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Distance Analysis of Multimodal Transportation Based on Traveling Salesman Problem with Particle Swarm Optimization Method

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***Abstract*— *The globalizing world and the growing economy cause the companies have to find new quests to survive in the economic competitive environment. The fact that raw materials and production costs are at almost the same level in the same sectors foreground the logistics. Because Logistics plays an active role at every stage from the supply of raw materials to the suplly of products to customers. An optimization that can be done at logistics will directly affect the corporate and enterprise economies. In this study, a multimodal transport optimization experiment was carried out with particle swarm optimization (PSO) based on the traveling salesman problem (TSP). Logistic villages and commercial ports were selected which are suitable for transportation mode change for multimodal transport. With optimization, we have solved the distance parameter for Unimodal Road Transportation and Multimodal Transportation which are widely used in our country. The solution for distance's parameter was compared and evaluated separately for Unimodal Road Transport and Multimodal Transport. Multimodal transport is seen to be more advantageous for distance's parameter as a result of evaluation. Finally, the integration of the optimization into intelligent transport systems (ITS) has been investigated.*

Keywords*— *Logistics Village, Multimodal Transport, Traveling Salesman Problem, Particle Swarm Optimization, Intelligent Transportation Systems

I. INTRODUCTION

Transportation systems consist of transport modes such as highways, sea routes, airlines, railways, pipelines. Performance analysis of transportation systems is very important. This is because transport shifts between modes cause significant changes [12, 13, 15, 16]. A lot of work has been done for efficiency in both freight and passenger transport [4, 11]. Logistics that can be summarized as the sector that includes all of the transportation activities; the marketing sector is in direct interaction with the economy as it starts with transportation. With the development of technology, globalization and the concept of distant day is decreasing, the development of the logistics industry in parallel with this development is of great importance for the development country's economy [2]. An optimization that can be achieved in logistics will contribute positively to the economy of the institutions and organizations directly involved with logistics, as well as to the economy of the country, in proportion to the minimization of all costs and transportation periods, and an important step will be taken in terms of sustainability in logistics [3, 14]. Logistics is carried out by means of single transportation called unimodal transportation, because the distance is relatively short when the internal transportation is considered on the basis of it. In international transport, countries with a sea connection usually prefer shipping, and after they enter the freight country they are transported to the buyer by changing the mode of transportation in the ports and in the inner stations according to the transportation infrastructure of the region to be visited. This type of transportation is made by changing the types of transportation is called multimodal transportation. Logistic villages are logistics centers where all logistics activities can be done together. Logistic villages have direct connections to at least two transportation routes, including railway and highway. Logistic villages are suitable centers for the change of transportation type as logistic activities such as handling, storage, loading-unloading can be done and direct connection to at least two transportation routes is available. The Traveling Salesman Problem is a problem that aims to find the shortest route to return a starting point to a starting point after a certain dealer has known certain points [7]. Although the Traveling Salesman Problem is an easy problem to understand, the linear solution is a rather difficult and difficult problem class, especially as the number of nodes increases, due to the increase of the total number of laps

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and the elongation of the accounts. In traditional solutions of Traveling Salesman Problem, solution is made with Euclidean relation according to bird flight distances. In this study, Particle Swarm Optimization intuitive method, which is developed by inspiring birds and fish in their herd behavior, has been preferred since it can be solved according to real values and modification to the algorithm is required. In the study, an optimization experiment was conducted for multimodal transport. Minimization of distance on multimodal transportation routes is aimed with the optimization made [4]. Based on the general solution of the Traveling Salesman Problem for optimization, the solution algorithm is written with particle swarm optimization.

II. MATERIAL AND METHODS

As a method of study, a solution algorithm is firstly written with Particle Swarm Optimization for the Euclidean Mapping of the Traveling Salesman Problem and for the bird flight linear solution. Then a modified Particle Swarm Optimization algorithm, which can make the route drawing according to the coordinates according to the input values, is designed by separating the inputs from the input coordinates so that the algorithm can be solved according to the actual values and the solution according to the actual values is done through this algorithm. In order to demonstrate the general solution of the Traveling Salesman Problem, a bird-flight linear solution was made on the points of account and then a solution was made for the unimodal road transport which is the common type of transportation in the account route and for the multimodal transportation by means of the distance parameters and the results are shown in Mathworks Matlab is compared and evaluated through a comparison function.

Unimodal Transportation

Unimodal transport with a single transport module is a transport system with one or more transporters and a single transport module. The constructed transport system is essentially a single transport method, such as land transport only, sea transport only or air transport only. The most widely used transport mode in single mode transportation is the land route. [1]

Multimodal Transportation

Multimodal Transport is a type of transport made by using multiple transport modes with different transport units or vehicles [3]. With the emergence of modern multi-carriage containers came to the agenda. The container in the standard container is a transport vehicle for the load; as well as packaging. In addition, the container, which is an investment in terms of bearing, is generally used as the main material of the multiple cargos. The first applications of multicast are container operators. Multimodal transport is a burden, between a seller and a buyer, with at least two transport systems and a single cargo ship. It can be applied within the national boundaries of a country as well as by making the international carriage of multiple carriages. Today's application is predominantly international multi-transport.

Traveling Salesman Problem

The Traveling Salesman Problem is the shortest tour problem that a traveling salesman who can travel from one point to the other by going to all the other points to return to the starting point [5]. Traveling Salesman Problem when you think of the problem as a graph, all the points to go are expressed as a linear line and the stops as a point. Traveling Salesman Problem expression is an easy problem. But solution is a difficult problem. The solution of problems with too many nodes is very difficult. The Traveling Salesman Problem is a difficult problem class.

Particle Swarm Optimization

Particle Swarm Optimization is a heuristic method inspired by the behavior of birds and fish in the wild [6]. The behavior of birds and fish swarms trying to find food in contact with each other in search of food in the nature is the basis of Particle Swarm Optimization. Particle Swarm Optimization is also the best in the population, the best of the crawl, and the best in the global. The solution algorithm continues by selecting from these three cases in each iteration.

Herd intelligence is not a specific algorithm or a system. Herd intelligence is a form of collective behavior of natural or artificially distributed, self-organizing systems. The best known examples of algorithms based on swarm intelligence are ant colony algorithm and particle swarm optimization algorithm. Compared to other evolutionary algorithms, it is seen that in these algorithms, the herd elements affected by each other's behaviors are spread more appropriately in the solution space than the individual motions. This allows the change in dynamically changing solution spaces to be more easily followed and the adaptation to be faster. [10]

In PSO, each particle has its own velocity, which speeds up the particle towards the optimum result with the information it receives from the other particles. In each generation this speed is recalculated taking advantage of the previous best results. By this means, the individuals in the population are in an increasingly better position. The steps of the algorithm are as follows; [9]

1. **Population formation**; particles are created with randomly generated starting positions and velocities.
2. **Calculation of eligibility values**; the fitness values of all the individuals in the population are calculated.
3. **Finding the best member**; every individual in each generation is compared to the best (pbest) found

in the previous generation. If a better individual is displaced.

4. Finding the global best; if the best value in the future is better than the global best value.
5. Renewal of positions and speeds;

$$V_{id} = W * V_{id} + C_1 * rand_1 * (P_{id} - X_{id}) + C_2 * rand_2 * \left(P_{gd} - X_{id}\right) \quad (1)$$

$$X_{id} = X_{id} + V_{id} \quad (2)$$

Where X_{id} is the position and V_{id} is the speed value, $rand_1$ and $rand_2$ are randomly generated numbers between 0 and 1. W is the inertia weight value. Here C_1 and C_2 are constant values and are generally considered to be close to 2.

6. Repeat the steps until the stopping criterion is met. Repeat steps 2-5 until the stop criterion is met.

Particle Swarm Optimization's Solution for Traveling Salesman Problem Algorithm and Modifications

In Particle Swarm Optimization, every particle in the herd has its own value. Throughout the solution, the particles are both searching for the best by sharing information among themselves and comparing their previous best state with their current state. In this way, they try to reach the optimum solution from all these evaluation criteria. Particle Swarm Optimization's operating system is as follows. First, the random position and velocity of each particle is created. Then the fitness values of the particles are determined. Subsequently the values of all the particles are replaced if they are better than the previous iteration. Then the best value of the iteration is compared to the global best value and replaced if it is better than the global best value. Subsequently, the Particle Swarm Optimization speed refresh formula renews the speed of all particles and continues the cycle until the stop criterion is met. This is the general solution of Particle Swarm Optimization. This method of solution does not reach the correct solution because local minimums cannot be avoided when applied directly to the Traveling Salesman Problem, and a number of modifications are required in the algorithm. In order to avoid local minimums, after the algorithm cycle has been completed and the optimum result has been found, a mutation has been added to the algorithm, and if the crossed result is better than the optimum result, it is replaced and the closer result is reached.

For example, the optimal term in the iteration for 6 points:

gbest=[2 4 3 1 5 6]; (3)

Form, when we make a reversion mutation on this tour:

gbest=[2 5 1 3 4 6]; (4)

It has come to shape. The algorithm compares the resulting turntable distance with the optimum lap distance, and if the mutated lap distance is better, the solution is transformed by displacement.

When solving according to the coordinates of Traveling Salesman Problem with Particle Swarm Optimization:

N number of points:

D=zeros(N,N); (5)

A matrix of 0 is formed and

D(i,j)=100*(sqrt((x(i)-x(j))^2+(y(i)-y(j))^2)); (6)

D(j,i)=D(i,j); (7)

The D distances found by the equation form the matrix D. The algorithm draws distances D from the matrix when solving. Expressions x and y in Equation (6) i. and j. Corresponds to the X and Y coordinates. Equation (7) with the formula i. and j. point distance between the point and the return is defined as equal. That is, the program will place the same value in D (j, i) after placing the matrix D (i, j).

The solution for the Traveling Salesman Problem with Particle Swarm Optimization was solved according to the actual values. The formula for the D matrix was closed and the D (N, N) matrix was manually entered by the number of points prepared according to the actual values. For example, the matrix of road distances D (18,18) divides the matrix by 0 values diagonally to the left, since the distance between the two matrices is equal. The lower and upper values are equal to each other. In addition, the optimum angle is plotted on the point coordinates of the route.

While solving the Traveling Salesman Problem with Particle Swarm Optimization according to the actual values, all the transportation type options between the two points are defined in the program. For example, if we consider the Iskenderun Port - Mersin Port for distance optimization:

Iskenderun.Mersin.Road=207;

Iskenderun.Mersin.Railway=204; [8]

Iskenderun.Mersin.Sea=122;

After defining the distances in the form, a distance matrix of Iskenderun Port Mersin Port is formed as follows.

Iskenderun.Mersin.Distance= [Iskenderun.Mersin.Road Iskenderun.Mersin.Railway Iskenderun.Mersin.Sea]

Then i. point Iskenderun Port j. point Let's accept Mersin Port. D (i, j) th value of the matrix D (N, N):

D(i,j)=min(Iskenderun.Mersin.Distance);

And for the optimization solution, it again subtracted the values from the D matrix. Here the algorithm chooses the algorithm if the transport type is more advantageous because the matrix forms the minimum distance values of the alternative transportation types. Therefore multimodal transport can be preferred. Again, the optimum angle is plotted on the point coordinates of the route. The following parameters are used in the solution algorithm.

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Herd Size: Although the size of the herd size depends on the type of problem being solved, a population size of 50 to 100 is generally preferred over the solutions made with the Particle Swarm Optimization algorithm. As the size of the crawl increases the scanning speed, the resolution time increases with the convergence. In order to obtain better results in the study, the size of the herd was selected as 100 with the extension of the solution.

Learning Coefficients: C_1, the particle learning coefficient, and C_2 learning coefficients, which are the herd learning coefficient, will slow the learning ability of the particle when values are too low, and the particle will be slow to reach the best position. When very high values are given, the particle will memorize and will accept its best in global best and stick to local minima and will not reach the correct results. In the Particle Swarm Optimization solution algorithms, values of 1 to 2 are usually preferred for the learning coefficients, while the learning of the correct particle is controlled and the values are changed. In the study, C_1 and C_2 learning coefficients were chosen as 0.5 to try to avoid both local minima and to obtain more close results.

Weight Coefficient: The weight coefficient prevents the particles from being scattered in the algorithm and allows them to converge at one point. Selecting an appropriate weighting factor creates a balance between local and global searches. In the literature, Particle Swarm Optimization shows that the best result is the variable weight coefficient between 0.5 and 1. Taking the weight coefficient value over 1 increases the speed vector, so it does not give very healthy results and the particle cannot search for values near. Global searches cannot be performed when very low values are obtained. In the study, the commonly accepted variable weighting coefficient was applied in the literature. Starting with 1, the weight coefficient is reduced by 0.001 in each iteration and decreased to 0.5 in the final iteration for the solution.

Stopping criterion: It is about stopping the problems such as Traveling Salesman Problem which enters the difficult problem class when the termination logic reaches the optimum result. Or the program defines an iteration number and the program stops when it reaches that iteration. When the number of iterations that need to be considered here is defined, it is absolutely possible to reach the optimum result when the termination is done. That is to say, a straight line must be reached from somewhere in the solution graph. Given the maximum number of iterations, in the number of stopping iterations, the solution is unnecessarily prolonged. The maximum number of iterations in the study was 500.

III. RESULTS AND DISCUSSION

Solution of the Problem According to Unimodal Highway Distances

The solution according to the unimodal road distances is shown in Fig.1 in the route drawing taken from the program. Route Map of Turkey finished the state is as in Fig.2. In Fig.3, the calculation of the algorithm is given. In addition, the irregularity in the shape is caused by the solution of the program according to the actual distances. Algorithm solutions are made according to the actual distances entered into the proofer. The program draws the route according to the classical resolution of the Traveling Salesman Problem, according to the coordinates. In other words, due to the fact that the coordinate distance based bird flight distance is different from the actual distance, irregularity has occurred in the drawing of the route. But the solution is provided. This is true for both solutions based on unimodal and multimodal distances.

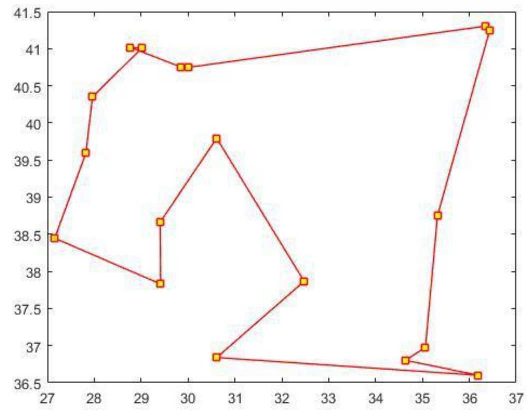

Fig. 1: Solution route drawing according to unimodal road distances

Fig. 2: Solution map display according to unimodal road distances

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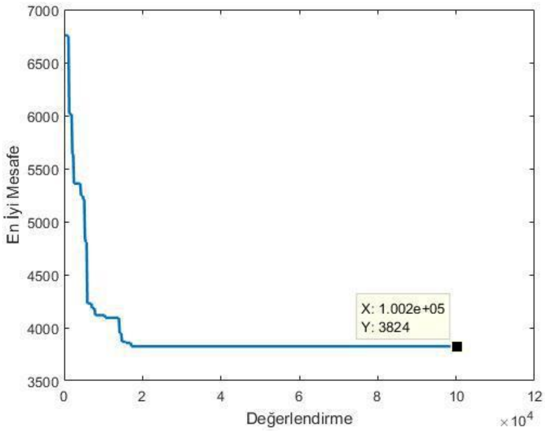

Fig. 3: Solution calculation chart according to unimodal road distances

Solution of the Problem by Multimodal Distance
The solution made according to the multimodal distances is shown in Fig.4 of the route diagram taken from the program. Route Map of Turkey finished the state is as in Fig.5. In Fig.6, the calculation of the algorithm is given.

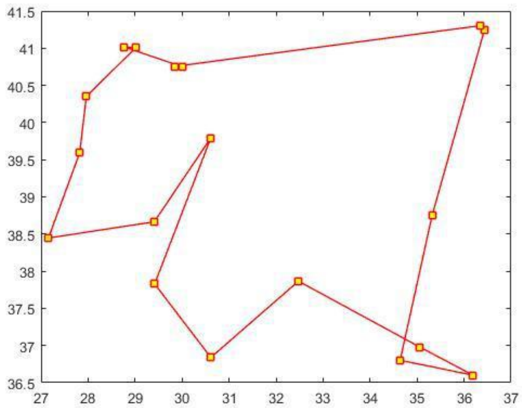

Fig. 4: Solution route drawing according to multimodal distances

Fig. 5: Display in solution map according to multimodal distances

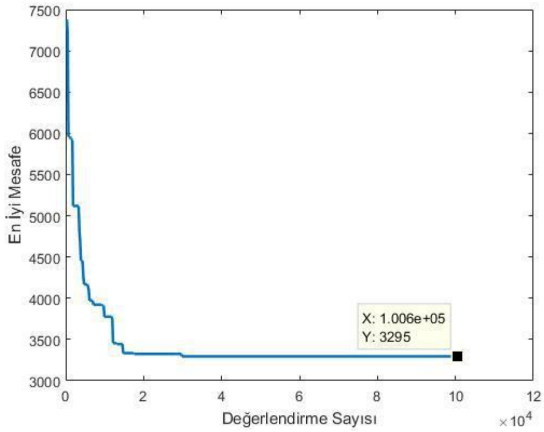

Fig. 6: Solution calculation chart according to multimodal distances

Comparison Function

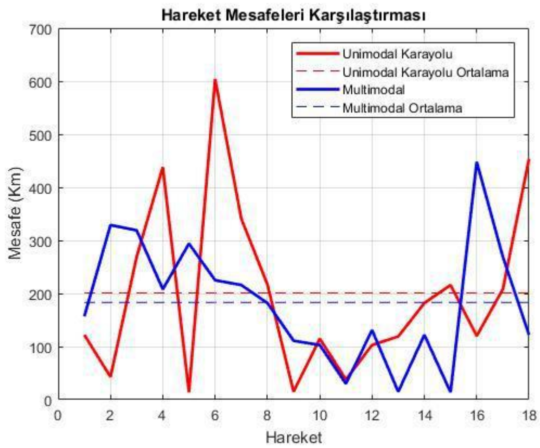

Fig. 7: Graphical distance comparison

Although multimodal transport is more advantageous in comparing movement distances during the round trip compared to optimization data, the distance reduction of multimodal transport is shown in Fig. 7, it is not too much to see. This is why; the road infrastructure is stronger and more accessible. This situation necessitates the investment in other types of transportation, especially railway transportation, in order to prefer multimodal transport in terms of distance. The most advantageous mode of transportation is maritime transportation because it provides approximately bird flight movement when considering the distance. The disadvantage of sea transport is that it cannot provide services in the interior.

IV. CONCLUSION

- In the solutions made, unimodal highway distance 3824 km, multimodal distance 3295 km.
- As seen in Fig.7, multimodal transport is more advantageous from the beginning to the end of the turn.
- When considered unimodal, the most advantageous type of transportation in terms of distance is maritime

transport. The reason for this is the fact that the vessels move about the bird flight.

- Related to the solution algorithm: correct selection of values such as weight coefficient, learning coefficient converges the solution. However, the extreme sensitivity in the values can extend the solution.
- With optimization to be done the optimum route can be determined according to the desired criterion without the load going further.
- With optimization to be done load equipment can be installed with equipment to be installed and the load can be directed while moving.
- With optimization to be done according to the new requirements, new routes can be created and transferred to the carrier or interim logistics center while the load is in motion and the route or mode of transportation can be changed.

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