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Generalized Bin Packing and Related Problems: A Systematic Literature Review

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Abstract:

Purpose: This systematic review aims to critically evaluate the literature on the Generalized Bin Packing Problem (GBPP) and related problems, with an emphasis on their practical applications in logistics, manufacturing, and transportation.

Design/methodology/approach: We reviewed recent papers published over the last eight years, from 2016 to January 2024, and systematically classified them based on the methods, techniques, models, and frameworks they employed. The studies are related to Operations Research, Engineering, Business, Manufacturing, or closely associated fields.

Findings: The primary goal of our Systematic Literature Review (SLR) is to identify thematic areas addressed by recent research on the GBPP and its associated challenges. Notably, only 1.7% of the reviewed articles incorporate sustainability considerations. Packaging is another underexplored area although mentioned in several studies, few focus on optimizing packaging dimensions to facilitate palletization and improve space utilization.

Originality/value: This article presents a comprehensive review of the literature on the Generalized Bin Packing Problem (GBPP) and related problems. We analyzed the distribution of publications by keyword, country, author and the quality of the papers. Our findings highlight the generality of the GBPP, as it encompasses various types of packing, cutting, and knapsack problems. We provide an in depth categorization of the GBPP and related problems based on problem type, solution techniques, and optimization criteria.

Keywords: generalized bin packaging problem, heuristic & metaheuristics algorithms, mixed-integer programming (MIP), linear programming (LP), multi-criteria optimization

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1. Introduction

The Generalized Bin Packing Problem (GBPP) is a modern extension of the traditional Bin Packing Problem (BPP), integrating related challenges such as cutting, pallet loading, and logistics. Its versatility arises from the diverse characteristics of both items and bins, and it allows for both mandatory and optional item selection. The GBPP unifies bin packing, cutting, and knapsack problems within a single modeling framework, highlighting their interconnections (Baldi, Crainic, Perboli & Tadei, 2012).

2. Systematic Literature Review (SLR)

A Systematic Literature Review (SLR) was conducted to address research questions related to the Generalized Bin Packing Problem (GBPP) and its associated challenges. Our objectives include analyzing thematic areas, mapping the overall research landscape, and identifying trends by publication and year. We aim to uncover research gaps and underexplored topics or fields to guide future investigations. In addition, we examine which countries have the most publications, analyze keyword co-occurrence, and assess the extent of cross-citations among authors in the final set of selected articles. Finally, we evaluate the quality of each paper.

The main purpose of an SLR is to systematically collect, analyze, and synthesize existing research on a specific topic or field. By following a structured approach, SLR provides a comprehensive understanding of current knowledge, highlights research gaps, and offers insights for future studies. It ensures that researchers gather high-quality, relevant studies, thereby minimizing bias and improving the reliability of conclusions. This method not only validates existing findings but also supports evidence-based decision-making in scientific, academic, and professional contexts. According to Fink (1998), a literature review is "…a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents." This review follows the classical four-step methodology (excluding the planning step), as outlined below:

Material Collection: Literature was reviewed from various sources (WoS, Scopus, Google Scholar) and screened according to defined selection criteria.

Descriptive Analysis: The extracted materials were analyzed, and duplicates were removed.

Material Selection: Abstracts were reviewed to exclude articles that were outside the scope of the review.

Material Evaluation: The selected materials were critically analyzed to identify key insights, issues, trends, and opportunities.

The Mapping in Literature Reviews technique (also known as Literature Mapping) is a valuable tool for brainstorming and scoping research. In this study, we analyze key aspects such as keywords, search rules (e.g., "AND", "OR"), and databases used. The review covers literature published from 2016 through January 2024. Boolean operators "AND" and "OR" are employed in the search process (Kwon, Kim & Kim, 2021).

Inclusions Criteria (IC)

IC1: The articles and books propose various solutions, including methods, techniques, models, tools, and frameworks.

AND

IC2: The articles and books were selected based on their application to the GBPP, using keywords such as Bin Packing, Loading, Optimization, Pallet Loading, MPLP-DPLP, Cutting, Packing, Heuristic, Sustainability, and combinations of these terms using Boolean operators (e.g., Loading "AND" Optimization and all other possible "AND" pairings).

AND

IC3: The selected papers and books are applied to fields such as Operations Research, Mechanical Engineering, Engineering Optimization, Production Engineering, Business Administration, Industrial Engineering, Materials Science and Engineering, the Manufacturing Industry, Mathematics and Statistics, Computers and Industrial Engineering, Management Science, and Computers and Operations Research.

AND

IC4: The papers and books are written in English

AND

IC5: The papers and books are documented in peer reviewed Workshop or Conference or Journal.

The study identification and selection process is presented in Figure 1 following the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) 2020 reporting guidelines. This flow diagram provides a comprehensive overview of the systematic approach used to locate, screen, and select studies for inclusion in the review, thereby ensuring methodological transparency and enabling readers to assess the rigor of the literature search strategy (Page, McKenzie, Bossuyt, Boutron, Hoffmann, Mulrow et al., 2021).

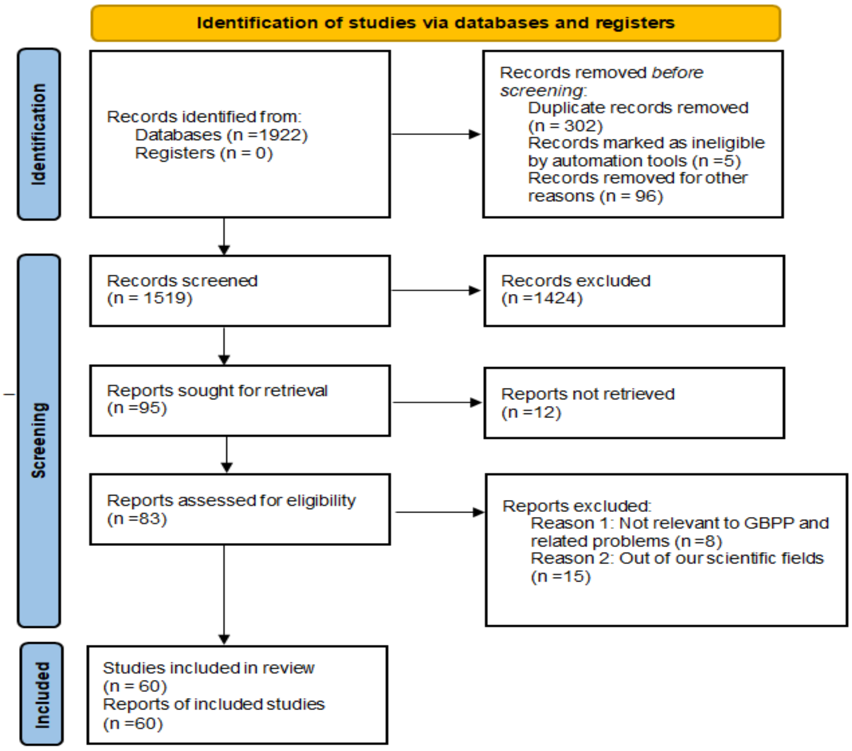

Figure 1. PRISMA 2020 flow diagram (Page et al., 2021)

The selection process began with 1,922 records identified from databases. After removing 403 records due to duplication, automation filtering, or other reasons, 1,519 were screened, with 1,424 excluded at this stage. Of the 95 reports sought for retrieval, 12 could not be accessed and 23 were excluded based on relevance or scientific scope, resulting in 60 studies included in the final review.

3. The Generalized Bin Packing Problem (GBPP)

3.1. Description of GBPP

The Generalized Bin Packing Problem (GBPP) involves allocating items to bins under multiple constraints, such as size, value, and cost. Items may be classified as either mandatory or optional, while bins differ in type, capacity, and associated costs. The primary objective is to minimize the total cost by balancing the cost of selected bins with the potential profit derived from including optional items. Unlike classical bin packing problems, the GBPP extends beyond simple volume constraints to include one-, two-, or three-dimensional spatial configurations. Item value may vary based on attributes such as material composition for example, gold and silver items of equal size may yield different profits. Similarly, bin costs can vary by material even when offering the same capacity. The GBPP seeks to optimize resource allocation by identifying the most cost-effective configuration of items and bins.

Figure 2 illustrates a representative instance of the one-dimensional Generalized Bin Packing Problem (GBPP). In the upper left quadrant, we observe the set of compulsory items, characterized by a uniform material composition and associated with profit values that are directly proportional to their lengths (e.g., 3, 6, 10, 12). The lower left quadrant presents the non-compulsory items, which differ in material type (denoted by color) and are assigned profit values independently of their length (e.g., 2, 5, 9, 11). Consequently, items of identical size may exhibit distinct profit values, as illustrated by the pair (length = 9, profits = 9 and 11). The upper right quadrant specifies the available bin capacities (e.g., 8, 13, 17), which serve as constraints in the packing process. Finally, the lower right quadrant displays an optimized packing configuration, wherein all compulsory items are successfully allocated to the available bins, while a selective subset of noncompulsory items is included in a manner that maximizes the overall bin utilization or objective function typically profit or total packed volume subject to the capacity constraints.

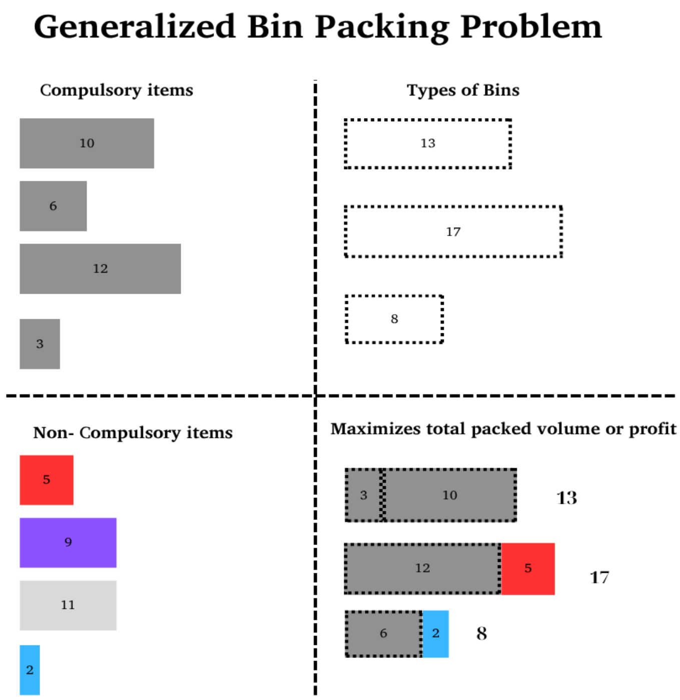

Figure 2. A typical example of the Generalized Bin Packing Problem (GBPP)

3.2. Formulation of the GBPP

GBPP optimally assigns objects, defined by volume and profit, into bins characterized by volume and cost. Volume is generalized across one, two, or three dimensions, meaning objects or bins of equal volume may differ in cost or profit due to material, density, or other properties.

Items are classified as compulsory (must be packed) and noncompulsory (optional). The goal is to minimize the total net cost, defined as the difference between bin costs and optional item profits. Since compulsory items must always be packed, their profit is constant and excluded from the objective function.

Define S be the set of items, where w_i and p_i are volume and profit of item $i \in S$. Define $S^C \subseteq S$ as compulsory items and S^{NC} as non-compulsory items. Let J be the set of bins and B the set of bin types, where each bin type $\beta \in B$ has an upper U_β and lower L_β usage limit, cost C_β, and volume W_β. The total available bins cannot exceed U.

Problem constraints:

1. All compulsory items (S^C) must be packed.
2. Bin volume cannot be exceeded.
3. Each item is assigned to only one bin.
4. The number of bins used per type must be within L_β and U_β.

5. The total number of bins cannot exceed U.
6. No bin is mandatory.

If bins are insufficient, an artificial bin v is introduced, large enough to hold all compulsory items, with a prohibitively high cost to discourage its use (Baldi et al., 2012).

Decision Variables:

- y_j = 1 if bin j is used, 0 otherwise.
- x_{ij} = 1 if item i is assigned to bin j, 0 otherwise.

The objective function minimizes net cost, aligning GBPP with Cutting and Knapsack problems. Constraints ensure valid packing, restrict bin usage within limits, and enforce integer decision variables (Baldi et al., 2012).

3.3. GBPP and related problems

The Generalized Bin Packing Problem (GBPP) includes both compulsory and optional items and extends across one-, two-, and three-dimensional spaces. Packing problems aim to load items into bins while minimizing overall costs. These problems are typically categorized into two types: Packing and Cutting problems, in which all items must be packed, and Knapsack problems, where item selection is optional.

- Cutting problems involve dividing standard sized materials into smaller pieces to meet specific demand requirements.
- Packing problems focus on arranging items within bins, like cutting problems but governed by different spatial or constraint-based considerations.
- Knapsack problems aim to maximize profit by selecting a subset of items that fit within defined capacity limits.

These problems are closely related to packing an item is conceptually like cutting it from stock, which allows for shared solution methods (Iori, De-Lima, Martello, Miyazawa & Monaci, 2021). For example, in cutting problems, bins represent raw material sheets, whereas in packing problems, they represent containers. Some applications, such as strip packing, involve containers with infinite height.

Stochastic GBPP Variants:

1. Item property stochasticity – Variability in weight, resistance, temperature, and durability.
2. Item arrival stochasticity – Items arrive sequentially, requiring immediate placement (e.g., Amazon order fulfillment).

GBPP also generalizes Knapsack Problems, Multiple Knapsack Problem, Multiple Knapsack Problem with Identical capacities (KP, MKP, MKPI):

- KP maximizes item value within a single knapsack's capacity.
- MKP extends KP to multiple knapsacks.
- MKPI restricts all knapsacks to equal capacity.

GBPP addressed by stochastic settings			
VCSBPP	OVCSBPP	S-GBPP	OGBPP
Variable Cost and Size Bin Packing Problem	Online Variable Cost and Size Bin Packing Problem	Stochastic Generalized Bin Packing Problem	Online Generalized Bin Packing Problem

Table 1. GBPP addressed by stochastic settings

GBPP addressed by the Bin Packing literature					
BPP	**VSBPP**	**BPRC**	**VCSBPP**	**MKP**	**MKPI**
Bin Packing Problem	Variable Sized Bin Packing Problem	Bin Packing with Rejections	Variable Cost & Size Bin Packing Problem	Multiple Knapsack Problem	Multiple Knapsack Problem with Identical capacities
CSP	**VSCSP**	**CSRC**	**VCSCSP**		
Cutting Stock Problem	Variable Sized Cutting Stock Problem	Cutting Stock with Rejections	Variable Cost & Size Cutting Stock Problem		

Table 2. GBPP addressed by the Bin Packing literature

Other GBPP variants exist but are beyond this study's scope (Baldi et al. 2012).

3.4. Key Findings of the SLR

Our Systematic Literature Review (SLR) examined the Generalized Bin Packing Problem (GBPP) and related problems using keywords defined in the Inclusion Criteria (IC). The review was structured as follows:

- Problem Type: Problems were classified based on references from the literature, including the Generalized Bin Packing Problem (GBPP), Packing, Cutting, Loading, Pallet Loading, the Manufacturer Pallet Loading Problem (MPLP), the Distributor-Pallet Loading Problem (DPLP), the Container Loading Problem (CLP), the Knapsack Problem, and their respective subcategories (see Tables 1 and 2).
- Solving Techniques: Problems were categorized based on the solution methods used, including linear programming, mixed-integer programming, heuristics, metaheuristics, neural networks, and genetic algorithms.

3.5. Optimization Criteria

Each problem and technique focused on optimizing key factors such as cost reduction, maximizing container utilization, minimizing queue lengths, enhancing sustainability, improving route efficiency, reducing operation time, addressing industrial constraints, and minimizing material waste in cutting processes.

4. Main Literature Review by Keywords and Structure Analyses

4.1. Packing

To begin, Haouari and Mhiri (2024) tackle the 1D bin packing problem with a concave cost function, emphasizing cost minimization rather than bin usage. They introduce a threshold-based heuristic that halts once improvements become negligible. While the approach is efficient, it may underperform in scenarios with complex cost landscapes. In a related study, Ao, Zhang, Li and Jin (2023) address a practical packing challenge by clustering order items and assigning them to bins using feedback driven neural network and heuristic procedures. Their model enhances adaptability and reduces computation time, though it depends heavily on the quality of neural training and the logic behind item grouping. Moreover, Almasarwah, Abdelall, Suer, Egilmez, Singh and Ramadan (2023) consider pallet stability under variable humidity and storage duration. A two-phase heuristic determines the loading pattern and stack height, contributing to warehouse safety. However, its performance is sensitive to changes in environmental conditions and input variability.

Expanding to 3D irregular packing, Lamas-Fernandez, Bennell and Martinez-Sykora (2023) propose a voxel-based strategy, using metaheuristics like tabu search to optimize space utilization. While their method achieves high spatial precision, it can be computationally intensive for dense packing instances. In another notable contribution, Hawa, Lewis and Thompson (2022) develop a heuristic based on Hamiltonian cycles to optimize carton layout in 1D packing with cutting constraints. Their solution integrates geometric rules effectively, though it may not generalize well to 2D or 3D variants. Focusing on dual perspectives, Silva, Coelho, Darvish and Renaud (2022) present two algorithms that treat 2D circular packing as both a cutting and packing problem. This dual framing enhances problem versatility but is limited to circular geometries. Further, Gardeyn and Wauters (2022) solve the 2D variable-sized BPP with guillotine constraints using a ruin and recreate heuristic. The model accounts for item rotation and bin heterogeneity but relies heavily on heuristic tuning for optimal performance. In the domain of e-commerce logistics, Vieira, Ferreira, Duque and Almeida (2021) address footwear packing by optimizing box sizes and minimizing pallet volume. A nonlinear to linear transformation accelerates computation, but the model is largely tailored to shoe orders. Turning to multi-objective optimization, Erbayrak, Özkır and Yıldırım (2021) introduce the concept of "object families" in 3D BPP, employing MILP to simultaneously address bin usage, placement stability, and delivery grouping. The framework is comprehensive, but competing objectives may limit its scalability. Providing a broader perspective, Iori et al. (2021) review 2D packing techniques, highlighting decomposition methods and constraint integration. While not systematic, their review offers meaningful insights for researchers dealing with added constraints. In a different context, Goldberg and Karhi (2019) propose an online heuristic for packing two item types into specialized and multipurpose bins with varying cost ratios. Their method is simple and fast but lacks flexibility for more heterogeneous item sets. In the same year, Braune (2019) addresses 1D BPP with linear cost functions, prioritizing the packing of high-cost bins. The method is intuitive but relies on a strict cost-size correlation that may not always reflect practical realities. For irregular 2D layouts, Sato, Martins, Gomes and Tsuzuki (2019) use a raster grid and iterative compression to achieve compact arrangements. The method is effective for polygonal items, though its computational burden increases with finer grid resolutions.

In an evolutionary framework, Hu, Wei and Lim (2018) propose a mimetic heuristic incorporating genetic elements like mutation, swapping, and selection to optimize 2D object placement under cost and capacity constraints. While powerful, the algorithm is complex to fine-tune. Specifically targeting aeronautics, Zudio, Da-Silva-Costa, Masquio, Coelho and Pinto (2018) combine BRKGA and VND to solve 3D BPP, improving box sorting efficiency in confined volumes. Their solution is effective for specialized domains but may be less generalizable. For complex shapes, Romanova, Bennell, Stoyan and Pankratov, (2018) introduce a nonlinear compression model for 3D hollow polyhedral objects, preserving minimal spacing between items. The approach achieves high-quality results but is computationally expensive. Addressing fragile items, Paquay, Limbourg and Schyns (2018) develop a two-phase 3D packing method that restricts fragile objects to the top layer. It ensures structural protection but sacrifices space efficiency. Focusing on sheet packing, Abeysooriya, Bennell and Martinez-Sykora (2018) use the Jostle algorithm to handle 2D irregular strip packing, allowing object reallocation to minimize waste. Though well-suited for cutting applications, the method depends on effective gap management. In earlier work, Martinez-Sykora, Alvarez-Valdés, Bennell, Ruiz and Tamarit (2017) apply MIP and metaheuristics to 2D irregular BPP, leveraging rotation and permutation to reduce bin usage. The method is robust but computationally intensive. From a graph-theoretical angle, Rodrigues and Toledo (2017) model irregular strip packing using a clique covering MIP and dot-grid structure. While powerful for precise packing, scalability remains a challenge. In a systems level approach, McDonald (2016) integrates packing with logistics using MILP, minimizing transportation, storage, and handling costs. The model captures real-world complexities but requires extensive calibration. Finally, Männel and Bortfeldt (2016) combine vehicle routing and 3D packing in a hybrid model, balancing travel efficiency and reloading effort. While flexible, the solution time may grow substantially with problem size.

4.2. Cutting

Terán-Viadero, Alonso-Ayuso and Martín-Campo (2024) present a 2D cutting stock model in the cardboard roll industry using MIP to minimize waste. Their method supports execution of up to 20 item sizes across flexible roll widths. While effective in multi-order environments, the model's performance may vary with industrial constraints. Additionally, Guimarães and Poldi (2023) propose a joint model for the Cutting Stock with Limited Open Stacks Problem and the Tool Switches Problem. Their LP based solution balances pattern grouping and cutting sequences under stack and tool-switching constraints. While promising waste reduction, performance may degrade under excessive pattern diversity. Furthermore, Xu and Yang (2022) address a real-world steel cutting problem using a hybrid genetic algorithm and heuristics. Their method incorporates multiple factors like shear changeovers, order sizes, and waste, achieving computational balance but requiring precise parameter tuning. In another contribution, Parreño and Alvarez-Valdés (2021) present a linear programming approach for cutting glass sheets, accounting for production defects, object rotation, and trim constraints. The model permits up to three guillotine cuts but may be less flexible in high precision environments. Moreover, Martin, Oliveira, Silva, Morabito and Munari (2021) investigate 3D guillotine cutting under industrial constraints, using heuristics that incorporate stage sequencing and object orientation. Their method enhances efficiency but assumes full control over object placements.

In a comprehensive review, Kwon et al. (2021) explore waste minimization in reinforced concrete production. Using genetic algorithms, coil techniques, and rebar meshes, they highlight significant reductions in cutting waste and CO_2 emissions, although their findings are specific to construction contexts. Similarly, Wu and Yang (2021) introduce the Iterative Sequential Heuristic Procedure (ISHP) for 2D guillotine cutting. By combining two- and three-stage methods, their algorithm performs competitively, though improvements depend on layout complexity. In a more specific application, Parreño, Alonso and Alvarez-Valdés (2020) tackle glass strip cutting under defect constraints using a heuristic beam search. Despite innovative features like reusable areas, the results were generally less effective compared to established models. Introducing a novel problem, Durak and Tuzun-Aksu (2021) define the Bun Splitting Problem (BSP), proposing a dynamic programming algorithm to optimize partitioning of baked goods trays. Their adaptable approach may extend to other sectors, although it assumes structured defect locations. With a graph theoretical approach, Silva, Oliveira, Oliveira and Toledo (2019) address cutting path optimization via RPP and TSP formulations. The presence of shared edges significantly boosts computational performance, though geometry constraints may limit broader applicability.

In another heuristic-based study, Clautiaux, Sadykov, Vanderbeck and Viaud (2019) propose branch and price methods for the 2D guillotine cutting-stock problem with leftovers. Their integration of dynamic programming supports pattern rotation, though setup complexity may pose challenges. Likewise, Wuttke and Heese (2018) develop a mixed integer programming heuristic for 2D fabric cutting. Their model optimizes knife arrangements and repositioning over full production cycles, with high realism but increased computational demands. To further reduce complexity, Huang, Lu, Wang, Chang and Gao (2020) reformulate the 2D flow problem using a logarithmic model that restricts large-object consideration. This speeds up computation significantly but narrows generalizability. Finally, Huang, Wang and Fang (2017) address LCD film cutting via heuristics for slit and strip cutting, balancing efficiency with production cost. The method incorporates cutting angles but is tightly bound to material-specific constraints.

4.3. Pallet Loading

In a specialized case of the pallet loading problem, Calzavara, Iori, Locatelli, Moreira and Silveira (2021) introduce a unique approach that incorporates both contiguity and visibility constraints. Items are first grouped based on height and weight similarity, then arranged layer by layer on the pallet. Within each layer, objects from the same or similar groups are placed to ensure full surface coverage. Crucially, the layout respects the requirement that identical items remain contiguous, while at least one object from neighboring groups remains externally visible. To achieve this, the authors employ a combination of heuristic (ERH) and metaheuristic (GRASP-GREP) algorithms. While effective for structured grouping and visibility control, the approach may face limitations when applied to highly heterogeneous item sets.

In a complementary direction, Arun-Prasad and Krishnakumar (2021) propose a second order for non-guillotine block heuristics to extend traditional block type Palleti loading strategies, such as MPLP and DPLP. Their method allows the formation of blocks containing up to six different items of equal height, without requiring homogeneity. These blocks are generated around a spawn area centrally located in the shape of an irregular hexagon. The model enhances flexibility in pallet design but may introduce complexity in ensuring balanced load distribution and structural stability.

4.4. Manufacturer's Pallet Loading Problem (MPLP)

Building on pallet loading strategies, Aljuhani and Papageorgiou (2021) propose a methodology for the Manufacturer's Pallet Loading Problem (MPLP) that achieves results superior to previous approaches. Central to their method is the concept of "blocks" groups of boxes sharing identical dimensions and orientations. These blocks facilitate more efficient loading and unloading operations, whether manual or robotic. The block-based structure enhances pallet space utilization and significantly reduces computational time. The approach consistently outperforms earlier algorithms, though its reliance on block uniformity may limit flexibility for mixed size product sets.

4.5. Distributor's Pallet Loading Problem (DPLP)

Addressing practical challenges in distribution logistics, Gzara, Elhedhli and Yildiz (2020) introduce a methodology for the Distributor's Pallet Loading Problem (DPLP) that emphasize loading safety over space optimization. Their approach prioritizes pallet stability by enforcing structural constraints such as preventing overhang and maintaining lateral integrity across layers. Specifically, each box must be supported by at least 70% of the area below it, and a defined portion of the pallet perimeter must be covered at every level. Unlike conventional strategies focused on maximizing pallet utilization or minimizing pallet count, this model shifts emphasis toward ensuring structural robustness and transport reliability, albeit with a trade-off in volumetric efficiency.

4.6. Container Loading

At the forefront of recent research, Gimenez-Palacios, Alonso, Alvarez-Valdés and Parreño (2023) present a hybrid LP and heuristic methodology for container loading that incorporates practical constraints such as order splitting, pallet stability, and fixed spatial positioning. Their decomposition-based approach enhances delivery alignment, though it deprioritizes minimizing container count. In a related advancement, Gajda, Trivella, Mansini and Pisinger (2022) introduce the Randomized Constructive Heuristic (RCH), which forms weighted 2D item blocks for efficient 3D assembly. By accounting for unloading sequence and load balance, their algorithm outperforms commercial tools in both runtime and capacity utilization. Focusing on non-standard geometries, Romanova, Stoyan, Pankratov, Litvinchev, Plankovskyy, Tsegelnyk et al. (2021) address a variant of the container loading problem involving cylindrical containers and irregular 3D items. Their nonlinear programming model uses the phi-function to maintain object spacing and weight distribution across cylindrical planes. To enhance structural integrity in packing, Da-Silva, Leão, Toledo and Wauters (2020) propose the SLOPP framework, an innovative metaheuristic that assembles homogeneous or semi-homogeneous blocks into modular structures. With an average volumetric efficiency of 90%, it excels in both stability and real-world applicability. Pursuing dual optimization goals, Araya, Moyano and Sanchez (2020) develop a beam search method that simultaneously maximizes container volume and loading profit. Their algorithm leverages VCS and VPD metrics, achieving superior outcomes compared to prior approaches.

From a logistics planning angle, Wang, Ni, Gao, Shen, Jia and Yao (2019) present a linear programming model that decomposes the container loading and transportation scheduling problems. Real-case validation with multiple container sizes and delivery points confirms the model's operational relevance. For compartmentalized loading, Ranck-Júnior, Yanasse, Morabito and Junqueira (2019) design a MIP-based heuristic where containers are divided into uniform-height levels. Their method adheres to key constraints on vertical strength and load stability. On the operational efficiency front, Jozefowska, Pawlak, Pesch, Moeze and Kowalski (2018) proposes a fast, heuristic MIP solution for loading up to five box types. Their model ensures stability and strength while maintaining execution times under two minutes. Addressing container rearrangement in ports, Tanaka and Tierney (2018) explore the pre-marshalling problem using a tree-search heuristic. They optimize container sequencing with gantry cranes to meet carrier-specific loading orders. With a staged approach to irregular packing, Wu, Leung, Si, Zhang and Lin (2017) presents a heuristic that first selects cartons, then consolidates them into crates, and finally loads them into containers maximizing fullness at each stage. Incorporating delivery deadlines, Sheng, Xiuqin, Changjian, Hongxia, Dayong and Feiyue (2017) develop a tree-based heuristic that builds stable walls during 3D container loading, prioritizing time-sensitive orders while maintaining structural coherence. Expanding to multi-container scenarios, Alonso, Alvarez-Valdés, Iori, Parreño and Tamarit (2017) introduce a comprehensive MCLP model that incorporates symmetry, pallet stacking, weight balance, and seven subproblems. Their combined LP and heuristic method achieve fast and feasible results. For simplified dimensional problems, Araya, Guerrero and Nuñez (2017) presents a 1D beam search algorithm that constructs larger blocks from prioritized items. Their heuristic balances completeness and overhang coverage to optimize space use. Addressing heterogeneous packaging, Correcher, Alonso, Parreño and Alvarez-Valdés (2017) apply a GRASP-based method for multi-bin loading. Their two-phase heuristic considers material grouping and layer completeness, outperforming alternatives in solution speed.

To solve the CLPIB, Sheng, Hongxia, Xisong and Changjian (2016) combines the QTS and GIB heuristics to first fill pallets and then address container voids with infill boxes. Their method demonstrates superior efficiency, even under complex constraints. Finally, Huang, Hwang and Lu (2016) propose a hybrid MILP and heuristic strategy that uses precomputed loading patterns and object motion techniques. While highly efficient for small-scale problems, its scalability is limited for large heterogeneous item sets.

4.7. The Knapsack Problem

Exploring a specialized variant of the Generalized Bin Packing Problem (GBPP), Kilincci and Medinoglu (2022) examine a case where containers rather than standard bins are used, each with equal volume but varying refrigeration capabilities, leading to different usage costs. Framed as a variant of the knapsack problem, their model incorporates real-world transportation constraints such as container weight capacity, product divisibility across trucks, and temperature requirements (standard, cooled, or frozen). To address these complexities, the authors develop a five-stage lexicographic search heuristic that prioritizes minimizing the number of refrigerated containers used, balancing operational cost and logistical feasibility. In an earlier contribution, Zhou, Li, Zhang and Du (2019) investigate a two-dimensional knapsack problem with block-based packing constraints. Items must be packed into multiple predefined blocks within the bin, and the objective is to maximize space utilization by selecting and fitting an optimal subset of items. A mixed-integer programming approach is employed to solve the problem, offering structured yet flexible solutions for constrained 2D space utilization scenarios.

4.8. Summary

All GBPP-related problems discussed are presented in Table 4, revealing that most studies address issues involving multiple parameters. Cutting and packing problems are closely related, as packing an item into a bin is analogous to cutting it from stock; both often share similar solution methods (Iori et al., 2021). Many studies address multiple problem types, employ diverse techniques, and pursue multi-criteria optimization.

A common parameter across all GBPP-related problems is the influence of temperature and humidity. Almasarwah et al. (2023) highlights that the dynamic compression strength of boxes decreases as relative humidity and storage time increases. Load height also varies dynamically depending on box dimensions, alignment, orientation, relative humidity, and storage duration. Higher relative humidity and longer storage times, especially when combined with an interlocked stacking pattern, tend to reduce pallet utilization but enhance pallet stability.

Recent studies, such as empirical investigations into constrained bin packing algorithms, emphasize the critical role of real-world physical attributes particularly temperature and humidity when managing perishable or climate-sensitive goods (Tsybina, Winstead & Kuruganti, 2024). Notably, contextual bandit-driven branch-and-price-and-cut frameworks have begun incorporating these environmental variables, modeling them as constraints that influence both bin selection and assignment strategies (Chen, Gao, Zhang, Li, Wahab & Jiang, 2025). This integration ensures that items requiring specific temperature and humidity conditions are assigned to bins with controlled environments, thereby optimizing profit while maintaining feasibility.

Consequently, such research not only deepens the theoretical foundations of GBPP by embedding realistic, multidimensional parameters, but also enhances its practical relevance particularly in cold chain logistics, where environmental controls directly impact economic performance.

5. SLR Results

This study classifies the reviewed articles into clusters, organized from the most recent to the oldest, based on various factors. In Table 3, articles are categorized according to Problem Type, Research Field, and Scientific Field. In Table 4, articles are classified based on Problem Type, Solving Techniques, and Optimization Criteria. Additionally, this table includes the frequency of keyword occurrences and key variables. In Table 5, articles are evaluated using a Quality Assessment Checklist. Finally, Table 6 presents the distribution of the main scientific fields as percentages.

Paper Title	Year	Levels of Analysis		
		Problem Type	Research field	Scientific field
A 2-dimensional guillotine cutting stock problem with variable-sized stock for the honeycomb cardboard industry	2024	Cutting Stock Problem	2D guillotine cutting stock problem	Production Research
Lower and upper bounding procedures for the bin packing problem with concave loading cost	2024	1D Bin Packing	Loading Cost	Operations Research
Mathematical models for cutting stock with limited open stacks problem	2023	Mathematics Subject Classification	2D Cutting	Operations Research
Learning to Solve Grouped 2D Bin Packing Problems in the Manufacturing Industry	2023	Grouped 2D Packing	2D Bin Packing	Manufacturing Industry
Multi-container loading problems with multidrop and split delivery conditions	2023	Multi Container Loading Problem	Container loading problem	Computers & Industrial Engineering
Pallet Loading Optimization Considering Storage Time and Relative Humidity	2023	Pallet Loading Optimization Considering Storage Time and Relative Humidity	3D Loading Problem	Industrial Engineering
Bin packing with lexicographic objectives for loading weight- and volume-constrained trucks in a direct-shipping system	2022	Loading weight- and volume-constrained trucks	Bin Packing	Operations Research
An efficient method for the three-dimensional container loading problem by forming box sizes	2022	Forming Box sizes	Three-dimensio nal container loading	Engineering Optimization
Exact and approximate methods for the score-constrained packing problem	2022	Score-constrained Packing problem	Bin packing problem	Operations Research
A cutting plane method and a parallel algorithm for packing rectangles in a circular container	2022	Packing rectangles in a circular container	Two-dimensiona l packing problems where rectangular items	Operations Research
A goal-driven ruin and recreate heuristic for the 2D variable-sized bin packing problem with guillotine constraints	2022	2D variable-sized bin packing problem	Bin packing	Operations Research
Multi-objective steel plate cutting optimization problem based on real number coding genetic algorithm	2022	Multi-objective steel plate cutting	Cutting optimization problem	Artificial Intelligence and Information Technology
Mathematical models and heuristic algorithms for pallet building problems with practical constraints	2021	PLP (Pallet loading problem)	Pallet building problems	Operations Research
Mathematical models for a cutting problem in the glass manufacturing industry	2021	Glass manufacturing industry	Cutting problem	Programming and metaheuristic algorithms
A Global Method for a Two-Dimensional Cutting Stock Problem in the Manufacturing Industry	2021	Two-Dimensional Cutting	Cutting	Operations Research
Higher order block heuristics for 2D pallet loading problems with multiple box inputs	2021	2D pallet loading	Pallet Loading Problems	Mechanical Engineering
On the packing process in a shoe manufacturer	2021	Packing process in a shoe manufacturer	Packing Process	Operations Research
Voxel-Based Solution Approaches to the Three-Dimensional Irregular Packing Problem	2021	3D Irregular packing	3D Loading Problem	Operations Research

Paper Title	Year	Levels of Analysis		
		Problem Type	Research field	Scientific field
Three-dimensional guillotine cutting problems with constrained patterns: MILP formulations and a bottom-up algorithm	2021	MILP formulations and a bottom-up algorithm	Three-dimensio nal guillotine cutting problems	Expert Systems With Application
An optimization approach for a complex real-life container loading problem	2021	container loading problem	3D Loading Problem	Operations Research
Cutting Waste Minimization of Rebar for Sustainable Structural Work: A Systematic Literature Review	2021	SLR research	Cutting waste minimization (CWM)	Sustainable Structural Work
A Heuristic Approach for Two-Dimensional Rectangular Cutting Stock Problem considering Balance for Material Utilization and Cutting Complexity	2021	Cutting Stock Problem	2D Cutting stock problem	Materials Science and Engineering
Sparsest balanced packing of irregular 3D objects in a cylindrical container	2021	Packing of irregular 3D objects in a cylindrical container	3D Packing	Operations Research
Multi-objective 3D bin packing problem with load balance and product family concerns	2021	Multi-objective 3D bin packing problem	Packing Problem	Computers & Industrial Engineering
Improved Layout Structure with Complexity Measures for the Manufacturer's Pallet Loading Problem (MPLP) Using a Block Approach	2021	Manufacturer's Pallet Loading Problem (MPLP) Using a Block Approach	3D Loading Problem	Industrial Engineering
The Pallet Loading Problem: Three-dimensional bin packing with practical constraints	2020	PLP (Pallet loading problem)	Pallet building problems	Operations Research
Exact solution techniques for two-dimensional cutting and packing	2020	Two-dimensional cutting and packing	Cutting and packing problems	Operations Research
Solving a large cutting problem in the glass manufacturing industry	2020	Cutting glass	Innovative Applications of O. R	Operational Research
Bun splitting: an online cutting problem with defects from the food industry	2020	Cutting problems with defects from the food industry	2D Cutting problem	Production Research
A metaheuristic framework for the Three-dimensional Single Large Object Placement Problem with practical constraints	2020	Single Large Object Placement Problem	3D Loading Problem	Operations Research
A beam search algorithm for the biobjective container loading problem	2020	A beam search algorithm for the biobjective container loading problem	Container loading problem	Operations Research
Exact approaches for the cutting path determination problem	2019	Cutting path determination problem	2D Cutting	Computers and Operations Research
Pattern-based diving heuristics for a two-dimensional guillotine cutting-stock problem with leftovers	2019	Cutting glass	Computational Optimization	Operational Research
Online packing of arbitrary sized items into designated and multipurpose bins	2019	Online packing into designated and multipurpose bins	Bin packing	Operation Research

Paper Title	Year	Levels of Analysis		
		Problem Type	Research field	Scientific field
The Loading Optimization: A Novel Integer Linear Programming Model	2019	Container Loading Problem (CLP)	Loading	Information Systems
A hybrid approach for a multi-compartment container loading problem	2019	A hybrid approach to a multi-compartment container loading problem	Containers loading problem	Expert Systems With Applications
Lower bounds for a bin packing problem with linear usage cost	2019	1D bin packing	Bin Packing problem	Operations Research
Raster penetration map applied to the irregular packing problem	2019	Irregular packing problem	2D Bin Packing	Computers and Operations Research
Two-dimensional knapsack-block packing problem	2019	Two-dimensional knapsack-block packing problem	Packing Problem	Applied Mathematical Modelling
Fast truck-packing of 3D boxes	2018	3D packing	Containers Packing	Operations Research
Cutting Optimization Problem Description	2018	Glass cutting	Cutting Optimization	Operations Research
The two-dimensional vector packing problem with general costs	2018	Two-dimensional vector packing problem	Bin packing	Management Science
BRKGA/VND Hybrid Algorithm for the Classic Three-dimensional Bin Packing Problem	2018	BRKGA/VND Hybrid Algorithm for the Classic Three-dimensional Bin Packing Problem	3D Packing	Mathematics & Statistics
Packing of concave polyhedra with continuous rotations using nonlinear optimization	2018	Packing of concave polyhedra	3D Packing	Operations Research
A tailored two-phase constructive heuristic for the three-dimensional Multiple Bin Size Bin Packing Problem with transportation constraints	2018	Two-phase constructive heuristic for the three-dimensional Multiple Bin Size	Bin Packing problem	Operations Research
Jostle heuristics for the 2D-irregular shapes bin packing problems with free rotation	2018	2D-irregular shapes bin packing problems	2D Bin Packing	Economics
Solving real-world sized container pre-marshalling problems with an iterative deepening branch-and-bound algorithm	2018	Pre-marshalling problems	Containers loading problem	Operations Research
Two-dimensional cutting stock problem with sequence dependent setup times	2017	2D cutting stock problem with sequence dependent setup time	Cutting problem	Operations Research
Three-stage heuristic algorithm for three-dimensional irregular packing problem	2017	Three-dimensional irregular packing problem	3D Packing	Applied Mathematical Modelling
Metaheuristics for the irregular bin packing problem with free rotations	2017	Two-Dimensional Irregular Bin Packing Problem (2DIBPP)	2D Packing	Operations Research
Heuristic algorithm for the container loading problem with multiple constraints	2017	Heuristic algorithm	Containers loading problem	Computers & Industrial Engineering

Paper Title	Year	Levels of Analysis		
		Problem Type	Research field	Scientific field
Mathematical models for multicontainer loading problem	2017	Multi Container Loading Problem	Containers loading problem	Management Science
A clique covering MIP model for the irregular strip packing problem	2017	Irregular strip packing problem	2D Bin Packing	Computers and Operations Research
VCS: A new heuristic function for selecting boxes in the single container loading problem	2017	Single container loading problem	Loading Problem	Computers and Operations Research
Solving a large multicontainer loading problem in the car manufacturing industry	2017	Multicontainer loading problem	Loading Problem	Computers and Operations Research
A heuristic algorithm for container loading pallets with infill boxes	2016	Container loading of pallets with infill boxes	3D Loading Problem	Operations Research
An effective placement method for the single container loading problem	2016	Single container loading problem	3D Packing	Computers & Industrial Engineering
Integrating packaging and supply chain decisions: Selection of economic handling unit quantities	2016	MPLP problem	Pallet building problems	Operations Research
Optimization of the LCD optical film cutting problem	2016	LCD cutting	1D cutting	Production Research
A hybrid algorithm for the vehicle routing problem with pickup and delivery and three-dimensional loading constraints	2016	Vehicle routing problem	Pickup and Delivery Problem (PDP)	Operations Research

Table 3. Levels of analysis by article title and year

Figure 3 presents a visual summary of the key findings based on the studies included in the review, as outlined in Table 3.

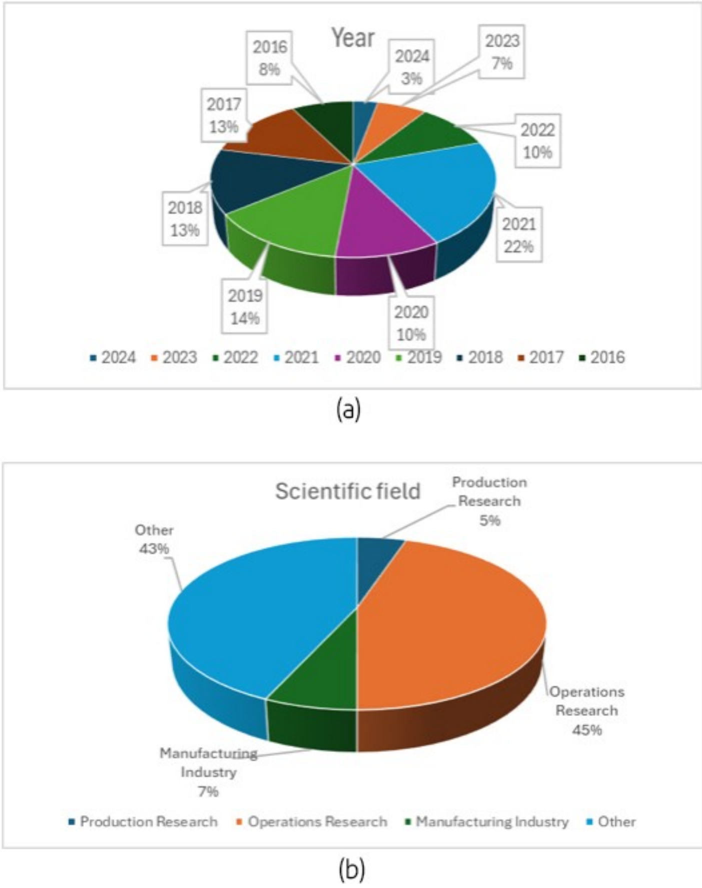

Figure 3. Visualization of basic results of Table 3

Specifically, Figure 3 illustrates: (a) the percentage distribution of studies by year of publication, and (b) the percentage distribution across the main scientific fields addressed by the included studies.

			Problem Type						Solving Techniques							Optimization Criteria						
Paper Title	Year	Keywords	Packing	Cutting	Knapsack	Pallet loading	MPLP-DPLP	CLP	Linear Programming	Dynamic programming	Mix Integer Programming	Integer Non Linear Programming	Heuristic - Metaheuristic	Genetic Algorithms	Neural Networks	Minimize - Maximize operation cost	Minimizing material waste	Pallet loading Optimization	Minimizing the total route	Reducing operation time	Practical Constraints	Sustainability
A 2-dimensional guillotine cutting stock problem with variable-sized stock for the honeycomb cardboard industry	2024	Cutting stock problem, 2-dimensional cutting, variable-sized stock, mixed integer linear optimization, cardboard industry.		√							√					√	√			√		
Lower and upper bounding procedures for the bin packing problem with concave loading cost	2024	Combinatorial optimization, Packing Lower bounds, Column generation, Heuristics.	√										√			√						
Mathematical models for the cutting stock with limited open stacks problem	2023	Cutting stock problems, open stack, pattern sequencing, mathematical formulation, integer linear programming, setup cost.		√					√								√					
Learning to Solve Grouped 2D Bin Packing Problems in the Manufacturing Industry	2023	Grouped bin packing, reinforcement learning, bi-level optimization.	√	√									√		√		√					
Multi-container loading problems with multidrop and split delivery conditions	2023	Multi-container loading, Split delivery, Stability Integer models						√	√				√					√				
Pallet Loading Optimization Considering Storage Time and Relative Humidity	2023	Pallet loading problem, two-phase heuristic algorithm, real conditions, dynamic compression strength, interlock stacking patterns.				√	√						√					√				
Bin packing with lexicographic objectives for loading weight- and volume-constrained trucks in a direct-shipping system	2022	Bin packing, Lexicographic objective, Heuristics, Column generation, Dual-optimal inequalities.			√			√					√			√						
An efficient method for the three-dimensional container loading problem by forming box sizes	2022	Container loading, 3D packing, forming box sizes, INLP, layer-building.						√				√				√						
Exact and approximate methods for the score-constrained packing problem	2022	Evolutionary computations, Packing, Combinatorial optimization.	√										√				√					
A cutting plane method and a parallel algorithm for packing rectangles in a circular container	2022	Packing Combinatorial optimization, Circular container, Cutting plane method, Parallel computing.	√								√							√				

			Problem Type						Solving Techniques							Optimization Criteria						
Paper Title	Year	Keywords	Packing	Cutting	Knapsack	Pallet loading	MPLP-DPLP	CLP	Linear Programming	Dynamic programming	Mix Integer Programming	Integer Non Linear Programming	Heuristic - Metaheuristic	Genetic Algorithms	Neural Networks	Minimize - Maximize operation cost	Minimizing material waste	Pallet loading Optimization	Minimizing the total route	Reducing operation time	Practical Constraints	Sustainability
A goal-driven ruin and recreate heuristic for the 2D variable-sized bin packing problem with guillotine constraints	2022	Packing 2D bin packing, Guillotine Heuristic, Variable-sized bins	√	√									√				√	√				
Multi-objective steel plate cutting optimization problem based on real number coding genetic algorithm	2022	Cutting, optimization, genetic algorithm.		√									√	√			√			√		
Mathematical models and heuristic algorithms for pallet building problems with practical constraints	2021	Pallet building problem, Practical constraints, Two-step heuristic, Reactive GRASP, Mathematical models, Real-world instances.				√							√					√				
Mathematical models for a cutting problem in the glass manufacturing industry	2021	Cutting stock problem, Three-stage cutting, Integer models.		√					√								√					
A Global Method for a Two-Dimensional Cutting Stock Problem in the Manufacturing Industry	2021	Two-dimensional cutting stock problem (2DCSP), rectangular items, optimal solution, deterministic model.		√					√											√		
Higher order block heuristics for 2D pallet loading problems with multiple box inputs	2021	Non guillotine cuts Block heuristics Distributer's pallet loading problem Multiple box inputs NP Hard Problems.				√							√					√				
On the packing process in a shoe manufacturer	2021	Packing; practice of OR; non-linear programming, shoe manufacturer	√			√					√	√						√		√		
Voxel-Based Solution Approaches to the Three-Dimensional Irregular Packing Problem	2021	3D irregular packing, open dimension problem, voxel, metaheuristics.	√										√					√				
Three-dimensional guillotine cutting problems with constrained patterns: MILP formulations and a bottom-up algorithm	2021	Cutting and packing, Constrained three-dimensional cutting, non-staged and 3-staged patterns, Mixed-integer linear programming models, Bottom-up packing.		√							√		√							√		

			Problem Type						Solving Techniques							Optimization Criteria						
Paper Title	Year	Keywords	Packing	Cutting	Knapsack	Pallet loading	MPLP-DPLP	CLP	Linear Programming	Dynamic programming	Mix Integer Programming	Integer Non Linear Programming	Heuristic - Metaheuristic	Genetic Algorithms	Neural Networks	Minimize - Maximize operation cost	Minimizing material waste	Pallet loading Optimization	Minimizing the total route	Reducing operation time	Practical Constraints	Sustainability
An optimization approach for a complex real-life container loading problem	2021	Container loading problem, Real-life constraints, Randomized constructive heuristic, Industry collaboration.						√					√			√				√		
Cutting Waste Minimization of Rebar for Sustainable Structural Work: A Systematic Literature Review	2021	Rebar cutting waste, minimization, optimization, structural work, systematic literature review.		√										√			√					√
A Heuristic Approach for Two-Dimensional Rectangular Cutting Stock Problem considering Balance for Material Utilization and Cutting Complexity	2021	Cutting, Heuristic, Two-Dimensional Rectangular, Cutting Stock Problem.		√									√				√					
Sparsest balanced packing of irregular 3D objects in a cylindrical container	2021	Packing 3D objects Balancing conditions Nonlinear optimization, Thermal debarring.	√									√						√				
Multi-objective 3D bin packing problem with load balance and product family concerns	2021	Bin packing, Load balance, Family unity, Container loading.	√								√					√						
Improved Layout Structure with Complexity Measures for the Manufacturer's Pallet Loading Problem (MPLP) Using a Block Approach	2021	Manufactures pallet loading problems, cutting and packing problems, mathematical programming, mixed integer optimization.					√				√							√		√		
The Pallet Loading Problem: Three-dimensional bin packing with practical constraints	2020	Pallet Loading Problem, Three-dimensional bin packing, Vertical support Load bearing, Layer based column generation.				√					√										√	
Exact solution techniques for two-dimensional cutting and packing	2020	Two-dimensional rectangle cutting and packing, Exact methods Relaxations.	√	√							√		√			√						
Solving a large cutting problem in the glass manufacturing industry	2020	Cutting stock problem, Heuristics Beam search algorithm.		√									√				√				√	
Bun splitting: an online cutting problem with defects from the food industry	2020	Cutting stock problem, dynamic programming, defects, optimization, food industry.		√						√										√		

Paper Title	Year	Keywords	Problem Type						Solving Techniques							Optimization Criteria						
			Packing	Cutting	Knapsack	Pallet loading	MPLP-DPLP	CLP	Linear Programming	Dynamic programming	Mix Integer Programming	Integer Non Linear Programming	Heuristic - Metaheuristic	Genetic Algorithms	Neural Networks	Minimize - Maximize operation cost	Minimizing material waste	Pallet loading Optimization	Minimizing the total route	Reducing operation time	Practical Constraints	Sustainability
A Mata heuristic framework for the Three-dimensional Single Large Object Placement Problem with practical constraints	2020	3D packing Mata heuristic, Practical constraints.						√					√	√				√				
A beam search algorithm for the biobjective container loading problem	2020	Multi objective optimization container loading problem, beam search greedy.						√					√	√		√		√				
Exact approaches for the cutting path determination problem	2019	Cutting path Mathematical model, Cutting and packing.		√					√							√				√	√	
Pattern-based diving heuristics for a two-dimensional guillotine cutting-stock problem with leftovers	2019	Cutting and packing, Dynamic programming, Column generation, Diving heuristic.		√						√			√				√					
Online packing of arbitrary sized items into designated and multipurpose bins	2019	Bin packing Type compatibility, Online algorithms, Competitive ratio analysis, Container shipping.	√										√			√						
The Loading Optimization: A Novel Integer Linear Programming Model	2019	Integer linear programming, distribution optimization, transportation, container.						√	√							√						
A hybrid approach for a multi-compartment container loading problem	2019	Container Loading Problems, Hybrid Approach, Multiple Compartments, Beverage Distribution.						√			√		√					√				
Lower bounds for a bin packing problem with linear usage cost	2019	Packing Combinatorial optimization, Lower bounds, Performance ratio, Branch and bound.	√										√					√				
Raster penetration map applied to the irregular packing problem	2019	Irregular packing problem, Separation and compaction, Penetration depth, Raster representation.	√										√					√			√	
Two-dimensional knapsack-block packing problem	2019	Two-dimensional knapsack problem, Block packing, Bin packing problem, Integer linear programming.			√				√									√				

			Problem Type						Solving Techniques							Optimization Criteria						
Paper Title	**Year**	**Keywords**	Packing	Cutting	Knapsack	Pallet loading	MPLP-DPLP	CLP	Linear Programming	Dynamic programming	Mix Integer Programming	Integer Non Linear Programming	Heuristic - Metaheuristic	Genetic Algorithms	Neural Networks	Minimize - Maximize operation cost	Minimizing material waste	Pallet loading Optimization	Minimizing the total route	Reducing operation time	Practical Constraints	Sustainability
Fast truck-packing of 3D boxes	2018	container packing, 3D-packing problem, heuristics	√					√			√		√			√		√		√		
Cutting Optimization Problem Description	2018	Cutting, Optimization, discrete programming.	√					√			√		√					√			√	
The two-dimensional vector packing problem with general costs	2018	Application Bin packing, Two-dimensional vector packing, General costs, Memetic algorithm.	√										√	√		√						
BRKGA/VND Hybrid Algorithm for the Classic Three-dimensional Bin Packing Problem	2018	Bin packing, Three-dimensional, BRKGA, VND.	√										√	√				√				
Packing of concave polyhedra with continuous rotations using nonlinear optimization	2018	Concave polyhedral, Continuous rotations, Mathematical modeling, Nonlinear optimization.	√									√	√					√				
A tailored two-phase constructive heuristic for the three-dimensional Multiple Bin Size Bin Packing Problem with transportation constraints	2018	Packing Heuristics, Air transportation, Extreme Points.	√					√					√					√		``	√	
Jostle heuristics for the 2D-irregular shapes bin packing problems with free rotation	2018	Cutting and packing, Heuristics, Irregular shapes, Bin packing.	√										√					√				
Solving real-world sized container pre-marshalling problems with an iterative deepening branch-and-bound algorithm	2018	OR in maritime industry, Container pre-marshalling, Terminal operations.						√					√			√					√	
Two-dimensional cutting stock problem with sequence dependent setup times	2017	Cutting stock problem, Sequence dependent setup times, Heuristics Application.		√							√		√							√		
Three-stage heuristic algorithm for three-dimensional irregular packing problem	2017	Packing Irregular packing problem, Three-stage heuristic algorithms.	√					√					√					√				
Metaheuristics for the irregular bin packing problem with free rotations	2017	Cutting and packing, Two-dimensional irregular bin packing, Integer Programming.	√								√		√					√				

			Problem Type						Solving Techniques							Optimization Criteria						
Paper Title	Year	Keywords	Packing	Cutting	Knapsack	Pallet loading	MPLP-DPLP	CLP	Linear Programming	Dynamic programming	Mix Integer Programming	Integer Non Linear Programming	Heuristic - Metaheuristic	Genetic Algorithms	Neural Networks	Minimize - Maximize operation cost	Minimizing material waste	Pallet loading Optimization	Minimizing the total route	Reducing operation time	Practical Constraints	Sustainability
Heuristic algorithm for the container loading problem with multiple constraints	2017	Container loading, Complete shipment constraint, Shipment priority Simulated annealing.						√					√					√			√	
Mathematical models for multicontainer loading problem	2017	Containers Integer programming Optimization Cutting stock problem.						√	√				√					√			√	
A clique covering MIP model for the irregular strip packing problem	2017	Cutting and packing, Irregular strip packing problem Clique covering Mixed integer programming.	√	√							√						√					
VCS: A new heuristic function for selecting boxes in the single container loading problem	2017	Container loading problem, Load planning Combinatorial optimization, Constructive algorithms, Evaluation function.						√					√					√				
Solving a large multicontainer loading problem in the car manufacturing industry	2017	Container loading, Optimization, Packing, Metaheuristics GRASP.						√					√			√		√			√	
A heuristic algorithm for container loading of pallets with infill boxes	2016	Packing Container loading, Heuristic algorithm, Tree search, Greedy algorithm.						√					√					√				
An effective placement method for the single container loading problem	2016	Container loading problem, Mixed integer linear program, Heuristic Loading placement.						√			√		√					√		√		
Integrating packaging and supply chain decisions: Selection of economic handling unit quantities	2016	Random stacking, strongly heterogeneous, Random sequence, Robotic palletization, Volumetric utilization.	√			√		√				√	√			√						
Optimization of the LCD optical film cutting problem	2016	Production planning; cost management; materials management, math programming, optimization, cutting, angle limit material.		√									√			√	√					
A hybrid algorithm for the vehicle routing problem with pickup and delivery and three-dimensional loading constraints	2016	Transportation Vehicle routing Packing Pickup and delivery.	√					√					√			√			√			
Total frequency of occurrence of keywords and fundamental variables			**25**	**18**	**2**	**6**	**2**	**21**	**8**	**2**	**15**	**5**	**43**	**6**	**1**	**18**	**13**	**30**	**1**	**13**	**10**	**1**

Table 4. Keywords and fundamental variables

In Table 5, a structured checklist was used to assess the quality of the selected studies. Each item was rated as Yes (Y), No (N), or Partial (P) to reflect how well the study met specific evaluation criteria. This approach supported a transparent and consistent appraisal of methodological soundness.

Paper Title	Year	Quality assessment: checklist (Y/N/partial)												
		Research aims clearly specified?	Study designed to achieve these aims?	Techniques clearly described and their selection justified?	Variables considered by the study suitable measured?	Data collection methods adequately described?	Is the data collected adequately described?	Is the purpose of the data analysis clear?	Statistical techniques used to analyze data adequately described and their use justified?	Negative results (if any) presented?	Do the researchers discuss any problem with the reliability of their results?	Are all research questions answered adequately?	How clear are the links between data interpretation and conclusions?	Are the findings based on multiple projects?
A 2-dimensional guillotine cutting stock problem with variable-sized stock for the honeycomb cardboard industry	2024	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lower and upper bounding procedures for the bin packing problem with concave loading cost	2024	P	P	P	P	P	P	P	P	P	P	P	P	P
Mathematical models for the cutting stock with limited open stacks problem	2023	P	P	P	P	P	P	P	P	P	P	P	P	P
Learning to Solve Grouped 2D Bin Packing Problems in the Manufacturing Industry	2023	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi-container loading problems with multidrop and split delivery conditions	2023	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Pallet Loading Optimization Considering Storage Time and Relative Humidity	2023	Y	Y	Y	Y	Y	Y	Y	Y	P	N	Y	Y	Y
Bin packing with lexicographic objectives for loading weight- and volume-constrained trucks in a direct-shipping system	2022	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
An efficient method for the three-dimensional container loading problem by forming box sizes	2022	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Exact and approximate methods for the score-constrained packing problem	2022	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A cutting plane method and a parallel algorithm for packing rectangles in a circular container	2022	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A goal-driven ruin and recreate heuristic for the 2D variable-sized bin packing problem with guillotine constraints	2022	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi-objective steel plate cutting optimization problem based on real number coding genetic algorithm	2022	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Paper Title	Year	Quality assessment: checklist (Y/N/partial)												
		Research aims clearly specified?	Study designed to achieve these aims?	Techniques clearly described and their selection justified?	Variables considered by the study suitable measured?	Data collection methods adequately described?	Is the data collected adequately described?	Is the purpose of the data analysis clear?	Statistical techniques used to analyze data adequately described and their use justified?	Negative results (if any) presented?	Do the researchers discuss any problem with the reliability of their results?	Are all research questions answered adequately?	How clear are the links between data interpretation and conclusions?	Are the findings based on multiple projects?
Mathematical models and heuristic algorithms for pallet building problems with practical constraints	2021	Y	Y	P	Y	N	P	Y	N	N	N	Y	P	Y
Mathematical models for a cutting problem in the glass manufacturing industry	2021	Y	Y	P	Y	Y	Y	Y	N	N	P	Y	Y	N
A Global Method for a Two-Dimensional Cutting Stock Problem in the Manufacturing Industry	2021	P	P	P	P	P	P	P	P	N	P	P	P	P
Higher order block heuristics for 2D pallet loading problems with multiple box inputs	2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
On the packing process in a shoe manufacturer	2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Voxel-Based Solution Approaches to the Three-Dimensional Irregular Packing Problem	2021	Y	Y	P	Y	P	N	P	P	N	Y	Y	Y	Y
Three-dimensional guillotine cutting problems with constrained patterns: MILP formulations and a bottom-up algorithm	2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	P
An optimization approach for a complex real-life container loading problem	2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cutting Waste Minimization of Rebar for Sustainable Structural Work: A Systematic Literature Review	2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A Heuristic Approach for Two-Dimensional Rectangular Cutting Stock Problem considering Balance for Material Utilization and Cutting Complexity	2021	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y
Sparsest balanced packing of irregular 3D objects in a cylindrical container	2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi-objective 3D bin packing problem with load balance and product family concerns	2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Improved Layout Structure with Complexity Measures for the Manufacturer's Pallet Loading Problem (MPLP) Using a Block Approach	2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Paper Title	Year	Quality assessment: checklist (Y/N/partial)												
		Research aims clearly specified?	Study designed to achieve these aims?	Techniques clearly described and their selection justified?	Variables considered by the study suitable measured?	Data collection methods adequately described?	Is the data collected adequately described?	Is the purpose of the data analysis clear?	Statistical techniques used to analyze data adequately described and their use justified?	Negative results (if any) presented?	Do the researchers discuss any problem with the reliability of their results?	Are all research questions answered adequately?	How clear are the links between data interpretation and conclusions?	Are the findings based on multiple projects?
The Pallet Loading Problem: Three-dimensional bin packing with practical constraints	2020	Y	Y	Y	Y	Y	Y	Y	P	N	N	Y	Y	Y
Exact solution techniques for two-dimensional cutting and packing	2020	P	P	P	P	P	N	P	N	N	N	P	P	P
Solving a large cutting problem in the glass manufacturing industry	2020	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Bun splitting: an online cutting problem with defects from the food industry	2020	Y	Y	P	Y	P	Y	P	N	N	Y	Y	P	N
A metaheuristic framework for the Three-dimensional Single Large Object Placement Problem with practical constraints	2020	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A beam search algorithm for the biobjective container loading problem	2020	Y	Y	P	P	Y	Y	P	Y	P	N	P	P	Y
Exact approaches for the cutting path determination problem	2019	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Pattern-based diving heuristics for a two-dimensional guillotine cutting-stock problem with leftovers	2019	P	Y	P	Y	Y	Y	Y	Y	N	N	P	Y	N
Online packing of arbitrary sized items into designated and multipurpose bins	2019	Y	Y	P	P	P	P	Y	Y	N	N	Y	Y	N
The Loading Optimization: A Novel Integer Linear Programming Model	2019	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y
A hybrid approach for a multi-compartment container loading problem	2019	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lower bounds for a bin packing problem with linear usage cost	2019	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	N
Raster penetration map applied to the irregular packing problem	2019	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Two-dimensional knapsack-block packing problem	2019	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fast truck-packing of 3D boxes	2018	P	P	P	P	P	P	P	P	N	P	P	P	P
Cutting Optimization Problem Description	2018	Y	Y	Y	Y	Y	Y	P	N	N	N	P	P	N

Paper Title	Year	Quality assessment: checklist (Y/N/partial)												
		Research aims clearly specified?	Study designed to achieve these aims?	Techniques clearly described and their selection justified?	Variables considered by the study suitable measured?	Data collection methods adequately described?	Is the data collected adequately described?	Is the purpose of the data analysis clear?	Statistical techniques used to analyze data adequately described and their use justified?	Negative results (if any) presented?	Do the researchers discuss any problem with the reliability of their results?	Are all research questions answered adequately?	How clear are the links between data interpretation and conclusions?	Are the findings based on multiple projects?
The two-dimensional vector packing problem with general costs	2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
BRKGA/VND Hybrid Algorithm for the Classic Three-dimensional Bin Packing Problem	2018	P	P	P	P	P	P	P	P	P	P	P	P	P
Packing of concave polyhedral with continuous rotations using nonlinear optimization	2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A tailored two-phase constructive heuristic for the three-dimensional Multiple Bin Size Bin Packing Problem with transportation constraints	2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Jostle heuristics for the 2D-irregular shapes bin packing problems with free rotation	2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solving real-world sized container pre-marshalling problems with an iterative deepening branch-and-bound algorithm	2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Two-dimensional cutting stock problem with sequence dependent setup times	2017	P	Y	P	P	P	P	Y	P	N	N	P	P	P
Three-stage heuristic algorithm for three-dimensional irregular packing problem	2017	Y	Y	Y	Y	Y	Y	Y	p	N	Y	Y	Y	P
Metaheuristics for the irregular bin packing problem with free rotations	2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Heuristic algorithm for the container loading problem with multiple constraints	2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mathematical models for multicontainer loading problem	2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A clique covering MIP model for the irregular strip packing problem	2017	Y	Y	Y	Y	Y	Y	P	Y	N	Y	Y	Y	Y
VCS: A new heuristic function for selecting boxes in the single container loading problem	2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solving a large Multicontainer loading problem in the car manufacturing industry	2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Paper Title	Year	Quality assessment: checklist (Y/N/partial)												
		Research aims clearly specified?	Study designed to achieve these aims?	Techniques clearly described and their selection justified?	Variables considered by the study suitable measured?	Data collection methods adequately described?	Is the data collected adequately described?	Is the purpose of the data analysis clear?	Statistical techniques used to analyze data adequately described and their use justified?	Negative results (if any) presented?	Do the researchers discuss any problem with the reliability of their results?	Are all research questions answered adequately?	How clear are the links between data interpretation and conclusions?	Are the findings based on multiple projects?
A heuristic algorithm for container loading pallets with infill boxes	2016	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y
An effective placement method for the single container loading problem	2016	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Integrating packaging and supply chain decisions: Selection of economic handling unit quantities	2016	P	P	P	P	P	P	Y	N	N	N	P	P	Y
Optimization of the LCD optical film cutting problem	2016	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
A hybrid algorithm for the vehicle routing problem with pickup and delivery and three-dimensional loading constraints	2016	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Table 5. Quality assessment: checklist (Y: Yes / N: No / P: Partial)

In Table 6, it is shown that the majority of the studies (51.6 %) belong to the field of Operations Research, indicating its dominant role in the literature. A substantial portion (35 %) falls under the "Other" category, while Production Research, Computer and Operations Research, and Economics contribute smaller shares at 5 %, 5 %, and 3.4 %, respectively.

Scientific field	Operation Research	Production Research	Computer and Operation Research	Economics	Other
%	51.6%	5%	5%	3.4%	35%

Table 6. Main scientific fields

6. VOSviewer Results

In this study, a bibliometric analysis was conducted using the Web of Science (WoS), Scopus and Google Scolar databases, in combination with VOSviewer software (version 1.6.20, 2024). VOSviewer is designed for constructing, visualizing, and exploring bibliometric maps and networks. In Figure 4, the lines connecting nodes represent co-occurrence relationships between keyword terms. When two terms frequently appear together in the same paper, they are linked. The most frequently mentioned keywords, which include pattern, industry, stock problem, container loading problem, and pallet loading problem.

Figure 5 displays relationships between researchers based on their joint publications. The larger the node, the more publications that author has (or the more frequently they appear in the dataset). Authors with larger names (e.g., Alvarez-Valdes, J.) are more prolific or central in the research field.

In Figure 6, we present the countries with the highest number of active publications.

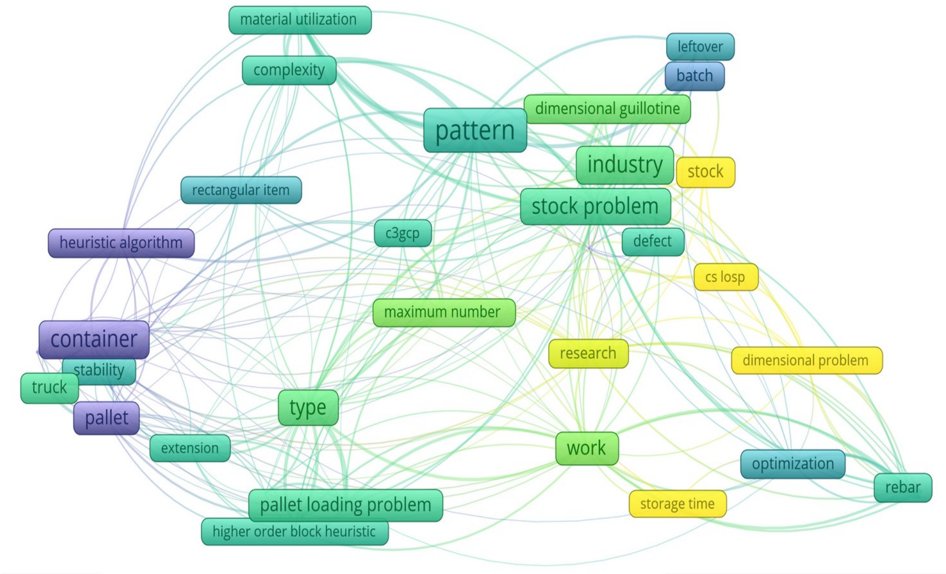

Figure 4. VOSviewer keyword co-occurrence map

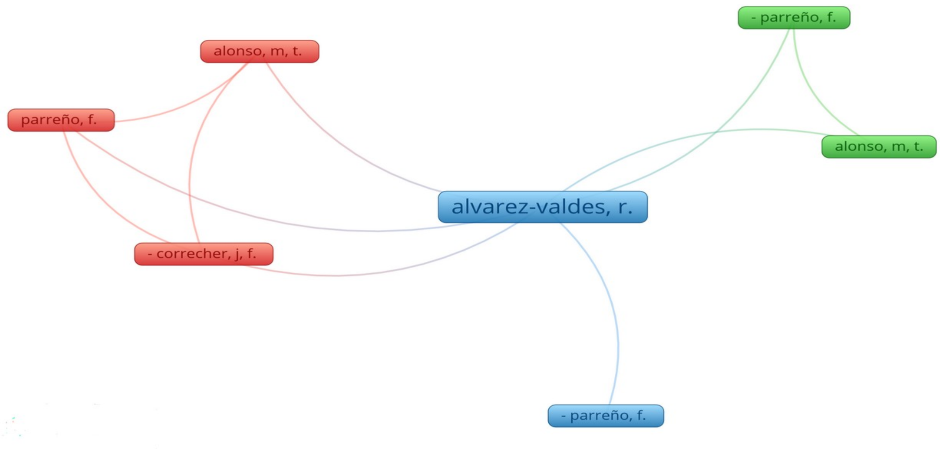

Figure 5. VOSviewer co-authorship network visualization (at least two papers)

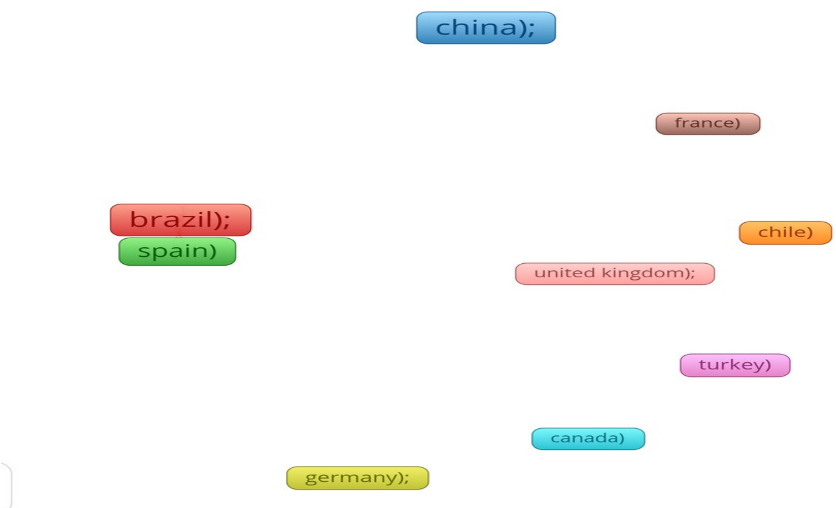

Figure 6. countries with the highest number of active publications

7. Discussion

Table 3 describes the thematic section, research field, and scientific discipline of each paper included in the review. The results from Table 3 are summarized in Table 6. Most of the papers fall within the field of Operations Research, representing 51% of the total, followed by Production Research with 5%, Computer & Operations Research with 5%, and Economics with 3.4%.

Table 4 presents all the accepted papers, organized by title, year, keywords, problem type, solving techniques, and optimization criteria. Among the solution techniques, heuristic and meta-heuristic methods are the most prominent, with 43 occurrences across the selected publications. This prevalence reflects the diversity of constraints that need to be satisfied in each research problem and the corresponding flexibility of heuristic and meta-heuristic approaches in addressing them. The results presented in this table offer valuable insights into future investigations and highlight underexplored areas within the field that may present opportunities for further research.

In terms of problem typologies, the Knapsack problem is addressed in 2 studies, while the Multi-Period Location Problem (MPLP) and the Dynamic Periodic Location Problem (DPLP) are each examined in 2 studies as well. Regarding solution methodologies, neural network-based approaches are applied in only 1 study, and dynamic programming techniques are employed in 2 studies.

Finally, with respect to optimization objectives, criteria such as minimizing total route cost and incorporating sustainability considerations (e.g., reducing carbon emissions) appear in only 1 study. The limited focus on sustainability is particularly noteworthy, given its growing relevance to both the academic community and broader societal challenges.

	Problem Type						Solving Techniques							Optimization Criteria						
Keywords and basic variables	Packing	Cutting	Knapsack	Palleti loading	MPLP-DPLP	CLP	Linear Programming	Dynamic programming	Mix Integer Programming	Integer Non Linear Programming	Heuristic - Metaheuristic	Genetic Algorithms	Neural Networks	Minimize - Maximize operation cost	Minimizing material waste	Filling Degree per pallet container-track	Minimizing the total route	Reducing operation time	Practical Constraints	Sustainability
Occurrence count across the reviewed studies	25	18	2	6	2	21	8	2	15	5	43	6	1	18	13	30	1	13	10	1

Table 7. Number of occurrences in the studies included in the SLR

Table 7 summarizes the number of occurrences in the studies included in the SLR, categorized by problem type, solution techniques, and optimization criteria. A quality assessment checklist for all the accepted papers is provided in Table 6. This checklist may prove useful for researchers looking to enhance their work by improving certain aspects of the papers listed.

Using the VOSviewer software, Figure 3 shows the most common keywords, such as pattern, container, and stock problem. Figure 4 presents a co-authorship network visualization, highlighting the most active authors. In Figure 5, the leading countries based on research activity are identified, with China dominating the field, followed by Brazil and Spain.

8. Conclusions

The primary objective of our Systematic Literature Review (SLR) is to identify the thematic areas that recent research on the Bin Packing Problem (BPP) has emphasized, particularly in relation to broader challenges within the field. In doing so, we also aim to uncover gaps in the literature to inform future research directions (see Table 6).

Main Scientific Fields: As indicated in Tables 4 and 7, only 1 out of 60 reviewed studies (1.7 %) addresses sustainability-related concerns. These include the conservation of natural resources (e.g., tree usage for paper production), reduction in fuel consumption and CO_2 emissions, and strategies for maximizing the reuse or recycling of materials such as paper, glass, metals, and cutting waste. This stark underrepresentation of sustainability highlights a critical research gap and presents substantial opportunities for further investigation.

Critical Analysis and Future Work: While recent literature on the Generalized Bin Packing Problem (GBPP) has demonstrated remarkable algorithmic advancements, it often remains narrowly focused on deterministic optimization models and highly constrained case studies. There is a distinct need to shift from descriptive to analytical perspectives, particularly concerning two critically underrepresented themes: sustainability and packaging optimization. Sustainability has frequently been marginalized, with only 1.7 % of reviewed studies integrating environmental concerns such as emissions reduction, materials circularity, and lifecycle impact. This omission is particularly problematic in an era where carbon accountability and sustainable logistics are becoming standard industrial expectations. As such, future research must prioritize the development of robust, quantifiable frameworks that assess the sustainability performance of bin packing models over time and across diverse operational settings.

Packaging, another neglected area, requires not only dimensional optimization for pallet efficiency but also attention to consumer interaction and post-consumption waste cycles. Longitudinal and life-cycle-based assessments are essential to understanding the broader environmental footprint. Standardized sustainability metrics, such as those used in eco-design or life cycle assessment (LCA) studies, should be incorporated into bin packing and palletization models. Moreover, the intersection of packaging optimization with consumer behavior, especially in e-commerce and retail sectors, presents rich opportunities for interdisciplinary research involving operations management, behavioral science, and marketing.

Additionally, most existing studies originate from industrialized nations with mature logistics infrastructures, potentially overlooking region-specific challenges in developing economies. This geographic bias highlights the need for localized research agendas and collaboration with global supply chain partners to contextualize optimization strategies.

Looking ahead, emerging technologies such as AI-driven adaptive packing systems, real-time IoT-based pallet tracking, and blockchain-enabled supply chain transparency offer transformative potential. Incorporating uncertainty, dynamic environments, and reverse logistics scenarios such as those found in last-mile delivery and smart warehousing could vastly increase the practical relevance of GBPP formulations. Studies must also go beyond cost-efficiency to critically evaluate trade-offs involving social, ethical, and environmental outcomes. Future research should adopt integrative, interdisciplinary approaches that bridge technical modeling with real-world industrial priorities to ensure that bin packing innovations contribute meaningfully to sustainable and responsible supply chain management.

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