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Judul : A NEW COMMODITY DISTRIBUTION APPROACH BASED ON  
ASYMMETRIC TRAVELER SALESMAN USING ANT COLONY ALGORITHM

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1 pesan

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**Industrial Engineering and Management Systems** <editor@iemsjl.org>

11 Juni 2022 01.01

Kepada: Yasser Fakri Mustafa<yassermustafa@uomosul.edu.iq>

Cc: Tua Halomoan Harahap<tuaholomoan@umsu.ac.id>

Hello,

Mustafa has submitted the manuscript, "A New Commodity Distribution Approach Based on Asymmetric Traveler Salesman Using Ant Colony Algorithm" to Industrial Engineering and Management Systems

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

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[Industrial Engineering and Management Systems](#)

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## Reviewer Comments

2 pesan

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Industrial Engineering and Management Systems <editor@iemsjl.org>

15 Juli 2022 09.11

Kepada: Yasser Fakri Mustafa<yassermustafa@uomosul.edu.iq>

Cc: Tua Halomoan Harahap<tuaholomoan@umsu.ac.id>

### Editor's Note

To Author: Thank you for the opportunity to read your paper. This is an interesting topic in an area of growing significance that is relevant to the A New Commodity Distribution Approach Based on Asymmetric Traveler Salesman Using Ant Colony Algorithm. I have a few suggestions that you may consider as you develop the paper further:

ABSTRACT In the abstract, talk more about your conclusion.

INTRODUCTION Paragraph 1, with no references, explaining the context of the research. Paragraph 2, with references, explaining very generally what we know about the topic introduced in Paragraph 1. Paragraph 3 explaining what we need to find out. Paragraph 4 explaining briefly what this paper will do to find out, method etc. Paragraph 5, with no references, explaining the structure of this paper.

LITERATURE REVIEW. Theoretical literature has not been considered and reviewed. It's better to observe the connection between the contents. Try to explain everything except the topics to establish the necessary coherence. Theoretical Development: The literature review must engage in the constructs of your analytical framing in a meaningful way. The literature review section could be improved by being more analytical. In other words, building on the existing literature to highlight what is missing and what is yet to be done and in so doing outline the theoretical puzzles or debates to which this work contributes. I have concerns related to theoretical development and note the need for a more rigorous critique of the literature to help deepen the theoretical underpinnings of the study. Long paragraphs are written without reference. It is better to be more concise. referenced sentences are personal statements of authors that have no scientific validity. Discussion and contributions. Findings and Conclusions Do not show the difference between this article and previous studies. How your research results can be used in other articles? What suggestions do you have for other researchers to continue your work? What components should be emphasized more? Which areas do you think should do more research in this area? What are the limitations of this research? Write suggestions for future research. What are the theoretical and practical implications of your study

REFERENCES References should be modified according to the journal format. The references used in the theoretical literature are old and authors should use references (2019-2020-2021).

Result this paper: Major revision

---

Reviewer A:

Paper length::

Quite long

Originality::

Acceptable

Scope of paper::

Industrial Engineering and Management Systems

Related work::

Acceptable

Language::

needs tighter editing. several grammatical errors found, incorrect spacings, and incoherent sentences/paragraph. There are parts that are too repetitive. And redundant words in the same paragraph.

References::

There is an adequate number of references. However, some in-text citations do not follow the APA format. Additional comments along the following lines: originality, literature review, methodology, evaluation of results, research implications, quality of communication, etc.: The design was not clear enough. An operational framework could have been presented where the variables and steps in the study are shown and applied to the 4D model. Please consider coming up with a framework of the methodology. The researcher did not adequately explained the sampling procedures, how many students and parents were involved in the study, the timeline, and the composition of the experts. Need more details about the research subjects and the data collection technique. What procedures were followed, and analysis procedures for the qualitative data

-----  
Reviewer E:

Paper length::

Originality::

Scope of paper::

Related work::

Language::

References::

Additional comments along the following lines: originality, literature review, methodology, evaluation of results, research implications, quality of communication, etc.:

-----  
Reviewer K

Paper length::

Ok

Originality::

Acceptable

Scope of paper::

Relevant to Industrial Engineering and Management Systems

Related work::

Acceptable

Language::

The paper must be improved in the use of English. It is tough to understand.

References::

At the moment, they seem to be ok. Additional comments along the following lines: originality, literature review, methodology, evaluation of results, research implications, quality of communication, etc.: The paper presents conceptual research based on a survey that seems not been applied and on a few interviews. It is not an exciting study despite the theme interest because the methodology is not entirely understood. The methodology description and implementation need to be improved, so the results are comprehensive, and it possible to analyse the pertinence of the discussion and conclusion.

---

Industrial Engineering and Management Systems <editor@iemsjl.org>

15 Juli 2022 09.11

Kepada: Yasser Fakri Mustafa<yassermustafa@uomosul.edu.iq>

Cc: Tua Halomoan Harahap<tuaholomoan@umsu.ac.id>

Dear Editor. I will revise my article as soon as possible and send it to you. Thank you for your consideration and time

Hopefully will published later

Warm Regards

Mesiono

# A new commodity distribution approach based on asymmetric traveler salesman using ant colony algorithm

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## Abstract

The traveling salesman problem is one of the most well-known hybrid optimization problems. It is one of the (NP-complete) problems that its various applications have theoretically and operationally attracted the attention of researchers. Given that the existing optimization methods to solve such problems include many variables and constraints and reduce their practical efficiency in solving problems with larger dimensions, we have seen the use of algorithms in recent decades. In this research, after determining a linear programming model for the asylum seeker problem with asymmetric distances and solving it in Lingo software, I used two ant cloning algorithms and a forbidden search algorithm to solve the problem in large dimensions. By adjusting the parameters of the two algorithms using the Taguchi method to prove the efficiency of the two algorithms, we compared their results by solving the linear programming model in small-dimensional problems. Then, to compare the results and execution time of the two algorithms, we solved the problem in medium and large dimensions.

**Keywords:** Asymmetric traveler salesman, hybrid optimization, Ant colony algorithm, small dimensional problems.

## 1. Introduction

The traveling salesman problem (TSP) is a well-known combinatorial optimization problem with extensive application in numerous fields of engineering, which has received much attention from scientists and researchers for several decades (Krueger et al., 2019). In this problem, it is assumed that a salesman starts a journey from an arbitrary node (often referred to as the warehouse or depot) to visit  $n$  customers (cities) with known distances from each other

47 exactly once and then returns to the starting point. The goal of this optimization is to determine  
48 the route that the salesman must take to minimize the cost of the journey or the distance  
49 traveled. For a TSP with  $n$  nodes (besides the warehouse), there will be as many feasible  
50 solutions as there are permutations from 1 to  $n$ , with the goal being to find the permutation with  
51 the lowest traveling cost/distance. Thus, this problem will have  $n!$  feasible solutions, which  
52 means the number of solutions increases exponentially with the number of nodes. Since this  
53 problem is NP-Complete (Batsyn et al., 2020), it could be difficult to compare all of these  
54 solutions within a reasonably short time to determine which one is the optimum solution. TSP  
55 is used in a wide variety of fields including vehicle scheduling (Barkaoui and Berger, 2020),  
56 airline crew scheduling (Saleh and Chelouah, 2004), workshop scheduling and ordering  
57 (Bozorgkhou & Hakimipour, 2014), mission planning for mobile robots (Partovi et al., 2018;  
58 Malayer et al., 2022; Sabouri et al., 2020) computer networking, and even genetics and satellite  
59 imagery from celestial bodies, (Cook, 2019). Of course, TSP also has many other applications,  
60 a full review of which can be found in (Bektas, 2006). While TSP is easy to understand, its  
61 large-scale instances can become difficult and sometimes impossible to solve. Assuming that  
62 the distance from node  $i$  to node  $j$  is denoted by  $d_{ij}$ , TSP is said to be symmetric if  $d_{ji}=d_{ij}$  and  
63 otherwise called asymmetric (Johnson et al., 2007).

64 As mentioned in the definition of TSP, one of the important applications of TSP is in vehicle  
65 routing for distribution companies. For example, consider a company distributing dairy  
66 products from a plant to  $m$  vendors in a city. Using TSP, one can minimize the distance traveled  
67 or the time spent on the roads to reach these vendors or minimize the number of vehicles needed  
68 to accomplish the task. Thus, this optimization problem can be used to reduce transportation  
69 costs, fuel consumption, air pollution, and traffic and increase productivity (Warren, 2021; Pour  
70 et al., 2022). It can also be applied to cases where some routes are one-way, the two-way routes  
71 have different amounts of traffic depending on the driving direction, or there is more than one  
72 route between two nodes (for example, a shorter but steep/winding road and a longer but more  
73 straightforward road), in which case the problem becomes asymmetric. Therefore, this problem  
74 is not only interesting from a theoretical point of view but is also highly useful in practice.  
75 Small-scale instances of this problem can be solved with exact methods such as linear  
76 programming with Lagrangian discount, branch and bound, etc. (Josiah et al., 2021; Javanmard  
77 et al., 2022). However, these exact methods are not applicable to large-scale instances of the  
78 problem because they cannot reach the optimal solution in a reasonably short time. Thus, these  
79 problems are now commonly solved with meta-heuristic algorithms, which can produce near-  
80 optimal (if not optimal) solutions in reasonably short times.

81 In this study, the asymmetric traveling salesman problem is solved with two metaheuristic  
82 algorithms: Ant Colony Optimization (ACO) and Tabu Search (TS), which will be described  
83 later in the paper.

84

## 85 **2. Research background**

86

87 The traveling salesman problem (called the traveling salesperson problem or TSP) requests the  
88 next inquiry: "Considering a list of cities and the distances between each pair of cities, what is  
89 the briefest viable way that visits each city precisely once and returns to the origin city?" It is  
90 an NP-hard problem in combinatorial optimization, essential in operations research and

91 theoretical computer science. The vehicle routing and traveling purchaser problems are both  
92 TSP generalizations (Batsyn et al., 2020; Kurniady et al., 2022). The traveling salesman  
93 problem was first mentioned in a book published in Germany in early 1932. Following the  
94 creation of the Rand Corporation in 1948, this institute conducted valuable research on TSP,  
95 which made the problem famous in the U.S. and Europe (Warren, 2021). Since then, this  
96 problem has received attention from many researchers, who have published numerous articles  
97 on the problem itself and the possible solution methods (Johnson et al., 2007). Asymmetric  
98 TSPs differ from their symmetric counterparts in two respects. Firstly, a symmetric TSP can  
99 be solved using half the memory required for solving a similar asymmetric TSP. Secondly, it  
100 is usually far more difficult to do optimization and approximation tasks for asymmetric TSPs  
101 (Johnson et al., 2007). According to Johnson, there has been relatively little progress in  
102 empirical research on asymmetric TSP. Provided in the following are some examples of studies  
103 conducted in this field. In one study on this subject, Yousefi Khoshbakht et al. proposed a  
104 modified imperialist competitive algorithm for solving this problem. This algorithm uses an  
105 evolutionary approach to solution, which is advantageous in terms of scalability and remains  
106 effective in many applications. This approach is suitable for situations where the algorithm has  
107 little information about the search space and the definition of a feasible solution for the  
108 problem, as it involves exploring the search space as much as possible by generating random  
109 solutions and then progressing towards better solutions (Yousefikhoshbakht et al., 2011). In  
110 another study, Ebadinezhad utilized a dynamic evaporation strategy to improve the  
111 effectiveness of ACO in solving TSP. They stated that while ACO is an efficient algorithm for  
112 solving combinatorial optimization problems, it has a low convergence rate and tends to get  
113 trapped in local optima. Thus, to eliminate these problems, they developed an ACO equipped  
114 with unique measures to improve convergence rate and handle stochastic variables more  
115 effectively, enabling the method to find the minimum cost/shortest path for each cluster. The  
116 test results of this study showed that the proposed method outperforms the ordinary ACO in  
117 terms of convergence rate and search accuracy (Ebadinezhad, 2020).

### 118 119 **3. Methods**

120  
121 NP-Complete problems are a large number of computational problems with a wide range of  
122 applications for which feasible solutions cannot be found in reasonably short times. It has been  
123 proven that there is no quick solution for these problems and if such a solution exists for one  
124 of these problems, other problems of this class can also be quickly solved with the same  
125 solution approach. Here, the term “quick solution” means a solution found in polynomial time  
126 (i.e. the solution time has a polynomial relationship with the problem size). Prime examples of  
127 NP-Complete problems include the traveling salesman problem, the Hamilton path problem,  
128 the knapsack problem, and the graph coloring problem. The common ways to deal with NP-  
129 Complete problems include (Shabgah et al., 2021; Khorsandi et al., 2021; Paliwal et al., 2022):  
130 -Developing an algorithm for finding exact solutions (only applicable to small-scale  
131 problems)  
132 -Using heuristic algorithms to search for solutions that are likely to be correct. -  
133 Partitioning the problem into smaller sub-problems that can be more accurately solved  
134 with heuristic algorithms.

135 In this study, after building a linear programming model for solving the small-scale instances  
 136 of the problem, its large-scale instances are solved with two metaheuristic algorithms, namely  
 137 ACO and TS, and in the end, their results are compared and discussed.

138

### 139 3.1. Mathematical formulation of TSP

140

141 Suppose the total number of cities is  $n$ , the cost of traveling from city  $i$  to city  $j$  (or travel  
 142 distance or travel time) is  $C_{ij}$ , and the binary variable  $X_{ij}$  is defined as follows:

143

144 1 If a trip takes place from city  $i$  to city  $j$  )1(

$$145 X_{ij} \begin{cases} 1 & \text{if a trip takes place from city } i \text{ to city } j \\ 0 & \text{otherwise} \end{cases}$$

146

147 The linear model of this problem, provided that  $i \neq j$ , is as follows (Ramalingam et al., 2022):

148

$$149 \begin{aligned} & \text{Min } Z = \sum_{i=1}^n \sum_{j=1}^n C_{ij} X_{ij} \end{aligned} \quad )2($$

150

151 Subject to

$$152 \sum_{i=1}^n X_{ij} = 1 \quad j = 1, \dots, n; \quad )3($$

$$153 \sum_{j=1}^n X_{ij} = 1 \quad i = 1, \dots, n; \quad )4($$

$$154 U_i - U_j + nX_{ij} \leq n - 1 \quad 2 \leq i \neq j \leq n \quad )5($$

$$155 U_j \geq 0, X_{ij} = 0.1 \quad i, j = 1, \dots, n. \quad i \neq j \quad )6($$

160

161 The goal of the problem is to minimize the total travel cost (or travel time or distance traveled).  
 162 Equations (3) and (4) state that only one edge can enter each node ( $j$ ) and only one edge can  
 163 exit each node ( $i$ ).

164 Equation (5) prevents the formation of sub-tours. For example, if the salesman goes from city  
 165  $i$  to city  $j$ , then:

166

$$167 U_i - U_j + n \times 1 \leq n - 1 \rightarrow U_i - U_j \leq -1 \quad (7)$$

168 Thus, we will have  $U_j - U_i \geq 1$ , which makes it impossible to return from  $j$  to  $i$ . Now, going  
 169 from city  $j$  to city  $k$  will make it impossible to return from  $k$  to either  $i$  or  $j$  because:

170

$$171 U_i - U_j \leq -1, U_j - U_k \leq -1 \quad (8)$$

172  
173 By adding these two inequalities together, we will have  $U_i - U_k \leq -2$  and therefore:  
174

$$175 \quad U_k - U_j \geq 1, U_k - U_i \geq 2 \quad (9)$$

176 These positive values prevent traveling from city k to city j and from city k to city i. Equation  
177 (6) defines the domain of variables used in the problem formulation.  
178

### 179 **3.2. Ant colony optimization**

180  
181 Ant Colony Optimization (ACO) is regarded as a probabilistic method generated for the aim  
182 od solving combinatorial optimization problems. Taking inspiration from the foraging behavior  
183 of ants, ACO is deemed as a population-based optimization method able to produce desirable  
184 and accurate solutions for complex optimization problems (Tarallo et al., 2019). Biological  
185 research have demonstrated that ants secrete a substance called pheromone, by which they can  
186 communicate with each other and share path information during foraging. In general, ACO  
187 comprises four major steps. The first step is to set the basic parameters of the algorithm (the  
188 number of ants, evaporation rate, etc.). In the second step, each ant produces an initial (feasible)  
189 solution (path). In the third and fourth steps, a local search is done iteratively and parameters  
190 are updated accordingly. More specifically, in the third step, a heuristic procedure is used to  
191 improve the solutions (paths) previously found by the ants. In the fourth step, the pheromone  
192 values assigned to each path are updated based on a given objective function. The two steps  
193 (local search and updating) will be repeated until a termination condition is met. The general  
194 procedure of ACO is provided below.

- 195 1- Set the algorithm parameters including the number of iterations, the number of ants, the  
196 objective function,  $\alpha$ ,  $\beta$ ,  $\gamma$ , etc. 2- Follow the below steps for every ant  
197 2-1- Select a random origin  
198 2-2- Follow the below steps until all nodes are visited  
199 2-2-1- Select one of the selectable nodes based on a given probability  
200 2-2-2- Remove the selected node from the list of selectable nodes  
201 2-3- Evaluate the constructed paths  
202 3- Let all ants move on their paths  
203 3-1- Make each ant secrete pheromone on its path  
204 3-2- Apply evaporation to pheromones secreted on every path 4- Stop if the  
205 termination condition is met, otherwise go to step 2.  
206

207 In this study, node (city) selection in Step 2-1-1 is performed using the roulette wheel  
208 mechanism. In this mechanism, the probability of an option being selected is proportional to  
209 its fitness (as determined by a fit function) as formulated in Equation 10 (Blickle and Thiele,  
210 1996).

---

$$\sum_{j=1}^N$$

214 The probability of option  $i$  being selected is equal to the ratio of its fitness value to the sum of  
215 fitness values of all options.

216

### 217 **3.3. Tabu search**

218

219 Tabu search is a metaheuristic method operating based on iterative local searches that is  
220 equipped with some additional mechanisms (tabu list and possibility of accepting worse  
221 solutions) to avoid getting trapped in local optima and better explore the solution space. In  
222 general, this algorithm starts with an initial solution and then determines the best solution that  
223 can be found in the neighborhood of that solution. The algorithm then moves to this  
224 neighboring solution unless this solution (or movement) is in a list called the tabu list, in which  
225 case the algorithm checks whether the solution (movement) satisfies an aspiration condition.  
226 This aspiration condition could be whether the neighboring solution is better than the best  
227 solution found so far. If the aspiration condition is met, the algorithm will move to the  
228 neighboring solution regardless of the contents of the tabu list. After moving to a neighboring  
229 solution, the algorithm updates the tabu list to avoid looping (returning to visited solutions). In  
230 other words, the algorithm uses the tabu list as a tool to avoid getting stuck in local optima. In  
231 each update of the tabu list, one or more solutions (movements) previously placed in the list  
232 could be removed from the list. How long a solution (movement) must remain in the tabu list  
233 is determined by a parameter called the tenancy period. Movements from one solution to a  
234 neighboring solution continue until a termination condition is satisfied. The general procedure  
235 of TS is provided below.

236

237 1- Set the algorithm parameters

238 S: Solution of the current iteration  $S^*$ :

239 Best solution ever found

240  $f^*$ : Value of the objective function for  $S^*$

241  $N(S)$ : Neighborhood of  $S$

242  $N(S)'$ : Feasible neighborhood of  $S$  (a subset of  $N(S)$  that is not on the tabu list or satisfies the  
243 aspiration condition).

244 2- Start

245 Generate the initial solution  $S_0$

246 Definition:  $S = S_0, f^* = f(S_0), S^* = S_0, T = \Phi$

247

248

249

250

251

252

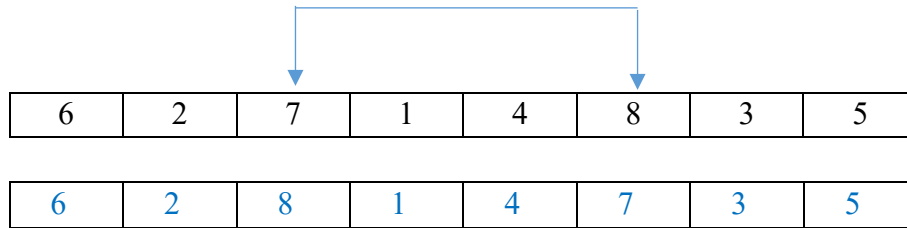
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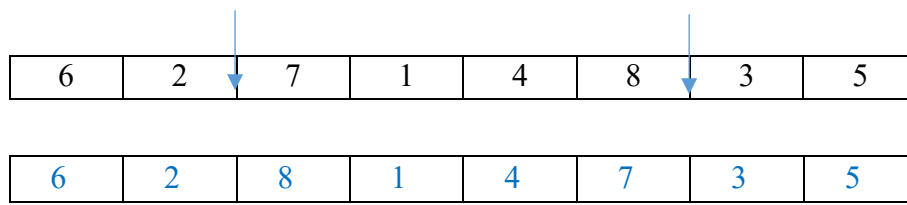
255

### **3.4. Solution representation**

256 Solution representation is an important part of the meta-heuristic approach to solving  
 257 optimization problems, determining how the algorithm works with each point in the feasible  
 258 solution space. In the traveling salesman problem, each solution can be represented as a  
 259 chromosome containing the sequence in which cities will be visited. In the current article, two  
 260 operators named Reversion and Swap are taken into account to change the sequence of visits  
 261 in the solution of TS for diversification purposes. In the Swap operation, as shown in Figure 1,  
 262 a chromosome is selected at random and then two randomly selected genes of that chromosome  
 263 are swapped with each other. In the Reversion operation, as shown in Figure 2, two random  
 264 points on the chromosome are selected and the sequence of genes between these two points is  
 265 reversed.



267  
268 **Figure 1:** representation of the Swap operator



271  
272 **Figure 2:** representation of the Reversion operator

273  
274 **4. Results and Discussion**

275  
276 For a great majority of real-world optimization problems, the performance of meta-heuristic  
 277 algorithms strongly depends on how well their input parameters are set. Thus, the values  
 278 assigned to these parameters determine how well and reliably the algorithm performs for the  
 279 intended purpose. The Taguchi method of experimental design is a method developed by  
 280 Taguchi (Malayer et al., 2019) for determining the optimal experimental conditions with the  
 281 fewest experiments, which can significantly reduce the time and cost of experimentation. In  
 282 the Taguchi method, the experimental plan is developed using a number of different orthogonal  
 283 arrays based on the number of parameters and their corresponding levels. In this method, the  
 284 desirability of the results is measured by a factor called the signal-to-noise ratio (S/N). Thus,  
 285 ultimately, the experimental plan with the highest signal-to-noise ratio is regarded as the  
 286 optimal choice (Malayer et al., 2019). In this study, we defined three levels for each parameter  
 287 as shown in Table 1, thus creating nine scenarios for parameter evaluation. Since the goal in  
 288 TSP is to minimize the cost of traveling to demand points (or distance traveled), the objective  
 289 function and the signal-to-noise (S/N) ratio can be calculated from Equations (11) and (12).

$$= -\frac{1}{n} \sum_{i=1}^n \log(L_i)$$

291  $SN = -10 * \text{Log}(Li)$  )12(

292  
293

**Table 1: Problem parameters and their levels**

	ACO		S		
Parameter/Level	Nant	Ro	Iter	LF	Iter
1	30	0.05	100	0.3	100
2	40	0.1	150	0.4	200
3	50	0.2	200	0.5	300

294  
295  
296  
297  
298  
299

In Table 1, Nant is the number of ants in ACO, Ro is the pheromone evaporation rate in this algorithm, and Iter is the number of iterations. Here, the parameters and values listed in Table 1 were chosen based on the authors' previous experiences in relation to these algorithms. For ACO, in the equation that computes the probability of a node being selected by ants  $p_{ij} =$

$$\frac{a_{ij}d_{ij}^\beta}{\sum_{j=1, j \neq i}^n a_{ij}d_{ij}^\beta}$$

---


$$\sum_{j=1, j \neq i}^n$$

302  
303

( $a_{ij}$ ) were set to 1. Also, here,  $d_{ij}$  was considered to be representing the desirability (utility) of the path.

304  
305  
306

For TS, we set the default number of swap and reversion operations to  $n \times (n - 1)/2$  and defined the tabu list using Round(LF  $\times$  possible/non-repeated operators) with LF values given in Table 1.

307  
308  
309

Using the solutions obtained from five runs in Minitab, the optimal parameter values for the algorithms were determined to be Nant=40, Ro=0.2, and Iter=150 for ACO and LF=0.3 and Iter=300 for TS.

310  
311  
312

After setting the parameters, the problem inputs (distance between cities or cost matrix entries) were randomly generated from the interval [1,100] and the resulting problems were solved with ACO and TS.

313  
314  
315  
316  
317

Table 2 compares the results of ACO and TS for small-scale problem instances with the optimal solutions obtained from Lingo. For large-scale problem instances, the results of these two algorithms are compared with each other. All computations were performed on a personal computer with an Intel Core i5.2.9GHz CPU and 8GB RAM. The "Best" and "Mean" values given in the table are the best and mean values obtained from 50 runs of the algorithm.

318  
319

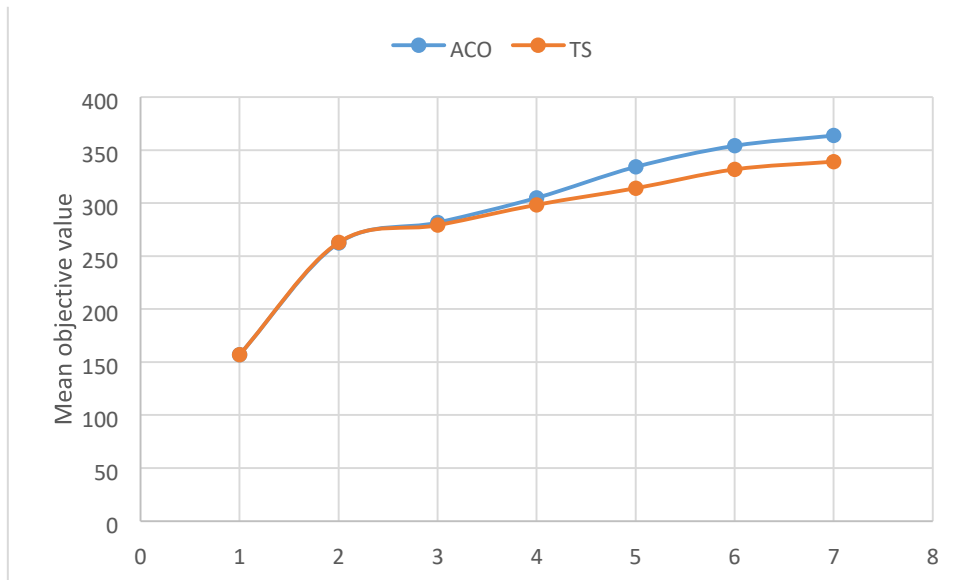
**Table 2: Results obtained for small and large-scale problems**

n	Lingo		ACO		TS			
	Opt	Time(s)	Best	Mean	Time(s)	Best	Mean	Time(s)
5	157	1.04	157	157	2.19	157	157	1.02
8	262	2.23	262	262.26	3.11	262	262.83	2.33

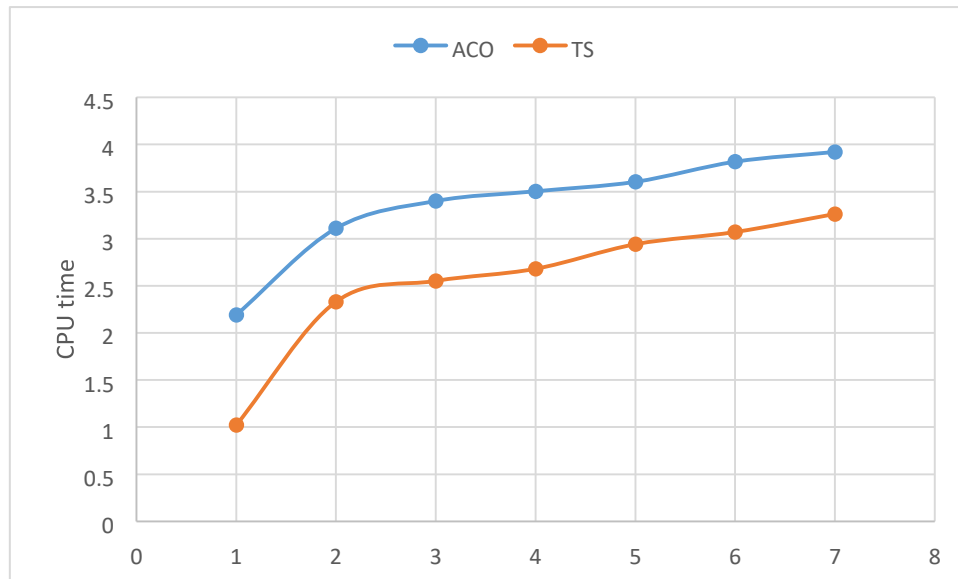
30	-	-	275.5	281.6	3.4	268.7	279.1	2.6
50	-	-	297.3	304.9	3.5	293.1	298.4	2.7
100	-	-	324.1	334.2	3.6	297.2	314.0	2.9
150	-	-	349.2	354.0	3.8	319.4	331.8	3.1
200	-	-	372.8	363.7	3.9	328.1	339.1	3.3

320 n: Number of cities:  
 321 Opt Lingo: Optimal solution obtained from Lingo Time:  
 322 Time needed to solve the problem  
 323

324 Since the solutions produced by meta-heuristic algorithms for small-scale problems (n=5, 8)  
 325 are the same as those obtained from the programming model, it can be concluded that the  
 326 algorithms are well capable of solving these problems. As shown in Table 2, however, the  
 327 results obtained from ACO are more desirable. The average results of the two algorithms in 50  
 328 runs are compared in Figure 3.  
 329



331 **Figure 3:** Mean solutions obtained from 50 runs of ACO and TS  
 332



**Figure 4:** Solution times of ACO and TS

334

335

336 As shown in Figure 4, TS has shorter solution times than ACO, but ACO provides better  
 337 solutions. Because of the random search and other mechanisms embedded in these  
 338 metaheuristic algorithms, they can very well explore the feasible solution space in different  
 339 directions and avoid getting trapped in local optima. However, these mechanisms also increase  
 340 the time these algorithms need to solve the problem, which makes them slower than other  
 341 heuristic methods. Therefore, in such meta-heuristic algorithms, the accuracy of solutions is  
 342 inversely proportional to how fast they have been produced. Tabu search starts with an initial  
 343 feasible solution, but as soon as reaching a local optimum and not observing any improvement  
 344 in consecutive iterations, it employs its memory mechanism (tabu list) to prevent looping and  
 345 avoid previously visited solutions. However, in this study, ACO managed to reach roughly  
 346 better solutions in shorter times compared to TS.

347

## 348 5. Conclusion

349

350 The traveling salesman problem is a well-known combinatorial optimization problem widely  
 351 used in many fields of science, including transportation planning and distribution management.  
 352 With the continued industrial expansion and the growth of competitive markets, this problem  
 353 has gained immense importance for acquiring and maintaining a competitive advantage by  
 354 reducing operating costs and, consequently, the cost of products and services. Indeed, using  
 355 such optimization methods in transportation planning and logistics management can result in  
 356 significant cost savings. The subject of this study was the asymmetric version of the traveling  
 357 salesman problem, where asymmetry may arise from the presence of one-way routes in the  
 358 network, the presence of two-way routes with different traffic levels in the two directions, or  
 359 having multiple dissimilar routes between two nodes (for example, a shorter but steeper road  
 360 and a longer but more straightforward road). After building a linear programming model for  
 361 solving the small-scale instances of this problem, its medium and large-scale instances were  
 362 solved with two metaheuristic algorithms, namely

363 ACO and TS. Comparing the solutions of ACO and TS for small-scale problems with the exact  
364 solutions showed the good performance of both algorithms in solving these problems. For  
365 larger problems, ACO managed to produce better solutions than TS and also in shorter times.  
366 In terms of the future studies regarding the studied subject, it is highly suggested to focus on  
367 solving this problem with extra constraints and furthermore, utilize other meta-heuristic  
368 algorithms to solve the large-scale instances of the problem and compare the results with one  
369 another.

370

371 **Acknowledgments:** not applied.

372

## 373 **References**

374

375 Batsyn, M. V., Batsyna, E. K., & Bychkov, I. S. (2020). NP-completeness of cell formation  
376 problem with grouping efficacy objective. *International Journal of Production Research*,  
377 58(20), 6159-6169.

378 Barkaoui, M., & Berger, J. (2020). A new hybrid genetic algorithm for the collection scheduling  
379 problem for a satellite constellation. *Journal of the Operational Research Society*, 71(9),  
380 1390-1410.

381 Bektas, T. (2006). The multiple traveling salesman problem: an overview of formulations and  
382 solution procedures. *omega*, 34(3), 209-219.

383 Blickle, T., & Thiele, L. (1996). A comparison of selection schemes used in evolutionary  
384 algorithms. *Evolutionary Computation*, 4(4), 361-394.

385 Bozorgkhoh, H., Hakimipour H. (2014). Studying the Impact of Brand Equity, Brand  
386 Experience, Brand Satisfaction and Brand Trust on Brand Loyalty (Case: ECCO  
387 Customers). *Modiriat-e-farda*, 36(36), 1-12.

388 Cook, W. (2019). Computing in combinatorial optimization. In *Computing and Software  
389 Science* (pp. 27-47). Springer, Cham.

390 Ebadinezhad, S. (2020). DEACO: Adopting dynamic evaporation strategy to enhance ACO  
391 algorithm for the traveling salesman problem. *Engineering Applications of Artificial  
392 Intelligence*, 92, 103649.

393 Javanmard, B., Nazari Sabet, M., Esfahanian, F., Neshat, S., Dehghan Niri, F., Mortezaei, A.,  
394 & Hasani, S. H. (2022). Transurethral Resection of the Prostate and Inguinal Mesh  
395 Herniorrhaphy: Does Single Session Surgery Work Better? A Randomized Clinical Trial.  
396 *Translational Research in Urology*, 4(1), 30-34.

397 Johnson, D. S., Gutin, G., McGeoch, L. A., Yeo, A., Zhang, W., & Zverovitch, A. (2007).  
398 Experimental analysis of heuristics for the ATSP. In *The traveling salesman problem and  
399 its variations* (pp. 445-487). Springer, Boston, MA.

400 Josiah, T., Suhada, A., Chetthamrongchai, P., Purbasari, H., Hazim, H. T., Shidiq, A. A. P., ...  
401 & Aravindhan, S. (2021). Optimization of the Location, Inventory and Routing of Capacity  
402 Vehicles with Interval Uncertainty. *Industrial Engineering & Management Systems*, 20(4),  
403 654-661.

404 Khorsandi, Z., Afshinpour, M., Molaei, F., Askandar, R. H., Keshavarzipour, F., Abbasi, M.,  
405 & Sadeghi-Aliabadi, H. (2021). Design and synthesis of novel phe-phe hydroxyethylene

406 derivatives as potential coronavirus main protease inhibitors. *Journal of Biomolecular*  
407 *Structure and Dynamics*, 30, 1-9.

408 Krueger, P. S., Hahsler, M., Olinick, E. V., Williams, S. H., & Zharfa, M. (2019). Quantitative  
409 classification of vortical flows based on topological features using graph matching.  
410 *Proceedings of the Royal Society A*, 475(2228), 20180897.

411 Kurniady, D. A., Denih, A., Vagabov, M., Rijanto, T., Artemova, E. I., Hoi, H. T., ... &  
412 Komariah, A. (2022). Modeling a Flexible Flow Shop Scheduling Problem without  
413 Unemployment by Considering Sequence-Dependent Preparation Times and Solving it  
414 with a Meta-Heuristic Algorithm. *Industrial Engineering & Management Systems*, 21(2),  
415 291-302.

416 Malayer, S. K., Ghourchian, H., & Azarian, M. (2019). Genotoxicity of noscapine  
417 nanosuspension on DU145 human prostate cancer (spheroid cell model). *Adv Cell Sci Mut.*  
418 2 (1), 1-7

419 Sabouri, M., Kordi, M., Shabkhiz, F., Taghibeikzadehbadr, P., & Geramian, Z. S. (2020).  
420 Moderate treadmill exercise improves spatial learning and memory deficits possibly via  
421 changing PDE-5, IL-1  $\beta$  and pCREB expression. *Experimental Gerontology*, 139, 111056.

422 Partovi, A., da Silva, R. R., & Lin, H. (2018, June). Reactive integrated mission and motion  
423 planning for mobile robotic manipulators. In 2018 Annual American Control Conference  
424 (ACC) (pp. 3538-3543). IEEE.

425 Paliwal, P., Webber, J. L., Mehbodniya, A., Haq, M. A., Kumar, A., & Chaurasiya, P. K.  
426 (2022). Multi-agent-based approach for generation expansion planning in isolated  
427 microgrid with renewable energy sources and battery storage. *The Journal of*  
428 *Supercomputing*, 5, 1-27.

429 Pour, E. S., Jafari, H., Lashgari, A., Rabiee, E., & Ahmadisharaf, A. (2022). Cryptocurrency  
430 Price Prediction with Neural Networks of LSTM and Bayesian Optimization. *European*  
431 *Journal of Business and Management Research*, 7(2), 20-27.

432 Ramalingam, P., Mehbodniya, A., Webber, J. L., Shabaz, M., & Gopalakrishnan, L. (2022).  
433 Telemetry Data Compression Algorithm Using Balanced Recurrent Neural Network and  
434 Deep Learning. *Computational Intelligence and Neuroscience*, 2022, 4886586

435 Saleh, H. A., & Chelouah, R. (2004). The design of the global navigation satellite system  
436 surveying networks using genetic algorithms. *Engineering Applications of Artificial*  
437 *Intelligence*, 17(1), 111-122.

438 Shabgah, A. G., Qasim, M. T., Mostafavi, S. M., Zekiy, A. O., Ezzatifar, F., Ahmadi, M., ... &  
439 Navashenaq, J. G. (2021). CXC chemokine ligand 16: a Swiss army knife chemokine in  
440 cancer. *Expert Reviews in Molecular Medicine*, 21, 23-27. doi: 10.1017/erm.2021.7.  
441 PMID: 33880989.

442 Sabouri, M., Kordi, M., Shabkhiz, F., Taghibeikzadehbadr, P., & Geramian, Z. S. (2020).  
443 Moderate treadmill exercise improves spatial learning and memory deficits possibly via  
444 changing PDE-5, IL-1  $\beta$  and pCREB expression. *Experimental Gerontology*, 139, 111056.

445 Tarallo, E., Akabane, G. K., Shimabukuro, C. I., Mello, J., & Amancio, D. (2019). Machine  
446 learning in predicting demand for fast-moving consumer goods: An exploratory research.  
447 *IFAC-PapersOnLine*, 52(13), 737-742.

448 Warren, R. H. (2021). Solving combinatorial problems by two D\_Wave hybrid solvers: a case  
449 study of traveling salesman problems in the TSP Library. arXiv preprint  
450 arXiv:2106.05948.  
451 Yousefikhoshbakht, M., Didehvar, F., & Rahmati, F. (2011). Application a Modified  
452 Imperialist Competitive Algorithm for Solving the Traveling Salesman Problem. Journal  
453 of Advanced Mathematical Modeling, 1(2), 29-49.  
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## [iems] Editor Decision

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11 July 2022 12.18

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Our decision is to: Accept Submission

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