# Driver Analysis to Solve Dynamic Facility Layout Problems: A Literature Review

Luis Miguel Sotamba[1], Mario Peña[2], and Lorena Siguenza-Guzman[1,3(✉)]

[1] Department of Computer Sciences, Faculty of Engineering, Universidad de Cuenca, Cuenca, Ecuador
{luis.sotamba,mario.penao}@ucuenca.edu.ec
[2] Department of Applied Chemistry and Systems of Production, Faculty of Chemical Sciences, Universidad de Cuenca, Cuenca, Ecuador
[3] Research Centre Accountancy, Faculty of Economics and Business, KU, Leuven, Belgium
lorena.siguenza@ucuenca.edu.ec

**Abstract.** The Dynamic Facility Layout Problem (DFLP) is concerned with finding an optimal facility design considering changes in the planning horizon. Since DFLP belongs to the non-polynomial hard class problem, different solutions have been used to find an optimal solution. However, a correct performance evaluation is needed to validate and compare the results with others. This performance evaluation refers to using both statistical and computational tests. When searching the literature on related papers, none consider these tests. The lack of such information and the constant evolution of algorithms motivated this work. The current document reviews the solution methodologies applied to solve DFLP and the manner the performance evaluation is done. In addition, the methods used to mix solution methodologies, called hybrid approaches, are included. This work was carried out using the Barbara Kitchenham methodology, in which studies from 2015 to 2022 were considered. A sample of 59 articles was analyzed, all about DFLP. As a result, this study identified two commonly used categories when solving DFLPs: hybrid and metaheuristic approaches. Furthermore, performance evaluation is done using different statistical methods in some cases, comparisons of some numerical results obtained from the algorithm output, and studies without comparisons. Finally, the results do not find any instances in which a methodology is applied to compose the algorithm when a hybrid approach is used. To the best of our knowledge, this work is the first in which performance evaluation is considered.

**Keywords:** Dynamic Facility Layout Problem · Optimization · Heuristics · Metaheuristics · Hybrid methods · Literature Review

## 1 Introduction

In today's industry, customer requirements challenge the manufacturing and production stage to be flexible when facing competitive pressure, increased demand,


F. J. G. Silva et al. (Eds.): FAIM 2023, LNME, pp. 242–249, 2024.
https://doi.org/10.1007/978-3-031-38165-2_29

and product complexity [1]. These problems lead to indirect costs, such as the acquisition and operation of material handling equipment (MHE). A good design of the facilities can reduce these costs and maintain a company's competitiveness [2]. In addition, the MHE can represent from 20% to 50% of a company's budget, so an efficient layout of the facilities can substantially reduce production costs [3]. Therefore, the Facility Layout Problem (FLP) deals with the allocation of facilities in the available space and aims to optimize the total material handling cost (MHC) [4]. FLP can be divided into the static facility distribution problem (SFLP) and the dynamic facility distribution problem (DFLP). In SFLP, the layout design is fixed for multiple periods, and there is no reorganization cost (RC) [5]. On the contrary, DFLP consists of a series of static design problems, each with its own material handling cost. Reorganization costs are incurred when facilities change locations in consecutive periods [2]. Therefore, the goal of DFLP is to minimize MHC and RC simultaneously.

In recent years, numerous reviews have been conducted on various topics covered by FLP. T. Zhu, J. Balakrishnan, and C. H. Cheng [6] identified some solution methodologies: exact methods, heuristics, metaheuristics, and hybrid approaches, of which exact methods are adopted in very few studies, and most of the effective algorithms used were heuristic, metaheuristic, and hybrid approaches. P. Perez-Gosende et al. [7] classified FLP as an extensive taxonomy based on the type of problem, approach, stage of planning, and characteristics of production facilities. P. Flores-Siguenza et al. [8] showed that FLP research has grown in the last five years, and the most common methodology used was the metaheuristic approach. J. Vazquez et al. [9] reviewed the literature on FLP research trends on design evolution, workshop characteristics, problem formulation, and solution methodologies. Their results showed that SFLP is the most frequently approached FLP variation when facility design is needed. Furthermore, genetic algorithms and simulated annealing are the most common metaheuristics used to solve FLP.

Due to the industry's dynamic environment, the trend to develop complex DFLP models is growing. However, current DFLP reviews do not consider essential factors such as algorithm performance evaluation or the methodologies used to mix algorithms (commonly called hybrid approaches or hybrid algorithms). The lack of this information motivated this systematic literature review on the different solution methodologies applied to DFLP, the evaluation techniques to evaluate the algorithms, and the process of composing a hybrid solution. This information will help researchers to build a robust methodological approach using the results of this study as a foundation. The current document is organized as follows. Section 2 describes the methodology used to carry out the systematic literature review. Section 3 depicts the findings through content analysis and a brief discussion. Finally, Sect. 4 presents the conclusions generated from the systematic literature review.

## 2 Methodology

The most common reporting guideline for systematic reviews is the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA), which contains a 27-item checklist for reporting in systematic reviews [10]. However, this methodology was created as a guide that describes in detail the process of preparing and maintaining systematic reviews on the effects of healthcare interventions [11]. As this systematic review was conducted in the engineering field, Barbara Kitchenham's methodology was selected to conduct this review. In fact, the engineering community has widely accepted this methodology as it attempts to tailor medical guidelines to the needs of engineering researchers [12]. This consists of three stages: Planning, Realization, and Reporting of the review. The planning stage is associated with developing a review protocol, the Realization stage is concerned with applying the review protocol from the planning stage, and the Reporting stage is related to the document's publication.

### 2.1 Planning

The planning stage consists of five steps: 1) research questions, 2) search strategy, 3) primary study selection criteria, 4) primary study selection, and 5) quality assessment.

**Research Questions.** PICO-based strategy was used to compose the research questions. PICO [13] represents an acronym for Patient, Intervention, Comparison, and Outcome and is used extensively by medical researchers. Still, in software engineering, [12] recommends using PIO strategy: Population, Intervention, and Outcomes. The Population helps to limit the search space, Intervention is associated with the tools or process applied to the population, and Outcomes are related to factors of importance. In this manner, the following research questions were defined following the PICO-based strategy:

1. **RQ1.** What methodologies are used to find an optimal solution to the problem in the DFLP context?
2. **RQ2.** How is the proposed methodology's performance evaluated on the solution methodologies used to solve the DFLP?
3. **RQ3.** When a hybrid algorithm is developed, what is the selection process carried out to choose the set of algorithms that will compose it?

**Search Strategy.** The search strategy is a sophisticated search string constructed with Boolean AND and OR [12] and is used to identify all relevant studies. The search strategy uses a combination of terms based on the research questions. This paper was carried out in three scientific databases: Scopus, Web of Science, and Scielo. The search strategy defined for this study was:

*"facility layout problem" AND ("optimization" OR "algorithm") AND ("Heuristic" OR "Metaheuristic" OR "Hybrid" OR "deterministic" OR "exact").*

**Selection Criteria for Primary Studies.** Selection criteria were defined to answer the research questions. The extraction criteria helps to classify the selected primary studies and obtain the necessary information for this study -see the Fig. 1.

| Criteria | Name |
|---|---|
| **RQ1. What methodologies are used to find an optimal solution to the problem in the DFLP context?** | |
| C01 | Solution methodologies |
| C02 | Algorithm's name |
| C03 | Year |
| C04 | Country |
| **RQ2. How is the proposed methodology's performance evaluated on the solution methodologies used to solve the DFLP?** | |
| C05 | Evaluation methods |
| C06 | Algorithm validation process |
| C07 | Algorithms for comparison |
| C08 | Method for algorithm parameter tuning |
| **RQ3. When a hybrid algorithm is developed, what is the selection process carried out to choose the set of algorithms that will compose it?** | |
| C09 | Methodology applied to develop the hybrid algorithm |

**Fig. 1.** Extraction criteria utilized for primary studies

**Selection of Primary Studies.** The results obtained by applying the search strategy in the scientific databases were subjected to a selection process. This selection consisted of three well-defined steps: 1) evaluation of the inclusion and exclusion criteria, 2) selection of articles by title and abstract, and 3) selection of articles after full reading. Figure 2 shows the number of articles obtained in each step. The search strategy used was limited from 2015 to 2021, and the inclusion and exclusion criteria were:

- Inclusion criteria
  - Articles focused on DFLP
  - Articles in Spanish and English
  - Articles from scientific journals, books section and proceedings
- Exclusion criteria
  - Duplicate articles
  - Theoretical articles

**Quality Evaluation.** Each article was checked for how many times, on average, it has been cited to avoid bias with articles published before others. Therefore, according to Google Scholar's scholarly citation counter, three categories were created: high, medium, and low, where the number of papers belonging to each category was 25, 13, and 21, respectively.

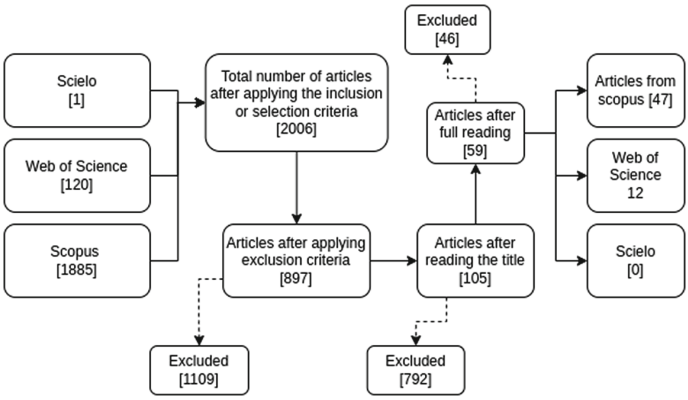


**Fig. 2.** Flowchart of the applied methodology

## 3 Results and Discussion

This section shows the results obtained in this work. The Rayyan tool was used to organize and manage the information retrieved from each study, and Python was used to perform the numerical analysis. Therefore, the results were divided into 1) Metadata analysis and 2) Descriptive analysis.

### 3.1 Metadata Analysis

The demographic information obtained from each article (C04) shows the geographic area of origin of the study. The findings report a total of 15 countries, in which Iran, China, and India remain at the top of the ranking, with 17, 12, and 12 papers, respectively, followed by USA, Turkey, Canada, and Malaysia, with three, three, two, and two papers, respectively. This group of articles represents approximately 69.50% of the selected papers. In C03, the year of publication is considered to know how many articles on DFLP are published using different solution methodologies. Figure 3 shows the trend of the investigations carried out to solve the DFLP, where from 2017 to 2021, a downward slope is shown, which means that interest in this important line has declined.

Finally, information about the document type (journal article or conference article) was obtained. The results give a total of 48 sources, one article was obtained from 38 sources, and two were brought from nine sources. The journal with the most articles published was "Annals of Operations Research", with three papers.

### 3.2 Content Analysis

To answer RQ1, the reviewed articles show a great inclination towards Metaheuristic solutions, which are applied to 39 articles representing 66.10% of the

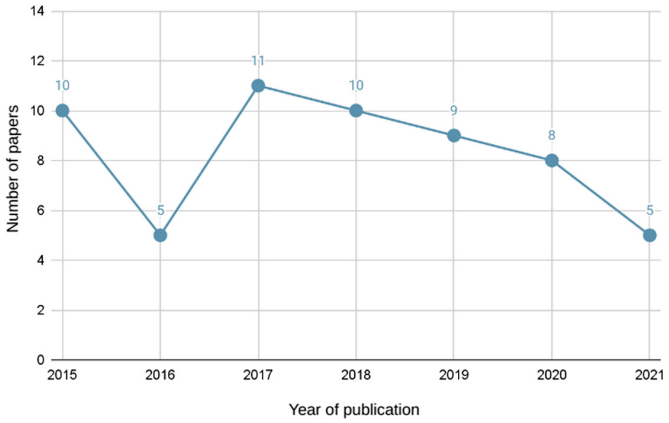


**Fig. 3.** Number of papers per year

total, followed by hybrid solutions, with 13 articles representing 22.03%. The remaining solution methodologies are Heuristic, Exact, and others. The most used metaheuristic algorithms were: 1) Simulated Annealing (SA), 2) Genetic Algorithm (GA), and 3) Particle Swarm Optimization (PSO) with 18, 8, and 4 occurrences, respectively, in which the ranking takes into account for variations of the algorithms. The most relevant articles are in [14–19]. Through this study, it can be seen that researchers are more interested in applying metaheuristic algorithms and hybridizing them to exploit the strengths of each metaheuristic and, therefore, obtain better-quality solutions in the shortest possible time.

To answer RQ2, the articles were classified into three groups: statistical comparison (SC), quantitative comparison (QC), and no comparison (NC). The results show that 16.94% of the studies apply one or several statistical methods to determine if there is a statistical difference between the article algorithm and the selected base algorithms regarding solution quality and/or computation time -about SC-. Whereas 45.76% of the studies do not show an objective comparison but rather compare their quantitative results and draw a conclusion from these - belonging to QC. 37.3% of the studies do not present any performance evaluation method - belonging to NC. The most common statistical methods used in the SC group were: Student's t-test, ANOVA, Tukey's test, Sign test, Mann-Whitney test, and Wilcoxon signed-rank test. Studies in the QC group obtain the objective function values after running their algorithms and performing a smooth comparison with other algorithms (62.96%) or results from other studies (37.04%). In addition, the Taguchi method was the most used parameter adjustment method, presented in 11.84% of the studies, followed by trial and error (8.47%) and article suggestions (5.08%). Finally, to answer RQ3, the results did not yield studies that explained the process or the methodology applied to form the hybrid algorithms. Sometimes, the studies refer to some advantages of the chosen algorithms [19] [21] but do not make a comparison with other promising algorithms.

## 4 Conclusions

This work was carried out to know the solution methodologies applied to solve DFLP, its performance evaluation, and the selection process followed to build a hybrid algorithm in case it is used. The results show that researchers are more interested in applying metaheuristic algorithms and hybridizing them to obtain better results, where 66.10% of the studies use metaheuristic approaches to solve DFLP. In metaheuristic approaches, three algorithms are commonly used: SA, GA, and PSO. Furthermore, the studies were labeled into three categories to understand the performance assessment: 1) best statistical comparison, 2) quantitative comparison, and 3) no comparison, where most studies fall into the second category. The first category recorded some statistical methods used to evaluate the developed algorithms: Student's t-test, ANOVA, Tukey's test, Sign test, Mann-Whitney test, and Wilcoxon signed-rank test. In addition, many studies use the Taguchi method to adjust the parameters of their algorithms to obtain the best values that make it work best. Unfortunately, the results of this work did not show studies that explained the process or the methodology applied to compose the hybrid algorithms. This work aimed to report studies where DFLP was solved with different solution methodologies to understand better the flow of the chosen solution methodology and its evaluation. In addition, the methods used when building a hybrid approach were also investigated. The lack of implementation of performance metrics to judge the performance of an algorithm and the poor selection process when using a hybrid system encourage future projects to consider these aspects. In addition, future work may include studies evaluating various facility design issues and the performance effects of the technology used when evaluating the algorithms.

**Acknowledgements.** The authors would like to thank to Corporación Ecuatoriana para el Desarrollo de la Investigación y Academia -CEDIA for the financial support given to the present research, development, and innovation work through its CEPRA program, especially for the CEPRA XV-2021-01-Resil-TEX. In addition, this research was partially funded by the University of Cuenca, Technical University of Ambato and University of Azuay.

## References

1. Toro, C., Wang, W., Akhtar, H. (eds.): Implementing Industry 4.0: The Model Factory as the Key Enabler for the Future of Manufacturing. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-67270-6
2. Lacksonen, T.A.: Preprocessing for static and dynamic facility layout problems. Int. J. Prod. Res. **35**, 1095–1106 (1997)
3. Garcia-Hernandez, L., Salas-Morera, L., Carmona-Munoz, C., Abraham, A., Salcedo-Sanz, S.: A hybrid coral reefs optimization-variable neighborhood search approach for the unequal area facility layout problem. IEEE Access. **8**, 134042–134050 (2020)
4. Ingole, S., Singh, D.: Fixed and flexible shape facility layout problems using biogeography-based optimisation algorithm. Int. J. Ind. Syst. Eng. **37**, 84 (2021)

5. Tayal, A., Singh, S.P.: Chaotic simulated annealing for solving stochastic dynamic facility layout problem. J. Int. Manag. Stud. **14**, 67–74 (2014)
6. Zhu, T., Balakrishnan, J., Cheng, C.H.: Recent advances in dynamic facility layout research. INFOR Inf. Syst. Oper. Res. **56**, 428–456 (2018)
7. Pérez-Gosende, P., Mula, J., Díaz-Madroñero, M.: Facility layout planning. An extended literature review. Int. J. Prod. Res. **59**, 3777–3816 (2021)
8. Flores-Siguenza, P., Siguenza-Guzman, L., Lema, F., Tigre, F., Vanegas, P., Aviles-González, J.: A systematic literature review of facility layout problems and resilience factors in the industry. In: Botto-Tobar, M., Montes León, S., Torres-Carrión, P., Zambrano Vizuete, M., Durakovic, B. (eds.) ICAT 2021. CCIS, vol. 1535, pp. 252–264. Springer, Cham (2022). https://doi.org/10.1007/978-3-031-03884-6_19
9. Hosseini-Nasab, H., Fereidouni, S., Fatemi Ghomi, S.M.T., Fakhrzad, M.B.: Classification of facility layout problems: a review study. Int. J. Adv. Manuf. Technol. **94**, 957–977 (2018)
10. Gunnell, K.E., Belcourt, V.J., Tomasone, J.R., Weeks, L.C.: Systematic review methods. Int. Rev. Sport Exerc. Psychol. **15**, 5–29 (2022)
11. Fleming, P.S., Koletsi, D., Pandis, N.: Blinded by PRISMA: are systematic reviewers focusing on Prisma and ignoring other guidelines? PLoS ONE. **9**, e96407 (2014)
12. Kitchenham, B.: Procedures for Performing Systematic Reviews. 08/2004. 33, 34
13. Santos, C.M. da C., Pimenta, C.A. de M., Nobre, M.R.C.: The PICO strategy for the research question construction and evidence search. Rev. Lat. Am. Enfermagem. **15**, 508–511 (2007)
14. Derakhshan Asl, A., Wong, K.Y.: Solving unequal-area static and dynamic facility layout problems using modified particle swarm optimization. J. Intell. Manuf. **28**, 1317–1336 (2017)
15. Wang, S., Zuo, X., Liu, X., Zhao, X., Li, J.: Solving dynamic double row layout problem via combining simulated annealing and mathematical programming. Appl. Soft Comput. **37**, 303–310 (2015)
16. Bozorgi, N., Abedzadeh, M., Zeinali, M.: Tabu search heuristic for efficiency of dynamic facility layout problem. Int. J. Adv. Manuf. Technol. **77**, 689–703 (2015)
17. Turanoğlu, B., Akkaya, G.: A new hybrid heuristic algorithm based on bacterial foraging optimization for the dynamic facility layout problem. Expert Syst. Appl. **98**, 93–104 (2018)
18. Tayal, A., Singh, S.P.: Integrating big data analytic and hybrid firefly-chaotic simulated annealing approach for facility layout problem. Ann. Oper. Res. **270**, 489–514 (2018)
19. Kulturel-Konak, S., Konak, A.: A large-scale hybrid simulated annealing algorithm for cyclic facility layout problems. Eng. Optim. **47**, 963–978 (2015)
20. Zhun, X., Liyun, X., Xufeng, L.: An improved pigeon-inspired optimization algorithm for solving dynamic facility layout problem with uncertain demand. Procedia CIRP. **104**, 1203–1208 (2021)
21. Tayal, A., Singh, S.P.: Designing flexible stochastic dynamic layout: an integrated firefly and chaotic simulated annealing-based approach. Glob. J. Flex. Syst. Manag. **18**, 89–98 (2017)