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A Survey on Multi Objective Dynamic Facility Layout and its planning

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ABSTRACT
This paper aims to deal with the current and future trends of research on facility layout problems based on previous research including formulations, solution methodologies and development of various software packages. New developments of various techniques provide a perspective of the future research in facility layout problems. A trend toward multi-objective approaches, developing facility layout software using meta-heuristics such as simulated annealing (SA), genetic algorithm (GA) and concurrent engineering to facility layout is observed.

Keywords: Dynamic multi-objective facility layout problem, Survey of facility layout problems, combinatorial optimization, Quadratic assignment problem (QAP), mixed integer programming (MIP)

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I. INTRODUCTION

Facility layout planning plays an important role in the manufacturing process and seriously impacts a company's profitability. The selected layout establishes the physical relationship between activities including material handling. Since material handling activities account for 20-50 percent of a manufacturing company's total operating budget), manufacturers can reduce product costs and improve their competitiveness if the departments are arranged optimally. "Facilities alone can make or lose millions of dollars per year for an organization. They can give corporate decision makers cost effective flexibility, or they can leave them without any realistic options for change".

Determining the physical organization of a production system is defined to be the facility layout problem (FLP). Where to locate facilities and the efficient design of those facilities are important and fundamental strategic issues facing any manufacturing industry. Tompkins and White [1] estimated that 8% of the United States gross national product has been spent on new facilities annually since 1955, that does not include the modification of existing facilities. Francis and White [2] claimed that from 20 to 50 percent of the total operating expenses in manufacturing are attributed to materials handling costs. Effective facilities planning could reduce these costs by 10 to 30 percent annually. For FLP, the most common objective used in mathematical models is to minimize the materials handling cost, which is a quantitative factor. Qualitative factors such as plant safety, flexibility of layout for future design changes, noise and aesthetics [2] can also be considered.

II. OVERVIEW OF FACILITY LAYOUT PROBLEM

The FLP is a well studied combinatorial optimization problem which arises in a variety of problems such as printed circuit board design; layout design of hospitals, schools, and airports; backboard wiring problems; typewriters; warehouses; hydraulic turbine design; etc. The focus of this review work is on the facility layout of industrial (manufacturing) plants, which is concerned with finding the most efficient arrangement of 'n' indivisible facilities in 'n' locations. Minimizing the material handling cost is the most considered objective but Mecklenburg [3] and Francis et al. [4] gave qualitative as well as quantitative objectives for FLP. Reduced material movement [5, 6] lowers work-in-process levels and throughput times, less product damage, simplified material control and scheduling, and less overall congestion. Hence, when minimizing material handling cost, other objectives are achieved simultaneously. The output of the FLP is a block layout that specifies the relative location of each department. Detailed layout of a department can also be obtained later by specifying aisle structure and input/output point locations which may include flow line and machine layout problems.

2.1 Quadratic Assignment Problem (QAP)

The facility layout problem of locating departments with material flow between them is often modeled as Quadratic Assignment Problem (QAP). Introduced by Koopman and Beckman (1957), The QAP is a problem of finding the best assignment of n department to n locations. The term "quadratic" comes from the fact that it involves the product of pairs of location decision variables. The quadratic assignment problem is widely encountered not only in factory layout planning but also in campus and hospital layout, keyboard layout and construction site planning. Despite its popularity, QAP is a difficult problem to solve using the traditional optimal algorithms. According to Francis, the QAP is "computationally intractable for problems with more than 15 to 20 facilities and this situation have changed very little since the mid-1970s."

To examine it closely, suppose there are a set of n facilities and a set of n locations. For each pair of locations, a distance is specified and for each pair of facilities a weight or flow is specified. (e.g., the amount of supplies transported between the two facilities). The problem is to assign all facilities to different locations with the goal of minimizing the sum of the distance multiplied by the corresponding flows. The mathematical expression for the quadratic assignment problem is shown below

$$\text{Minimize } z = \sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{h=1}^{n}\sum_{l=1}^{n} c_{jkhl}\, x_{jk}\, x_{hl}$$

2.2 MIP model

MIP has received some attention as a way of modeling the FLP. Montreuil first formulated FLP as MIP where a distance-based objective was used in a continuous layout representation that was an extension of the discrete QAP. Hegaru and Kusiak developed a specialized case of this MIP. Lacksonen proposed a two-step algorithm for solving the FLP while assuming variable area which can solve a general dynamic facility layout with varying departmental areas assuming that all are rectangular. Lacksonen then extended the proposed model to deal with unequal areas and rearrangement costs. However, the model could only be optimally solved for small problems. Kim and Kim considered the problem of locating input and output (I/O) points of each department for a given block layout with the objective of minimizing the total transportation distance. A new branch-and-bound algorithm was proposed that seems to perform efficiently even for large-size problems. However, the simultaneous solution of the block problem and the I/O points layouts has not yet been solved. Barbosa Povoa et al. Proposed a mathematical programming approach for the generalized facilities detailed layout problem.

III. LITERATURE SURVEY

LiuJingfa ET AL. (2018) this paper, we put forward a heuristic configuration mutation operation and subsequent local search based on the gradient method to satisfy the non-overlapping constraint, and the multi-objective particle swarm optimization (MOPSO) algorithm, which has recently proven its high effectiveness and robustness in solving multi-objective problems, to obtain a set of Pareto-optimal solutions of the problem. The novelty of the paper lies in the use of an objective space division method in the MOPSO which governs the neighborhood topology and the local best swarm used to assess the global fitness of a solution and choose the global leader particle. The proposed algorithm is tested on three sets of different UA-FLPs from the literature with the size of the problem up to 62 facilities. The numerical results show that the proposed method is effective in solving the multi-objective UA-FLP.

Xin Ning ET AL. (2018) conducted safety improvements in the CSLP to establish a tri-objective ACO-based optimization model to generate site plans. In the model, bi-objective functions for safety are initially built on the basis of interaction relationship analysis, which revealed the importance of the interaction relationship on the safety improvement. The optimization algorithm combining Pareto optimization theory with ACO proposed in this study can be expanded to solve other multi-objective optimization problems in construction management. Meanwhile, this study offers a reasonable and scientific method to design a safe construction site layout, and give constructive suggestions to site managers when they face decision-making on how to organize temporary facilities in construction sites.

Jinying Li ET AL. (2018) As many said, industry 4.0 is an epoch-making revolution which brought the manufacturing market much faster changes and severer competitions. As an important part of the manufacturing system, facility layout has direct impact on business beneft; at the same time, despite the intelligent factory, intelligent production has its own characteristics. However, there is one point on which industry and academia have basically formed a consensus: it is not true that industry 4.0 does not need human beings; on the contrary, human initiative plays an unabated role in the development of industry 4.0. Tis paper will focus on the dynamic facility layout of the manufacturing unit. Based on the system above and the traditional optimization model, a mathematic model is built to fnd the best solution combining safety, sustainability, high efciency, and low cost. And penalty function with adaptive penalty factor and advanced artifcial bee colony algorithm is used to solve the constrained model. In the end, by studying few cases, the model is proved to be efective in both efciency improvement and the implementation of safe and comfort human-machine interaction.

Akash Tayal et al. (2018) proposes a novel integrated framework by combining Big Data Analtics and Hybrid meta-heuristic approach to design an optimal facility layout under stochastic demand over multiple periods. Firstly, factors affecting a facility layout design are identified. The survey is conducted to generate data reflecting 3V's of Big Data. Secondly, a reduced set of factors are obtained using Big Data Analytics. These reduced set of factors are considered to mathematically model a weighted aggregate objective for Multi-objective Stochastic Dynamic Facility Layout Problem (MO-SDFLP). Hybrid Meta-heuristic based on Firefly (FA) and Chaotic simulated annealing is used to solve the MO-SDFLP. To show the working methodology of proposed integrated framework an exemplary case is presented.

Zhinan Zhang et al. (2019) Facing the new trend of Industry 4.0, manufacturing factories are required to have a more flexible structure to finish producing customized products within the limited time and at a reasonable cost. Although virtual factory technology is believed to be helpful for plant layout design and production planning, there still lacks a general framework and algorithms of simulation-based approach to design an optimized plant layout and the production process. This paper proposes a framework of simulation-based approach and develops a procedure for the implementation of the proposed framework. The paper also integrates mathematical algorithms and heuristic methods when applying simulation to balance the operation performance and the planning cost. An illustrative case demonstrates that the proposed approach can achieve the goal of better plant layout design and production planning.

Zhang Lin et al. (2019) Layout problems are common in various manufacturing systems. Actually, the layout problems are related to the location of facilities in a plant, and they have great impact on system performance. However, real systems are large and complicated, and the computation cost of them is high. Thus, the most of layout problems are NP hard. The notion of survival signature is introduced to preprocess the layout problem, and it reduces the economic costs and complexity of computation. Then, the optimization of layout solutions are presented by the genetic algorithm(GA). This study demonstrates that the proposed algorithm is effective, and it can be used in solving the larger layout problems.

Panagiotis M. Farmakis et al. (2017) this paper presents an approach for site layout planning that considers, in addition, safety and environmental issues resulting from the proximity or remoteness of certain facilities to others or to existing eco-sensitive assets (e.g., rivers). The optimization model developed includes the necessary constraints resulting from physical and operational limitations and can additionally model given priorities or preferences set by the project or site manager depending on particularities of the project or the construction site. The model is developed to handle more than one project phases which may optimally require facility relocation (especially in projects where the site layout "is moving" regularly (e.g., highway construction). The inclusion of several project phases and site reorganization requires solving a significantly larger problem than considering a static layout, if full optimization is done. For this reason, the development integrates the required robust search objective with the optimization capabilities of genetic algorithms (GAs). The model has been tested on several case studies considering both static and dynamic site layout planning and results indicate that it provides rational solutions, in response to decision parameters and problem constraints, and that dynamic modeling develops more effective layout planning than a static one.

IV. CONCLUSION

The Dynamic Construction Site Layout Planning (DCLP) is a complex, combinatorial, multi-objective optimization problem which deals with the efficient arrangement of temporary construction facilities within a dynamically changing construction site considering, the characteristics of the facilities and their interrelationships, the characteristics of the construction site and the time-varying project needs. In the current published literature about dynamic facility layout problems, the attention is given mainly to the quantitative or distance-based objective to find the minimum total cost among various alternative facility layouts. In the real world scenarios, the quantitative aspect of the facility layout may not be sufficient; the qualitative factors are also something to be considered.

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