Computers & Operations Research 52 (2014) 123–134

Contents lists available at ScienceDirect

Computers & Operations Research

journal homepage: www.elsevier.com/locate/caor

Solving the bi-objective corridor allocation problem using a permutation-based genetic algorithm

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ARTICLE INFO

Available online 19 July 2014

Keywords:
Combinatorial optimization
Corridor allocation
Multi-objective optimization
Genetic algorithm

ABSTRACT

The corridor allocation problem (CAP) seeks an effective placement of given facilities in two parallel rows on opposite sides of a central corridor. The placement of the facilities in both the rows starts from the same level along the corridor and no gap is allowed between two facilities of a row. The CAP is formulated here as a nonlinear bi-objective optimization problem, in which both the overall flow cost among the facilities and the length of the corridor are to be minimized. A permutation-based genetic algorithm (pGA) is applied to handle the CAP as an unconstrained bi-objective optimization problem. The performance of the pGA is demonstrated through its application to a number of instances of varying sizes available in the literature. The results presented in this paper can be used as benchmark instances in the future work on the CAP.

1. Introduction

A layout is an arrangement of departments or machines in space. Associated with a layout is the material handling cost (or flow cost), which is to be minimized. The material handling cost depends upon the type and order of arrangement of given facilities around a central corridor. The single row facility layout problem (SRFLP) seeks to arrange the given facilities in a row on one side of a corridor. The SRFLP has applications such as the arrangement of machines on a straight path traveled by an automated guided vehicle, arrangement of books in a shelf, arrangement of departments in office buildings, and so on. It has received much attention in the literature (see, e.g., [1–5,7,10,15–25]).

In recent years, Amaral [3] and Chung and Tanchoco [6] have described the double row layout problem (DRLP), which seeks to arrange given facilities, on two sides (two parallel rows) of a central corridor or aisle, by minimizing the total material handling cost among the facilities. In their DRLP formulations, the placement of facilities in the two rows can be started from two different points along the corridor. Moreover, some gap (free space) can also be allowed between two adjacent facilities of a row, if that gap further minimizes the overall material handling cost among all the facilities (it is to be noted that this gap is not any mandatory clearance between two machines, which might be required for the purpose of maintenance and/or for storing jobs). Such considerations may be acceptable in some applications, like planning machines in a big hall or workshop. However, in many cases, such as the office rooms in an administrative building or the shops in a supermarket, the placement of facilities (rooms or shops) in two rows is to be started from a common point along the corridor. Further, any physical gap between two adjacent facilities of a row is generally not preferred even if such a restriction increases the material handling cost. This scenario is studied here as the *Corridor Allocation Problem* (CAP), in which given facilities are arranged in two rows starting from a common point along the corridor and no gap is allowed between two adjacent facilities of a row.

The CAP is formulated here as a bi-objective optimization problem for minimizing (i) the overall flow cost among the facilities arranged on two sides of a corridor and (ii) the required length of the corridor. A permutation-based genetic algorithm (pGA) is investigated for the bi-objective CAP model. An individual of the pGA is defined as a permutation of given facilities, which is later on split into two parts in order to form a valid CAP solution. The pGA population is initialized by random permutations of the facilities, and then it is gradually improved towards the final trade-off optimum solutions using problem-specific genetic operators. The operators are designed specially to generate only feasible permutations of the facilities, so that the pGA can handle the CAP as an unconstrained optimization problem. A number of instances of various sizes from 9 to 80, available in the literature, are considered for evaluating the performance of the pGA.

The rest of the paper is organized as follows: the CAP is analyzed and formulated as a bi-objective optimization problem

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http://dx.doi.org/10.1016/j.cor.2014.07.008
0305-0548/

in Section 2. The proposed pGA is explained in Section 3. The computational experiments are presented in Section 4, followed by the conclusions of the paper in Section 5.

2. Bi-objective CAP model

The CAP involves the placement of n_1 facilities on one side of a corridor and another n_2 facilities on the other side of the corridor, starting from a common point along the corridor and without allowing any gap between two adjacent facilities of a row. An effective placement of the facilities is expected to minimize the overall material handling cost as well as the required length of the corridor. Since two different requirements are there, the nature of the CAP is first studied before formulating a CAP model.

2.1. Nature of the CAP

If the facilities in a layout design are arranged in two parallel rows, instead of in a single row, certainly the overall flow cost will be reduced as the distances among many facilities arranged across the corridor would be reduced. Accordingly, the required length of the corridor will also be reduced. In that sense, it seems that the overall flow cost and the length of the corridor are correlated, i.e. both will get minimized/maximized simultaneously. However, it is not always true, but sometime they may conflict with each other at the optimum (it is observed from the numerical experiments in Section 4 that the flow cost and the corridor length conflict with each other in most of the cases, while they are correlated in some instances only). Accordingly, the nature of the CAP is investigated here through two examples.

As the first illustrative example of the CAP, consider a case of 9 facilities having a length vector of {2,8,9,7,3,4,6,8,9} and an upper-triangular flow cost matrix of {0,2,8,7,4,0,1,6; 8,0,2,7,4,4,6; 2,7,8,0,2,6; 5,0,8,8,6; 5,4,7,6; 8,2,6; 4,6; 6}, where the facilities are to be arranged on two sides of a corridor starting from its left end (it is the instance marked by S9 in Table 1 under Section 4.1). For simplicity, a negligible corridor width, i.e. $w=0$, is considered. Fig. 1 shows the ordering of the facilities with the minimum of both the flow cost and the corridor length (having values of 1181.5 and 28, respectively), where x_i is the centroidal distance of the ith facility measured along the corridor from its left end (see Eqs. (1)–(4) below for computations). Since both the flow cost and the corridor length are optimized (minimized) together, in this example they are clearly correlated with each other.

In the second example, consider a case of 10 facilities having a length vector of {6,3,9,4,2,6,8,9,6,7} and an upper-triangular flow cost matrix of {0,9,5,1,4,5,4,7,0; 4,5,2,7,2,9,0,7; 0,7,2,5,0,9,4; 7,9,0,5,2,5; 0,4,7,2,12; 4,9,3,5; 0,2,9; 1,7; 0} (it is the instance marked by S10 in Table 1 under Section 4.1). Fig. 2(a) shows the ordering of the facilities obtaining the minimum flow cost of 1374.5 over a corridor length of 31. Another interesting and important observation in the case of this example is shown in Fig. 2(b), where a better corridor length (=30) than that in Fig. 2(a) is obtained just by interchanging the last two pairs of facilities of the two rows (i.e. shifting the first and third facilities from the upper row to the lower row, and the seventh and ninth facilities from the lower row to the upper row). The better corridor length in Fig. 2(b), however, degrades (increases) the flow cost from 1374.5 to 1393.5. Therefore, Fig. 2(a) and Fig. 2(b) reveal that, in this example, the flow cost and the corridor length conflict with each other.

The above two examples depict that the nature of the CAP is instance-specific; some can be handled as single-objective

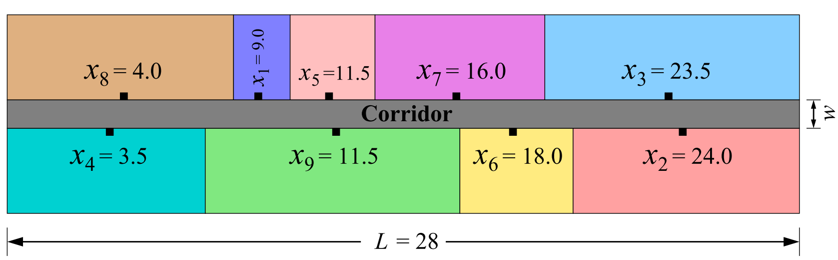

Fig. 1. A CAP example of 9 facilities with correlated flow cost and corridor length.

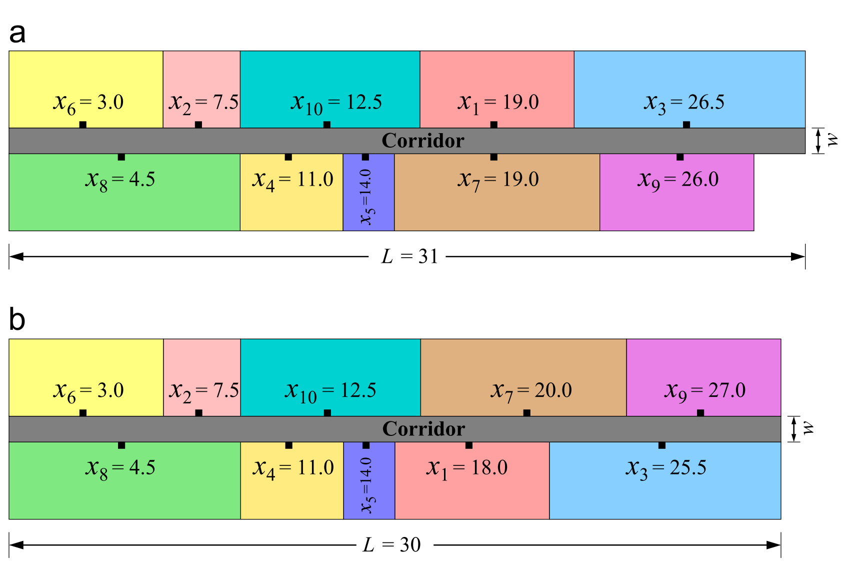

Fig. 2. A CAP example of 10 facilities with conflicting flow cost and corridor length. (a) Flow cost = 1374.5 and corridor length = 31, (b) flow cost = 1393.5 and corridor length = 30.