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Order Picking Process: State-of-the-art on Classification

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***Abstract** – An order-picking system (OPS) is essential to meet customer needs and orders in inbound logistics. Failure to perform the process properly results in high costs and customer dissatisfaction. To properly execute the OPS and to be able to meet the needs of customers with maximum efficiency, different aspects of the order picking process should be carefully considered. Research works have been conducted to improve OPS. This article attempted to review study components, study methods, and results in internal logistics while focusing on OPS. We also examined the composition of different aspects of OPS, including cost, equipment, warehousing, assignment, routing, batching, sequencing, and tardiness in 157 articles performed from 1958 to 2020 and studies on the process of time (Makespan). The reviewed studies were classified based on the simultaneous use of batching variables, assignment, routing, sequencing, and tardiness, the methods used in the research work, and finding research gaps for future investigations to clarify the relevance and application of routing, assignment, batching, sequencing, and tardiness aspects in the order picking process.*

***Keywords**– Picking, Routing, Batching, Assignment, Tardiness.*

I. INTRODUCTION

Manufacturing companies confront different challenges to fulfill customer orders and distinguish between them. Many manufacturing companies consider reducing and eliminating costs and improving productivity in their logistic system important improvement activities (De Koster et al., 2007). On the other hand, the warehouse is one of the most critical in-house logistics components playing a crucial role, among other activities, in the supply chain of any manufacturing company. To meet customer needs, the OPS, as part of the warehouse preparation process, produces lines to have a special place in the studies (De Koster et al., 2010). 60% of all productive activities and 55% of warehouse operating costs include order picking process De Koster et al. (2010); in each supply system, there are parts-warehousing-related activities, such as receiving parts, warehousing, ordering, and shipping along product lines (Van Gils et al., 2018a). For reducing warehouse operating costs, in assembly lines, it is highly significant for the company to supply necessary materials within the factory to promote its Competitive power. In a factory (company), materials should be provided with high efficiency and flexibility. Components should also be provided at assembly stations to facilitate assembly operations (Dallari et al., 2009). The multiplicity of demands in an internal supply system reflects the intrinsic complexity of the systems (Elsayed & Lee, 1996). The complexity of the material and parts transportation system will lead to an increase in production simultaneously. Researchers, in recent years, have been increasingly motivated to develop OPS enhancement policies (Franzke et al., 2017). internal logistics aspects also need a great deal of attention due to the constraints and resources available to reduce costs and increase the flexibility of production

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schedule changes to meet customer demands by expanding the ability of line feeding systems and offshore components. In this regard, using new methods of feeding materials and parts such as picking seem necessary (Battini et al., 2017). Picking refers to some of the factors, including moving, picking, deploying, and packing parts according to the amount of order required to meet the production schedule (Žulj et al., 2018). Receiving materials and parts from the warehouse, preparing them, and moving them along product lines are the most strenuous activities in an internal logistic system. According to studies, they account for 65% of total operating costs in the internal logistics process. The order pickings are based on the workforce and the flexibility of the workforce against changes due to existing constraints (Grosse et al., 2015). Timing and sequencing are two critical factors in picking operations (Lerher, 2018).

Other concepts used in the picking process are as follows:

travel distance, travel time, layout, channel configuration, dimension and size of the picking, order batching, ordering of picking parts, minimizing travel distance, maximizing occupational health, picking list (required orders), Stress, and Psychological Conditions (Grosse et al., 2015).

The process of OPS is performed in different ways, as discussed below:

1- to allocate the piece to the picker
2- Picker assignment for parts

In the part assignment method for picking parts, the picker is carried by a parts transporter or courier container, or he picks up the pieces himself. (Valle et al., 2017). In this method, the picking station is defined separately for each individual. The type of transfer operation is also proportional to the kind of concerned picking process. The part assignment method is also ergonomically beneficial to the operator (Battini et al., 2017). On the other hand, the method of assigning a piece refers to time, when each part has its picker in a specific place (Valle et al., 2017). Figure 1. shows the process map of the picking operation.

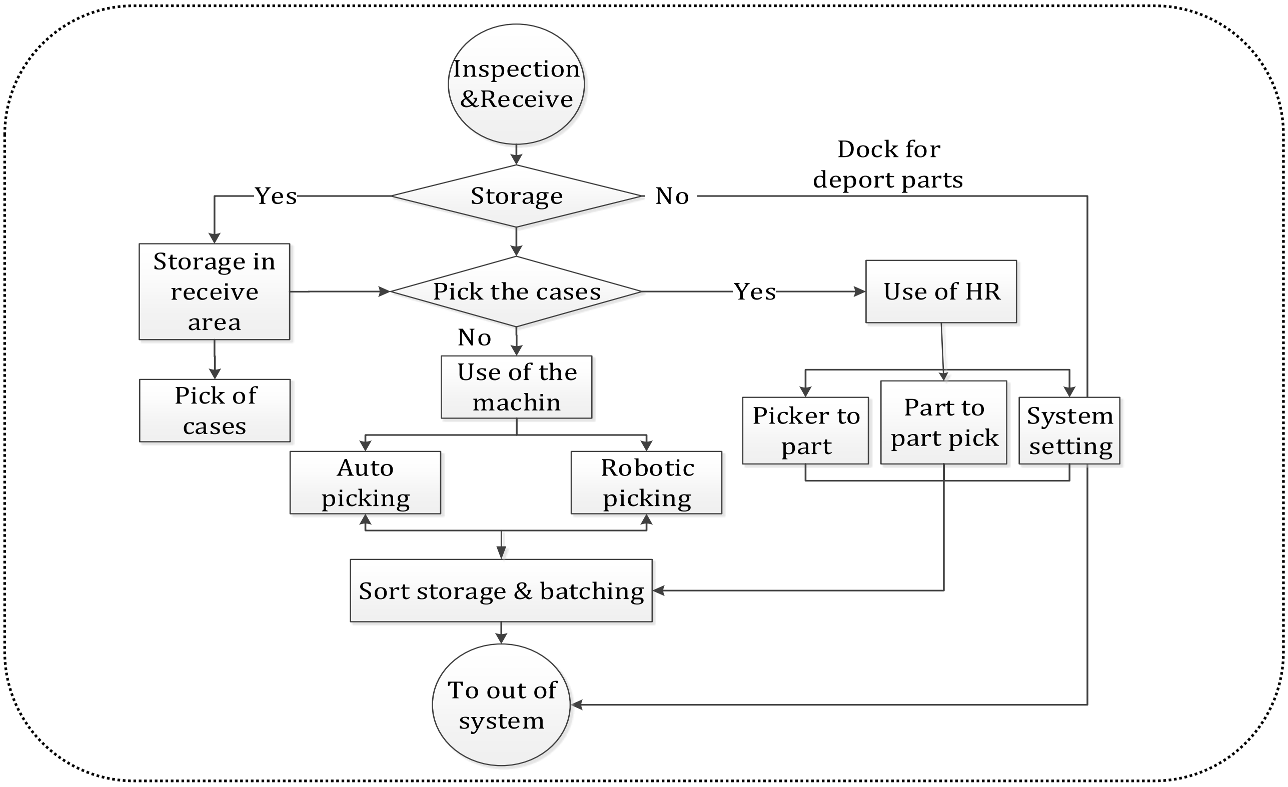

Figure1. Process map of the picking operation

Figure 1 illustrates OPS. As seen, picking begins with receiving parts from the warehouse (Kim & Moon, 2003). There are two different ways of warehousing: batching and picking operations. If the received items do not meet the quality standards and documentation required for the factory, they will be returned to the manufacturer's dock. Picking operations are performed either manually or automated, using semi-robotic or robotic equipment. Each moving part to the picking area is also selected based on batching order and picking operations. Because warehouses provide busy services to customers, poor performance can lead to high costs (job demand) and customer dissatisfaction (Wruck, Vis, & Boter, 2016). Newmarket developments encompassing e-commerce, globalization, increasing customer expectations, and new regulations have intensified the competition between warehouses. It has forced warehouses to manage large numbers of small orders in limited opportunities (March et al., 2015). Managing order-picking operations and investigating the relationships between order-planning problems are two complex tasks to do by warehouse managers (Gu, Goetschalckx, & McGinnis, 2007). A successful e-commerce ordering process contains multiple different suppliers and programs that need to be quickly implemented. In this regard, completing orders is one of the most important fundamentals to succeed in the online business.

Moreover, to overcome shortcomings in the ordering process, several aspects should be carefully considered. The easier the process for the end customers is, the more satisfied they would be with you. Furthermore, to decrease the warehouse costs and applying new methods in the internal procurement system, some recent trends need to be more efficiently performed in the procurement industry. Previous studies have focused on order-picking and route selection and warehousing operations. However, the problems of picking operations are integrated. Marchet et al. (2015) provided a comprehensive empirical analysis of the choice of order-picking systems (e.g., focus and strategic decision making) (Van Gils et al., 2018a,b).

Van Gils et al. (2018a) focused on a combination of tactical and operational planning problems and how they could support new market developments. In this regard, some issues, such as ergonomics and order tardiness, have been rarely considered by the researchers. On this account, this paper investigated how warehouse managers can take advantage of combining several operational planning issues by reviewing previous articles. This paper sought to answer the following questions through reviewing the scientific literature related to combining order-picking problems, such as cost/equipment/warehousing/assignment, routing, batching, sequencing, and tardiness:

1. What problems have the related literature mentioned in order picking?
2. How have the order-picking problems been resolved and categorized in the reviewed articles?
3. What kind of warehouses have the reviewed studies mentioned?

Therefore, the purpose of this study was to investigate aspects of OPS.

The remainder of this paper is organized as follows: Section 2 describes OPS literature taxonomy. Section 3 discusses the research background. Section 4 describes the literature review methodology. Section 5 mentioned OPS problem planning. The managerial implications resulting from the literature overview are discussed in Section 6. Finally, Section 7 presents conclusions.

II. ORDER PICKING SYSTEM LITERATURE TAXONOMY

According to the objective of this paper, the OPS literature taxonomy surveys the scientific literature related to combining order picking problems to answer the following questions:

1. What problems have the related literature mentioned in order picking?
2. How have the order-picking problems been resolved and categorized in the reviewed articles?
3. What kind of warehouses have the reviewed studies mentioned?

This paper is organized as follows to answer the above questions; first, it considers the OPS definitions. Next, some previously conducted studies in OPS are discussed to provide a clear picture of prior research in this field. Then, the research questions and their objectives are elaborated in detail based on the research gap found in the literature. Afterward, the research method is presented. Subsequently, in the following steps of this research, discussions, and conclusions will be conducted. Figure 2 illustrates the classification proposed by the OPS literature.

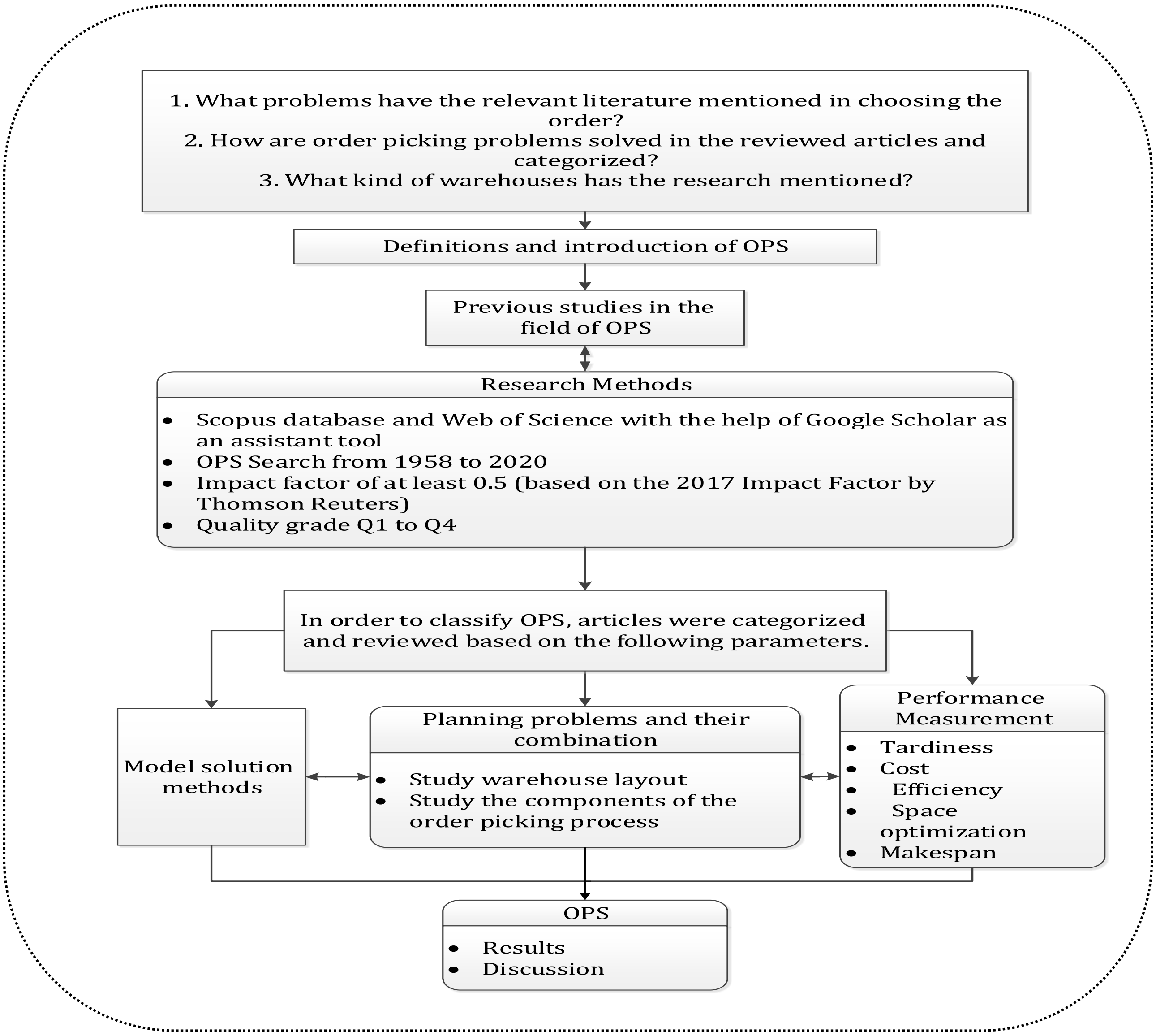

Fig. 2: Proposed classification to review the OPS literature

III. ORDER PICKING SYSTEM RESEARCH BACKGROUND

During the past decades, awareness about OPS problems has been increasing worldwide thanks to industry and research. However, despite many efforts over the past few decades, OPS has not yet effectively matured. Therefore, it is essential to pay attention to warehousing activities, such as parts receiving, warehousing, orders, internal routing (Van Gils et al., 2018).

It is also crucial to consider the OPS classification developed by researchers to understand previously conducted research on OPS and the boundaries of OPS research. For instance, (Laporte, 1992) addressed routing and collection problems about the geographical distribution of warehouses. For this purpose, they classified a wide variety of variables. Rouwenhorst et al., 2000 proposed another classification dealing with problems related to warehouse control and specifically the warehouse design. Furthermore, Roodbergen & Vis (2009) developed another category through reviewing the literature on OPS. This classification concentrated on a wide range of problems, such as configuration, travel time estimation, storage, location, and sequencing. They also introduced some solutions for the mentioned problems.

Also, Park & Kim (2010) proposed the problems related to school bus routing. In this matter, some limitations, such as the maximum capacity of the bus, the maximum time to get on and off a bus, and the time window, were discussed. This class of surveyed problems has several subsets, including device transportation selection, routing, transport schedules, and completion time of the operation. Meanwhile, Van Gils et al. (2018) developed a classification for warehouse managers' benefit. They stated that since warehouses offer several services to customers, the poor performance of warehouses may result in high costs and customer dissatisfaction with demand. Van Gils et al. (2018) also declared that new market developments force warehouses to handle many orders within tight time windows. Accordingly, Van Gils et al. (2018) studied the related review and classification of the scientific literature with combinations of tactical and operational order picking planning problems.

Investigating a bunch of articles has also shown that the new policies on warehousing, ordering, routing, batching using fuzzy parameters as well as innovative algorithms have been developed for planning resources and optimizing performance by considering the number of the workforce (Kaur & Kumar, 2011; Gupta & Kumar, 2012; Bahrami et al., 2017; Kuo et al., 2016; Scholz et al., 2016; Jia & Heragu, 2009). On the other hand, most of the studies on OPS design with a combined program have been conducted to re-evaluate warehouse activities, routing problems, equipment, order selection in a warehouse, and warehouse design (see Table I) (Van Gils et al., 2018; Laporte, 1992; Park & Kim, 2010; Roodbergen & Vis, 2009; Rouwenhorst et al., 2000; Hansen & Mladenovi, 2001). Besides, some studies have been performed on the components of the order picking process (Scholz et al., 2017; Zhang et al., 2017; Chen et al., 2015).

Table I. Areas of Study in the Review Articles

References	***Articles***	***Performance index***
(Van Gils et al.2018; De Koster et al. 2007; Rouwenhorst et al, 2000; Roodbergen & Vis., 2009)	5	Design
(Hansen & Mladenovi, 2001)	2	Process changes
(Laporte., 1992; Park & Kim, 2010)	2	Routing

The advantage of the present study over the one conducted by Van Gils et al. (2018) is addressing the issues of order tardiness and warehouses. Van Gils et al. (2018) proposed, on a large scale, tactical and strategic decision-making issues. Likewise, the research method used in their paper was mathematical programming, analytical models, and simulations that are different from the classification of our paper. The current work was tried to consider the necessity of internal aspects of procurement, the limitations and available resources to reduce costs and increase adaptability to customer requirements by increasing productivity, and the use of OPS systems. Although in the review studies, the mentioned factors in the OPS system have been classified in terms of tactic, strategy, and design. But they have failed to present a proper classification, including performance measurement indicators, problem-solving methods, planning, and combination. Thus, this paper reviewed a combination of cost, equipment, warehousing, assignment, routing, batching, sequencing, and tardiness in the scientific literature on a combination of planning problems. To achieve the aim of this research, which is to classify the order picking process, first, planning problems and their combination should be surveyed. After that, the performance measurement indicators and the chosen solution methods should be specified and investigated. The relationships between planning problems should be finally analyzed based on such indicators and solutions.

IV. METHODOLOGY OF REVIEWING OPS LITERATURE

This research work chose a three-step strategy to identify the most critical research papers, database selection, search, and sample modification. The literature-review method is depicted in Fig. 3.

A. Database selection

To track academic publications, several database engines can be utilized, such as Scopus, Web of Science, PubMed, and Google Scholar. Research conducted by Falagas et al. (2008) showed that the Scopus database is superior to other databases. However, in another study by Wang and Waltman (2016), journal classification of Web of Science is preferred. This paper similarly employed Scopus and Web of Science database; Google Scholar is also used as an assistant tool.

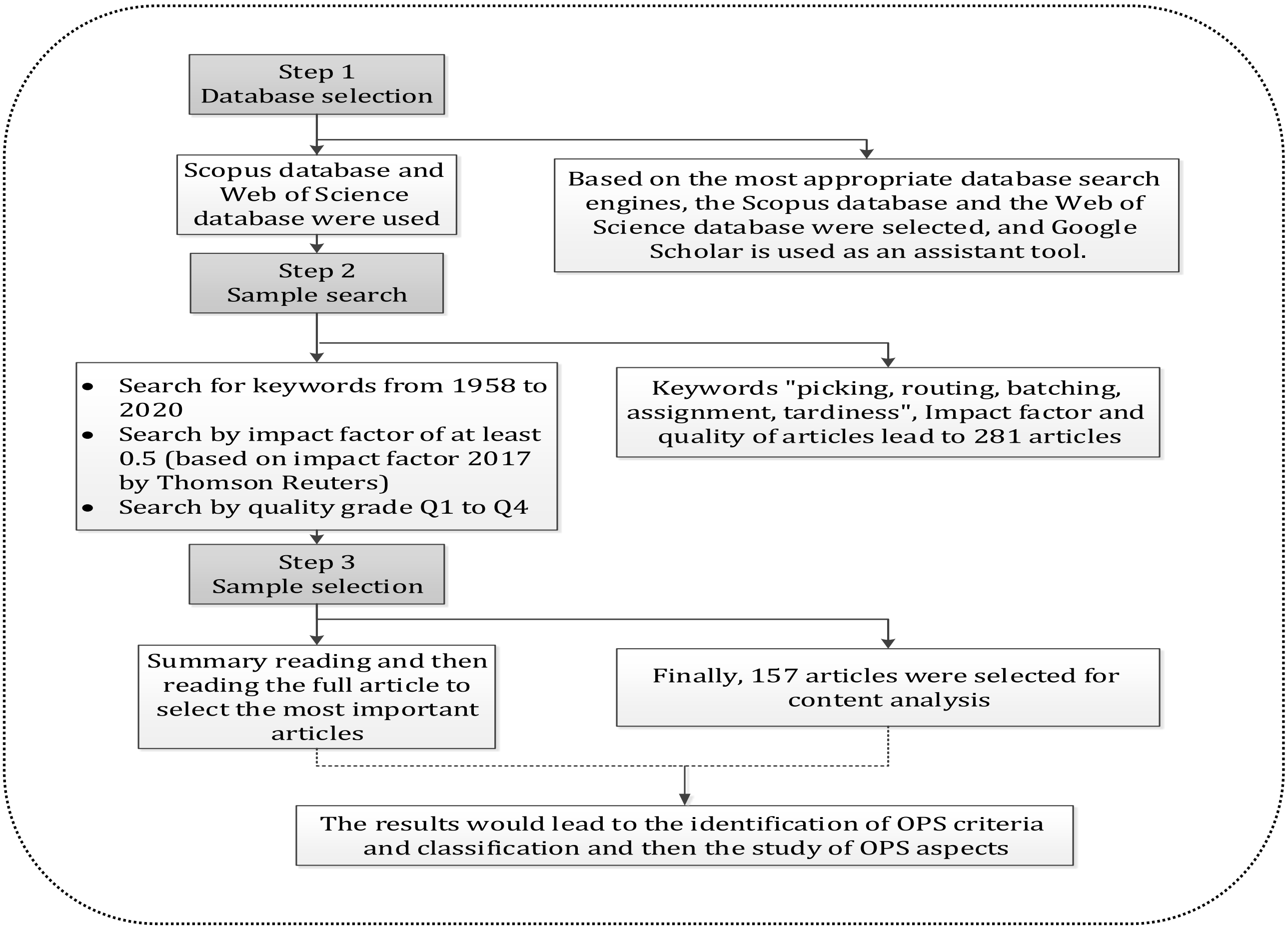

Fig. 3. OPS-literature-review method

B. Sample Search

Target articles of the present research were limited to those papers on planning and selection problems. Interestingly, this paper can also show the potential relationship between two or more planning problems. This study reviewed the recent literature in which critical issues in the picking process have been highlighted. It also focused on planning problems, such as time performance or productivity metrics that can affect economic objectives, which are highly important in warehouse operations. For this purpose, "picking, routing, batching, assignment, tardiness" were searched as keywords in papers titles, abstracts, and keywords among articles and review papers from 1958 to 2020 (as exhibited in Fig. 4) in both Scopus and Web of Science. The initial search returned 281 articles. Fig. 4 shows that 97 articles have been published between 2010 and 2020, accounting for 62% of the total article. Those articles, which have been published in English language journals with an impact factor of at least 0.5 (According to the impact factor of 2017 by Thomson Reuters) and have a quality level of Q1 to Q4, were also considered. Books and conferences were excluded from the category.

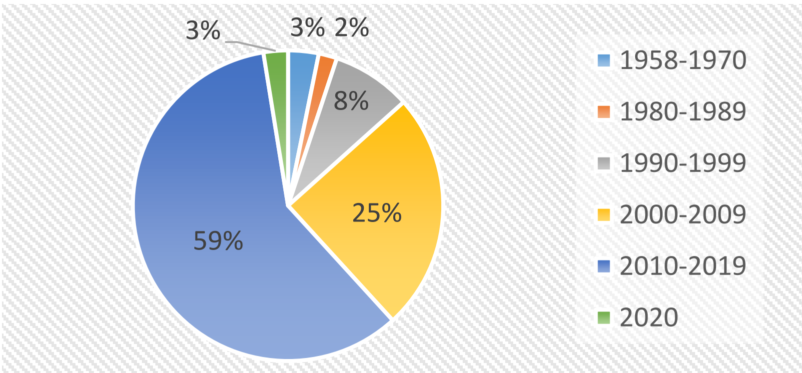

Figure 4. Article Sharing Rate based on Number of publication Years

C. Sample selection

By applying abstract reading of 281 papers in the first step and subsequently, by the in-depth reading of the whole paper in circumstances in which it is impossible to identify the suitability of papers, the number of 157 papers with the most relevant content is selected. The results of this paper revealed that only 77 studies had been published in Elsevier, 21 studies in Taylor and Francis, and 16 studies in IIE Transactions. Table II classifies the articles based on their publication.

Table II. Number of articles published in the study

Electronic Publications	*Number of articles*
Elsevier	77
Taylor & Francis	21
IIE Transactions	16
Springer	12
Informs	10
Wiley Periodicals	6
Emerald	5

Continue Table II. Number of articles published in the study

Electronic Publications	*Number of articles*
Bundesvereinigung Loistik	3
IFAC	2
World Scientific Publishing Co	1
Lippincott	1
Bailiere Tindall	1
Institute of mathematical statistics	1
Indin society for development and environment	1

To achieve the aim of the study, two issues were considered as follows: articles related to planning problems and articles exploring the interaction between planning problems in manual order selection systems. Based on Fig. 5, in the current research, the quality level of 157 articles was reviewed. As can be seen, 99, 28, 25, and 5 of the reviewed articles have journals of Q1, Q2, Q3, and Q4 quality, respectively. So, it is evident that most of the articles have been selected from high-quality journals. Sources of articles can be observed in Table III.

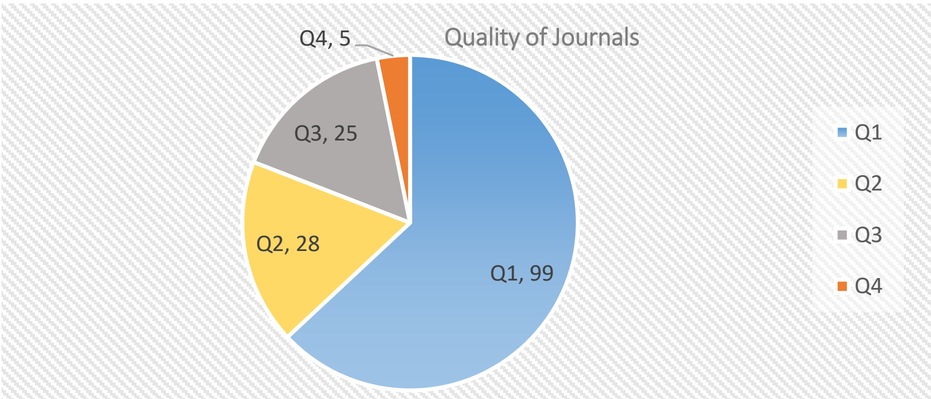

Figure 5. Number of Qualitative articles in journals

V. DISCUSSION

In this section, to help the managers decide more efficiently and overcome problems in the order picking process, the 157 chosen articles were classified and evaluated from three perspectives. Firstly, they were surveyed considering the problems of order-picking planning issues and the combination of problems to determine what essential issues are there in this area and which problems are simultaneously considered to optimize the order-picking performance. Such classification helps warehouse managers determine how they can solve a combination of issues related to order-picking planning so that they consider some fundamental issues in the order picking process. Secondly, all the articles were classified based on the performance measurements to analyze the relationship between planning problems and identify the performance indicators and their impact on the combination of problems. Thirdly, the articles were classified based on the methods used to solve the combination of order-picking planning problems to help the warehouse managers make better decisions.

Table III. Number of articles published in the study

References	*Qualitative Survey Journals*
Scholz et al., 2017; Van Gils et al., 2018a; Öztürko et al., 2019; Van Gils et al., 2018b; Cergibozan & Tasan., 2019; Kaur & Kumar., 2011; Jane & Laih., 2005; Gupta & Kumar, 2012; ; Letchford et al., 2013; ; Cortes et al., 2017; Muppani et al., 2008b; Öztürkog et al., 2014; Hwang et al., 2004; Geisser & Greenhouse., 1958; Brynzer & Johansson., 1996; Yung & Chung., 2004; Roodbergen et al., 2015; ; Zulj et al., 2018; Acimovic et al., 2014; Aghezzaf , 2007; Andriansyah et al., 2001; Battini et al. (2016); Battini et al., 2017b; Bouleimen & Lecocq, 2003, Bozer and Kile, 2008;Caron et al., 1998; ; Chabot et al., 2017; Chackelson et al, 2013; Chen et al., 2016; Chen.t.l et al., 2015; Chen.c.y et al., 2015; Dagenais et al., 2008; De Koster et al., 2010; De Koster et al., 2007; De Koster et al., 2012; Elbert et al., 2017; Elsayed et al., 1993; Geem., 2012; Giannikas et al., 2017; Glock & Grosse, 2012; Glock et al., 2016 ; Grosse et al., 2013; Grosse et al., 2015; Gu et al., 2007; Gu et al., 2010; Henn & Wäscher, 2012; Ho & Lin, 2017 ; Hong et al., 2015; Hong et al., 2016; Hsieh & Huang, 2011; Calzavara et al., 2017; Scholz et al., 2016; Luo et al., 2016; Jewkes et al., 2004; Kim & Moon, 2003; Kuo et al., 2016; Laporte., 1992; Lee et al., 1996; Lee & Geem., 2005 ; Lerher et al., 2015; Pohl et al, 2009a; Leung et al., 2018; Chun et al, 2016; Luo et al, 2016; Manzini et al, 2015; Marchet et al, 2012; Matusiak et al, 2014; Matusiak et al, 2017; Mowrey & Parikh., 2014; Muppani & Adil., 2008a ; Pan & Wu, 2012; Pan et al., 2015; Parikh & Meller., 2008; Park & Kim, 2010; Petersen ; 2002, Petersen et al., 2005 ; Petersen, 1999; Petersen et al., 1997; Petersen & Aase ., 2004; Roodbergen & de Koster., 2001; Roodbergen & Vis., 2009; Rouwenhorst et al., 2000; Roy, 2016; Hansen & Mladenovi, 2001; Schleyer & Gue., 2012 ; Schrotenboer et al., 2017a; Schrotenboer et al., 2017b; Theys et al., 2010; Tsai et al,2008; Valle et al., 2017; Volgenant & Jonker., 1982; Won & Olafson., 2005; Zhang et al., 2017; Helsgaun., 2000; Ardjmand et al., 2020;Kübler et al., 2020;Cano et al., 2020; Valle et al., 2020; Li et al., 2017;	Q1
Ene et al., 2012; Bahrami et al., 2017 ; Teng & Hwang., 2017; Çeven et al, 2015; Clarke & Wright., 1964; Everett., 1963; Held & Karp., 1970; ; Ratliff & Rosenthal., 1983 ; Azadnia et al., 2013; Chien et al.,2010; Cordeau et al., 2007; Dallari et al., 2009; De Vries et al., 2016; Franzke et al., 2017; Grosse et al., 2013; Henn, 2015; Henn et al., 2013; Isler et al., 2016; ; Jia & Heragu,2009; Koch & Wäscher., 2016; ; Kulak et al., 2012; Manzini et al., 2007; ; Marras et al., 1993; Tappia et al., 2017; Hong, et al., 2015; Yu et al, 2015; Scholz et al., 2017; Pansart et al., 2017	Q2
Grosse et al., 2017; Battini et al., 2017, Akilbasha et al., 2018; Roodbergen et al., 2008; Berglund & Batta, 2012 ; Clark & Meller., 2013; Davarzani & Norrman., 2015; Elsayed & Lee, 1996 ; Gademann et al., 2001; Gademann & van de Velde., 2005; Garg, 1986; Gong & De Koster, 2011; Gong & De Koster, 2008; Gue & Meller, 2009; Hall, 1993; Hart et al., 1968; Bevan, 2015; Jarvis & McDowell., 1991; De koster & Van der Poort., 1998; Ma et al., 2009; 2010; Petersen et ; Ramtin & Pazour., 2015 ; Roy et al., 2012 ; Thomas & Meller, 2014; Park et al., 1999;	Q3
Moeller., 2011 ; Albareda et al ; Dekker et al, 2004; Pohl et al., 2009; Tang et al, 2011	Q4

A. Investigating the problems of order-picking planning and their combination

In this section, planning problems and their combinations were surveyed and, all the articles with at least two simultaneous planning issues were analyzed.

1) Study the warehouse layout

A warehouse comprises various areas and domains, including transportation operations, parts receiving area, parts warehousing area, and order picking area (Gu et al., 2007). Aisle is also referred to as the path between the rows of a cellar. Also, block layout is used refers to the contents of the repository by the segmentation method (Hong, 2014). Moreover, in the recent literature related to customized picking, three types of assignments have been introduced to determine the optimum anchors.

1. Assignment of storage and batching
2. Allocating storage and routing location
3. Wrapping and routing

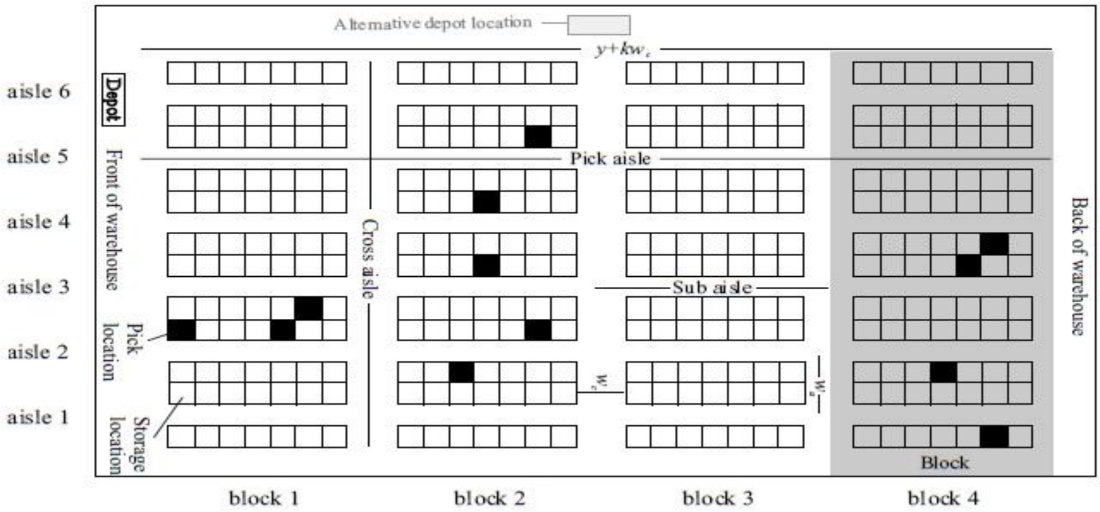

Figure 6. Order Picking Area in Stock (Roodbergen, 2007)

Figure 6 determines that the effect of the warehouse position on the pick travel distance is less than 6% and, the cascade is 1% if there are 15 pickings or more per route. Some of the reviewed works have also introduced a model to minimizing travel distance in a fixed-structure warehouse (Roodbergen et al., 2008), (Petersen, 1997), (Hall, 1993), examined the effect of parts layout on order-picking efficiency by an analytical estimation of travel distance in single-block warehouses.

Table IV. Areas of study of warehouse layout types in picking

Auditors	***Layout method***	***Number***
Gademann et al., 2001; Hwang et al., 2004; Gademann and Velde, 2005; Won & Olafson., 2005 ; Schrotenboer et al., 2017; De Koster et al., 2008 ; Ho & Lin, 2017;Tsai et al., 2008; De Koster et al., 2010; Henn, 2012; Theys et al., 2010; Henn and Wascher, 2012; Hong et al., 2015; Azadnia et al., 2013; Henn et al.,2013; Chen et al., 2015; Chen et al., 2015; Glock et al., 2016 ; De Kostereng et al., 2015; Manzini et al., 2007; Henn, 2015; Isler et al., 2016; Cortes et al., 2017; Hong et al., 2016; Ratliff & Rosenthal., 1983 ; Gong & De Koster, 2008 ; Gue & Meller, 2009	Parallel aisle	27
Roodbergen & de Koster., 2001	Parallel aisle and a middle aisle	1
Valle et al., 2017; Scholz et al., 2017; Li et al., 2017	Parallel aisle with a middle aisle	3
Bozer and Kile, 2008	Parallel aisle & one main aisle	1
Chen et al., 2016 Ling & Huang, 2011;	Parallel aisle with one cross aisle	2
Kulak et al, 2012	Single and multiple cross aisles	1
Matusiak et al., 2014	Parallel aisle with 3 cross aisles	1
Pan et al., 2015	Pick-and-Pass system	1
Pansart et al., 2017	Parallel aisle with multiple middle aisle	1
Pohl et al, 2009	Fishbone Aisles	1
Valle et al, 2020	parallel aisles and two or more cross-aisles	1
	Total	40

According to Table IV, most of the studies in the warehouse were on parallel aisles and, other methods were less favored by the researchers.

Van Gils et al. (2018) and Scholz et al. (2017) stated that the process of picking and selecting pieces for picking is complete when the picker returns to the original location after selecting the last batch. In these papers, the authors used the mathematical model to solve small samples; In contrast, for larger samples, they used a variable neighborhood descent (VND) algorithm than by numerical experiments showed that the algorithm offers excellent solutions for path optimization (Theys et al., 2010).

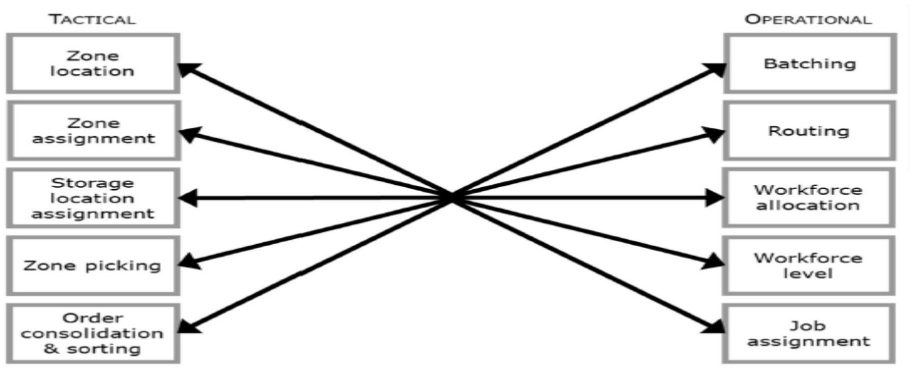

Figure 7. Order picking process aspects (Van Gils et al., 2018)

(Van Gils et al., 2018) Figure 7 introduces items in an interconnected structure, such as storage location assignment, zone assignment of the warehouse, picking area, ordering, routing, labor assignment, labor force level, and labor assignment.

2) Study the Components of the Order Picking Process

Investigating the assignment and sequencing of the batch to multi-pickers concurrently with the optimal routing problem, checking the overall time of the custom multi-picker picking process, or applying a categorized warehousing method are generally done to maximize profit. In Figure 8, phases occurring in the study section on the components of the order picking process can be observed. As shown, it tries to optimize order assignment (sorting and routing of the shippers resulting in minimizing process time). Also, the workload balanced between the shippers is maintained. Also, from the start to the end of the picking process, this distance is kept to optimize the assignment.

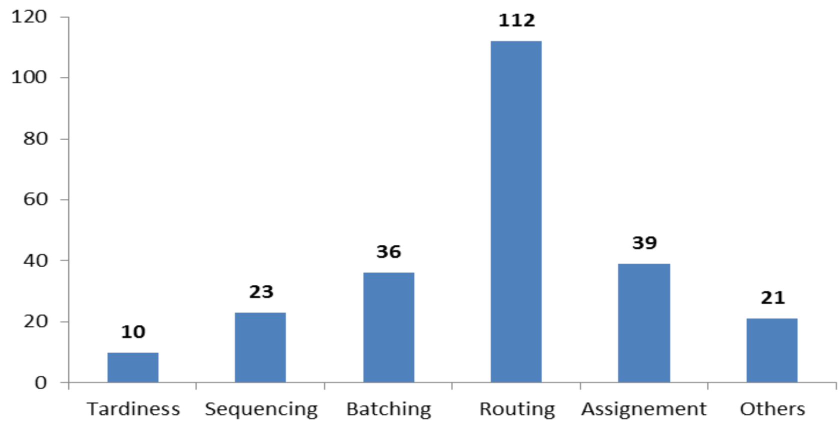

Figure 8. Frequency of study areas examined in this study

Table V. The Picking Process Components Study Section

Performance index	*Articles*
Cost	51
Equipment	23
Storage space	76
Assignment	39
Routing	112
Batching	36
Sequencing	23
Tardiness	10
Ergonomy	6

Furthermore, considering cost(Table V), there were 51 articles (Hall, 1993; Öztürko et al., 2019; vanGils et at al., 2018; Ene et al., 2012; Grosse et al., 2013; Battini et al., 2016; Grosse et al., 2015; Battini et al 2017; Jane & Laih, 2005; Akilbasha et al., 2018; Letchford et al., 2013; Muppani et al., 2008; Çeven et al., 2015; Acimovic et al., 2014; Azadnia et al., 2013; Chabot et al., 2017; Chackelson et al., 2013; Chien et al.,2010; Chen et al.,2016; Cheng et al., 2015; Cordeau et al., 2007; Dagenais et al., 2008; Dekker et al., 2004; Elbert et al., 2017; Aghezzaf , 2007; Elsayed et al., 1993; Gademann et al., 2001; Gademanm & van de Velde, 2005; Glock et al., 2016; Gong & De Koster, 2008; Grosse & Glock, 2013; Grosse et al., 2017; Gue & Meller, 2009; Hart et al., 1968; Held & Karp, 1970; Bevan, 2015; Battini et al., 2017; Kuo et al., 2016; Muppani & Adil, 2008b; Petersen, 1999; Petersen, 2002; Parikh & Meller, 2008).

Most of the cost-related studies focused on changes in the warehouse system, reductions in routes, improvements of the assignment process, changes in the shape and size of warehouses, travel times, and changes in warehouse design processes.

This group of studies has provided methods for solving order-picking problems to help managers make better decisions. They have also considered some of the most critical aspects of order-picking for identifying scheduling problems and issues with different topics. Further, some research works have investigated order-picking other than resources (Scholz et al., 2017; van Gils., 2018; Henn & Wäscher, 2012; Azadnia et al., 2013; Chen et al., 2015; Elsayed et al., 1993; Elsayed & Lee, 1996; Gue & Meller, 2009; Henn, 2015; Schrotenboer et al., 2017; Tsai et al., 2008). One study on latency has simultaneously investigated five critical aspects of the order-picking process (assignment, routing, batching, sequencing, and tardiness) (Bouleimen & Lecocq, 2003). Four more studies (Sholz & Wäscher, 2017; Azadnia et al., 2013; Elsayed & Lee, 1996; Tsai et al., 2008) have also simultaneously studied routing, batching, sequencing, and tardiness. Table VI provides an overview of the combination of order picking scheduling problems about various aspects of its implementation. Five main aspects defined in the order picking process were included in 30 research on implementing the combined planning process problem. Fourteen studies did not study these five categories and solely focused on ergonomics, cost, equipment, and storage space. Therefore, we can state that only 9% of the reviewed studies did not focus on the five main categories of research, indicating the importance of assignment, routing, batching, sequencing, and tardiness in the order picking process (Öztürkog et al., 2014; Roodbergen et al., 2015; De Vries et al., 2016; Gong & De Koster, 2011; Glock & Grosse, 2012; Gu et al., 2007; Gu et al., 2010; Lee et al., 1996; Park et al., 1999; Pohl et al., 2009; Rouwenhorst et al., 2000; Hansen & Mladenovi, 2001; Tappia et al., 2017; Thomas & Meller, 2014). According to Table VI, the most significant combination of routing and batching studies with 21 studies and assignment and routing with 18 cases reflects that researchers have focused on routing.

Chackelson et al. (2013) used both simulation solutions to simultaneously examine picking processes to reduce operating costs and a hybrid algorithm to generate batches and assignment and sequencing customer needs. Several studies have studied scheduling problems together in a multi-block warehouse while combining batching and routing into a single scheme. After assigning the order to the packer, any order picker can begin the journey to the warehouse to select and pick. The orders should be prioritized according to the production plan and delivered to the pickings. In the meantime, the lost time is one of the most important factors to consider to prevent tardiness and increase productivity. For example, when a picker stops to prepare an order batch (Van Gils et al., 2018), it is one of the cases of tardiness in the order picking process.

The studies reviewed in this paper have addressed the reduction or elimination of tardiness through redesigning the picking process, batch organization, routing, prioritization, and picking activities. In Fig. 8, it can be seen that the most studied areas were routing and storage space since a total of 98 articles studied warehousing and design of a picking warehouse to reduce or, in other words, optimize routes.

Moreover, to find the most economical routes, warehouse layout, piecewise assignment, and parallel scheduling of equipment pickings have been studied. Travel routes in all logistic processes are mainly the most influential factors in terms of costing and timing, as shown in Table V.

This section deals with researchers with several studies associated with the topic of this paper. Five articles had been conducted by Henn as a lead author or contributor. Four studies by E.H. Grosse, Hong & Sholz, as a lead author or contributor. Also, from each of the following researchers, 2 studies were investigated (Ma et al., 2009; Muppani & Adil, 2008; Hwang et al., 2004; Ene & Öztürk, 2012; Calzavara et al., 2017; Aghezzaf, 2007; Berglund & Batta, 2012; Bozer & Kile, 2008; Caron et al.,1998; Yu et al., 2015; Gademann et al., 2001; Pan & Wu, 2012; Franzke et al., 2017; Garg, 1986; Gong & De Koster, 2011; Gu et al., 2007; Gue & Meller, 2009; Ling & Huang, 2011; Pohl et al., 2009; Manzini et al., 2007; Matusiak et al., 2014; Parikh & Meller, 2008; Roy et al., 2012).

In Scholz et al. (2018), mathematical programming modeling was considered in the above categories for the first time. This research, indeed, evaluated order batching and picker routing in OPS under the title of; "the benefits of integrated routing."

Another article Scholz & Wäscher. (2017) stated that the order batching problem involves grouping a set of customized picking orders to minimizing the entire picker journey so that the picking will be considered based on the calculation of the picking trip length. The strategy of this research was to simplify the order picking activity by simplifying the custom picker journey.

Table VI: Areas of Study in the Picking Process

Auditors	*Assignment*	*Routing*	*Batching*	*Sequencing*	*Tardiness*	*SUM*
(Bouleimen & Lecocq., 2003 ; Kübler et al, 2020)	X	X	X	X		2
(Scholz et al, 2017; De Koster et al.2007; De Koster et al.,2012; Ling & Huang, 2011; Ene et al., 2012; Chun et al., 2016; Matusiak et al. 2017)	X	X	X			7
Hwang et al., 2004; Clarke & Wright., 1964 ; Brynzer & Johansson., 1996; Caron et al., 1998; Chien et al., 2010; Dekker et al, 2004; Franzke et al., 2017; Glock et al., 2016; Grosse et al., 2015; Jewkes et al., 2004; Manzini et al., 2015; Matusiak et al. 2017 ; Pan & Wu, 2012; Chun et al, 2016 ; De Koster et al.2007; Ramtin & Pazour., 2015; Yu et al, 2015; Scholz et al. 2017;)	X	X				18
(Elsayed et al, 1993; Henn, 2015)	X		X	X	X	2

Continue Table VI: Areas of Study in the Picking Process

Auditors	*Assignment*	*Routing*	*Batching*	*Sequencing*	*Tardiness*	*SUM*
(Azadnia et al., 2013; Cheng et al., 2015; Elsayed & Lee, 1996; Tsai et al, 2008;)		X	X	X	X	4
(Schrotenboer et al., 2017; Gue & Meller, 2009)		X			X	2
Henn, 2015			X	X	X	1
(Tang et al, 2011; Chackelson et al, 2013; Zhang et al, 2017)	X		X			3
Van Gils et al., 2018; ; Ene et al., 2012; ; Zulj et al., 2018; Albareda et al, 2009 ; Chen et al., 2015; De Koster et al, 2007 ;De Koster et al, 2012; Gademann & van de Velde., 2005 ; Gong & De Koster, 2008; Henn & Wäscher., 2012; Hong et al., 2016; Ling & Huang, 2011; Koch & Wäscher., 2016; Kulak et al., 2012; Chun et al, 2016 ; Matusiak et al., 2014; Matusiak et al., 2017; Schleyer & Gue., 2012 ; Valle et al. ,2017; Valle et al, 2020)		X	X			21
(Moeller., 2011; Scholz et al, 2016; Ho & Lin, 2017 ; Caron et al, 1998; Theys et al, 2010; De Koster et al, 2010 ; Scholz et al, 2016).		X		X		6
(Parikh & Meller, 2008; Chackelson et al, 2013; Zhang et al, 2017)			X	X		3
(De Koster et al, 2010 ;Bouleimen & Lecocq., 2003 ; Cano et al, 2020)		X	X	X		2
(Chackelson et al, 2013; Zhang et al, 2017)	X		X	X		2

Cano et al. (2020) introduced a mathematical programming model for the order batching and routing problem and a model for the batching, sequencing, and routing issue. For this purpose, they provided some formulas for the distance traveled and the pick time in the picking process in single-block and multi-block warehouses.

Moreover, Battini et al. (2017) focused on human communication and ergonomic parameters in OPS by noting that human operators manually perform most warehouse activities. This paper also emphasized that performance and cost are profoundly dependent on availability and productivity affected by operator fatigue.

A Pareto chart was also created to understand the effect of the assignment policy on the targeted activities to ultimately both provide a quantitative approach to integrate the rate of energy consumed at the estimated time for the entire OPS and introduce rest and unemployment time. On the other hand, Battini et al. (2016) proposed a new model for understanding the dual efforts of custom converters by highlighting the human capacities, the concept of time off, and unemployment. This article titled "Fatigue and Recovery" provided opportunities in an order-picking system. It is clear that the goal of OPS is not only to reduce costs but also to achieve better performance and overall benefits. Improving the performance of such a system can the advantage of human factors so that they receive more attention. In such a system, the operator preparation time is also considered to promote the picker efficiency and analyze the whole picking process.

Furthermore, various forms of assignment of the official and effective model in warehouse areas with comparative numerical capability have been developed. For example, in a study entitled "Maverick picking," Glock et al. (2016) argued that having sufficient curiosity for new issues such as modifying the workflows in customized picking is a significant challenge for most warehouse managers. The purpose of the above research was to describe the Maverick picking process, its executive roots, and shape to demonstrate its potential effect on the order picking process. In Franzke et al. (2017), the author developed an integrated model to improve ergonomic and economic performance in custom piking with rotary pallets. This study entitled "Order picking Routing in Warehouse: A Comparison between Innovative and Optimal Solutions" was conducted in a warehouse whose components were located on pallets in both upper and lower rows.

Additionally (De Koster & Van der Poort, 1998) aimed to find optimal order picking routes for two types of conventional warehouses in which pickers could operate in a central warehouse. This would be important since order picking is a centralized work process. Taking into account some concepts such as (First-come, First-served) (FCFS), some scholars have considered combined orders about the route and the order of picking items (De Koster et al., 2007). In another review, Pohl et al. (2009) investigated the control and design of an order-picking warehouse. The authors stated that picking is a centralized and costly activity for most warehouses. It should be mentioned that 55 % of the total warehouse costs are related to the order picking process. (De Koster, 2010). It also declared that this share would be allocated to optimal interior design, warehouse assignment methods, routing methods, order batching, and zoning. In the present study, we considered travel time as a distance-dependent item and stated that travel time increased by distance; thus, travel distance could be a significant goal in designing and optimizing order picking warehouses. Additionally, in warehousing-related literature, two types of travel distances have been used; 1) the average pick travel distance (or average travel length and 2) overall travel distance (Roodbergen & de Koster, 2001). In (De Koster et al., 2012), as shown in Fig. 9, the researcher showed the distribution percentage of order picking time types.

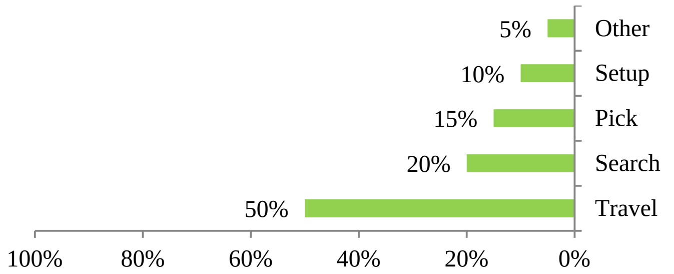

Figure 9. Distribution Percentage of Order picker Time Types

In De Koster et al. (2012), research was performed by determining the number of domains in a travel picking system and simultaneously sequencing from different regions with a group of custom pickers.

Moreover, a study entitled "Custom Warehouse Coordination and Production Planning in a Cabinet Production Factory" proposed a hybrid integer planning model for warehouse order picking coordination and production planning. Simulated analysis and optimization have also been provided by Ant Colony to ultimately reduce the overall duration of picking operations by pickers and increase the capacity of the pickings concerning orders (Öztürko & Hoser, 2019).

Another study entitled "a discrete channel design model for an order picking warehouse" attempted to develop a model to reduce the travel distance for picking operations, and thereby lowering the cost of operations. To this end, the concept of warehouse design with large discrete channels was introduced. There is a linear transverse corridor called a tunnel. An efficient algorithm is used to calculate the tunnel (Van Gils et al., 2018). In this article, research was conducted on how to increase the effectiveness of order pickings using integrated warehousing, branding, regional picking, and routing policy decision-making: Delivering parts on time reduces search time and component selection, also, in Ene & Öztürk. (2012), a study on the assignment of warehouse space and optimization of order pickings in the automotive industry, the assignment and order of the collection system was developed using mathematical modeling and random evolutionary optimization.

B. Performance measure

This section classified articles based on the performance measurement parameters to analyze the relationships between planning problems. Papers were also considered based on two tactical details and the details under consideration (Fig. 10).

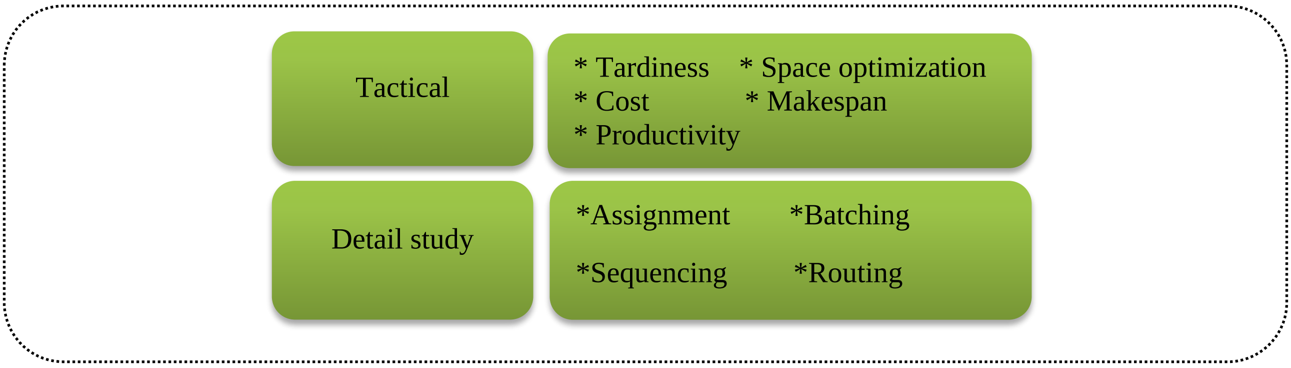

Figure 10. Study areas of the investigated articles

1) TARDINESS

This section assessed order picking performance using the performance index for peak and tardiness times (i.e., the difference between order completion time and order delivery time).

Table VII is an overview of tardiness minimization in the order picking process considered in selecting the literature. Accordingly, only assignment, routing, batching, and sequencing could affect tardiness minimization of the assumed goal. Table VII also shows nine research works aimed at tardiness minimization, five of which simultaneously investigated routing, batching, and sequencing.

Moreover, Table VII shows the works, which had focused on routing, batching, sequencing to minimizing the overall tardiness. Based on this Table, it can be seen that six out of nine research works aimed at tardiness minimization, three of which simultaneously studied routing, batching, and sequencing.

Table VII. Overview of the reviewed articles in minimizing Tardiness

Auditors	*Assignment*	*Routing*	*Batching*	*Sequencing*
(Sholz & Wäscher, 2017 ; Azadnia et al, 2013; Chen et al, 2015; Elsayed & Lee, 1996 ; Tsai et al, 2008)		X	X	X
(Henn, 2015 ; Elsayed et al, 1993)	X		X	X
(Henn et al., 2013)			X	X
(Roy, 2016)				X

Furthermore, in Scholz & Wäscher. (2017) stated that customer orders are due to the availability of a specific time to collect, prepare, and sequence the orders according to customer needs. Some works had also simultaneously studied the categories of assignment, batching, and sequencing. For example, Elsayed et al. (1993) considered the problems of sequencing and their effects on batching by considering components' assignment for the JIT technique in production control.

2) COST

The process of receiving materials and parts from the warehouse and preparing is the most costly activity in the intra-factory logistics system (Glock et al., 2016). Here, to decrease the warehousing costs, attention to past research reveals that order picking as one of the methods employed in an intra-factory logistics system contains more than 55% of the warehouse operating costs (Grosse et al., 2017).

Table VIII shows the focus of the studied articles on routing, batching, sequencing to minimizing the cost.

Table VIII. Overview of the reviewed articles in minimizing cost

Auditors	*Assignment*	*Routing*	*Batching*	*Sequencing*	*Tardiness*	*Others*
(Letchford et al ., 2013; Giannikas et al., 2017; Dallari et al., 2009; Cordeau & Laporte., 2007; Aghezzaf., 2007; Acimovic & Graves., 2014; Isler et al., 2016; Mowrey & Parikh., 2014; Neumann & Medbo., 2010; Petersen et al., 1999; Petersen., 2002)		X				
(Everett., 1963)	X					
(Pan & Wu., 2012)	X		X			
(Gong & De Koster., 2008)		X	X			
(Scholz et al., 2016)		X		X		
(Schrotenboer et al., 2017)		X			X	
(Won & Olafson., 2005)			X			
(Kaur & Kumar., 2011; Battini et al., 2016; Gupta & Kumar., 2012; Hart et al., 1968; Luo et al., 2016; Dagenais et al., 2008; Marche et al.,2012)						X

3) PRODUCTIVITY

Twenty-four further studies focusing on the goal of maximization of productivity were reviewed. The reviewed articles have pointed out that:

1. Small size orders are performed with a great variety of parts.
2. Some orders will affect the efficiency of the order picking process due to either the seasonality of the order, the intention of moving the order forward, or various delivery locations based on point-of-sale information.

Table IX shows an overview of the studied articles regarding the maximum productivity of the order-picking process.

Table IX. Overview of the reviewed articles in maximization of Productivity

Auditors	*Assignment*	*Routing*	*Batching*	*Sequencing*	*Tardiness*	*Others*
(Bahrami et al, 2017 ; Hong et al, 2015 ; Yu et al, 2015)			X			
(Hong., 2014 ; Lee & Geem., 2005 ; Pohl et al, 2009 ; Park & Kim., 2010 ; Schwerdfeger & Boysen., 2017)		X		-		
(Pan et al., 2015)				X		
(Grosse et al., 2015 ; Battini et al., 2017; De Vries et al., 2016; Gu et al., 2007; Kim & Moon., 2003; Lee et al., 1996; Cortes et al., 2017).						X
(Valle et al, 2017)		X	X			
(Clarke & Wright., 1964; Glock et al. 2016; Pan et al. 2015)	X	X				
(Parikh & Meller., 2008)			X	X		
(Scholz & Wäscher., 2017 ; De koster et al. 2007)	X	X	X			
(Elsayed & Lee., 1996)		X	X	X	X	

As can be seen in Table 9, most studies have focused on routing; however, in Elsayed & Lee. (1996), simultaneous research was performed on batching, routing, sequencing, and tardiness. Two Papers have simultaneously studied categories of assignment, routing, and batching to maximize the productivity in OPS.

4) SPACE OPTIMIZATION

De Koster et al. (2007) believed that OPS is one of the most challenging and costly activities of warehouses, leading to customer dissatisfaction if not done correctly. In the area of order selection, the installation of OPS facilities and equipment has been considered. Table X Shows the studies performed to optimize the space available for OPS.

Kübler et al. (2020) mentioned three problems: order assignment, order batching, and picking routing in the warehouse for quick order selection. This paper solved the problem in combination using an innovative iterative method.

Table X. Overview of the reviewed articles on Space optimization

Auditors	*Assignment*	*Routing*	*Batching*	*Sequencing*	*Tardiness*	*Others*
(Van Gils et al., 2018)					X	
(Geisser & Greenhouse., 1958)				X		
(Roy et al, 2012; Berglund& Batta., 2012)						
(Jewkes et al, 2004; Manzini et al, 2015)	X	X				
(Guo et al., 2007)		X		X		
(Gue & Meller., 2009)		X			X	

Continue Table X. Overview of the reviewed articles on Space optimization

Auditors	*Assignment*	*Routing*	*Batching*	*Sequencing*	*Tardiness*	*Others*
(Caron et al, 1998; De Koster et al, 2007 ; Ene & Öztürk, 2012; Kübler et al, 2020)	X	X	X			
(Matusiak et al, 2014; Cano et al, 2020; Valle et al, 2020)		X	X	X		
(Ratliff & Rosenthal., 1983; Roodbergen et al., 2015; Gong & De Koster., 2011; Geem., 2012; Marras et al., 1993; Muppani & Adil., 2008; Pohl et al., 2009; Rouwenhorst et al., 2000; Thomas & Meller., 2014; Andriansyah et al., 2001)						X

There were also 25 studies in this field, with four articles on assignment, routing, and batching simultaneously.

5) MAKESPAN

To minimize the order picking makespan, it is necessary to solve order batching simultaneously, assignment and pickers routing.

Regarding makespan minimization, according to Table XI, it is clear that most of the works are concurrent studies so that five papers were on the simultaneous analysis of the assignment, routing, and batching, one on the simultaneous analysis of assignment, routing, batching, and sequencing, one on the concurrent analysis of routing, batching, sequencing, and tardiness, and one paper on the concurrent analysis of sequencing, routing, batching, and performance tardiness. According to Table XI, it is also evident that in all studies, routing has been one of the most significant topics for researchers. There were only 23 research studies on routing that we will discuss in more detail in Table XI.

Table XI. Overview of the reviewed articles on Minimization of Makespan

Auditors	*Assignment*	*Routing*	*Batching*	*Sequencing*	*Tardiness*	*Others*
(van Gils et al., 2018)	X	X	X		X	
(Tsai et al., 2008)		X	X	X	X	
(Bouleimen & Lecocq., 2003)	X	X	X	X		
(Ene & Öztürk., 2012; DeKoster et al, 2012; Ling & Huang., 2011; Chun et al, 2016; Matusiak et al, 2017)	X	X	X			
(Chackelson et al., 2013)	X		X	X		
(De Koster et al., 2007)		X	X	X		
(Caron et al. 1998)	X	X		X		
(Hwang & Lee., 2004; Brynzer & Johansson., 1996; Dekker et al., 2004; Franzke et al., 2017; Grosse et al., 2017; Ramtin & Pazour., 2015 ;Yu et al., 2015)	X	X				
(Tang et al. 2011)	X		X			

Continue Table XI. Overview of the reviewed articles on Minimization of Makespan

Auditors	*Assignment*	*Routing*	*Batching*	*Sequencing*	*Tardiness*	*Others*
(Van Gils et al., 2018; Zulj et al., 2018; Albared et al., 2009; Cheng et al., 2015; Gademann & van de Velde., 2005; Henn & Wäscher., 2012; Hong et al., 2016; Koch & Wäscher., 2016; Kulak et al., 2012; Schleyer & Gue., 2012; Gademann et al., 2001; Scholz & Wäscher., 2017)		X	X			
(Moeller., 2011; Ho & Lin., 2017; Theys et al. 2010)		X		X		
(Parikh & Meller. 2008)			X	X		
(Glock & Grosse, 2012; Jane & Laih., 2005; Jarvis & McDowell., 1991; Kuo et al, 2016; Petersen et al, 2005)	X					
(Öztürko & Hoser., 2019; Teng & Hwang., 2017; Akilbasha & atarajan., 2018; Cortés et al., 2017; Roodbergen et al., 2008; Chabot et al., 2017; Chen et al., 2015; Clark & Meller., 2013; Davarzani & Norrman., 2015; Hall., 1993; Held & Karp., 1970; Helsgaun., 2000; MaLaporte., 1992; Lerher et al., 2015; Leung et al., 2018; Lu et al., 2016; Manzini et al., 2007; Marchet et al., 2012; Petersen et al., 1997; Petersen & Aase ., 2004; Roodbergen & de Koster., 2001; Volgenant & Jonker., 1982; Tappia et al., 2017)		X				
(Bozer & Kile., 2008; Cergibozan & Tasan., 2019)			X			
(Jane & Laih., 2005; Öztürkog et al. 2014; Yung & Chung., 2004; Calzavara et al. 2017; Ma et al. 2009; Park et al. 1999)						X

C. Measurement and Solution Methods

This section classified all the reviewed articles according to the solving methods used in the reviewed articles. Table XII shows the frequency of the solution methods used in the articles.

Table XII. Solving methods used in Studies

Solution methods	*Articles*	*Percentage*
Mathematical model	39	27.0%
Geometric matrix	3	2.1%
GA	9	6.4%
ACO	3	2.1%
VND	4	2.8%
VNS	7	5.0%
PSO	5	3.5%
Sequence optimization	1	0.7%

Continue Table XII. Solving methods used in Studies

Solution methods	*Articles*	*Percentage*
Other algorithms	33	22.0%
Simulation	30	21.3%
Fuzzy logic	4	2.8%
Graph	6	4.3%

According to Table XII, it can be seen that the mathematical modeling method has been the most commonly used solution in the research works, while the least used has been sequencing optimization. In this table, we have listed the use of statistical.

Table XIII. Solving Research Methods in Aspects of the Picking Process

Aspects / *Solution method*	*Assignment*	*Routing*	*Batching*	*Sequencing*	*Tardiness*
Mathematical model	X	X	X	X	X
Geometric matrix		X			
GA	X	X	X	X	X
ACO		X	X	X	X
VND	X	X	X	X	X
VNS	X	X	X	X	X
PSO	X	X	X	X	X
Sequence optimization		X		X	
Other algorithms	X	X	X	X	X
Simulation	X	X	X	X	X
Fuzzy logic		X			
Graph		X			
Statistical survey	X	X	X	X	X
Other Methods	X	X	X	X	X

Research works in the field of order picking, the use of statistical analysis methods, mathematical modeling, geometrical matrix, genetic algorithm, ant algorithm VND, VNS, PSO, and other algorithms, simulation, fuzzy, graph, and other methods. According to Tables XII and XII, it can be seen that most of the research works had focused on mathematical modeling with a 27% assignment percentage and other algorithms. Moreover, in the investigated research works, mathematical modeling, a variety of linear, nonlinear, integer, and dynamic models have been used. These models are, indeed, is a set of mathematical parameters and indicators related to the performance of process variables with several parameters. Besides, the simulation experiments for the behavioral analysis of processes and their numerical experiments were examined.

In this review article, papers on OPS published from 1958 to 2020 with scientific degrees shown in Table III and Fig. 5 were comprehensively studied. First, the articles, according to Table IV, examined the warehouses mentioned in the papers, and then it was found that parallel aisles with 27 were the most studied warehouses. Next, the picking order problems were investigated (Fig. 8 and Table V). Then, the combinations of picking order problems were surveyed (Table VI). Afterward, the objectives of the articles were addressed, and the reviewed articles were classified in terms of minimizing tardiness (Table VII). Moreover, those articles on cost minimization were addressed (Table VIII). Later, studies on maximum productivity and storage space improvement were addressed (Table IX and X, respectively). Finally, the objectives of articles on minimizing makespan were provided (Table XI). In the following, the research methods used in the reviewed papers were presented in Table XII, and the methods used were classified according to the order-picking problems in Table XIII.

VI. Results

The results of this review study revealed the importance of integrating the problems related to multi-objective picking planning to effective management of order picking operations. The results indicated that the time horizon of decisions could significantly affect the proper approach to solving the hybrid planning problems. On the one hand, issues can be combined by analyzing the interactions between predetermined policies specific to each planning problem. On the other hand, two or more planning problems can be integrated and solved.

Fig. 2 and Table VI present an overview of the approach implemented in most articles intended to solve any combination of picking planning problems, as well as the number of articles that analyze each combination. Regarding the first research question, Figure 8 and Table V show that in the order picking area, a combination of planning problems, such as cost/equipment/warehousing/ assignment, routing, batching, sequencing, and tardiness, have been considered.

In this matter, it was found that the most studied issue (about 112 articles) had been related to routing; in comparison, tardiness had received the least attention with ten articles, indicating that researchers' tendency towards studying the issue of routing compared to other aspects of picking operations. Through investigating the order picking problems in the articles (based on Table VI), it was found that most of the combined studies had been on routing and batching with 21 works, followed by assignment and routing with 18 cases. This reflected the fact that the research base in the order picking area is routing. One of the crucial points in the picking process improvement is the integrated review of all aspects of the picking process. For example, there are two studies on the categories of assignment, classification, and sequencing (Chackelson, 2013; Zhang et al., 2017), and two studies on the categories of assignment, batching, sequencing, and tardiness (ELSAYED, 1993; Henn, 2015) (see Table VI). As can be observed in Table IX, most studies have focused on routing to increase productivity. However, Elsayed & Lee (1996) explored a concurrent survey on batching, routing, sequencing, and tardiness and two simultaneous studies on batching, assignment, and routing to maximize the productivity in OPS (Scholz & Wäscher., 2017; De Koster et al. 2007).

De Koster et al. (2007) believed that OPS is one of the most costly and challenging warehousing activities that could lead to customer dissatisfaction if it is not properly performed. Moreover, in terms of order picking, the installation of OPS facilities and equipment has been considered. On the other hand, different combinations of picking problems have been utilized to improve storage space (Table X) and minimize the makespan (Table XI). In addition, According to the fields of study, the articles reviewed in this work can be approached in terms of either tactic or component.

The reviewed literature observed three types of articles: Articles presenting new approaches and methods in the picking process, reviewer articles, and articles focusing on the components of the order-picking process. The classification of these studies helps warehouse managers differentiate between planning problems, become aware of the minimum combinations used, and detect which planning problems should be simultaneously considered.

The warehouse is one of the main internal logistic components in any manufacturing company and plays a critical role in organizations' supply chains. Among the considered activities in the warehouse, the order picking process (production lines) has a special place in studies as a process of preparing parts in stock to satisfy customers' needs.

It should be mentioned that 60% of all activities and 55% of costs in the warehouse include the order picking process (De Koster, 2010). The parts warehouse activities, such as receiving parts, warehousing, order classification, and transportation along with production lines, are critical in any internal supply system (Van Gils, 2018). Considering the third research question of the present study, Fig. 6 shows that one of the main uses of a cross-dock warehouse is to route the picker in cross aisles. Therefore, it is necessary to assign routes to reduce picker travel in a warehouse and decrease the number of visits to the block by passing the aisle.

In the previous studies, a classification of the warehouses can be seen. In Table IV, it is obvious that parallel-aisle warehouses were the most studied warehouses. The classification of these studies helps warehouse managers differentiate between planning problems, determine the least-used combinations, and specify which planning problems should be simultaneously considered.

VII. CONCLUSION

Newmarket developments such as e-commerce, globalization, rising customer expectations, and new market regulations have forced warehouses to handle more orders in less time. In this matter, awareness of the impact of individual planning on picking planning for performance management and thus increasing customer service are required in overall performance. In this paper, studies, which have highlighted the picking process's main issues, were classified by reviewing the literature.

By focusing on planning problems that affect an economic goal, such as time-related performance or productivity indicators, problems are investigated as these goals are the most important warehouse operations. In this paper, regarding a combination of order-picking planning problems, articles reviewed by analyzing different tactical and operational planning problems simultaneously were classified to determine which planning problems are related, how various individual planning issues are related, and how can warehouse managers take advantage of the combination of multi-objective planning problems to cope with new market developments. The obtained results confirmed that all planning problems have to be incorporated due to different time horizons of decisions made one after another. At the operational level, there is still a need to integrate more planning problems and calculate the real-world features. Based on Fig. 8, planning problems are identified. In this figure, the classification of the issues surveyed indicates tardiness in the least number of articles.

For example, tardiness, which is critical to show commitments to the customers, has been studied in 10 cases in the picking process. The routing problem has been investigated in 112 cases, indicating a lack of attention to challenging programs of customers in terms of simultaneous tardiness and routing. The analyses also revealed some innovative methods had been proposed to obtain suitable solutions. As different industry managers look for ideal, simple, intuitive, and reliable solutions, cost reduction solutions are suggested in the order picking process. Furthermore, based on Table V, there are 112 studies on routing, 76 studies on storage space, 51 studies on cost, 36 studies on batching, 39 studies on assignment, 23 studies on sequencing, and ten studies on tardiness, indicating an insufficient balance between in decision-making variables about planning problems as well as a tendency towards more studies about routing and storage space at a higher speed than other aspects. Additionally, taking the 51 articles on cost minimization, it is clear that this issue has not been sufficiently surveyed.

It should be noted that cost reduction includes a wide range of issues, one of which is tardiness that can reduce costs. According to Table XII, it can be observed that the most common solving method used in the literature is the mathematical modeling method; in contrast, the least common one is the sequence optimization method.

Concerning the literature and methodologies of research works carried out in the area of order picking, it was found that statistical analysis methods, mathematical modeling, geometric matrix, genetic algorithm, ant algorithm, Variable Neighborhood Descent (VND) algorithm, variable neighborhood search (VNS) algorithm, Particle swarm optimization (PSO) algorithm, other algorithms, simulation, fuzzy, graph, and other methods have been significantly employed. Base on Table XII, it can be observed that most of the research works have emphasized mathematical modeling with a 27% allocation percentage and other algorithms.

Furthermore, based on Tables XII and XIII, mathematical models have been mainly used for routing and assignment problems to explore the aspects of the picking process simultaneously. This reflects that the majority of researchers have tried to minimize distance in order to reduce cost and time, mainly because routing is metric and calculable. Moreover, at the operational level, there is still a need to integrate more planning problems and calculate the real-world features.

Despite the importance of human resources in the warehouse environment, a small number of articles have evaluated the labor planning problems, such as determining the daily labor force level, assigning the labor in order picking areas, and assigning jobs to pickers.

It should be further noted that as the warehouses offer multiple services to customers, the availability and performance of human resources ensure the quality of service to customers and the performance of order picking. For instance, determining the level of the workforce combined with the assignment of order pickers and the planning problem makes focusing on the number of pickers a challenging opportunity for future research. Previous studies have mainly focused on reducing order picking time. Working in an atmosphere with increasing pressure and limited time raises the likelihood of selection errors. In recent years, the number of articles analyzing multi-objective picking planning problems has risen dramatically. Nonetheless, currently, research works are mostly on storage location, order batching, and routing. At the tactical level of picking a problem, little attention has been paid to research. Previous studies not only have combined planning problems but have also simplified the order collection systems. The results developed in this paper indicated the need for more research on the congestion of warehouse aisles and the combination of picking operations problems in the future.

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