This section introduces a classification scheme to categorize the selected articles. Table 1 lists the classification criteria and features used in this overview paper to categorize the articles. The first classifier divides papers into categories based on the performance measure used to analyze the relation between planning problems with the aim of identifying relevant performance indicators to evaluate the effect of combining planning problems. Next, all 61 considered articles are classified with respect to the research method used to analyze the combination of planning problems. This classification identifies methods for solving combinations of planning problems that may help managers to take better decisions. Finally, articles are classified according to the investigated combination of order picking planning problems in order to identify how planning problems are related and which planning problems should be considered simultaneously to optimize the overall order picking performance. Moreover, the classification identifies how warehouse managers could solve the combination of planning problems while taking real-life issues into account to support order picking processes in practice.

本节引入分类方案，对选定的文章进行分类。 表1列出了本概述文件中用于对文章进行分类的分类标准和类别。 第一个分类器根据用于分析规划问题之间关系的穿孔测量将论文分为类别，目的是确定相关的绩效稻谷托尔斯，以评估合并规划问题的影响。 其次，对用于分析规划问题组合的研究方法，对所有61篇经考虑的文章进行了分类。 此分类确定了解决规划问题组合的方法，这些方法可以帮助管理者采取更好的分项。 最后，根据订单采摘规划问题的调查组合对文章进行分类，以验证规划问题有何关联，同时考虑哪些规划问题，以优化整体订单采摘绩效。 此外，该分类还确定了仓库经理如何解决规划问题的组合，同时考虑现实生活中的问题，在实践中支持或去采摘流程。

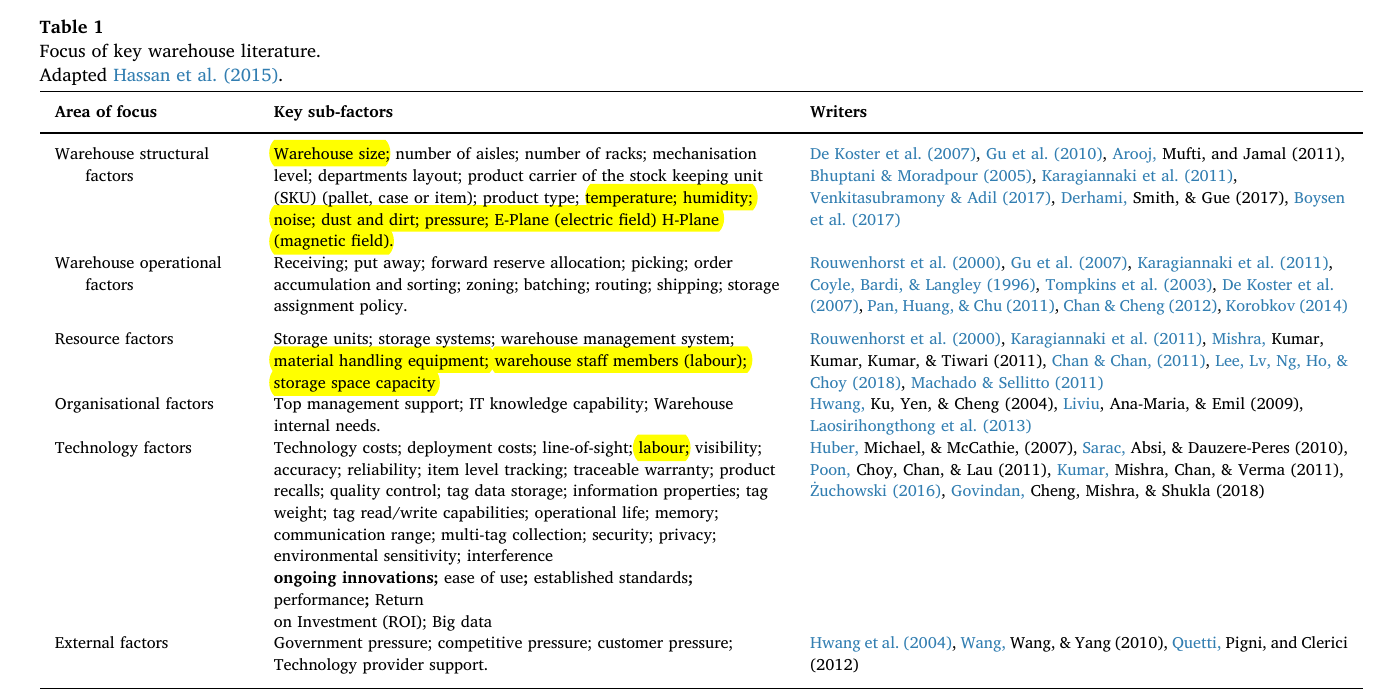
First, all considered articles are classified according to the order picking performance evaluation used to analyze the relations between planning problems. Note that only performance measuresused to analyze the combined effect of multiple planning problems are considered. Articles are classified according to the performance evaluation dimensions distinguished by Staudt, Alpan, Mascolo, and Rodriguez (2015), in particular time, cost, productivity, and service (or quality) related performance indicators. These performance evaluation dimensions are commonly used and help warehouse managers to assess the performance of the operations and to make consequential decisions.

Next, the literature is classified according to the research method used to analyze the effect of combining two or more order picking planning problems or to formulate and solve the integrated problem. The reviewed articles either use analytical models, perform a simulation study, or use mathematical programming to evaluate the combined effect of order picking planning problems. Simulation experiments can be used to determine which combination of factors results in the best order picking performance (Chan & Chan, 2011) and how these factors influence each other. Analytical models predict the performance by relating the performance variable to the main order picking parameters, such as batch capacity and layout (Caron, Marchet, & Perego, 1998). Mathematical programming models refer to the set of equations and related mathematical expressions that describe the problem. An objective function and constraints define the overall structure of the problem (Hillier & Lieberman, 2010).

首先，所有考虑过的文章都按照用于分析规划问题之间关系的顺序挑选绩效评估进行分类。请注意，仅考虑使用绩效衡量标准来分析多个规划问题的综合效应。文章根据 Staudt、Alpan、Mascolo 和 Rodriguez（2015 年）区分的绩效评估维度进行分类，特别是时间、成本、生产率和服务（或质量）相关绩效指标。这些绩效评估维度通常用于帮助仓库经理评估操作的绩效并做出相应的决策。

其次，根据分析两个或两个以上订单采摘规划问题或制定和解决综合问题效果的研究方法对文献进行分类。被审查的文章要么使用分析模型，进行模拟研究，要么使用数学编程来评估订单拾取规划问题的综合效果。模拟实验可用于确定哪些因素组合能够产生最佳的拾取性能（Chan & Chan，2011），以及这些因素如何相互影响。分析模型通过将性能变量与主要订单拾取参数（如批次容量和布局）联系起来来预测性能（Caron、Marchet 和 Perego，1998 年）。数学编程模型是指描述问题的方程集和相关数学表达。客观的功能和约束定义了问题的总体结构（希利尔和利伯曼，2010年）。

Accordingly, Table 1 presents some of the key focus from within the warehousing literature.



[15]

Focusing on the warehouse design, the literature agrees to introduce five interrelated decisions to take, i.e., overall structure, department layout, sizing and dimensioning, equipment selection, and operation strategy (see [4, 8] for a detailed discussion of the goals to achieve). In parallel, a panel of measurement indicators quantifies the system per-

formances along the time, quality, cost, and productivity dimensions [9–11].

Unit-load (UL) warehouses are diffuse solutions to receive, store, and ship items stocked in pallets [12]. Their best design is essential to increase the inbound logistic performances and

to reduce the operative handling and inventory costs [13, 14]. Rouwenhorst et al. [5] defined the warehouse design as “a structured approach of decision making to meet a number of well-defined performance criteria” and point out the following three decisional levels:

Strategic level, facing the long term, e.g., 5 yearlong, decisions;

Tactical level, facing the medium term, e.g., 2 yearlong, decisions;

Operational level, facing the short term, e.g., 1 yearlong or below, decisions.

Such decisional levels intersect the following decisional categories to face, as widely discussed by Gu et al. [7]:

Structure conceptual design, about the number of storage departments, the adopted technologies, and the order fulfillment methods, typical of the strategic level;

Sizing and dimensioning, to set the storage capacity and floor space, typical of the strategic and tactical levels; Warehouse layout, about the shape and the pickup and delivery (P&D) point position, typical of the tactical level;

Equipment selection, about the best level of automation, the type of storage and material handling systems, typical of the tactical and operative levels;

Operation policy selection, about the storage/retrieval policies and adopted command cycles, typical of the operative level

The introduced decisional levels and categories are strongly interrelated with fruitful bottom-up feedbacks

Warehouse benchmarking is the process of systematically assessing the performance of a warehouse, identifying inefficiencies, and proposing improvements. Data Envelopment Analysis (DEA) is regarded as an appropriate tool for this task because of its capability to capture simultaneously all the relevant inputs (resources) and outputs (performances), to construct the best performance frontier, and to reveals the relative shortcomings of inefficient warehouses. Schefczyk (1993), Hackman et al. (2001), and Ross and Droge (2002) shows some approaches and case studies of using DEA in warehouse benchmarking. An Internet-based DEA system (iDEAS) for warehouses is developed by the Keck Lab at Georgia Tech, which includes information on more than 200 warehouses (McGinnis, 2003).

仓库基准是系统地评估仓库性能、识别低效设施以及提出改进建议的过程。数据包围分析 （DEA） 被视为此任务的适当工具，因为它能够同时捕获所有相关输入（资源）和输出（性能），构建最佳穿孔边界，并揭示低效仓库的相对缺点。舍夫奇克（1993年）、哈克曼等人（2001年）和罗斯和德罗格（2002年）展示了在仓库基准中使用DEA的一些方法和案例。佐治亚理工学院的凯克实验室为仓库开发了一个基于互联网的DEA系统（iDEAS），其中包括200多个仓库的信息（麦金尼斯，2003年）。

Analytic performance models fall into two main categories: (1) aisle based models which focus on a single storage system and address travel or service time; and (2) integrated models which address either multiple storage systems or criteria in addition to travel/service times.

Performance evaluation has been considered from various perspectives including warehouse design and operation (Gu et al., 2010), improvements of warehouse operations, in particular, postponement operations (Tse et al., 2012) and relationships between operational policies and performance (Nair, 2005). Beamon (1996) presented characteristics which make a performance measurement system effective and they are inclusiveness, universality, measurability and consistency.

A performance indicator is a numeric value that represents a complex empirical phenomenon. For adequate support to decision-making processes, it is necessary to evaluate performances to give insights to the management office. The elementary data gathered by sensors or operators must be aggregate into useful tools that are representative of system performance (Neely et al., 2005).\

Warehouse needs are key factors that may have a significant effect on auto-ID decisions (Liviu, Ana-Maria, and Emil 2009). Technological perspectives have received considerable attention since the late 1950s, but less have been undertaken from other perspectives such as an organisation and environment level when firms make an auto-ID selection decision (Sarac, Absi, and Dauzère-Pérès 2010). However, warehouse contextual factors such as structure, workflow and resources are major considerations in many RFID selection decisions (Karagiannaki, Papakiriakopoulos, and Bardaki 2011). In this regard, the most efficient RFID solution in a warehouse environment can be formulated by studying the actual physical and internal environment of a warehouse first and then analysing various RFID technologies (Poon et al. 2009). Technological factors are more notable than strategic factors such as network structure, business processes and management components when firms decide to use auto-ID technology in their supply chain (Ilie-Zudor et al. 2011). The key factors affecting auto-ID selection have not been studied as a whole. For this purpose, we used the technology–organisation–environment (TOE) framework (Tornatzky and Fleischer 1990) as the theoretical basis to categorise the factors identified through the literature review and organise them into six categories: organisational, operational, structural, resources, external environmental and technological. For each category, we identified the key factors that may affect auto-ID decision-making based on a combinatorial synthesis and an analysis of the literature on IS implementation in supply chain management and warehouse management.

仓库需求是可能对自动 ID 决策产生重大影响的关键因素（利维乌、安娜-玛丽亚和埃米尔 2009）。自 20 世纪 50 年代末以来，技术观点受到相当大的关注，但在公司做出自动 ID 选择决策时（萨拉克、阿布西和 Dauzére-Pérés 2010 年）时，从组织和环境层面进行的技术观点较少。然而，仓库环境因素，如结构，工作流程和资源是许多RFID选择决定的主要考虑因素（卡拉吉安纳基，帕帕基里亚科普洛斯和巴尔达基2011年）。在这方面，可以通过先研究仓库的实际物理和内部环境，然后分析各种 RFID 技术（Poon 等人 2009 年）来制定软件内部环境中最有效的 RFID 解决方案。当公司决定在其供应链中使用自动 ID 技术时，技术因素比战略因素（如网络结构、业务流程和管理组件）更为显著（Ilie-Zudor 等人 2011 年）。影响自动 ID 选择的关键因素尚未作为一个整体进行研究。为此，我们利用技术-组织-环境（TOE）框架（托纳茨基和弗莱舍1990年）作为理论基础，对通过文献审查确定的因素进行分类，并将它们分为六类：组织、运营、结构、资源、外部环境心理和技术。对于每个类别，我们根据组合综合和对供应链管理和仓库管理中 IS 实施文献的分析，确定了可能影响自动 ID 决策的关键因素。

Some of the key IS theories on technology adoption are technology acceptance model (TAM) (Davis Jr 1986), theory of planned behaviour (TPB) (Ajzen 1985), unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al. 2003), diffusion of innovation (DOI) (Rogers 1995) and TOE (Tornatzky and Fleischer 1990). In this research, we discuss only the DOI and the TOE because they are at the firm level, while TAM, TPB and UTAUT are at the individual level (Oliveira and Martins 2011). According to the TOE, a technological innovation adoption is based on factors in the technological, organisational and environmental contexts (Tornatzky and Fleischer 1990). The technological context refers to internal and external technologies relevant to the firm. The organisational context refers to descriptive measures about the organisation such as the firm’s structure and resources, scope (the horizontal extent of a firm’s operations), size, top management support and complexity of its managerial structure. The environmental context is the arena in which an organisation conducts its business. This includes the industry, competitors and dealings with the government.

技术背景是指与公司相关的内部和外部技术。组织背景是指有关组织的描述性措施，如公司的结构和资源、范围（公司运营的横向范围）、规模、最高管理层支持以及其管理结构的复杂性。环境环境是组织开展业务的舞台。这包括行业、竞争对手和与政府打交道。

Warehouses can be categorised with respect to their processes, resources and structure (Rouwenhorst et al. 2000; Bhuptani and Moradpour 2005; Karagiannaki, Papakiriakopoulos, and Bardaki 2011). Products arriving at a warehouse are taken through a number of steps called processes or operations. Resources include all means, equipment and staff needed to operate a warehouse. Finally, warehouse structure consists of a set of physical and internal environmental factors considered when starting-up a new warehouse or renewing/adding to an older one.

The TOE framework is consistent with the DOI theory where technological characteristics, individual characteristics, and both the internal and external characteristics of the organisation are antecedents to any adoption decision (Zhu, Kraemer, and Xu 2006). These are similar to the technology and organisation context of the TOE framework; however, the TOE framework also has the environment context that includes constraints and opportunities for IT innovations (Oliveira and Martins 2011). Therefore, the TOE framework makes the DOI theory better able to explain intra-firm innovation adoption (Hsu, Kraemer, and Dunkle 2006). For this reason, the TOE framework provides a good starting point when analysing and considering appropriate factors for understanding the technology adoption (Wang, Wang, and Yang 2010). RFID and barcode are enabled by The TOE framework is consistent with the DOI theory where technological characteristics, individual characteristics, and both the internal and external characteristics of the organisation are antecedents to any adoption decision (Zhu, Kraemer, and Xu 2006). These are similar to the technology and organisation context of the TOE framework; however, the TOE framework also has the environment context that includes constraints and opportunities for IT innovations (Oliveira and Martins 2011). Therefore, the TOE framework makes the DOI theory better able to explain intra-firm innovation adoption (Hsu, Kraemer, and Dunkle 2006). For this reason, the TOE framework provides a good starting point when analysing and considering appropriate factors for understanding the technology adoption (Wang, Wang, and Yang 2010). RFID and barcode are enabled by

Tornatzky, L. G., and M. Fleischer. 1990. The Process of Technology Innovation. Lexington, MA: Lexington Books.

According to the Theory Of Constraints (TOC), every activity is strictly bounded to the others in a complex system. It could be possible to estimate system performances by analyzing a few factors that should have a waterfall effect on the whole system (Goldratt, 1990). Moreover, focusing on a defined set of key indicators allows for avoiding information overflow (Tangen, 2004). A performance evaluation system should be layered in different levels linked with the hierarchical organization levels (Cross & Lynch, 1988) in order to align the objectives of different business functions, stimulate concurrent activities, and ensure a link between the strategic vision and operations (Cross & Lynch, 1988), (Tangen, 2004).

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