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Open Field Layout Problem Using Hybrid Approaches: A Systematic Review

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ABSTRACT

The Open Field Layout Problem (OFLP) is a facility layout variant that allows free configuration, characterized by the absence of floor constraints and an unlimited number of potential solutions. Despite its growing relevance to modern manufacturing and logistics, no existing systematic literature review (SLR) has specifically addressed OFLP, resulting in fragmented insights and limited understanding of its modeling assumptions and solution strategies. Existing studies often treat OFLP as a single, monolithic concept, whereas in reality it contains several subtypes, including layouts with and without aisles, and with or without boundaries. Among these, layouts with aisles but no boundaries remain particularly underexplored, even though aisles are essential for accessibility, safety, material handling efficiency, and operational flexibility. Their inclusion introduces additional trade-offs between space utilization and transportation efficiency, creating unique theoretical and practical challenges. This study contributes by systematically classifying the principal OFLP types and emphasizing the neglected yet practically important subtype of layouts with aisles but without boundaries. A systematic literature review was conducted by analyzing over 3,000 Scopus-indexed articles using the keyword facility layout problem and related terms, from which 154 studies employing hybrid strategies, such as two-stage, multi-stage, and other combinations, were identified. The classification revealed that only 36% of studies addressed layouts with aisles, and within this group, the case without boundaries was rarely investigated, despite its higher complexity in aisle placement decisions such as orientation, number, and spacing. This is the first SLR that explicitly distinguishes OFLP subtypes and highlights the underexplored variant of layouts with aisles but without boundaries, offering novel directions for developing hybrid strategies that more accurately capture realistic facility settings.

1. Introduction

This paper reviews the evolution of the Facility Layout Problem (FLP) highlighting key developments, methodologies, and emerging trends that continue to shape its future especially for Open Field Layouts (OFLP) configurations and hybrid methods. The Facility Layout Problem is a classical problem in operations research and industrial engineering that has evolved significantly over the past six decades (Tayal & Singh, 2018). Initially formulated to optimize the arrangement of machines and workstations within manufacturing plants, FLP aims to minimize transportation costs, improve material handling, and enhance overall operational efficiency (Liu et al., 2020). Early studies focused on simple layouts, employing mathematical models and heuristic methods (Singh & Sharma, 2006). Over the years, the complexity of FLP has increased, with the introduction of more dynamic and varied objectives such as minimizing total time, accommodating flexible workflows, and integrating modern technologies like automated material handling systems (Klausnitzer & Lasch, 2019; Kovács & Kot, 2017). As industries have grown more complex, the need for innovative solutions, including mixed-integer programming, metaheuristics, and artificial intelligence (Burggraf et al., 2021), has driven further advancements.

Today, FLP continues to be a vital area of research, influencing various sectors beyond manufacturing (Ludwika et al., 2024), such as healthcare (Benitez et al., 2019), logistics (Jiang, Li, Tang, et al., 2023), warehouse (Magableh et al., 2024) and retail (Kuşakcı & Cesur, 2020), while also incorporating sustainability and energy efficiency (Zhang et al., 2022) into the optimization criteria. A comprehensive literature review by (Pérez-Gosende et al., 2021), various layout configurations have been examined in the FLP literature from 2010 to 2019, ranging from single-row layouts to OFLP. Among the 268 articles reviewed, OFLP emerged as the most frequently studied configuration, discussed in 110 articles, accounting for approximately 41% of the total. However, although this review included solution approaches, its treatment of hybrid methods remained general and did not explore their application in OFLP nor differentiate types of hybridization (e.g., high-level vs. low-level). This leaves open the need for a systematic review dedicated to hybrid strategies in OFLP.

OFLP refers to a facility layout configuration in which the material handling path is neither linear nor follows a predefined pattern such as single-row, double-row, multi-row, or looped layouts, as illustrated in Fig. 1 (Hosseini-Nasab et al., 2018). In OFLP, the configuration of the material handling path is determined by the resulting layout structure rather than a fixed pattern. Conversely, in non-OFLP configurations, facilities are arranged to conform to standardized material flow paths, such as those found in single-row, double-row, multi-row, or looped systems (Pérez-Gosende et al., 2021). Although layouts such as chessboard or grid configurations may feature non-linear or curved material handling paths, characteristics that superficially resemble OFLP, they are generally constrained in movement. As such, they do not fulfill the core objective of OFLP, which is to allow unrestricted positioning of facilities.

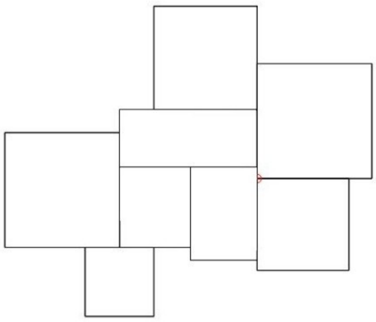

Fig. 1. Open Field Layout configuration

In industrial applications, OFLP is common in job-shop types, particularly in manufacturing industries that do not involve mass products such as aircraft and ship production (Kanike, 2023). However, solving OFLP is extremely challenging because its configuration produces infinite possible solutions (S. Ma et al., 2023), making it computationally expensive to identify a global optimum (Zhan et al., 2022). Many studies employ heuristics or metaheuristics to shorten search time, but these often sacrifice layout quality compared to exact optimization (Alizadeh et al., 2020; Jin et al., 2018). In this study, a hybrid approach refers to the integration of two or more solution strategies, such as heuristics, metaheuristics, or exact methods, in order to exploit their complementary strengths. While heuristics are fast but often suboptimal, and exact methods guarantee optimality but are computationally expensive, hybrids seek to balance efficiency and solution quality, making them particularly relevant to the complexity of OFLP. For example, Allahyari & Azab (2018) combined Simulated Annealing (SA) with heuristic rules to improve job-shop layouts, Zha et al., (2020) integrated SA with Particle Swarm Optimization (PSO) for large-scale aircraft assembly, and Junior et al., (2023) applied a hybrid of Genetic Algorithm (GA) and ELECTRE to address shipyard layouts. These combinations illustrate how complementary techniques, such as heuristic–metaheuristic or multi-metaheuristic integration, can enhance both solution quality and computational efficiency. Given the growing demand for practical yet high-quality layouts in industry, hybrids have become particularly relevant in addressing the scale and complexity of OFLP.

OFLP is also frequently used as an initial approach to derive layouts for grid or multi-row configurations, since the OFLP configuration often produces the shortest travel distance by assuming straight routes, even though real-world flows involve curves. For example, Amaral & Letchford (2013) used OFLP as an initial solution phase before directing points to double-row, multi-row, or grid layouts. Improvement phases were then performed with pairwise exchanges such as CRAFT and extended with metaheuristic techniques (Bouraima et al., 2025; Krajčovič et al., 2019). This shows that hybrid methods, often involving multiple stages, are already implicit in many OFLP studies, as researchers believe that scalable initial solutions followed by iterative improvement yield better final layouts.

Despite the widespread use of hybrid methods in OFLP, there has been no comprehensive study that consolidates and compares these approaches. Existing research remains fragmented, with hybrid strategies applied in diverse but uncoordinated ways (e.g., two-stage, multi-stage, or heuristic-metaheuristic combinations), making it difficult to determine dominant practices or knowledge gaps. This fragmentation highlights the need for a structured synthesis of existing studies to provide a clearer understanding of hybridization patterns in OFLP research.

The objective of this study is to systematically review hybrid approaches in the Open Field Layout Problem (OFLP). It aims to identify how hybrid strategies have been applied across various OFLP variants, classify their methodological characteristics, and highlight emerging patterns and research trends. The review also seeks to uncover underexplored hybrid configurations, thereby providing a structured foundation for future research and practical development in facility layout optimization. This study makes three key contributions: (1) a systematic classification of OFLP variants, (2) an in-depth analysis of research trends in hybrid solution approaches, and (3) the identification of critical directions for future investigation.

2. Method

This research adopts a systematic literature review (SLR) as the type of study, focusing on the Open Facility Layout Problem (OFLP). The analysis combines qualitative synthesis and descriptive statistics to categorize studies, identify methodological trends, and highlight research gaps. To ensure data validity, the review applied predefined inclusion and exclusion criteria, employed Scopus as the primary database due to its comprehensive coverage, and to mitigate potential bias, Mendeley was used to remove duplicates and organize studies systematically. In addition, screening and data extraction were independently cross-checked by three researchers, with discrepancies resolved through discussion to enhance the reliability of the findings.

The data required for this study consists of a collection of abstracts from articles sourced from the Scopus database. This review employed Scopus as the primary database due to its wider coverage, which exceeds that of Web of Science (WOS) by approximately 20%. Moreover, around 67% of articles overlap between the two databases (Vieira & Gomes, 2009). Scopus also offers a broader disciplinary scope, indexing a larger number of journals and encompassing emerging areas in engineering (Zhu & Liu, 2020).

All articles were retrieved using the primary keyword ‘facility(ies) layout(design) problem’. A total of 1.955 journal articles and 1,289 proceedings were identified. This study also references previous research, including a systematic literature review (SLR) by (Pérez-Gosende et al., 2021), which analyzed up to 100 articles on the OFLP. In particular, it draws on the summary table of the Static Facility Layout Problem (SFLP), highlighting significant similarities and complementary findings.

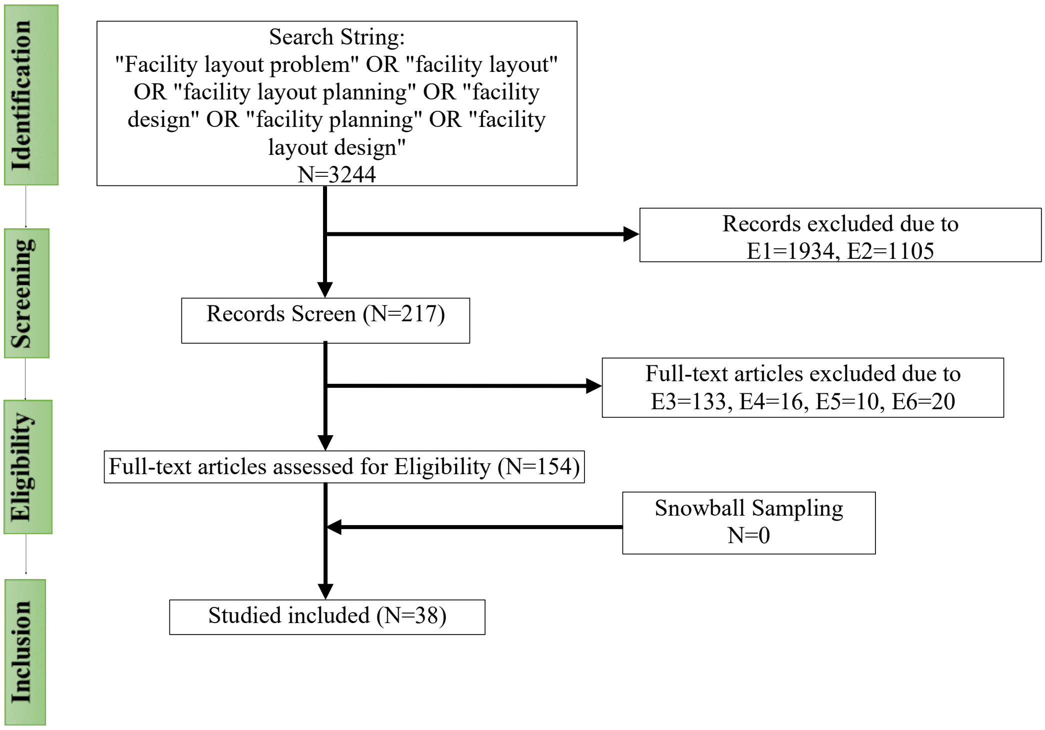

Fig. 2. Prisma diagram adopted from (Isnaini et al., 2025)

The identification process began by excluding studies published before 2015 and those unrelated to FLP contexts, such as a new facility construction, warehouses, Covid-19 conditions, or rural settings. Articles containing the keyword *hybrid* and its synonyms were then grouped, and non-OFLP configurations, such as *single-floor*, *double-row*, *multi-row*, *corridor*, and *U-shape* layouts, were excluded. A full-text review followed to retain only studies proposing OFLP-based final layouts. Articles without final layouts were also excluded to avoid bias, while studies showing partial similarity to OFLP configurations are addressed in the Discussion. The overall review procedure is summarized in Fig. 2.

The characteristics of layouts without cross-movement can be observed in the FTC table. Specifically, they are indicated by a diagonal pattern in which the nonzero cells are surrounded by zeros. In contrast, an FTC table that contains dispersed values greater than zero across multiple cells reflects business processes involving cross-movement. FTC tables without cross-movement characteristics are more effectively addressed using a single-row layout problem approach. Accordingly, articles presenting FTC tables with predominantly diagonal patterns surrounded by zeros are categorized as E3.

Snowball sampling was not applied in this review because the search strategy was designed to achieve comprehensive coverage through a well-established database and systematic inclusion criteria. All articles were retrieved exclusively from Scopus, which provides extensive coverage of high-quality journals and conference proceedings relevant to the Facility Layout Problem domain. In addition, clearly defined keywords and exclusion criteria ensured that only studies directly addressing the topic were included, making supplementary citation chasing unnecessary. Therefore, the decision to omit snowball sampling helped maintain objectivity and reproducibility while minimizing potential bias from manual reference selection.

Table 1. Inclusion and Exclusion Criteria

	Description	Total Occurrences
Exclusion	E1: Articles are not in the year 2015-2024 range	1879
	E2: Articles are other FLP context-sensitive	260
	E2: Articles are not Hybrid Approach	1105
	E3: Articles are not OFLP-related	133
	E4: Articles does not have a final layout	16
	E5: Full-text can not be accessed	10
	E6: Duplicate with previous studies	20
Inclusion	Open-field layout problem with hybrid approach is the main topic	38

3. Results and Discussion

From the initial set of articles retrieved using the keyword facility(ies) layout(design) problem and its variants, 340 were found to contain the term *hybrid* or its synonyms. Subsequent screening restricted to publications from 2015 to 2024 yielded 174 articles. This literature study shares several titles, specifically 20 articles, on OFLP with a previous literature review by (Pérez-Gosende et al., 2021). As a result, the number of articles included in this study was reduced to 154. Based on the identification process involving titles, abstracts, keywords, and final layouts, 57 articles were found to employ the OFLP configuration. However, some of these articles did not present a final layout, and others did not apply hybrid methods. Consequently, the total number of articles included for further analysis is 38.

Table 2 presents the scientific journals and conferences, ranked by frequency, in which the final 38 selected articles were published. Interest in OFLP appears to be relatively evenly distributed, with no single journal or conference showing significant dominance. This pattern contrasts with the findings of a literature review by (Pérez-Gosende et al., 2021), which identified eight journals as the primary venues for FLP-related publications over a ten-year period from year 2010 to 2019.

Table 2. Journal Occurrences

No	Journal Name	Occurence
1.	European Journal of Operational Research	3
2.	Journal of Intelligent Manufacturing	3
3.	International Journal of Production Research	2
4.	INFOR	2
5.	Others	28

The majority of journals discussing OFLP using hybrid methods originate from Europe. Journals that consistently publish on the topic of OFLP and hybrid methods are listed in Table 2. Meanwhile, 28 other journals each published only one article on this topic. There is no single journal that dominates publications in OFLP research, indicating that this topic is multidisciplinary and attracts interest from diverse academic communities, not only from industrial engineering, but also from mathematics, computer science, and even maritime engineering.

Based on the analysis of the publication year distribution from the articles included in this study, the trend reveals a fluctuating pattern over the past decade. The highest number of publications occurred in 2019, with a total of 8 articles, indicating a peak in academic interest on the topic during that year. Other notably productive years include 2015 and 2017, each contributing 6 articles to the literature. Following the peak in 2019 as shown in Fig. 3, there was a significant decline in the number of publications, particularly between 2020 and 2022, which saw only 3, 2, and 1 publication, respectively. This drop may be attributed to several factors, such as a shift in research focus, temporary saturation of the topic, or external influences such as the global COVID-19 pandemic that may have impacted academic publishing activities.

Interestingly, the number of publications rose again in 2023, reaching 5 articles, suggesting a renewed interest in the topic among researchers. However, in 2024, the number declined once more to just 1 article. It is important to interpret this decrease with caution, as the data for 2024 may be incomplete due to the study being conducted before the year has concluded.

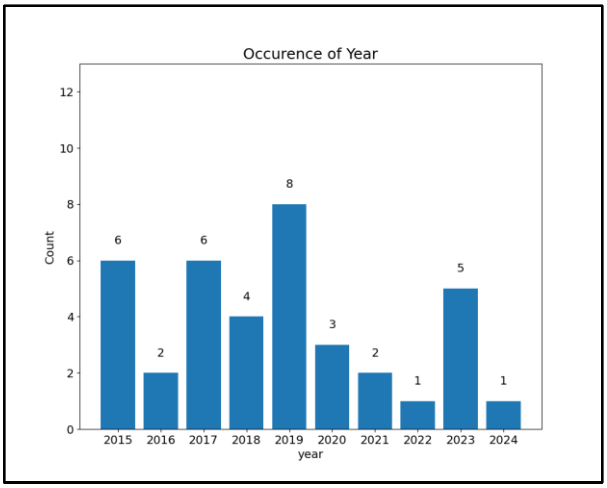

Fig. 3. Distribution of year published

Overall, the publication trend indicates that while there have been ups and downs, the reviewed topic continues to maintain relevance over time. The period from 2015 to 2019 can be considered a growth phase, whereas the subsequent years reflect a phase of consolidation or transition toward more specific research directions.

Many articles employ the keyword *facility layout problem* (FLP) and its derivatives, yet do not actually address the design of facility layouts in the conventional sense of FLP. Consequently, these articles were not included in the in-depth review process. For instance, such studies include the determination of battery-swapping facility locations, the design of logistics facilities and routing, conveyor systems, bibliometric analyses, systematic literature reviews, the contribution of human factors to facility layout, facility design on Mars, specialized vehicle parking layouts, underwater pipeline routing, warehouse layout, multi-criteria decision making (MCDM), input/output point determination, the use of travel time data, production planning, scheduling problems, 3D visualization, among others.

A significant number of articles used both the term *hybrid* and expressions such as *two-phase* or *two-stage*, leading to duplication when collecting articles using keywords like *two-phase*, *three-phase*, and similar terms. Reference management software was utilized to detect and remove duplicate titles, resulting in a total of 174 unique articles obtained through these keywords. However, this set still included several irrelevant topics, such as studies on Industry 4.0, lecture notes lacking empirical research findings, and even several articles classified as OFLP in the systematic literature review by Pérez-Gosende et al., (2021) that, upon closer examination, featured constrained floor configurations, for example, by Anjos & Vieira (2016) and Xie et al., (2018), as summarized in Table 3. In contrast, study by Forghani et al., (2020) involved a layout with a sufficiently large and open floor space, allowing the facilities to move relatively freely.

The reviewed studies show that OFLP is applicable across diverse industrial sectors. Most implementations are found in manufacturing systems, particularly job shops and flexible manufacturing lines, where open floor configurations enable better adaptation to product variety. Several studies also extend OFLP to logistics and warehouse operations (Guan et al., 2019; Kulturel-Konak, 2017), while others apply it in maritime and service-oriented layouts. This cross-industry adoption demonstrates the versatility of OFLP as a facility design approach.

The characterization of OFLP is further discussed in Subsection 4.1. Articles that include the term *hybrid* or its equivalents but do not meet the criteria to be classified as hybrid methods are addressed in Subsection 4.2.

3.1. Open Field Layout Derivatives

Referring to Fig. 4, a considerable number of articles in this review exhibit configurations that closely resemble the open-field layout depicted in Fig. 4(d), as defined by (Pérez-Gosende et al., 2021). Variants that approximate Fig. 4(d) characterized by limited space, absence of aisles, flexible dimensions, and non-linear material handling paths are illustrated in Fig. 4(a). Careful attention is required when assessing these variants, particularly in cases where spatial constraints are extremely tight, causing the facility layout to resemble a double-row structure, as seen in the study by (Lakehal & Aitzai, 2024).

The final layout in Nordin et al., (2023) also bears similarities to a double-row configuration; however, the spatial constraint is imposed on only one side is this of the layout, allowing greater freedom of movement for other facilities on the opposite side compared to the final layout in (Lakehal & Aitzai, 2024). Furthermore, sequential placement methods such as the Flexible Bay Structure (FBS) tend to follow a multi-row material handling path, as demonstrated in (Kulturel-Konak, 2017).

The variant illustrated in Fig. 4(b) exhibits a free-form pattern, includes aisles, and has land boundaries. It is evident that this variant still falls within the category of open-field layout, despite the presence of spatial constraints. Identifying this variant requires considerations similar to those applied in Fig. 4(a), although the visualization in Fig. 4(b) is generally more difficult to recognize due to the less densely packed facility positions compared to (Lakehal & Aitzai, 2024). An example of a final layout excluded from the OFLP category in this review is the study by Sengazhani Murugesan et al., 2020), based on two considerations. First, the visualization suggests a double-row configuration. Second, the business process flow follows a sequential pattern, making it more efficient to adopt a material handling path structured as a row or U-shape layout.

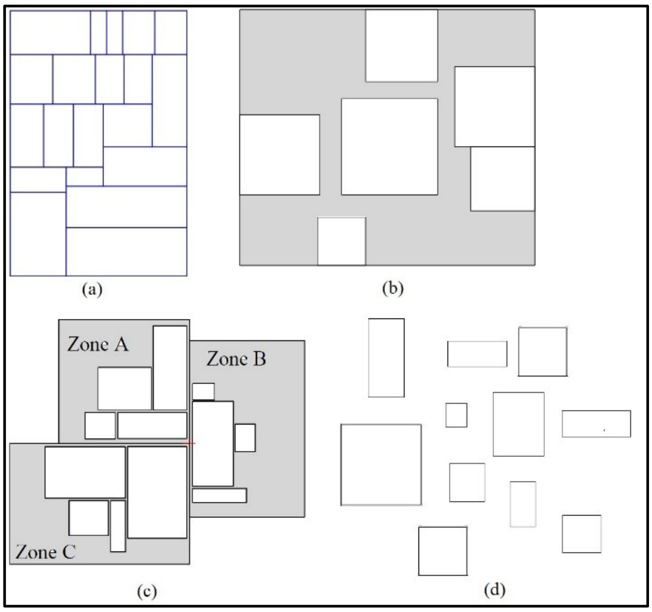

Fig. 4. Open field layout with characteristic variant. A considerable number of articles in this review exhibit configurations that closely resemble the open-field layout

The variant shown in Fig. 4(c) essentially shares the same characteristics as that in Fig. 4(b), in that each zone is initially defined with spatial boundaries. However, at the final layout stage, these zonal boundaries are removed and replaced by a constraint on the total available land area, as seen in Paes et al., (2017) and Y. Xiao et al., (2017). The key distinction lies in the denser placement of facilities in the Fig. 4(c) variant. Meanwhile, the difference between Fig. 4(d) and Fig. 4(b) is limited to the presence or absence of land constraints.

The method for identifying layouts corresponding to configuration Fig. 4(b) involves observing whether at least two facilities are aligned parallel to the boundary of the available land, as seen in the final layout of study (Nordin et al., 2023). In contrast, variant Fig. 4(d) does not display any facilities aligned with the land boundary. Study J. Ma et al., (2023), for example, presents a final layout that tends toward variant Fig. 4(d) due to the lack of clearly defined boundaries. However, since two facilities are aligned in parallel, this indicates the presence of spatial constraints, and thus, the material handling path is more accurately categorized under variant Fig. 4(b).

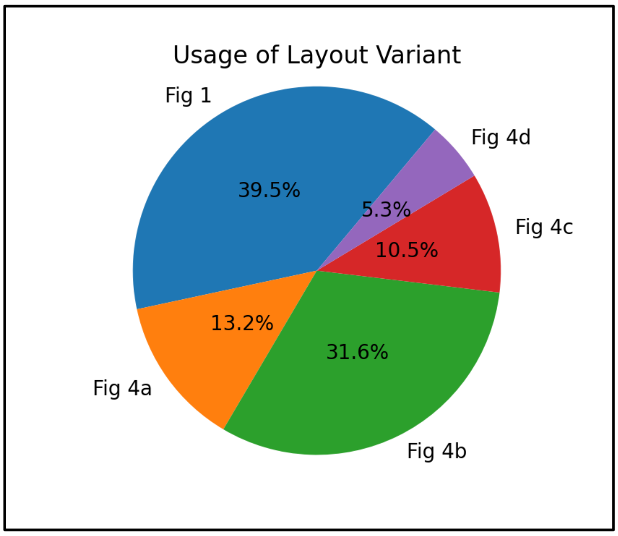

Fig. 5. Distribution of layout variant

Fig. 5 illustrates the percentage of articles employing each layout type. Variants Fig. 4(a), Fig. 4(b), and Fig. 4(c), which represent constrained land scenarios, are the most frequently discussed in Table 3, with a total of 21 articles or 55%. The configuration depicted in Fig 1 is discussed in 15 articles, or approximately 39%. This configuration is likely the most commonly applied in industrial practice, presents meaningful complexity or challenges, and offers greater opportunity for algorithmic development or optimization. The least-discussed layout configuration is variant Fig. 4(d), appearing in only 2 articles or 5%.

There are three possible reasons why variant Fig. 4(d) is rarely discussed in this literature review. First, many authors may assume that facility layouts inherently include aisles, and thus do not explicitly show gaps between facilities. Second, aisle widths in real-world applications may vary considerably, making it difficult to develop methods that consistently produce efficient layouts. Third, several relevant articles do not employ hybrid methods and therefore were not included in Table 3.

3.2. Hybrid Methods

In Fig. 6, hybridization as defined by Talbi (2009), consists of two main types: high-level and low-level. High-level hybridization involves two or more metaheuristics working together sequentially toward a common goal without being embedded within each other. In contrast, low-level hybridization refers to the embedding of two or more metaheuristics within one another.

Within the high-level category, there are two subtypes. The first is relay, in which the initial solution of one metaheuristic is derived from the final output of another. The second is teamwork, where two or more metaheuristics each generate their own initial solutions, run in parallel, and produce separate global solutions. In the teamwork system, these metaheuristics can exchange information as input, a mechanism commonly referred to as the *island model and migration*.

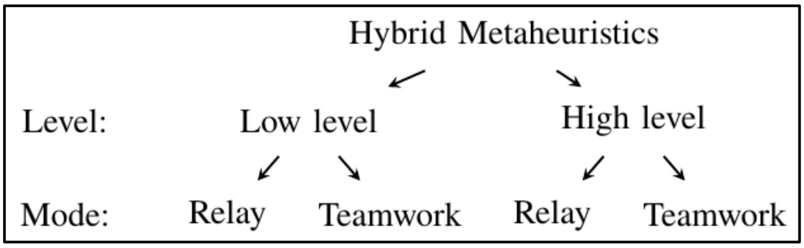

Fig. 6. Hybrid Classification A

Hybridization as described by Rodríguez et al., (2022) involves the use of two or more approaches to arrange facilities. This characteristic aligns with the definition of hybrid methods by Heragu (2018), also known as *composite algorithms*, which involve combining two or more solution techniques, typically a construction algorithm and an improvement algorithm, or blending exact and heuristic characteristics, as illustrated in Fig. 7.

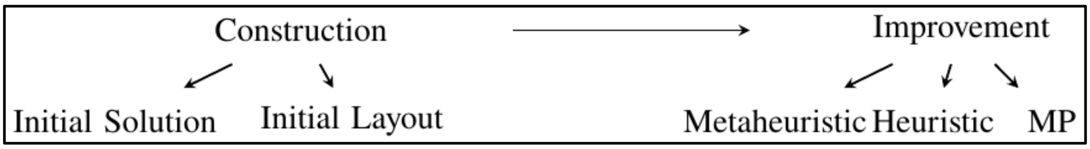

Fig. 7. Hybrid Classification B

The notion of high-level hybridization in Table 3 primarily refers to the sequential application of a construction algorithm followed by an improvement algorithm, as illustrated in Fig. 7 and aligned with the definition by (Heragu, 2018). In contrast, low-level hybridization in Table 3 refers to the embedding of one metaheuristic within another, typically two or more, without involving a construction phase, as depicted in Fig. 6.

The term *construction* refers to algorithms that place facilities onto an empty layout space one by one. Subsequently, the *improvement algorithm* rearranges the constructed layout using either heuristic or metaheuristic methods. Repeated constructive steps using the same algorithm, such as in Nordin et al., (2023), do not fulfill the hybrid criteria defined by Heragu (2018), as the improvement stage still employs the same algorithm. The same applies to repeated improvement steps using a single method.

Study Anjos & Vieira (2016), although solved through a hybrid approach that is neither constructive nor metaheuristic, is classified as high-level in Table 3 (entry number 8), because the solution process is continuous, starting with nonlinear approximation to generate the initial layout, followed by exact convex optimization for improvement. Similarly, study Choi et al., (2017) is categorized as high-level, using a metaheuristic in the initial layout phase and *Stochastic Growth* for position adjustment in the final layout phase.

Zone-based approaches are also considered high-level hybridizations. Although the initial solution is generated randomly, facilities are placed sequentially from zone to zone, which reflects a constructive pattern. Once the construction phase is completed, improvement is performed using *Simulated Annealing* (SA), as in (Kulturel-Konak, 2017).

Study by Guan et al., (2019) also begins with a random initial solution, followed by sequential facility placement starting from the bottom-left corner of the layout to generate the initial layout. This is then refined using *Particle Swarm Optimization* (PSO) during the improvement stage.

The "Other" column in Table 3 is primarily used to indicate the application of less common metaheuristic methods, in order to conserve table space. This column may also include the names of heuristic methods. For example, study Choi et al., (2017) utilizes the Stochastic Growth Algorithm, which is considered a domain-specific heuristic algorithm with stochastic elements. Its inclusion in the "Other" column helps clarify the nature of its hybridization.

Study by Moatari-Kazerouni et al., (2015) is the only OFLP-related research that employs solely a heuristic approach while still exhibiting high hybridization. This is due to the use of Systematic Layout Planning (SLP) as a construction algorithm, followed by an improvement stage using pairwise exchange.

In study by Grobelny & Michalski (2020), the article is included in the OFLP group for review because it employs SP (Scatter Plot), a two-dimensional visualization showing the distribution of data points with respect to two variables, which corresponds to the configuration shown in Fig. 4(d), even though SP is used only as a measured initial input leading to a final grid layout. The final outcome of the SP process retains OFLP characteristics, making it particularly interesting to evaluate how effective SP results are compared to other methods. SP offers significantly faster processing compared to MP (Mathematical Programming) as used in (Amaral & Letchford, 2013).

Table 3. Research of OFLP with hybrid method

No	Author	GA	SA	PSO	MIP	LP	LS	Heu	Other	Level	Design
1.	(Asl & Wong, 2015)	✔					✔			Low	Fig. 1
2.	(Moatari-Kazerouni et al., 2015)							✔		High	Fig. 4(b)
3.	(Luo et al., 2015)			✔				✔		Low	Fig. 4(b)
4.	(Al-Saleh et al., 2015)			✔					TS	High	Fig. 1
5.	(Gonçalves & Resende, 2015)	✔						✔		High	Fig. 1
6.	(Kulturel-Konak, 2017)		✔		✔		✔			Low	Fig. 1
7.	(Y. Xiao et al., 2017)		✔			✔				High	Fig 4(c)
8.	(Anjos & Vieira, 2016)								NLP	High	Fig 4(a)
9.	(Hasda et al., 2017)	✔					✔			High	Fig. 1
10.	(Derakhshan Asl & Wong, 2017)						✔			Low	Fig. 1
11.	(Choi et al., 2017)	✔							SG	High	Fig. 4(b)
12.	(Paes et al., 2017)	✔						✔		High	Fig. 4(c)
13.	(Y. Xiao et al., 2017)						✔		PEA	High	Fig. 4(c)
14.	(Liu et al., 2017)							✔	WLA	High	Fig. 1
15.	(Kaveh & Rastegar Moghaddam, 2017)								WOA,CBO	Low	Fig. 4(b)
16.	(Turgay, 2018)		✔						Entr	Low	Fig. 1
17.	((Jeong & Seo, 2018)		✔						GSS, TS	High	Fig. 1
18.	(Allahyari & Azab, 2018)		✔					✔		High	Fig. 1
19.	((Jerin Leno et al., 2018)	✔	✔		✔					Low	Fig. 1
20.	(Guan et al., 2019)				✔				VNS	High	Fig. 4(b)
21.	(Kulturel-Konak, 2017)		✔		✔				SP	High	Fig. 4(c)
22.	(Grobelny & Michalski, 2020)		✔					✔	CRAFT	High	Fig. 4(d)
23.	(X. Xiao et al., 2019)						✔			Low	Fig. 4(b)
24.	(Liu & Liu, 2019)								ACO	Low	Fig. 4(a)
25.	(La Scalia et al., 2019)								FFA	Low	Fig. 4(a)
26.	(Park & Seo, 2019)		✔					✔		High	Fig. 1
27.	(Moradi, 2019)		✔						INLP	Low	Fig. 4(b)
28.	(Besbes et al., 2020)	✔							A*	Low	Fig. 4(b)
29.	(Forghani et al., 2020)		✔			✔				Low	Fig. 4(b)
30.	(Zhu & Liu, 2020)		✔	✔						Low	Fig. 1
31.	(Aurich et al., 2021)								TS, A*	High	Fig. 4(b)
32.	(McKendall & Hakobyan, 2021)	✔				✔			BS	Low	Fig. 4(a)
33.	(Karateke et al., 2022)							✔	DW	High	Fig. 4(a)
34.	(J. Ma et al., 2023)			✔					GWO	High	Fig. 4(b)
35.	(Jiang, Li, Zhu, et al., 2023)		✔						FD, TOP	High	Fig. 4(d)
36.	(Junior et al., 2023)	✔							Electre	High	Fig. 4(b)
37.	(Şenol & Murat, 2023)	✔	✔					✔	CA	High	Fig. 1
38.	(Seyedi et al., 2024)	✔		✔	✔					High	Fig. 1

Based on the data presented in Fig. 8, metaheuristic approaches are the most dominant method used in the studies, with a total of 45 occurrences. This indicates that many problems in this context tend to be complex and require flexible and adaptive solution strategies. In contrast, the use of classical optimization methods is relatively limited, with only 9 occurrences, suggesting the limitations of deterministic approaches in addressing non-linear problems or those with multiple local optima. Additionally, the use of heuristic methods and other categories is also quite significant, with 33 occurrences, reflecting the diversity of approaches employed in problem-solving.

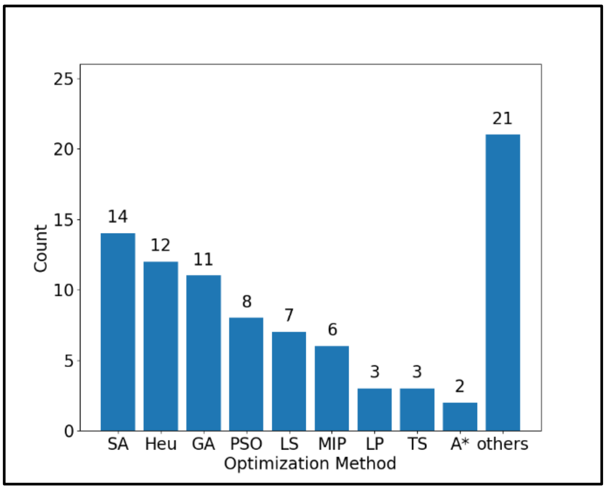

Fig. 8. Distribution of optimization methods

Based on the hybrid classification illustrated in Fig. 6 and Fig. 7, and as detailed in Table 3, a total of 22 articles are categorized as exhibiting high-level hybridization, while 16 are classified under low-level hybridization. Among the high-level hybridization group, 18 articles exclusively implement high-level relay hybridization, and 16 incorporate Heragu's hybrid algorithm. Notably, 12 articles apply both high-level relay hybridization and Heragu's hybrid algorithm concurrently. An overview of the distribution of hybridization levels, based on this classification, is depicted in Fig. 9.

In comparing the hybrid methods, several observations can be made. High-level hybridization generally offers greater flexibility and interpretability, as each algorithm performs distinct stages (e.g., construction followed by improvement). However, this approach may require more computational effort and parameter calibration. In contrast, low-level hybridization, where algorithms are embedded within each other, often achieves faster convergence but can be more sensitive to parameter settings and problem-specific configurations.

Regarding specific metaheuristics, PSO tends to provide faster convergence and better exploration in continuous spaces, while GA offers more robust diversification in discrete problems, making it more adaptable to irregular layout structures. Simulated Annealing (SA), although simpler, remains effective as an improvement method due to its ability to escape local optima with fewer parameters. These complementary strengths explain the frequent combination of constructive algorithms with SA or PSO in high-level hybrid systems observed in the reviewed literature.

This systematic literature review is limited by its reliance solely on published literature, which may not fully represent all research conducted on the Open Field Layout Problem (OFLP). The database used for this review is restricted to Scopus, as it offers the most comprehensive coverage of relevant literature in the field of Facility Layout Problem. Consequently, studies published outside of Scopus, including those potentially offering alternative approaches or unanalyzed findings, were not considered, even if they may provide more comprehensive or representative insights. One article that does not thoroughly discuss its approach but presents a final layout in the form of OFLP was still included in this review. The authors' subjective assessment of layout types, particularly those resembling OFLP, aside from the standardized form shown in Fig. 1, also contributed to the entries in the "Design" column in Table 2. As such, some articles may not represent a specific, formally defined OFLP configuration.

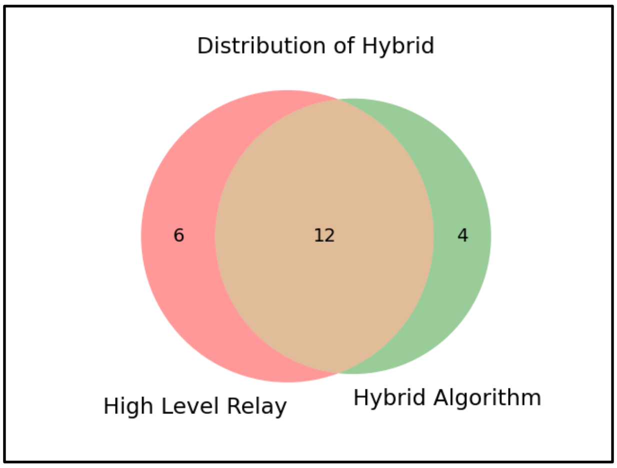

Fig. 9. Distribution of hybridization.

In this review, we combined two definitions of hybridization: one from Heragu (2018), illustrated in Fig. 7, and another from Talbi (2009), illustrated in Fig. 6. This resulted in a duality in the interpretation of high-level hybridization. If a study applies two metaheuristics sequentially and employs sequential placing, it is categorized as high-level hybridization according to Heragu (2018) , as in the case of study J. Ma et al., (2023). However, if sequential placing is absent, it is still considered high-level hybridization according to Talbi (2009) as seen in study Hasda et al., (2017), which uses Local Search (LS) as an initial solution before being processed by Genetic Algorithm (GA).

These interpretations are based on the authors' understanding of each study's goals and methodology, and may differ from other interpretations. The relay and teamwork modes of hybridization are not discussed further in this review, as an in-depth analysis of hybrid methods was intentionally avoided to maintain focus on the core aspects of OFLP and its hybrid definitions.

Irregularly shaped facilities were excluded from this review, as they do not reflect typical real-world conditions. Moreover, regular-shaped facilities are more prevalent and align more closely with the objectives of this study. All layout variants depicted in Fig. 4(a) and Fig. 4(c), as well as Fig. 1, are assumed to include aisles.

Several articles that could not be accessed are presumed to discuss OFLP, based on their titles, which suggest hybrid characteristics, and their references to previous OFLP-related studies. However, to maintain the credibility and reliability of this review, articles that do not present any layout visualization were excluded from the analysis, even though it is possible that they implicitly address OFLP-type layouts.

In addition to the above methodological limitations, the hybrid methods identified in this review also present several challenges and inherent limitations. Many hybrid approaches rely heavily on combinations of metaheuristics, which often lack mathematical rigor and require extensive parameter tuning to achieve satisfactory performance. Moreover, the absence of standardized evaluation benchmarks across studies makes it difficult to objectively compare the effectiveness of different hybrid methods in addressing the Open Field Layout Problem (OFLP).

Over time, the quality of research outcomes has steadily improved, indicating promising opportunities for developing more effective methods. Most existing studies rely on metaheuristics to obtain global solutions. A promising future direction is the adoption of high-level hybridization Heragu (2018), which integrates constructive and improvement algorithms. For instance, a constructive phase could be designed to produce an initial feasible layout that captures key flow relationships among facilities, followed by an improvement phase such as Simulated Annealing (SA) to refine the layout toward a global optimum. Compared with low-level hybrids that depend on random initial inputs, such high-level hybrids may yield more reliable and optimal solutions.

Future studies may also focus on enhancing the determinism and standardization of hybrid approaches. This includes developing evaluation frameworks, benchmarking datasets, and consistent performance metrics to ensure that results are replicable and comparable across studies. Such advancements will be essential for advancing hybrid solution strategies and supporting more rigorous and generalizable research in complex layout design problems.

4. Conclusion

This systematic literature review identifies and categorizes the diverse methodological approaches applied to the Open Field Layout Problem (OFLP), demonstrating that OFLP is not a uniform concept but consists of five principal types. This finding challenges the long-standing assumption that a single, universally applicable facility layout model exists. Among these types, layouts without aisles and floor boundaries have received the greatest research attention, while those incorporating aisles yet lacking clear floor boundaries remain significantly underexplored. Furthermore, the lower representation of certain variants, such as Type 4(d), does not distort the broader understanding of OFLP trends but instead reveals an uneven focus within existing studies. This research contributes by offering a structured classification of OFLP types, refining the conceptual clarity of hybridization definitions, and mapping the dominance of metaheuristic methods compared with classical optimization approaches, thereby strengthening the theoretical foundation for future studies. Building upon these insights, future research should further investigate the underrepresented OFLP Type 5 to uncover its practical and algorithmic complexities. In addition, the integration of visual analysis tools, such as scatter plots and computer-aided layout representations, into quantitative optimization frameworks is recommended to enhance decision-making efficiency and interpretability. Finally, developing standardized evaluation frameworks and benchmarking datasets is essential to ensure the consistency and replicability of hybrid method comparisons. Advancing these directions will enrich methodological diversity and expand the applicability of OFLP research across increasingly complex and flexible manufacturing environments.

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