City travelling salesman problem with minimizing truck weight in fragile road

R Aurachman
Telkom University, Bandung, Indonesia

E-mail: rioaurachman@telkomuniversity.ac.id

Abstract. The process of delivering goods can be modeled in the TSP model; Traveling Salesman Problem. Several existing TSP models try to minimize the mileage so as to minimize transportation costs from vehicles. In the context of city logistics, the quality of the roads used to deliver goods is also used by city residents’ vehicles. The route taken for the first time contains a heavy mass because the cargo being transported still contains all the goods that will be delivered later. Then the mass of the truck cargo will gradually decrease from the heavy mass to the very light mass at the final destination, because the entire load has been delivered. Through this paper, we propose a TSP model development that can choose the order of delivery by considering the road conditions taken, so that a route will be obtained that minimizes the risk of road damage due to the large mass of the load.

1. Introduction
Increasing number of urbanization made the city population even bigger. This causes several economic activities to be increasingly concentrated in the city. Industrial centers that were once located in rural areas are now starting to shift to cities. This is because workers who initially lived in villages began to move to cities. The increase in population in cities also causes consumption in cities to increase. The flow of goods in the city has become large as a result of this change. The large flow of goods causes the transportation and supply chain processes to be higher. This has led to a new scientific field called Urban Logistics [1, 2].

Urban logistics has different stakeholders than the general logistics system [3]. Each of these stakeholders has different requirements and concerns compared to the rural logistics system. Urban logistics also has different constraints and contexts. This causes the behavior and limitation of the system to be different. For example, there is a paper that discusses the peak hour factor in logistics management [4].

One of the problems discussed in the field of logistics is the vehicle routing problem (VRP), which is how to manage vehicle travel routes. VRP has several variants and developments [5, 6]. There are also studies that have reviewed papers examining VRP in the context of urban logistics, namely city-VRP [7].

Several studies have discussed the variations in the application of VRP in urban logistics. One of the variables that we will discuss is the load that a road receives when it is passed by a cargo vehicle. To simplify the problem [8, 9], we will discuss these variables in the traveling salesman problem (TSP) model. By obtaining the solution formulation in the form of TSP, it will be easily adapted to the VRP model.
The existing TSP generally considers distance minimization. However, a TSP optimization process has not been carried out by considering the load received by a road. It may be that an order of delivery results in a short distance, but, by reducing the weight of delivery, is inefficient. One of the objectives is that the order of delivery from a destination with a large load needs to take precedence, so that the load carried by vehicles can be reduced immediately. This causes the load carried by vehicles to be minimum, as well as the loads carried by the road.

2. Method and Algorithm

The method used in this research is the system approach [10]. The problem is studied using a systems approach. From the formulation of the problem, it is obtained what are the objectives of the problem and the criteria in selecting solutions. In the formulation of the problem, it is also found alternative decisions that may be taken and constraints that limit alternative decisions that can be taken.

Based on the formulation of the problems obtained, the next step is to formulate a mathematical model that becomes a model of the problem formulation [11]. The alternative course of action becomes the decision variable. The limitations in the problem become constraints. Goals become an objective function in the model.

After obtaining the mathematical model formulation, the next step is to solve the model using the optimization method. The optimization method chosen to be tested now is metaheuristic with a brute force algorithm.

3. Result and Discussion

Generally TSP is designed without considering the load that must be carried by the vehicle. This is different from VRP, which considers vehicle capacity in deciding how many vehicles to operate on the route of delivery of goods. The model we propose has two objective functions, namely minimizing the distance traveled from the vehicle and also reducing the load that the vehicle has to carry in one long trip. This means that when a heavy load is quickly delivered to the destination, the model will indicate that it is the right decision. On the other hand, if the heavy load is not delivered immediately, the model will indicate that it was the wrong decision.

There is a trade-off here. It may be that the fastest route is reached when the destination that has the greatest delivery load is positioned at the end of the route. This causes the vehicle to carry heavy loads quite a long way, namely the entire route. However, a destination with the largest delivery load may be positioned at the beginning of the route, causing the overall vehicle mileage to be long. The problem that arises here is the multi-objective optimization problem.

In Figure 1, you can see an illustration of TSP problems that need to take 3 destinations. Vehicles depart from the depot and return to the depot. In the illustration, destination 3, which has the largest delivery load, is positioned at the end, which is 5 items. This causes the vehicle to carry as many as 5 of these items along the route from the depot to destination 1 then to destination 2 and then to destination 3. This causes a heavy burden for the vehicle for long distances. However, this solution may provide a minimum distance solution.

![Figure 1. Rich picture of integrated system.](image-url)
The next stage is to explain the phenomena and events in the system. The diagram that can be used is the causal effect diagram. As shown in figure 2, Causal effect diagrams explain how events are related to each other and affect each other. This diagram can be said to be a development of the fishbone diagram which explains the linear causal relationship. In the causal effect diagram, the causal relationship can be made cyclically so that a loop can occur. This diagram is very good at explaining the complexity of the system. The complexity of the system is a hallmark of an integrated system.

However, the causal effect diagram needs to be modified so that it fits the characteristics of an integrated system. The causal effect diagram is divided into several regions, namely event areas that are closely related to the human aspect, event areas that are closely related to aspects of machines and devices, and other areas for each element of the integrated system. This is intended so that analysts are not trapped in analyzing a system in one aspect only and forgetting other aspects.

For example, if only the aspects of machines and equipment are analyzed, the object that can be studied and developed will use the mechanical engineering approach and industrial engineering cannot be used. For example in the E-Learning system, if only aspects of equipment and devices are analyzed, then the science that can play a more important role is Computer Engineering or Information Engineering. However, when all events and events for each element of the integrated system are analyzed, Industrial engineering science can play a role in analyzing and developing the system.

Figure 2. Integrated causal effect diagram.

Whereas in Figure 2, it can be seen that the solution illustrated is that the vehicle delivers to destination 3 first. This causes the burden carried by the vehicle, for heavy loads, to be closer, namely only from the depot to destination 3. The heavy load for destination 3 does not need to be invited to travel to destination 1 and destination 2. So, when the vehicle travels from destination 3 to destination 1, then from destination 1 to destination 2, not with heavy loads. This solution is based on the lower delivery load times the mileage. However, it could be that in calculating the mileage, the vehicle travels a longer distance.

The model needs to be able to perform the calculation of these two objectives simultaneously. One of the objectives could be used as a constraint in decision making. Meanwhile, the other objectives are still used as objective functions. In this model we designed, we position both objectives as part of the objective function. Each solution produces a final score that includes distance traveled and distance of the load. The two objective values are added up after previously normalized.
Figure 3. Optimization algorithm.

Complete algorithm of programming codes are shown in Figure 3. Here we attach the programming code for the function that calculates the score from the mileage load. The variable we use is wd for weight distance. Weight distance means the value of the load times the distance. If the load carried is very heavy but the distance traveled is zero, the WD value becomes zero. Likewise, if the distance traveled is very far but the load carried is zero, the WD value will be zero.

```python
def weightxdistance(tur, dist, w):
    wd=0
    WeightNow=sum(w)
    for i in range(0, len(tur)-1):
        WeightNow=WeightNow-w[tur[i]]
        wd=wd+WeightNow*dist[tur[i]][tur[i+1]]
    return wd
```

The variable weight now is the load being traveled at each destination stop. The weight now value will decrease at each destination stop, because the load carried will be given to the customer at each destination. Iteration is carried out as much as the number of destinations visited. The distance between the destinations becomes a multiplier of the weight now variable.
Figure 4 shows the moving distance value and load distance value for each iteration. Because the algorithm used is the bruter force algorithm, when the iteration moves, the values are independent and not interrelated between one iteration and another. The best solution in calculating distance is not necessarily the optimal solution for calculating distance loads.

The two evaluated scores are then combined in the final score. The movement of the score for each iteration can be seen in Figure 5 which is colored blue. Meanwhile, the red graph shows the optimal value movement in each iteration. Each iteration tries to evaluate a different alternative solution. If the iteration gets a better value than all the previous iterations, then that value is stored as the optimum value. However, if it turns out that the resulting value in that iteration is not better than the previous iteration, the resulting value will not be saved. So in this way, every iteration will always get a better value. If there is no better value in the next iteration, then that value can be considered as the maximum value.

4. Conclusion
Urban logistics has different types of problems. After conducting research, testing, and evaluation, an algorithm and programming code have been obtained to solve one of these types of problems. The model obtained is able to calculate how the optimal solution has two objectives, namely minimizing the mileage and minimizing the total load times the distance carried by the vehicle. This model still needs consideration from decision makers to give weight to optimization, whether it tends to minimize distance or to minimize load distance.

Some further research can be done. One of them is to consider other objectives in the calculation process. For example evaluating the noise generated by the transportation process. This research can
also be developed for a pick up delivery system. It can also be integrated with several other systems in the urban logistics group, for example the Hub and Spoke system.

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