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A new solution method of ant colony-based logistic center area layout problem

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Abstract. In today's world, logistic centers not only play an important roles in sustaining the nation's economy, they also significantly contribute to the economic and social development of the regions in which they are located. The layout of the center is crucial in ensuring that such important centers are both efficient and productive. To achieve this, this study focuses on the development of a logistic center layout that is integrated with the ant colony optimization algorithm. To this end, the logistic center area layout was developed by applying the developed algorithm to an actual logistic center planned to be constructed. The efficiency of the suggested algorithm was tested in accordance with the benchmark problems in the literature. In addition, a case study was carried out to illustrate the effectiveness of the proposed approach. The obtained results revealed that the suggested algorithm provided more efficiency than other layouts.

Keywords. Logistic; logistic center; area layout; ant colony optimization algorithm; optimization.

1. Introduction

Logistic centers are special areas where all the national and international logistic activities are performed. Such activities as transportation, delivery, storage, handling, consolidation, customs clearance, export, import and freight transit activities, insurance and banking are carried out in these areas [1]. Logistic centers require to be well-equipped with the facilities and infrastructure and have a good layout plan for efficient and productive performance of these activities. Such challenges as transportation costs, facility costs, energy loss, chaos, exceeding the freight delivery deadline, control difficulty are unavoidable in the centers which are established before a logistic center plan is constituted systematically. The facility layout problem (FLP) ranks as the most discussed and best-known of all optimization problems. Optimizing the layout of the facility provides a significant amount of reduction in the transportation and logistics expenditures [2]. FLP should be implemented in a rectangle (LxLy) of n piece of rectangular departments whose square measures are known. These should not overlap and should be situated in such a way that they minimize the flow (Enk Z=$\sum_{ij}^{n} f_{ij}.d_{ij}$) between two departments [2]. Chen *et al* [3] have listed the general restrictions of FLP: (1) All sections should be located in the determined facility; (2) sections should not overlap, and (3) the layout should be designed according to width and height ratios. Researchers say that the solution of the problem lies in the correct presentation of the block layout of each section [3].

It is often asserted that the FLP ranks as the hardest problem to solve in NP-hard class, and that it belongs to the complete NP class. Logistic center layout acts as a kind of a facility layout problem that is derived from the placement of the facilities in a defined area, and is one of the hardest problems which belongs to the complete Np class. Therefore, institutional algorithms should be developed for logistic center layout [3].

In this study, a meta-intuitive algorithm was suggested for logistic center layout by using the ant colony algorithms. The study consists of seven sections. The second section of the study consists of a survey of the literature that focuses on the facility layout problem and that provides logistic center layouts. The third section presents and discusses the Ant Colony Optimization Algorithm, while the fourth section explains the Ant Solution Structure as it applies to a logistic center layout. The fifth section implements the algorithm in the development of an actual logistic center layout. The sixth section benchmarks the suggested algorithm against the FLP problem presented in the literature. The seventh section is a conclusion that discusses the results of the study.

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2. Literature survey

A survey of the literature reveals about studies focusing on issues related to logistic centers and the kinds of problems confronted when a facility layout is developed with the ant algorithm. In the last several years the impacts of the layouts utilized in logistic center design have been gaining additional attention and interest. Examination of the related literature reveals numerous studies that focus on the use of the multi-criteria decision-making method and intuitive methods in the design of layouts of logistic center. In their study Ballis and Mavrotas [4] used the promethee method (a multi-criteria method that presents three alternative designs) to select the most suitable design for a logistic village. Their logistic village design alternatives included a railway line, an international road network, storage areas, a railway transfer area and an administrative area. They selected the most appropriate layout by comparing the alternative designs based on variables of logistic village layout, cross delivery, and direct railway transition and circulation conditions. Li and Zhank [5] used criteria of investment, project revenue, technology, use area of human and load flow and environment to evaluate a logistic center layout with the entropy fuzzy-based comparison method. Yue *et al* [6] defined three different logistic village designs and evaluated these designs according to four indexes that they determined. Their logistic village designs included a pallet storage area, a container storage area, a packaging area, a storage area, an open storage area, an incoming and outgoing load area, and load assembly areas. The four indexes they utilized in their evaluations were a facility order evaluation index, capacity index of equipment systems (storage, material transportation, conveyor system), project evaluation index, and operation costs index. Yet another study was carried out by Zhang *et al* [7] who developed a logistic park layout. They created eight facilities into a single logistic park area and used the genetic algorithm system in their design.

FLP (facility layout problem) is one of the most researched topics in the literature. When the studies in the literature are examined, it is understood that a variety of different modeling and solutions have been presented on the issue. While mathematical models were initially developed to solve facility layout problems, it soon became evident that these models were useful in solving minor problems. Intuitive algorithms were better suited to the solve major problems. Solimanpur *et al* [8] used the ant algorithm to solve a single flow facility layout problem in flexible production systems and in the determination of machinery placement. The authors analyzed the algorithm by acquiring solutions through the triple problem sets, and also presented its results. Demirel and Toksarı [9] developed an ant colony optimization algorithm as a solution for quadratic assignment problems and analyzed the algorithm by using the quadratic assignment problems available in the literature. Alan *et al* [10] developed a hybrid ant system to solve a dynamic facility layout problem, which they used in the solution of problems available in the literature and shared the results. Baykasoğlu *et al* [11] developed the ACO algorithm for the facility layout problems. They applied this algorithm, which considers budget restrictions, in the layout of facilities with 6, 15 and 30 departments. Hani and Amode [12] developed an ant colony optimization for the layout of a six-department railway maintenance facility. Ning and Lam [13] used one of the ACO algorithms, the max-min ant system, for the placement of different facilities used in the construction stages of a construction project. Their study, which focused on the minimization of construction costs, included the development of an algorithm and a comparison of this algorithm against other enhanced optimization algorithms. Komarudin and Wong [14] used for the first time the ant colony optimization for the layout of facilities with unequal areas and applied the algorithms they formed in the solution of problems in the literature. Chen [15] used the ant colony optimization for the solution of dynamic facility layout problems and developed a solution for a layout of thirty departments. Guan and Lin [16] used ACO in their study of a single flow facility layout problem and analyzed their algorithm against sixty well-documented problems.

a) When we examine the logistic center studies in the literature [4–6], it is decided which layout is appropriate for the logistic center after existing projects on the logistic center are compared by using multi-criteria decision-making method. In the study made by Zang *et al* [7] eight facilities were located in the logistic center by employing the genetic algorithm method. No logistic center layout studies made with the ant colony algorithm were encountered. To eliminate such a deficiency in the literature and to introduce a systematic approach and a new point of view for the logistic center layout in the literature, an ant colony-based logistic center layout model was proposed.

b) When ant colony optimization (ACO) studies in the literature were examined, it was discovered that facility layout problems led efficient results. ACO finds rapid solutions for optimization problems and it also considers multiple parameters to reach a solution constituted basic principles ensuring that it was used for this study. Within the scope of this study, an algorithm specific for such a logistic center layout was written and the proposed algorithm was composed of two steps. The first step is performing an efficient order for the facilities to be located in the logistic center. ACO is used for such an order. In the second step, the area layout is made by using the logistic layout procedure. Unlike the traditional ant colony algorithm, pheromone matrix together with the facility area values matrix and facility flow values matrix were used to calculate the probability values when the location order is determined out of alternative facilities. Additionally, the roulette wheel approach was used in the operation of facility designation which prevents the emergence of any convergence. The fact that length and/or width restrictions are not employed which serves to enhance the effectiveness of the suggested algorithm.

3. Ant colony algorithm

Researchers have long focused their studies and attempted to solve real-life problems and have developed new optimizations. In this context, meta-intuitive methods have been developed for the solution of NP-hard optimization problems. The ant colony optimization, which gains its inspiration from ant colony behaviors, is one of these meta-intuitive methods [17].

Dorigo and his colleagues were inspired by the ability of colony ants to find the shortest path between their nests and nutritional sources – despite the fact that they are blind. In 1996 Dorigo introduced a system and he termed "the Ant System" and the algorithm he then developed as "the Ant Algorithm". An ant system consists of artificial ants which imitate real life ant behaviors. According to Dorigo's system:

- Artificial ants have memories;
- They are not totally blind;
- They live in a discrete time environment [18].

Ants living as a colony are social insects. The survival of the colony is the primary aim and takes precedence over the lives of individual ants [19]. Ant algorithms were inspired by this collective behavior of ants. While ants have basic individual abilities, the whole colony comprises a high structure. When ants are part of a colony, they produce clever solutions to such of their problems as transporting big objects, forming a bridge, and finding the shortest way between the nest and nutrition sources. These kind of clever solutions derived from the organization and indirect communication among ants were established [20].

To understand the ant colony algorithm, we must first understand how ants find the shortest path between their nests and food sources. While ants forage, as they move each releases a special liquid called a pheromone from Dufour glands in their abdominal region. Other ants find their way by following these pheromone odors [20]. Ants tend to follow those paths with higher amounts of pheromones. Gradually, all of the ants will choose the shortest way between the nest and a food source [8]. If ants mistakenly choose a longer path, they will quickly reform their route. However, a single ant does not have the ability to find the shortest way between the nest and the nutritional source. Colony behavior provides the best solution as a result of collective intelligence [20].

An ant colony optimization algorithm generally consists of four steps. The first step is the determination of parameters; the second step is to compile data related to the problem; the third step is the formation of ant solution structure; and the last step is the updating of pheromone information [14]. Ant colony algorithm general structure is given in table 1.

Table 1. Ant colony algorithm general structure [8].

```
procedure ACO algorithm
  Set parameters, initialize pheromone trails
  while (termination condition not met) do
     Construct Solutions
     Apply Local search     % optional
     Update Trails
  end
end ACO algorithm
```

4. A newly proposed solution method based on ant colony algorithm

This study proposes a new ant colony-based layout for logistic center layour problem. The steps of the algorithm are given in table 2.

This paper also proposes a new logistic center layout procedure, and this is given in table 3.

4.1 *The ant colony-based area layout algorithm structure*

The details of the ant colony-based layout logistic center layout algorithm is explained below step-by-step.

Step 1. Defining the parameters: With the parameter values related with the algorithm, a flow matrix (f_{ij}), an area matrix (A_i) showing the area information of each facility to be located, a pheromone matrix (F_{ij}), and the coefficients α, β, θ were defined in this part. Basic matrices to be used throughout the algorithm are as follows. Flow Matrix (f_{ij}): This matrix displays the freight flow between the two facilities. In the suggested algorithm, this matrix was used

Table 2. The ant colony-basedlLayout algorithm.

```
Step1. Define parameters, Flow matrix, Area matrix, Pheromone matrix and α, β, θ values
Step 2. Generate Layout Sequence Matrix with random values
While termination criterion not satisfied do
   For each ant of the colony do
      Step 3. Apply Logistic Center Layout Procedure using Layout Sequence Matrix
      Step 4. Control and save the best value, achieved so far
   End For
   Step 5. Apply Evaporation process
   Step 6. Apply Pheromone Updating process
   Step 7.  Updating the Layout Sequence Matrix by using the updating procedure
End While.
```

Table 3. Logistic center layout procedure.

```
1. Divide whole area into small equal units
For each facility area in Layout Sequence Matrix do
   While (feasible layout is not achieved and repetition limit is not exceeded) do
      2. Choose the start point (an area unit) for related facility area at big area
      3. Choose the layout direction (north-south-east-west)
      4. Apply the layout process
  End While
  5. Determine the objective function value of related ant
End for
```

to calculate the objective function and to perpetually re-obtain the Layout Sequence Matrix of the colony.

Area matrix (A_i): This matrix shows the pre-determined area values of the facilities to be located. In the suggested algorithm, this matrix is used to perpetually re-obtain the Layout Sequence Matrix. Pheromone Matrix (F_{ij}): This matrix provides the amount of pheromone left by the ants between the two sites. In the suggested algorithm, the amount of pheromone between the two facilities was initially determined as 1. Alternative solutions are obtained with this matrix, which is also used to perpetually re-obtain the Layout Sequence Matrix of the colony.

α, β, θ values: In the suggested algorithm, when the α, β, θ parameters are re-determined for the Layout Sequence Matrix of the colony showing the layout sequence of facility areas at the end of each step, such parameters are used to determine the relative significance of the pheromone amount, area information, and flow information. In the suggested algorithm, literature utilizations were used to define these parameters as 0.1.

Step 2. Generating the Layout Sequence Matrix: This study also develops a logistic center layout procedure for the facility area layout. This developed procedure uses the area sequence matrix generated from the ant colony algorithm. The layout sequence matrix is the matrix that explicates the sequence to be followed when the facilities are located in a logistic center. In the first step, the layout sequence matrix is generated to the extent of the flock dimension and with random values. Each value on the sequence matrix shows the facility number and each facility is located once. Figure 1 shows a randomly-generated example layout sequence of 9 facility areas.

It is shown in the example that the algorithm will initially attempt to locate the area of facility 4 and then to locate the other facilities respectively.

Step 3. Applying the Logistic Center Layout Procedure: In this study, a logistic center layout procedure was developed to obtain more efficient results in the facility area layout. The developed procedure uses the layout sequence matrix derived from the ant colony algorithm as an input. By considering the sequential facilities one by one, the logistic center layout procedure executes the layout activity in the main area where the logistic center to be established. Area dimensions of these facilities are considered in such a layout process. Our study, in contrast to other facility layout studies, did not use a constant ratio to determine the aspect ratio. This allowed for the attainment of better solution results because of the absence of an aspect ratio restriction when the layout was being executed.

4	2	3	5	1	9	6	7	8

Figure 1. Layout sequence matrix.

Logistic center layout procedure steps are specified below in detail.

1. The main areas of the logistic center are divided into equal unit areas. Each facility in the layout sequence matrix is considered in its order of the matrix. Aspect (width and length) values of the facilities on the matrix are randomly determined by the algorithm. For example: Aspect values for a facility of 100 units may be randomly generated as 25-4, 4-25, 2-50, 50–2, 100-1, 1-100, 10-10.
2. Starting unit area must be determined for layout fulfillment subsequent to the random generation of aspect values. Two different approaches are used to select the starting point: (i) the first approach is to find the first empty unit area by applying the scanning method commencing from the top left corner; (ii) the second approach is to randomly select the starting unit area to be located. The algorithm randomly determines which one of these two approaches will be used.
3. After the starting unit square is determined, which direction is used to implement the layout (north-south-east-west) is randomly determined. Direction selection of north-south-east-west expands the solution space and also ensures that better solutions are obtained.
4. Subsequent to the determination of the starting point and the layout direction, layout activity is executed by using the width and length information of each facility.
   It is obvious that the layout does not always provide a better solution. Thus, layout recurrence in the number of pre-determined value number is allowed. Layout activity is achieved by recording the facility names (facility numbers) to the unit areas. A facility name existing in a unit area means that this area has been reserved for it. It is concluded that any unnamed areas are empty. In case of an unsuccessful layout activity, all the name records of the layout activity are revoked. If an appropriate layout is not executed and the allowed recurrence number is not exceeded, step 2 of the logistic layout

procedure is returned to, and layout runs are repeated after a different starting unit area is selected. If the allowed recurrence number is exceeded, the objective function value of the related ant is assigned as zero and the next ant is passed to.

The algorithm monitors whether the facilities overlap in the determination process of appropriate solutions and whether the whole area for which the layout activity of the logistic center is executed and is not exceeded. In consequence of such controls, overlapping solutions and/or solutions exceeding the whole area of the logistic center are deemed as inappropriate solutions.

5. Objective function values are calculated for all solutions whose area layout is performed in the whole logistic center area in an appropriate manner. Calculation is performed by using Eq. (1) in order to reach the objective of minimization of the flow between facilities. Distances between the facilities are calculated by determining the coordinate values of the center of gravity for each facility for which appropriate layout solutions exist. Flow matrix and the distance values are used to calculate the objective function. For inappropriate solutions, this value is determined as zero and it is ensured that the algorithm ignores it.

$$\text{Enk Z} = \sum_{i,j}^{n} f_{ij}.\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{1}$$

Subsequent to the calculation of the objective function value, logistics layout procedure ends and the main algorithm is passed to.

Step 4. The solution obtained at each step of the algorithm is compared to the best solution so far and the best solution updated.

Step 5. Evaporation: After all of the ant solutions are obtained, evaporation activity is made. $F_{ij}(t)$ shows the pheromone amount stored between the facility i and facility j at t time. In the suggested algorithm, pheromone amount at t+1 time is calculated by employing Eq. (2).

$$F_{ij}(t+1) = \rho.\ F_{ij}(t) \tag{2}$$

Value of ρ in the formula 4 is the evaporation coefficient. It is used to prevent the pheromone from growing unlimitedly. In the suggested algorithm, evaporation coefficient is calculated by using Eq. (3).

$$\rho = \frac{1}{\textit{iteration number}} \tag{3}$$

Step 6. Updating the pheromone: Pheromone information of the related areas is increased in compliance with the best solution layout sequence matrix. This ensures that better solutions affect prospective solutions of the next colonies.

Step 7. An Updating Procedure for The Ant Layout Sequence Matrix: As stated above, the layout sequence matrix was randomly generated at the beginning of the algorithm. Subsequent to obtaining the solutions for each ant flock, the layout sequence matrices to be employed for each new solution are updated. $P_i(t)$ value is used for the updating operation. $P_i(t)$ value is the probability of locating k. ants at t time to the facility i. This probability value is calculated according to Eq.(4) by using the values of flow matrix, area matrix and pheromone matrix with weighted effect of α, β and θ.

$$P_i(t) = \alpha \cdot\ F_{ij}(t) + \beta.A_j(t) + \theta \cdot f_{ij}(t) \tag{4}$$

$P_i(t)$ value calculated for each facility area is used to generate new layout sequence matrices. This stage employs the roulette wheel method, which is a stochastic search feature of the genetic algorithm. While this method quite probably provides the areas having better pheromone, area, and flow value when the layout sequence matrix is generated, it ignores solutions that have bad $P_i(t)$ values. This thus decreases the possibility of being trapped by the local minimum points.

5. Application

The suggested logistic center layout algorithm was implemented in the design of a logistic center which is planned to be constructed in Kayseri, Turkey. The total area of this planned logistic center in Kayseri covers 10,00,000 m^2. Facilities to be included in the center consist of a customs area, a rig-truck park, administrative and social facilities, a gas station, a maintenance and repair area, an enclosed storage area, an open-air storage area, a container area, a silo area, a tank storage area, a cold storage area, a warehouse area, a hazardous substance storage area, distribution center stores, packaging areas, cargo areas, assembly areas and green areas. A total of fourteen facilities which will be able to provide freight flow were considered in the implementation. Fourteen facilities were located to the total area with the suggested algorithm and the implementation results were shared.

The steps of the suggested algorithm are described below for logistic center layout.

5.1 *Determination of parameters*

Flow Matrix (f_{ij}): This matrix displays the possible freight flow among the 14 facilities areas to be located in the logistic center. This freight was transported to Kayseri by railway and highway. f_{ij} flow matrix in table 4 is formed by assuming that all the incoming railway freight and 30% of the incoming highway freight will come to the logistic center [21].

Area Matrix (A_j): Thirty-eight companies that conduct international transportation activities and are located in Kayseri completed a questionnaire concerning the kinds of

Table 4. f_{ij} flow matrix.

	T.C.	C.A.	O.S.	C.S.	Silo	T.S.	C.	C.S.	W.	H.A.	D.C.	P.A.	G.C.C.	A.
Transfer Center	0	100	0	0	0	0	0	0	0	0	0	0	0	0
Container Area	0	0	5	45	5	5	0	5	20	3	5	0	0	0
Open Store	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Closed Store	0	0	0	0	0	0	40	0	0	0	10	0	0	0
Silo	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tank store	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Customs	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Cold Store	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Warehouse	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Hazardous area.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distribution center	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Package area	0	0	0	0	0	0	0	0	0	0	0	0	0	0
General Cargo center	0	0	0	0	0	0	0	0	0	0	10	0	0	0
Assembly area	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5. A_j area matrix.

Facilities	Area (*1000)
Transfer Center	300
Container Area	200
Open Storage	60
General freight Store	30
Silo area	20
Tank Storage	10
Customs	20
Cold Storage	30
Warehouse	50
Hazardous Substance Storage Area	10
Distribution Center	20
Packaging Facility Area	20
General Cargo Center	50
Assembly Area	20

facilities that should be located in a logistic center. These questionnaire results were used to determine the number of square meters the facilities in the logistic center would require. Table 5 gives the area information for the facilities to be located in the center.

Pheromone Matrix (F_{ij}): The amount of pheromone between i and j facilities was determined as 1. The pheromone matrix created for the fourteen facilities is given in table 6.

α, β, θ values: α, β, θ values were taken as 0,1 value by using the literature [8, 12–15].

5.2 *Layout sequence matrix*

The layout matrices of the fourteen facilities to be located in the logistic center were randomly obtained with the suggested algorithm. 100 ants were used. Table 7 shows the layout sequence matrix obtained by using 100 ants.

The layout process was repeated for each ant solution and the best solutions were stored in the memory. The

Table 6. F_{ij} Pheromone matrix.

	TC	CA	OS	CS	Silo	TS	C	CS	W.	D.S.	D.C.	P.F.	G.C.C.	A.
Transfer C	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Container A	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Open Store	1	1	0	1	1	1	1	1	1	1	1	1	1	1
Close Store	1	1	1	0	1	1	1	1	1	1	1	1	1	1
Silo	1	1	1	1	0	1	1	1	1	1	1	1	1	1
Tank store	1	1	1	1	1	0	1	1	1	1	1	1	1	1
Customs	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Cold Store	1	1	1	1	1	1	1	0	1	1	1	1	1	1
Warehouse	1	1	1	1	1	1	1	1	0	1	1	1	1	1
Dangerous S.	1	1	1	1	1	1	1	1	1	0	1	1	1	1
Distribution C.	1	1	1	1	1	1	1	1	1	1	0	1	1	1
Packaging F.	1	1	1	1	1	1	1	1	1	1	1	0	1	1
General C.C.	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Assembly	1	1	1	1	1	1	1	1	1	1	1	1	1	0

Table 7. Ant solution.

3	5	2	10	11	7	1	4	6	9	14	13	12	8

logistic center layout procedure was implemented for 100 ant solutions. Subsequent to the procedure, objective function values were calculated and stored in the memory. The values found were then compared with the best solution. If it is a good solution, the best value is updated.

5.3 *Evaporation and pheromone update*

An evaporation and pheromone update was carried out by using an evaporation and pheromone matrix with 100 ants for the solution. A total of 1000 iterations for the area layout of 14 facilities to be located in the logistic center were conducted. Among the results obtained as a result of 100 ants and 1000 iterations, the best result was found Enk Z:748,996. The solution matrix of this result is given below. The logistic center layout that best complies with the best solution matrix is given in figure 2, table 8.

6. Numerical experiments

The efficiency of the suggested solution for the logistic center layout was tested by using the comparative method with facility layout problem sets and the results were

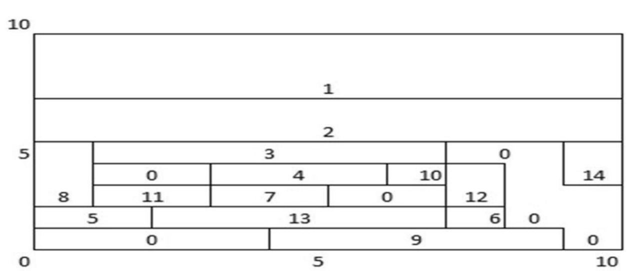
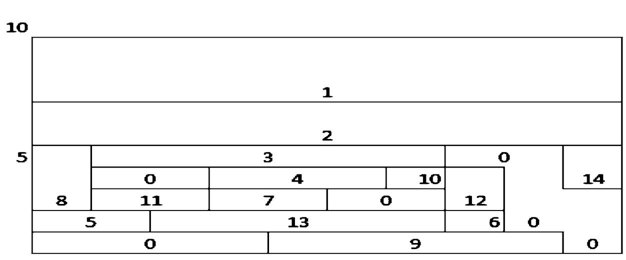


Figure 2. Logistic center layout.

Table 8. The best solution matrix.



shared. Because the example algorithms are not found in the literature, these common problems sets given in table 9 are used for FLP.

In the problem set created for the suggested algorithm, this study uses the 7 and 8 facility layout problems as per Meller and his colleagues [22], the 12 and 14 facility layout problems as per Van Camp and his colleagues [23], the 30 and 35 facility layout problems as per Liu and Meller [2], and the 62 facility layout problems of Dunker and his colleagues [27]. These problem sets are preferred as they contained facility layout in different dimensions and as they are used commonly in the literature.

The proposed algorithm was improved in the programming language of Delphi and all the experiments were made by using 2.4, GHz İntel i7 processor and 8 Gb RAM and Windows PC. 100 ants and 1000 iteration steps were realized for each problem set. Algorithm was operated 5 times for each test and the obtained best results were saved. Algorithm operation durations were not considered because it was not specified in the other studies where the results were benchmarked. The results are presented in table 10. Located ant solutions are given in Appendix A.

The suggested algorithm for the logistic center layout was compared with developed algorithms and an efficient performance was observed for the layout. When the results in table 10 were examined, it was seen that the obtained results proved to be better than those previously known and represented the most optimal solutions for each test problem. A better result approximately %10 better than the best values obtained so far for O7 problem was observed. A better result approximately %15 better than the best values obtained so far for O8 problem was seen. A better result approximately 3% better than the best values obtained so far for Ba12 problem was noticed. A better result approximately %11 better than the best values obtained so far for Ba14 problem was seen. A better result approximately %12 better than the best values obtained so far for SC30 problem was noticed. A better result approximately %2 better than the best values obtained so far for SC35 problem was also seen. Finally, a better result approximately %1 better than the best values obtained so far for DU62 problem was observed.

In addition to the benchmarking,the improved algorithm was benchmarked with Particle Swarm Algorithm (PSO) [27–32] which is widely-used in the optimization problems of the literature and thus it was endeavored that algorithm efficiency is reflected more. Particle Swarm Algorithm (PSO) is an optimization method which was improved by Kenedy and Eberhart who were inspired by fish and insects flocking [27]. PSO is based on social information-sharing among individuals. Search activity is made to the extent of generation number like genetic algorithms. Each individual is called as particle

Table 9. Problem set.

Problem set	References	Number of Departments	Facility size	
			Width	Height
O7	Meller *et al* [22]	7	8	13
O8	Meller *et al* [22]	8	11	13
Ba12	Van Camp [23]	12	7	9
Ba14	Van Camp [23]	14	6	10
SC30	Liu and Meller [2]	30	15	16
SC35	Liu and Meller [2]	35	16	15
Du62	Dunker *et al* [24]	62	100	137

Table 10. Benchmark problem results.

Data set	[24]	[2]	Komarudin Ant System [14]	Bozer and Wang MIP-based hear. [25]	Gonçalves Genetic Algorithm [26]	Results of Authors
O7		131,63	131,68	115,93		**104,86**
O8		245,41	243,12	239		**206,24**
Ba12		8702	8252,67	8552	8020,97	**7715,03**
Ba14		4852	4724,68		4628,79	**4165,243**
SC30		3707	3868,54	3601,2	3367,87	**2985,283**
SC35		3604	4132,37	3351,12	3316,77	**3243,8828**
Du62	4181054		3720521,13			**3677981,472**

The best values were shown in bold

and the population composed of the particles is called as flock. Each particle arranges its own position towards the best position at the flock by using its prior experience [32]. Each literature data were operated 5 times with the improved ACO algorithm (100 ants, 1000 iteration) and also with the traditional PSO algorithm (100 particle, 1000 iteration) in a manner of keeping same the algorithm layout procedure proposed by employing PSO algorithm features. Comparison of the best results obtained with PSO to the results obtained with ACO are given in table 11.

Results in table 10 and table 11 show the efficiency of the proposed algorithm. Reasons for the superiority of the proposed approach may include use of pheromone matrix together with facility area values matrix and facility flow values matrix and use of roulette wheel technique in the determination step of facility layout order.

7. Conclusion

This study developed a logistic center layout procedure based on the Ant Colony Algorithm to efficiently locate each facility area in the logistic center. To date, no other applications regarding logistic center layout have been found in the literature. Because there were no other studies to compare and contrast this study results, we implemented the suggested algorithm on facility layout problems. Our evaluations using this algorithm provided efficient solutions for all the problems.

Table 11. PSO and ACO benchmark problem results

Data set	Result of classical PSO	Results of proposed ACO	% Differences
O7	105,74	**104,86**	0,8
O8	211,91	**206,24**	2,7
Ba12	8248,26	**7715,03**	6,9
Ba14	4652,94	**4165,243**	11,7
SC30	3684,30	**2985,283**	23,4
SC35	5429,19	**3243,8828**	67,3
Du62	4390369,28	**3677981,472**	19,3

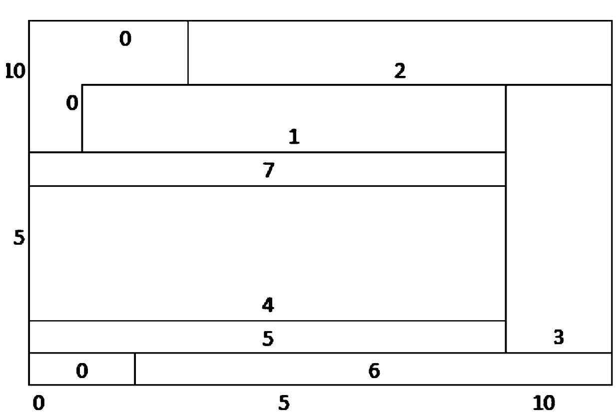
This logistic center layout algorithm consists of two basic steps, In the ant colony algorithm the first step is used to obtain the most efficient layout sequence for the facilities and the logistic center layout procedure. The second step achieves the most efficient area. In contrast with the traditional ant colony algorithm, in this study the facility area values matrix and facility flow values matrix, without distance matrix were used with the pheromone matrix in order to calculate the probability values used to determine the layout sequence from the alternative facilities. The roulette wheel method was also implemented in the determination of the facility layout sequence. Thus, being trapped by the local minimum points is prevented while the optimum solutions are being created. The developed new logistic center layout algorithm uses not only the scanning method but also the random layout method by dividing the whole area into unit areas in the layout process. Furthermore, other strong features of this algorithm include the facts that the area layout activity can be conducted in four different directions (north-south-east-west) and that no aspect (width and length) ratio restriction exists. Evaluations of the test problems revealed that the Ant Colony Algorithm-based logistic center layout procedure worked efficiently.

This study will serve to illustrate the logistic layout problems which have been discussed in the literature. In our future studies, the efficiency of each algorithm will be compared by using artificial bee colony algorithm and harmony search algorithms for the logistic center layout.

Appendix 1: Data set and the best layout obtained for O7.

Departments	Area
1	16
2	16
3	16
4	36
5	9
6	9
7	9

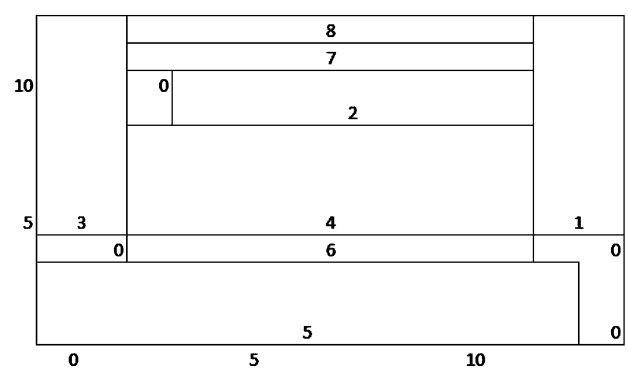
f_{ij}	1	2	3	4	5	6	7
1	_	0	0	5	0	0	1
2	0	_	0	3	0	0	1
3	0	0	_	2	0	0	1
4	0	0		_	4	4	0
5	0	0	0	0	_	0	2
6	0	0	0	0	0	_	1
7	0	0	0	0	0	0	_



Appendix 2: Data set and the best layout obtained for O8.

Dept.	Area
1	16
2	16
3	16
4	36
5	36
6	9
7	9
8	9

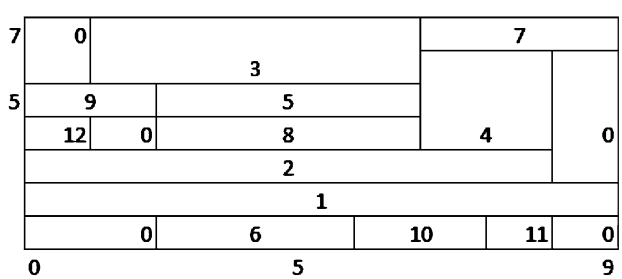
f_{ij}	1	2	3	4	5	6	7	8
1	_	0	0	5	5	0	0	1
2	0	_	0	3	3	0	0	1
3	0	0	_	2	2	0	0	1
4	0	0		_	0	4	4	0
5	0	0	0		_	3	0	4
6	0	0	0	0	0	_	0	2
7	0	0	0	0	0	0	_	1
8	0	0	0	0	0	0	0	_



Appendix 3: Data set and the best layout obtained for Ba12.

Dept.	Area
1	9
2	8
3	10
4	6
5	4
6	3
7	3
8	4
9	2
10	2
11	1
12	1

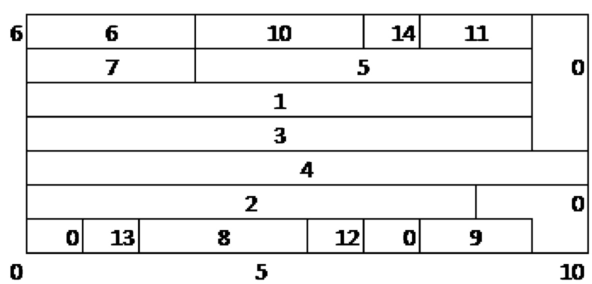
f_{ij}	1	2	3	4	5	6	7	8	9	10	11	12
1	_	288	180	54	72	180	27	72	36	0	0	9
2		_	240	54	72	24	48	160	16	64	8	16
3			_	120	80	0	60	120	60	0	0	30
4				_	72	18	18	48	24	48	12	0
5					_	12	12	64	16	16	4	8
6						_	18	24	12	12	3	3
7							_	0	6	6	3	6
8								_	16	16	16	4
9									_	4	4	2
10										_	2	2
11											_	2
12												_



Appendix 4: Data set and the best layout obtained for Ba14.

Dept.	Area
1	9
2	8
3	9
4	10
5	6
6	3
7	3
8	3
9	2
10	3
11	2
12	1
13	1
14	1

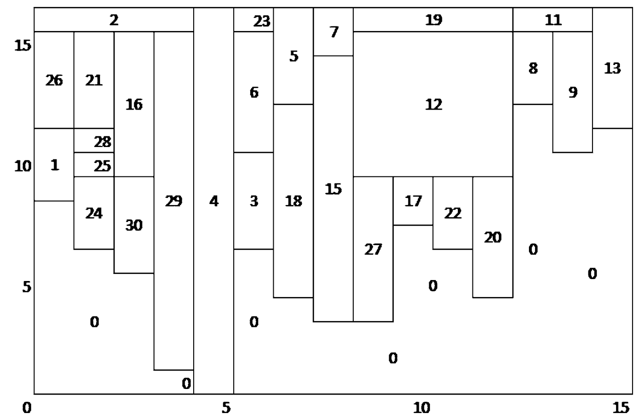
f_{ij}	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	_	72				162	90							
						108	27	0	0	18	27	18	0	0
0														
2		_	72	80	0	48	0	48	32	0	16	8	0	0
3			_	45	54	27	27	27	0	27	0	9	18	0
4				_	30	0	30	30	20	0	20	10	10	0
5					_	18	0	18	12	18	24	0	0	0
6						_	9	9	0	0	6	6	6	0
7							_	9	12	9	6	3	0	0
8								_	6	9	0	3	0	0
9									_	6	4	6	2	0
10										_	6	3	6	0
11											_	2	0	0
12												_	4	0
13													_	0
14														_



Appendix 5: Data set and the best layout obtained for SC30.

Dept.	Area	Dept.	Area
1	3	16	6
2	4	17	2
3	4	18	8
4	16	19	4
5	4	20	5
6	5	21	4
7	2	22	3
8	3	23	1
9	5	24	3
10	6	25	1
11	2	26	4
12	24	27	6
13	5	28	1
14	3	29	14
15	11	30	4

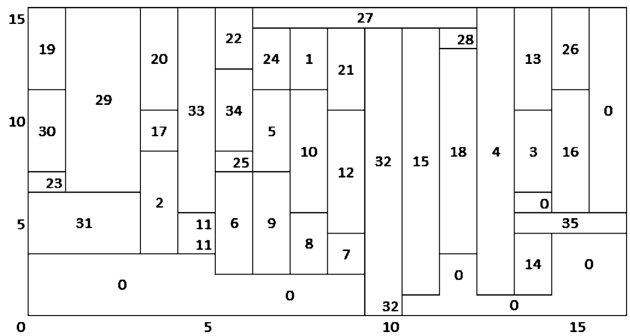
fij	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6,3	1,3	2,1	1,3		14
2	0	_	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	4,5	3,6	2,9	1,3	1,4	0	0	0	0	0	0	0
3	0	0	_	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	394	_	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	_	0	0	0	0	0	4,1	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	8,9	_	2,1	4,8		4,6		1,8	0	0	0	0	0,6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	_	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	_	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	_	0	4,8	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	_	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	_	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	_	0	4,7	53	1,8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	_	0	4,7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	_	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	64	0	0	0	0	0	0	0	0	0	0	_	0	0	191	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,6	_	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,8	0	_	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	191	0	0	0	0	0	0	0	0	0	0	0	0	0	_	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	_	0	0	0	0	0	0	0	0	0	9,2	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	_	0	0	0	0	0	0	0	0	7,4	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	_	0	0	0	0	0	0	0	6	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	_	0	0	0	0	0	0	2,6	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	_	0	0	0	0	0	2,9	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	_	0	0	0	0	5,9	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	_	0	0	0	13	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		_	0	0	2,5	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		_	0	4,2	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			_	2,5	0
29	0	0	0	190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		_	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	_



Appendix 6: Data set and the best layout obtained for SC35.

Dept.	Area	Dept.	Area	Dept.	Area
1	30	16	60	31	90
2	50	17	20	32	140
3	40	18	100	33	100
4	140	19	40	34	40
5	40	20	50	35	30
6	50	21	40		
7	20	22	30		
8	30	23	10		
9	50	24	30		
10	60	25	10		
11	20	26	40		
12	60	27	60		
13	50	28	10		
14	30	29	180		
15	130	30	40		

fij	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6,3	1,3	2,1	1,3	0	14	0	0	0	0	0
2	0		0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	4,5	3,6	2,9	1,3	1,4	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	226		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0		0	0	0	0	0	4,1	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	8,9		2,1	4,8		4,6		1,8	0	0	0	0	0,6	0	0	0	0	0	0	0	0	0	0	0	0	0	3,9	0	0	0	0
7	0	0	0	0	0	0		13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0		43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0		0	4,8	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0		0	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0		8,8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0		0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0		4,7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	64	0	0	0	0	0	0	0	0	0	0		0	0	191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,8	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	191	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	9,2	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	7,4	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	6	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	2,6	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	2,9	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	5,9	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	13	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	2,5	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	4,2	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		2,5	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	190	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60		0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		23	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	13	4,7	53	1,8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		168	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	



Appendix 7. Data set and the best layout obtained for Du62.

Dept.	Area	Dept.	Area	Dept.	Area	Dept.	Area
1	210	21	140	41	204	61	210
2	130	22	304	42	204	62	272
3	224	23	300	43	99		
4	260	24	162	44	160		
5	208	25	252	45	357		
6	294	26	196	46	260		
7	323	27	176	47	190		
8	266	28	144	48	280		
9	441	29	221	49	180		
10	340	30	130	50	104		
11	143	31	182	51	198		
12	168	32	136	52	160		
13	342	33	399	53	200		
14	357	34	210	54	361		
15	420	35	150	55	231		
16	147	36	108	56	140		
17	380	37	357	57	77		
18	144	38	144	58	187		
19	187	39	252	59	231		
20	240	40	135	60	91		

fij	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
1		51	93	60	42	0	13	6	45	0	63	96	0	14	0	32	0	43	0	52	45	0	94	55	30	0	59	72	29	0	0	0	32	51	19	0	23	30	40	0	85	89	48	90	97	0	0	0	0	0	41	75	52	84	69	9	0	59	68	24	95	59
2			44	0	88	22	32	16	25	37	12	46	23	0	99	10	86	0	18	23	16	0	74	93	8	7	57	69	30	41	21	37	51	25	64	0	25	40	41	84	0	70	77	63	0	0	47	0	6	18	0	0	28	97	0	74	52	0	68	0	18	72
3				33	35	6	8	45	13	14	71	94	17	92	54	56	67	62	63	29	93	21	55	85	84	73	37	24	9	85	7	52	0	54	63	47	36	26	77	23	93	25	6	22	21	0	8	45	28	16	99	32	71	51	49	72	68	0	31	27	54	68
4					92	90	11	56	11	0	18	18	98	0	0	83	0	56	0	81	23	71	84	0	27	0	5	0	61	91	0	65	12	0	0	28	52	0	82	0	84	53	0	0	94	27	5	0	12	43	84	0	74	51	91	50	0	76	33	0	10	0
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7									83	60	41	62	94	11	0	62	0	0	0	42	83	71	0	0	26	0	26	14	91	0	0	0	65	0	0	0	9	16	16	0	0	0	20	64	0	12	47	91	92	85	0	45	59	13	0	35	83	0	17	0	33	8
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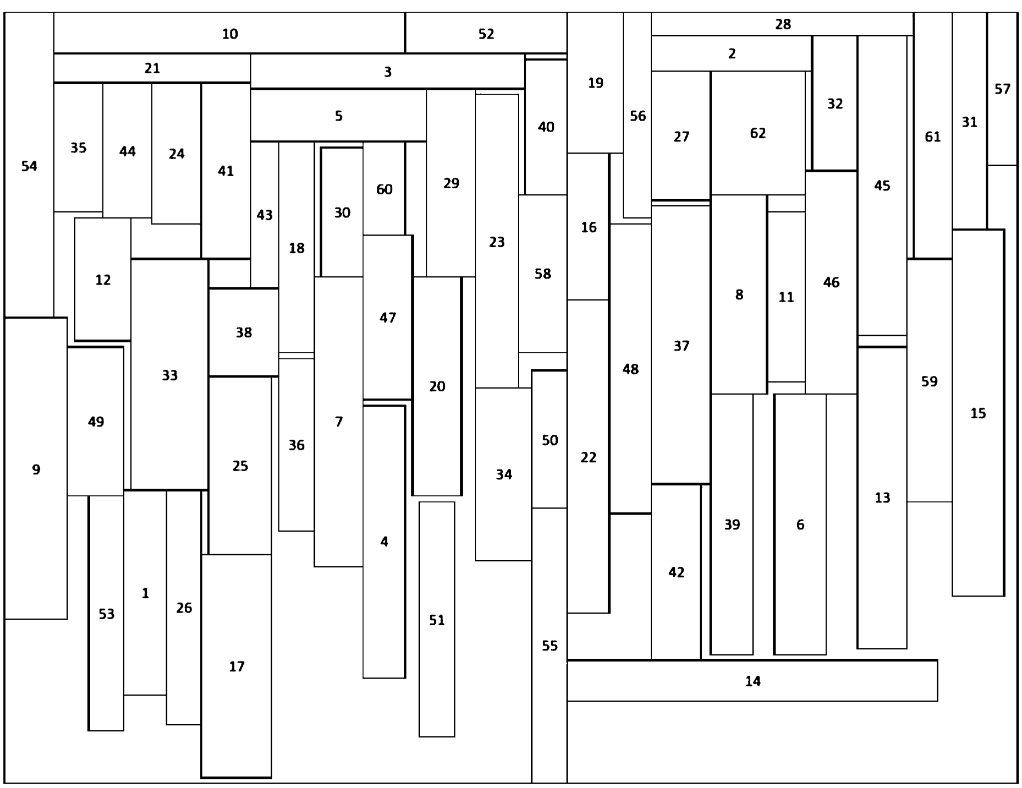

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