated topics in recent years than earlier. Additionally, the area-specific numbers of WMS taxonomy and features topics still have a steady interest compared to warehouse characteristics and WMS deployment issues. Interestingly, warehouse characteristics score fewer mentions in the found literature in comparison to other topics. Noticeably, the subtopic of WMS integration with other automation and communication systems has recently been increasingly recognized in most studies on the main topic of WMS deployment.

Secondly, the two horizontal bottom rows in Table 1 show how the selected literature contributes to the named main topics and subtopics. The bottom row depicts the total sum of links from different studies, referring to other WMS main aspects. In contrast, the row before shows the separate count of the references to the individual subtopics. This indicates the number of references to that specific subtopic in the analyzed literature set. The summary allows a fact-based numeric comparison of the literature on different subtopics under the main topic areas. Based on the numbers alone, "WMS functions and features" is the least discussed main WMS-related topic area (39 references).

Interestingly, the WMS taxonomy had a wide range of references (50), but only two clear subtopics and discussion directions were found within that main topic. This might indicate a narrow view in the WMS taxonomy area, showing a need to widen the research scope. Thirdly, in the last vertical column on the left, the numbers of subtopic areas under the main topics were separately counted for topics and sources. For example, in [21], one can see a total of four mentions of the evaluated main topics and subtopics connections. Additionally, this study has neither reference to 3PL nor a discussion of WMS taxonomy.

Reviewing the last vertical columns reveals a scarcity of research to discuss or involve all four topics related to WMS. Only four of the 86 sources touch on all four WMS main topics (a high evaluation score and significance for the specific literature). These four publications are specially color-coded with dark grey and highlighted with a dashed line in the table. The other publications lack links (mentions) to at least one of the four available topic categories. Those findings show a specific theme between observed research links on the topic areas and WMS studies in the 3PL context.

In conclusion, WMS has yet to be studied from a holistic point of topic view. From the numeric analysis point of view, if a reviewed source had discussed all the specific aspects available under the four main topics, the number of points assigned would have been 17. Only seven sources (a bit more than 8%) received five points or more but less than 10, and only a total of five references (less than 6%) were assigned 10 points or more. In sum, over 80% of the sources had a tight and narrow focus on discussing only specific WMS matters. Thus, it is hard to identify published materials addressing these topics from a broad perspective of WMS and 3PLs. Only a few studies discuss WMS as the main subject from multiple perspectives simultaneously. This finding points out the necessity for further research while pointing to a high-level research gap in WMS studies.

All 86 sources referencing to 3PLs and WMS and four WMS main topics and their subtopic areas were analyzed and scored in the same manner. The following sections address the most critical discussed content within the five main topics and topics-subtopic areas.

3.1 Reference to 3PLs and WMSs

All 86 publications were evaluated based on their references to 3PLs and WMS context areas. From 86 selected literature, only 19 studies mentioned both 3PLs and WMS [60-78]. All these studies formed a separate group of publications referencing 3PL and WMS.

There were no mentions of 3PLs using WMSs, but there were no mentions of both terms together [72,73,76]. For example, 3PLs were mentioned as one actor for reverse logistics [72] and the one to whom companies outsource and transfer their business operations for optimizing activities [67]. In this way, 3PL does warehousing operations for the account of business customers [63]. Logistics service providers have yet to adopt recent information technologies [73]. For example, WMS is one of the challenges of digitalization declared in 2019 for the transport-forwarding logistics sector in Poland [78]. The research of [77] aimed to identify the service packages offered by logistics operators leading to the greater efficiency of logistics service providers, where WMS is only a variable in the analysis. In [76], WMS should communicate and synchronize inbound and outbound shipments for effective cross-docking practice. Also, [69] mentions 3PL and WMS, however, the focus point of the study focused is to improve the genetic algorithm for warehousing.

Also, it was mentioned that 3PLs could advance in their business efforts through WMS utilization. According to warehouse experts, a 3PL should implement WMS to efficiently and effectively perform warehouse logistics activities [62]. For instance, logistics service providers can combine the data from various systems such as WMS, Enterprise resource planning (ERP), and transportation management system (TMS) and collaborate with these systems providers to obtain competitive dynamics of the logistics service industry [75]. Besides, as found software providers adapt their WMS design and functionality for the 3PLs' needs [65]; for example, if a 3PL needs to be flexible in changing customers' order mixes and types, they can easy access WMS via online [60] having visible data about warehouse processes and operations [61].

Besides, a couple of studies discussed the design of WMS, especially for 3PL [60,66]. For example, [79] reports a 3PL company case utilizing drones for an effective stock-take method mentioning the difficulty of integration with the current WMS. Also, [66] named wholesalers as potential WMS users apart from 3PLs.

There is also a discussion about information systems in omni-channels for logistics service providers to use [71]. [70] describe the digital twin of WMS developed to demonstrate different work scenarios suitable for WMS. [68] discuss the case of a logistics service company in the Republic of Croatia that uses WMS for managing warehouse operations and processes. In addition, [64] reports 3PLs for deploying a cloud-based WMS to save time and nearly immediately handle warehousing operations for new clients. At the same time, [74] builds a framework for an Italian 3PL to introduce a new storage assignment policy and reduce the traveling time for order picking in warehouse performance improvement projects. Overall, 17 contributions totally to this topic are not much, still missing a solid connection and vivid emphasis from the academic research point of view on 3PLs using and selecting WMSs.

3.2 Warehouse characteristics as a basis for WMS

This section focuses on warehouse characteristics discussed in the literature to be significant for WMS. Table 1 includes four main warehouse characteristics and related subtopics: warehouse type, operational specifications, physical parameters, and automation systems. In the following, all four subtopics are discussed separately.

3.2.1 Warehouse type

Within the found literature, only six out of 17 sources were related to warehouse-type/style as an essential factor for WMSs. A warehouse's processes and activities identify its distributional or productional type [20,80]. Specifically, distribution warehouses may have high order volume and complex business processes [81]. In contrast, production warehouses store raw and/or semi-finished products to be used later in manufacturing [82]. Also, warehouse types derive from stored product category purposes such as sorting centers for letters and parcels, cross-docking for perishable items, and e-commerce fulfillment, consolidation, and transshipment break-bulk warehouses (e.g., automotive parts) [63]. [83] describe a particular warehouse type called a public warehouse (commercially serving different clients). In such a warehouse, multiple companies get warehousing services without hiring their staff or using resources as a ready-made logistic management and service platform.

3.2.2 Warehouse operational specifications

Warehouse operational specifications are a subtopic discussed in 15 different literature sources. Strategic warehouse planning and operating policies are essential to warehouse operational elements [84]. Proper warehouse management includes knowledge of warehouse organization, processes, and resources [85]. Here, processes include goods receiving, storing, order picking, packing for dispatching, documentation administration, and other value-adding logistics services [21,85-88]. Stock-keeping unit's (SKU) storing restrictions as physical (sizes, shapes, and weight dimensions) [45,89] and environmental (flammable, frozen, and hazardous) [90] pose requirements for warehouse design [91,92]. The warehouse performance indicators and task complexity are measured in the number of SKUs, handled order lines per day, and the various processes [21,90]. Additionally, the warehouse's operating capabilities depend on its capacity utilization rate, associated with the number of processed order lines.

Well-defined warehouse key performance indicators (KPIs) are connected to overall warehouse logistics performance capability and metrics, specific process department assessments, and equipment technology performance levels [84]. For instance, [70] define KPIs such as warehouse buffer utilization rates, picking order traveling, and temperature stresses distance. Other warehouse performance determinants include warehouse resources (the technical equipment utilized in warehouse processes and storage) and warehouse personnel (people assets in the warehouses) [85,89]. The warehouse layout and size also determine the effect on the complexity of warehouse performance [82].

Following the recent e-commerce trend, warehouses are increasing in size [93]. Warehouse's process documentation flow [85] and control policy [89] should be carefully deemed too. Work scheduling and health issues (psychological, ergonomics, safety) concerning warehouse personnel must be considered [84] as part of the workforce caring models. Furthermore, according to [94], a WMS should also suit the customer's warehouse parameters to design WMSs based on warehouse prerequisites [85] systematically.

3.2.3 Warehouse physical parameters

The topic of the warehouse's physical parameters is addressed in 10 different sources. For example, wrong picking and storage area zoning, layout design, and storage policies could lead to problems in space utilization [84]. A poor warehouse layout hinders productive operational performance and generates inefficient space usage, unwanted additional costs, warehouse performance complexity, and increased picking time [21,45,82,89]. Picking time consists of three different time components: traveling from one to another SKU, actual picking, and other associated activities [69]. An outline of the warehouse can offer an optimal decision parameter for processes planned to allow adequate warehouse storage capacity [95].

Other benefits are practical and effective allocation and handling of product storage area, input and output points for receiving and dispatching products, and easy access to products from picking aisles [85,88-90]. For instance, despite WMS's role in optimizing warehouse storage, [69] emphasized that the role of proper goods placement can result in a 60% picking time reduction. Modern WMS can use traditional ABC analysis and genetic algorithm-based approaches to relocate inventory and shorten picking distance.

Warehouse layouts vary from a traditional rectangle with parallel straight aisles [90] to more modern and even innovative layouts design such as v-shaped cross aisles, a flying-v, or chevron, and warehouses with fishbone-like aisles [89,90]. Figure 1 depicts the differences in the layouts.

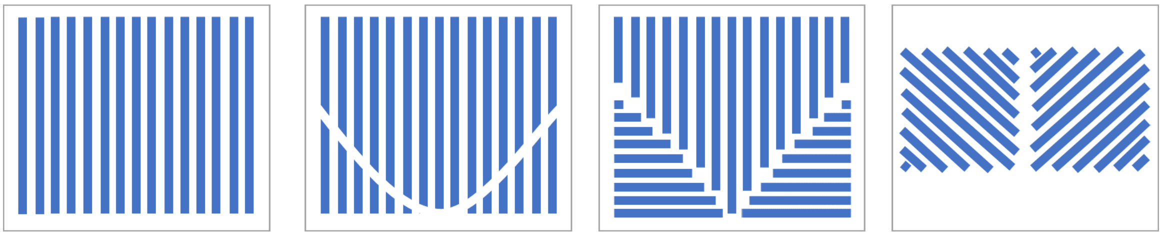

Figure 2 Warehouse layouts (from left to right): a traditional rectangle with parallel straight aisles, Flying-V, Fishbone, and Chevron)

3.2.4 Warehouse automation and automated system descriptions

The most discussed warehouse characteristics (in 21 sources) relate to automated warehouse systems. Software and hardware are common technologies installed in a warehouse [84]. Deploying advanced technologies is an ongoing trend to decrease data errors [96] and reduce the increased complexity of warehouse tasks [97] through hardware systems [82], so customers refrain from stock depletion, overdue deliveries, and backorders [44].

Today, portable mobile terminals [98] and next-level advanced technologies with real-time instructions [90] assist a warehouse picker via, e.g., light-directed indicators for put-to-light and pick-to-light [85], pick-by-voice, and virtual display picking systems. Other helpers are automated product-to-picker storage and item retrieval system (e.g., automated cranes), picker-less systems (automated dispensers and robots) [85,97,99], and frequently deployed AGV [84]. In addition, automated data collection equipment facilitates data exchange using supportive data capture technologies [70] such as RFID [96], barcoding [95,100,101], and different sort of robotics [63,87,88]. With the help of automated data collection, especially for a cross-docking facility, warehouse data can be captured accurately and continuously without manual data entry [76]. Other examples of technology-based solutions are horizontal and vertical carousels, frame dispensers, and other automated rack systems [85,97]. However, in the opinion of warehouse managers and senior consultants, adding more automation to warehouses causes a reduction in warehouse flexibility [84]. For WMS efficiency, all hardware and automatic measuring devices should be integrated into a WMS for information flow and operations optimization [86,91]. Additionally, in [79], drone technology checks pallet IDs in a warehouse; however, this approach faces difficulty in the process of integrating drones with WMS for matching stock activities. Discussing futuristic warehousing, [102] suggests 3D printers for on-the-fly items and parts production.

3.3 WMS taxonomy

The topic of WMS taxonomy is discussed in 42 sources. These sources reflect two main directions. The first includes the definition of WMSs, and the second cover different WMS types. Within the found literature, the majority focused on WMS definitions (31) and less studied categorization of WMSs with different types (19). Eight sources touch upon both WMS definition and categorization.

3.3.1 WMS definition

Generally, a WMS supports and enhances the functionality inside warehouse tasks through IT and automated services to communicate real-time inventory and resource information [80] and bring warehousing to the next level [103]. There are two approaches to the WMS definition in the selected literature. In the first, WMS solutions are considered "just another software", while in the second view, WMS is seen from a holistic point of view, where scholars deny its simplified interpretation toward more being a leading cause for changes in the company's warehousing operations. The authors' literature points of view can be divided into two separate groups. The first group (16 studies) considers WMS as a computational system to control the warehouse's "physical activities and arrangements" [104] from order execution to fulfillment [82,90] to utilize warehouse resources, equipment, workforce efficiently, processes [45,87,105] and transport [106]. With WMS support, operational targets can be achieved faster and more accurately [92]. WMS manages internal warehouse subsystems [97,107]. Namely, a WMS collects, registers, and manages data about warehouse inventory activities and processes [68,71,108,109] and identifies possible errors and improvement areas [110], adding transparency to all orders, delivery processes, and activities [106]. Also, a WMS offers design guidance for picking lists, goods allocation, order division [111], instructional documentation [112], and recognizes customer order patterns [94]. WMS as a material tracking tool rather than a decision-making one [83]. WMS is a data analysis system supporting warehouse IT management decisions [68]. The second group (10 different literature sources) considers a WMS as a combination of IT products and a complete project management tool for operational development in technology and the workforce [113]. Assigning an operating team and creating stepwise guidance for WMS implementation and intelligent systems installation [96] is essential [114]. Such project management starts with a documented function request list from a WMS vendor [63, 103]. Additionally, these authors count a WMS as a mini enterprise resource planning (ERP) system designed specifically for managing and optimizing warehouse activities. So, warehouse key processes can be more transparent [73,76,86,114] with blended information and material flows [113]. [115] extends a WMS definition to an overall system whose activity scope exceeds physical warehouse boundaries.

3.3.2 WMS types

Within the WMS taxonomy referencing literature (36 sources), three main discussion lines are based on WMS software solution aspects: 1) type, 2) provision, and 3) functionality scope. Here, in terms of software system types, a WMS can either be tailor-made to meet a set of unique requirements and developed from scratch or a standardized off-the-shelf package configured with a set of functionalities to solve frequently repeating needs in different warehouses [66,67,80,82,105]. The diversity of warehouse products and processes and SC uncertainty dictate the requirements of a more highly customized WMS [90]. A WMS should have a specially designed technical structure, operational framework, and system control [86]. Moreover, a customized WMS is developed especially for businesses to gain a competitive advantage by differentiating warehouse operations from their competitors [65]. According to the literature, a noticeable new trend is occurring, as WMSs were initially built and highly customized [67]. Still, in recent years, demand has been increasing for more standardized off-the-shelf WMSs [60,105]. The wrong decision to install either a standard WMS or a customized WMS can lead to high costs, lost time, and loss in company competitiveness in warehousing activities [82]. A WMS can also be used as a plug-in module within ERP systems to perform at least some of the typical WMS functions [104], not delivering as many benefits as a complete WMS does (e.g., enhanced productivity, minimized errors, and space-efficient warehouse storage allocations [71,100,116].

Based on the literature [60,63,64,67,71,117], three typical WMS implementations are: 1) standalone (installed and hosted at a customer's premise for long-term usage); 2) Software as a Service (SaaS) (implemented on a system provider's server rented to different customers) [67] and 3) cloud-based solution (a vendor operates hardware and software, while clients access WMS via a web interface/system integration). Other authors [60,63] also identified web hosting as a new WMS deployment method. According to [112] Golinska (2014), cloud-installed WMS provides process standardization, remote control, and lower operational costs. Besides, web-enabled WMS can be integrated easily into other SC systems [60]. [64] discusses more cloud and premise-placed WMS types and their specifics. In the next five years, retailers plan to put more weight on utilizing cloud-based WMS types [71].

In addition, based on the system functions' scope and complexity, WMSs can be classified into three subcategories. For example, WMS's functions could be basic (recording inventory status and location information), advanced (planning and monitoring the warehouse's resources and activities in addition to basic WMS functions), or complex (fully optimizing the warehouse's operations with the help of automation and value-adding planning) [20,82,118]. Discussing the complex systems, [65] references best-of-breed WMS providers specializing in the needs of both small and large companies and offering different WMSs (traditional licensed, low-cost, small, and on-demand solutions). Notably, all the mentioned system scope and complexity-based subtypes of WMS are presented in the survey of warehouses and distribution centers [93].

3.4 Warehouse functions and features as discussed in the literature

WMS functions and specific aspects were covered in 39 sources with explicit and not exploration of WMS functions. Most literature sources (21) discuss the benefits of WMS functions assisting with installation and implementation rather than naming exact functions [6,21,72,79,82,88,89,94,95,105,106,110,111,114,117,119-124]. Twelve sources studied WMS functions comprehensively [60,71,80,81,86,90,91,96-98,104,118, 125]. Four studies [98,104,118,126] compare WMS functions to other logistic software systems.

In the research by [82], the authors distinguish three types of WMS functional categories: 1) inventory analysis as quantity tracing and associated documentation; 2) warehouse management of processes, resources, and reporting; and 3) warehouse execution functions assisting in managing logistics flows inside the warehouse. However, the scope of WMS functions is more on warehouse operations than resources because the final decision on the utility of recourses is left to the warehouse manager [110], as a WMS just controls all warehouse activities from SKUs arrival until shipment [122]. WMS functions are designed for warehouse replenishment [102,111,119], order picking, and storage options [86]. Significantly, a WMS optimizes operations greatly in the case of mixed single and batch-picking methods [123]. A WMS, together with automated warehouse solutions, supports inventory picking-up processes [90] and accelerates goods sorting and packing activities [95], prioritizing critical order fulfillment and close delivery destinations [123]. [70] develop a digital WMS twin to combine other research on WMS modules and warehouse operations. WMS is also found to play a vital role in e-commerce logistics for real-time monitoring, management, maintenance, and scheduling information for warehouse logistics [124] and real-time shipment and receiving status notifications [126]. A WMS facilitates inventory and data visibility [79] because of records transactions of order numbers and quantity anomalies [6]. WMS can provide information on picked orders, receipts, returns, and SKU numbers to verify the accuracy of system inventory records [127]. Based on the literature, customers demand WMSs to support cross-docking material flows, what-if scenarios, and postponement strategies [60]. A WMS should allocate products via IoT for paperless information exchange [21, 88] with web technology-based interfaces for different user groups [121] and advanced shipment notices about the status of materials [80]. Moreover, a WMS can aggregate and consolidate shipments sent to and from a warehouse into a truck [106]. One standardized WMS function is to support picking algorithms such as FIFO, FEFO, FMFO, and LIFO [71,106,127].

In documenting day-to-day warehouse operations [91], a WMS can perform recording functionalities such as SKUs cycle accounting [71,96,114], damages, and operational mistakes [117]. Moreover, an advanced module in a WMS can be added to manage the warehouse routing optimization in SKU picking activities [89].

Vendors try to widen the range of WMS functions by adding transportation, yard, and order management modules to give WMSs more power [60,102] to design systems for 3PLs' needs [65]. Meanwhile, other advanced secondary WMS functions cover SKUs inspection, audits, quality measurement, and essential reporting associated with labor management [80]. A WMS can provide advanced functions for inventory replenishment, cycle accounting [128], and business strategy optimization [97]. [125] indicates that WMS help in mitigating problematic consequences of any returns via discipline, automation, and repeatable actions and makes performance reports such as inventory, equipment, and warehouse space utilization [104], single transaction expenses [106], and inventory location maps [129].

Developing a framework for reverse logistics operations, WMS has a role in calculating and optimizing storage space, time, and costs required for returned goods [72]. Among WMS functions, the system informs warehouse resources and labor equipment rate utilization [120] and analyses customer orders to forecast required SKU levels. As a result, a WMS increases inventory accuracy [94] and minimizes the amount and upstream inventory [105]. Most typical WMS functions to implement in the next five years include added reliance on cross-docking, advanced near-future inventory plans for optimized receiving and decanting operations, new picking strategies with dynamic and static picking locations, and novel mobile units plus integrations in shipment schedules synchronization [71].

3.5 WMS deployment considerations

Most WMS deployment literature considers deployment issues from the successful implementation and operation use point of view (41 studies). The research on this topic was quite broad, as the analysis divides the WMS deployment topic into ten different subtopics.

3.5.1 WMS fitness to business, scalability, and modularity

Several sources point out a need to understand the company's business operations before making a WMS investment and development. Basically, a company should select a WMS considering its business complexity realities [21], process flow, and requirements of operational capabilities [67,80,82,90,114,130,131]. In turn, a WMS provider should fully understand the previously mentioned issues [63] rather than persuade customers to change warehouse activities for a WMS [103]. Furthermore, [86] and [63] urge to assess WMS scalability for the possible new modules added to meet future business needs. At the same time, a WMS vendor should have a solid knowledge of the business processes and operational possibilities of different customers and future WMS operational potential [132].

Investing in WMSs, companies should decide upon proper warehouse material handling equipment and allocate their resources and labour for their own needs [110], e.g. SKUs' characteristics, such as quantity, size, weight, and temperature conditions, are essential factors [92]. Plus, a WMS should suit the client's warehouse type [98,105] and support the warehouse's operational processes and functions [86].

3.5.2 Integration with logistics automation and communication systems WMS fitness to business, scalability, and modularity

This subtopic had the highest number of sources-based connections (34). The reviewed sources emphasized WMS's integration with other systems and subsystems [86,105] and other software products [132] for future business growth possibilities [80]. Data and event messages between systems should be transferred in the same standardized format and structure [100,130], allowing the accurate and precise exchange of essential business data [133] via open or standardized interfaces [98]. As stated in one retail company survey [71], less than half of the companies utilize direct real-time updates and information synchronization operations in their WMS solutions. However, the rest do this, e.g., only on an hourly basis. Moreover, WMS benefits from integrating system users into other SCs for additional knowledge-based optimization [112]. [70] bring up an interesting issue called the product intelligence paradigm, especially how a product's physical entity relates to its informative content, WMS should have all input information and data sets from its customer, such as correct order numbers and goods capacity.

From a practical point of view, choosing a WMS that can interplay with an ERP system makes sense to avoid additional investment costs [91] and boost the system's performance figures [97]. The obvious benefit here is more accurate long-term activity planning [82,104] with a better transfer of customer order queues [86,98].

With an ERP system, WMS can integrate capacity and demand planning systems to achieve JIT operations [72]. A standalone WMS can integrate with an ERP via EDI [71] messages. An ERP integrated with WMS shares prioritized urgent orders. A WS can also be combined with a transport administration system [123] and TMS to exchange core data [44,98] for SC-level process optimization purposes coordinating vehicle load and schedule plan activities [102,106], shipping and transportation [60], and exchange warehouse and transport activity information [94].

A WMS integrated with a warehouse control system gets greater power over automated system machines in the warehouse [102], while a warehouse execution system optimizes the warehouse's resource usage [107,112]. RFID and barcode technologies exchange inventory data with WMS [104], which is added to an electronic product network [126]. Other warehouse subordinate systems for WMS integration include forklifts and hardware peripheral devices for material handling (e.g., barcode readers [113], RFID scanners and computer terminals [98], label printers [82,102], conveyor systems [60], voice, light, and virtual displays and order-picking control equipment [60,63,90,93,134].

[122] studied integration and constant communication of voice-picking technology and WMS supplying files with item data, location, and operation tasks. A WMS can interface with material planning and manufacturing execution systems [60]. [135] address implementing RFID technology in WMS for technology-based benefits over barcodes used on product-level scanning. A robotic arm with RFID reader solutions over a conveyor belt can help to modernize work practices and boosts information transparency [136]. [109] were the first to discuss about network/video stream technology, named as a video management system, to be integrated with WMS. [137] gather various WMS integrational cases of IoT, RFID, augmented reality, and cloud-based systems in the literature.

[73] strongly emphasize the role of IoT implementation and integration of WMS with all sensors on a warehouse in/out gateways, forklifts, shelves, heating ventilation, and air conditioning system to transform all this data into useful information (e.g., energy consumption, inventory, and warehouse safety) and plan of actions. Business information and SC dynamics should be united to align integration and system capabilities with 3PLs. The first recommended step is to create an SC enterprise architecture to become the foundation for all logistics systems' selection, investment, and implementation decisions [99].

3.5.3 Warehouse database integration

Based on the literature, a common central database is required for WMSs and execution systems [80,100,130,138] to support warehouse processes and activities [67]. The critical ingredient for efficient WMS is good data input, such as storage policies, operations flow, and operational performance capabilities [86,108]. Warehouse operational data (e.g., pallet naming system and SKU identification schemas, among others) can differ between warehouses causing global WMS integration challenges [139].

3.5.4 WMS user interface

As the language heavily affects the operational suitability of the human-computer interface, it should be in the users' native language to minimize the possibility of misinterpreting the content of the instructions. At a minimum, the language used in a user's interface should be native to the activities and processes at the warehouse; additionally, all processes should follow the same general pattern for language and terminology [86]. Additionally, WMS should be easily accessed remotely via the web [63]. In other words, having a web access configuration is a vital functionality in today's WMS [130]. A user coordinates warehouse activity by logging into the warehouse's internal database knowledge query system [99]. Operability characteristics and customization designs for the user interfaces still need further studies [80,131].

3.5.5 WMS replacement

The two main ways to replace a WMS are 1) new WMS onboarding together with the old system and 2) direct replacement of an old system [86]. The second option is favorable when a customer launches a new WMS to stabilize warehouse material flows [63]. The literature sources [132] and [102] state that old IT platforms may be replaced due to WMS's inability to respond to changes in a customer's business model, growth in business activities, or new business-related requirements. These account for fundamental factors leading to customers' willingness to upgrade a WMS. Current WMSs may also be replaced due to age, lack of support for old software, or a heavily customized solution that cannot be upgraded [102]. In the [115] research, an analysis of old WMS serves as a basis for designing and implementing a new WMS.

3.5.6 WMS implementation time and cost

When implementing a WMS solution, required software installation time and financial costs should be studied broadly before making investment decisions [20,82,105,113,130]. Also, companies should understand how a new WMS will affect their administrative operations [131].

The implementation time required for WMS setup depends on the integration of the current systems [96] and WMS customization or standardization [82,105]. A WMS implementation cycle can vary from three months for small systems to nearly 30 months for complex systems [20,98]. There should be a stepwise WMS launch with contingency planning [80] with pre-installation performance testing [96]. In case of system adjustments, there should be a time buffer of several months [86,131]. Moreover, a WMS should be tested with complete information and sensor input loads during the quietest operational time in the warehouse [63].

In some cases, a system's implementation and updating cycle never actually ends, as the system is in a continuous/constant development cycle over its entire lifetime; this development time might even exceed the system's operational lifetime [98]. On a customer's premise, a traditionally deployed WMS's lifetime is 15 years or more [64]. At the same time, WMS vendors are under constant pressure to implement new solutions for customers as quickly as possible [60]. This might indicate shorter WMSs lifetimes in the near future, more upgradable design choices, or a move towards SaaS (Software as a service) / Cloud service.

On the costs front, WMS solution providers should predict all system installation time-related costs. In the 1990s, the average WMS prices continuously decreased due to healthy market growth [60]. Notwithstanding, WMS implementation includes multiple expenses related to software installation and system maintenance, development, and updates [63,130,140]. Other warehouse equipment costs include purchasing sensor and technology equipment like barcode readers, hardware infrastructure, and printing identification cards [115]. [115] presents a list of software and hardware costs in WMS implementation. Different license WMS costs come from IT services are user ratio per terminal, transactions, annual or monthly base service, and professional integration [86,98,104,131]. Other costs account for designing the host interface [96], positioning forklifts and digital users' identification [104], warehouse personnel training [80], and integration with other systems [104]. Traditionally, WMS providers decrease implementation costs by leveraging offshore programming talents and the Internet as a software distribution tool [65]. As expected, implementing a highly customized WMS takes more effort and money to maintain than off-the-shelf WMS solutions [60]. Replacing an old WMS with a new one reduces costs associated with employees and warehouse equipment [115]. There are three known WMS payment models for clients: SaaS, on-demand (a multi- customer arrangement where a customer pays only for the time of WMS usage), and a hosted software option (software provider installs a WMS either at its premises or the customer's and manages a WMS ultimately) [125]. Despite the costs, a WMS is still a favourable investment for 3PLs to optimize operations, reduce labour costs, improve overall efficiency, and minimize errors [90,114].

3.5.7 WMS vendor support service

WMS installation and after-sales original investment services are essential components to consider in WMS implementation projects [63,131]. A compelling argument for vendor selection is attention to training assistance and procedures [80,86,100] in the supplied documentation, manuals, and handbooks [86,96,140]. A WMS vendor should also be assessed based on contract and guarantee duration [80] and provided help-desk services [82].

3.5.8 WMS quality verification

WMS customer service includes a system quality examination [90]. Clients benefit from WMS vendors' routine software updates and quality validation cycles [63]. Besides, a software vendor following international software quality standards should be considered a better partner [131].

3.5.9 WMS vendor reputation

WMS vendors' reputation comes from the industries where it has operated, provided software, and has experience supporting WMS implementation projects [63,131,140]. This experience is a mix of served client warehouse types, SKU categories, and warehouses' degree of manual labor vs. used automated equipment [86]. The stability of the vendor's operations is reflected in the success of its WMS installations and operational use [96], feedback from clients of past installations, and years of business operation [80]. The vendor's creditworthiness can be measured by the worldwide presence of the company/software offering [130].

4 Discussion

This study has systematically mapped the literature on WMS characteristics relevant to 3PLs selecting such systems. With the proper understanding of WMS-related specifics, 3PLs could better choose a WMS and improve customer service. The goal was to understand the current state and direction of research in WMS characteristics and 3PL context. Based on the findings surfacing from the SLR process, we now answer into the set RQs.

Regarding our answers to RQ1 - What are the WMS characteristics discussed in the literature relevant for 3PL warehousing activities involved in selecting WMS activities, we provide Table 2, presenting the identified WMS and 3PL reference and WMS-related topics and subtopics in our analysis based on the 86 literature sources on 3PLs and WMS selection. 17 studies are mentioning 3PL and WMS; however, not all studies directly reference 3PL using WMS. For WMS, 17 subtopics were identified (in italic letters) and noticed to be unevenly distributed under the four main topic areas (in bold capital letters). For example, 10 of the 17 were under the main topic of "WMS deployment considerations"; however, "WMS functions and features" had only one subtopic area in the analyzed literature. Identifying the 17 subtopics and their uneven distribution leads to the RQ2 answer. This question looks more closely at the directions of the studied literature. Thus, the subareas that produce new knowledge can be identified where researchers might fill gaps left in the WMS and 3PL research cross-section.

Table 2.SLR topics and related subtopic areas

MAIN TOPICS	SUBTOPICS
REFERENCE TO 3PL OPERATORS AND WMS (19)	
WAREHOUSE CHARACTERISTICS FOR WMS FUNCTIONALITY (52)	*Warehouse type (6)*; *Warehouse operational specifications (performance, processes, SKUs characteristics, order lines, etc.) (15)*; *Warehouse physical parameters (size, layout, etc.) (10)*; *Warehouse automation systems description (21)*
WMS TAXONOMY (50)	*WMS definition (31)*; *WMS types (19)*
WMS FUNCTIONS AND FEATURES (39)	*WMS functions and features (39)*
WMS DEPLOYMENT CONSIDERATIONS (117)	*WMS fitness to business, scalability & modularity (warehouse characteristics, functions & processes) (16)*; *Integration with logistics automation and communication systems (34)*; *Warehouse database integration (8)*; *WMS user interface (6)*; *WMS replacement (5)*; *WMS implementation time (12)*; *WMS costs aspects (18)*; *WMS vendor support service (7)*; *Quality verification (4)*; *Vendor's reputation (7)*

Continuing with the RQ2 - What is the current focus of 3PL logistics selecting WMS, the largest group of subtopics fell under "WMS deployment considerations," identifying it as the most focused area for WMS selection considerations. In contrast, a minor focus fell under the "WMS functions and features" with only one subtopic. From this study's point of view, "WMS functions and features" seem to be a focus area that needs further research because of the functions' broad scope. WMS deployment needs additional research on the newest technologies and innovations on the hardware and software side. From the point of view of 3PL operators, it is easy to see how added knowledge about the newest technology solutions and operations enhances functions. These aspects are also highly valuable considering new WMS investments.

Most of the literature was narrowly focused, without multiple viewpoints or simultaneous WMS topics and aspects connections. 3PLs should view the big picture encompassing system implementation and investment considerations. These actions should be undertaken to support 3PLs in business process development and efficient IT management via additional research to connect broad, high-level views of this topic with more detailed subtopics. More research will help close the research gaps on WMS and other related systems integration into business plans, allowing new knowledge on the relationship between IT, organizational performance, and structures.

The RQ1 findings and previously mentioned practitioners' needs support our steps towards RQ3 - Are any relevant WMS aspects that need to be added to academic research on 3PL warehousing operators selecting WMSs? To study the specifics and evaluate what might be missing in the literature, we collaborated with a well-known, award-winning, and technically frontline-oriented 3PL operator to help us answer RQ3 by comparing their views with our research findings. Thus, the literature only covers some of the WMS technology deployment issues, and some new research areas are appearing. Moreover, the 3PL experts mentioned these as fundamental aspects from a practical point of view. Some examples referenced WMS control issues and information exchange considerations between systems missing discussion in the academic literature, where several communication protocols are required. Therefore, we suggest new research on those areas and follow-up research with 3PLs to cover other aspects/subtopic areas, for example, sustainability [141] and evaluation aims [142,143], which might reveal additional missing subtopic aspects. Consequently, these aspects should add more value to the WMS selection done by 3PL, as these systems significantly influence warehousing activities.

5 Conclusion and future research directions

The present study was designed to investigate research performed in WMS and 3PL context, to synthesize and systemize knowledge on this topic, to identify current research status, and to define future academic research directions based on the 3PLs validation review. Our research findings offer several contributions in both academic and practical words, enhancing the topic of WMSs used by 3PLs.

In addition to mapping topic literature, a novel and holistic view of 3PL warehousing operations in the context of WMSs is also provided. The current findings add to the growing literature on this topic and demonstrate the exact research gaps/scarcity of research for further study directions in this cross-sectional area.

This study provides the system knowledge-based decision for practitioners and executives in fast-changing management system markets. As for practical implementations, the structured findings of our research can work as a baseline for constructing a WMS evaluation framework for systems selection and deployment matters. Gathering WMS materials, our work helps make comprehensive framework(s) to assist with well-educated WMS-related decisions. This information can also be used for the educational purposes of 3PL warehouse and seasoned managers to utilize the information for recruits. Growing talents' educational material as warehousing is among the 12 key topics in studying SC management [144].

The scope of WMS functions needs to be researched more as the current literature does not answer clearly, e.g., how to divide different functions into clear classes for WMS selection purposes. For 3PL practitioners, this area-related research could help practitioners make even better decisions and enhance business intelligence.

The RQ3-related fieldwork revealed research gaps in the newest WMS features and technology integration possibilities. Area specialist interviews indicated demand for WMS and sustainability knowledge as WMSs already manage decision-supporting systems and analytical reporting of current sustainability levels of 3PL operations. Besides, 3PLs are essential in orchestrating warehouses [145,146] and SC decarbonization [32]. As a note, previous studies suggest a 15-year WMS lifetime, which seems highly unlikely compared to fast software development cycles created by global digitalization activities leading to a need for more precisely defined system lifetime expectations.

The interviewed 3PL operator pointed out WMS deployment issues not discussed in the reviewed literature, indicating a need for additional studies and collaboration with a broader 3PL operator base to map any uncharted territory for future research. An acknowledged limitation of the study is global generalizability, even when we have used internationally operating practitioners and academically educated specialists to evaluate our work. Since these consulted company experts serve customers in the European Union area, future research should cover more extensive experts to generalize results globally. In short, we suggest the collection of knowledge inputs from a wider group of 3PLs concerning other customer populations, use cases, and geographical locations [79] (Cao et al., 2018). For this purpose, we conclude this article with the future study of general big-picture studies to widen the narrow research focus connecting all main and subtopics, leaving plenty of room for an additional holistic view. It is already proved that WMS can enhance the perceived value of logistics services, which is a crucial driver of customer loyalty and retention [147]. So, it would be interesting to examine full-fledged research on how 3PL investments in chosen WMSs influence activities using financial metrics analogous to [148] for measuring ERP systems' contribution to firms' performance and extend WMS selection reasoning and justification studies [149].

Lastly, the frontline innovative 3PL operator, especially the CEO, managers, and customer support specialists, validated these research results to pinpoint any missing topics in the literature. With the help of the participation of high-level industry specialists, practically important research area directions were identified to be covered in extant research. The practitioners were able to highlight only a few additions to the findings. Given the literature's answers to the set RQs, we suggest widening the research of WMSs and 3PL operators, especially in the previously mentioned niche areas. More research with practitioners can be held into the realm of 3PLs and WMSs to address the knowledge shortage in the 3PL and WMS selection intersection; specifically, the practitioners' point of view is barely visible in extant literature and technologies like artificial intelligence [150] for sustainability, are hardly visible in WMS context, at least till now.

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