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An Intelligent Approach of Vehicle Routing of Super Shop Shawpno

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ABSTRACT

Rising automation usage in the supply chain and logistics sectors has made the system more convenient, efficient, and useful. Vehicle routing is an essential segment of logistics. Nowadays, Super shops are suffering from faulty scheduling and improper planning of vehicle routing. In this paper, vehicle routing and scheduling have been investigated for the Super shop Swapno of Dhaka, Bangladesh. This research aims to make vehicle routing more effective and automotive by making it intelligent. It used the demands of different outlets, combined those demands, and clustered these by territory. The scheduling and routing plans were developed by using those clustered territories. The Application is based on artificial intelligence to respond to the real-time data of traffic that makes the vehicle routing intelligent. As a result, the scheme changed its prior direction to find the shortest available path based on the instant location. Firstly, we used the demand at different outlets for scheduling by using the solver toolbox of the google sheets-vehicle routing feature. After scheduling, the Shortest Path First algorithm (SPF algorithm) was used to identify the best route to reach the next outlet based on the instant location. HTML and Javascript languages were used to develop the Application. This research aims to make the vehicle routing of the Super Shop more optimized and intelligent by responding in a real-time scenario.

Keywords: Intelligent Vehicle Routing, Scheduling, Route Optimization, SPF algorithm, Super shop

1. Introduction

The vehicle routing problem (VRP) is a generic title given to a set of issues in which initially vehicles are located at a hub to deliver a fixed quantity of products to several customers. The vehicle routing problem aims to form an optimal route that provides the lowest transportation to its organization. The solution to the vehicle routing problem is a group of optimal routes that start and end in the hub, which satisfies all the customers to serve only once.

1.1 Vehicle Routing

Vehicle routing is one of the most dynamic sectors that requires continuous improvement. It is a sector where one can minimize the total cost of an organization by optimizing that organization's vehicle routing. But it is not that easy to optimize vehicle routing in a dynamic situation. Due to increasing competition in every sector, the optimization of supporting things of an organization has become a vital issue to sustain in a competitive environment. For the Super shop chain, vehicle routing is one of the most critical aspects to think about. To serve customers cost-effectively, the transportation of products is essential for the super shop. As vehicle routing is the core part of transportation, it requires much attention to improve on. The general cost structure of vehicles is fuel-39%, driver salary-26%, cab and trailer-17%, maintenance-12%, insurance, and fees-5%. The other elements are almost fixed spending except for fuel costs. The optimization of vehicle routing can reduce that cost. The vehicle routing problem's main objective is to serve the nodes of a logistic network more efficiently and effectively. Significant work has been done on making the vehicle routing efficient. Among them, intelligent vehicle routing optimization is making more impact nowadays. Intelligent vehicle routing is about responding to real-time data and making decisions automatically.

1.2 Problem Statement

A super shop chain needs to deliver several products to different outlets. They face issues while scheduling and routing for delivering products to outlets—most of the super shops having problems due to improper planning of vehicle routing. In our research, we identified the problem that super shop Shawpno is facing. Shawpno is one of the biggest super shop chains in Bangladesh. But the vehicle routing system for delivering products to outlets is not efficient. Manual scheduling and routing are used to deliver products using limited capacity vehicles where, most of the time, the optimal result is not found. Improper scheduling causes extra travel and decreases transportation efficiency.

Moreover, traffic conditions on the road are not always the same. It is tough to find out an optimal route based on the real-time traffic on the road. Navigating on the road without knowing the traffic condition cannot have optimal vehicle routing. So, the problem is to deliver products to the outlets of the super shop with proper scheduling matching the capacity of vehicles and navigating vehicles according to the real-time traffic on the road that corresponds to find out the optimal vehicle routing.

1.3 Literature Review

An online rational scheduling approach is made combining the qualitative and quantitative research methods using operational research and artificial intelligence to solve a significant scale vehicle routing

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problem for B2C e-commerce urban logistic problems [1] and reduced the average traveling time by using an intelligent system of traffic image processing and shortest path first algorithm of a more extensive traffic management system. This method was applicable for knowing the traffic's current condition in a dynamic situation and deciding on navigating the driver to drive in an effective way that makes sure to determine the shortest available path [2]. An intelligent transportation system incorporating both the scheduling and vehicle routing of dynamic vehicle routing problem with time windows (VRPTW) model developed and applied to the road test network. Total vehicle cost was reduced by developing the time windows model and using real-time travel information [3]. A real-time decision making on traffic conditions based on the cellular station network was established to provide real-time data of traffic on the road. [4]. Three parallel strategies were approached for real dynamic time routing, which is the computational effort required for an optimal solution, overall computation for available power, and average inter-arrival time [5]. For adapting changes, a model developed using the Dijkstra algorithms, which is also known as the shortest path first algorithm to find an optimal route plan based on the optimal real-time route. To implement the algorithm, SUMU was used to simulate the route plan, and TRACI was used to update the route plan regularly according to the real-time traffic [6]. The modified algorithm of Dijkstra algorithm named as Dijkstra's classic double bucket algorithm was used to develop commercial SIS software to be used as vehicle routing and rerouting considering both static and dynamic search heuristics for simulated earthquake conditions [7]. The usage of both the Dijkstra algorithm and traffic image processing made the system intelligent to respond to the dynamic traffic condition [2]. An assignment algorithm was proposed for the scheduling bus trip to assign many short trips[8]. A two-step approach of clustering assignment of the customers' gathered part to depots with designing and analyzing six heuristics for the cluster part using graphic tool development and studied their performance [9]. A routing design problem where the objective is to assign customer demand points to days of the week to minimize weekly travel distances and to balance vehicle requirements[10]. Allude the potential in more improvement of the transportation and assignment algorithms where individual attention is paid to the reduction of zero pivots and reduced the CPU time [11]. Vehicle routing algorithms alone are not sufficient to make a system effective and efficient. To take the real-time data tool like a global positioning system (GPS) is much useful. Input like real-time location, vehicle tracking can be achieved using it, and based on these data, the algorithms provide the optimal solution [12]. For decreasing accidents, A GPS and cloud computing-based model was developed that could take all the necessary inputs of the vehicles like real-time location, speed, etc. that helped in intelligent monitoring [13]. Unlike responding to global static customer demand, a service developed to respond to real-time customer demand, real-time traffic based on a variable neighborhood search algorithm which is adopted in google maps API [14]. Immense scope in garment sector considering significant factors lies in proper implementation of TQM [15]. A bi-level model using genetic algorithm is used to solve profit distribution problem between collaborative logistics platform and vehicle owners [16]. A three stages optimization and vessel routing model is proposed to clean up debris [17]. It is able to achieve perfect control limit using TQM reducing material cost [18]. A multi-period, two-stage stochastic programming model is developed to determine a reliable set of reliable paths above the horizon reducing total cost [19]. All the interrelationships and skill tests are performed simultaneously using a two-wave longitudinal design [20]. A two-stage stochastic mixed-integer programming model is developed to reduce costs & reduce emissions from supply chain network [21]. Grid genetic algorithm used to improve vehicle routing problem by introducing an experimental MiniGrid [22]. Based on this research, we came to the point that dynamic vehicle routing optimization is the most effective and efficient way to attain the most optimal output in this sector. So, our goal of this research is to implement the ways of making vehicle routing optimized and intelligent by responding it to real time traffic.

2. Methodology

This research was conducted through several steps. Data were collected using physical questionnaire survey with Operation head of Super shop Shawpno and drivers of Shawpno.

2.1 Assumptions and data collection

For our problem, we have considered some assumptions:

1. Each vehicle must visit one node only once.
2. Each vehicle should start from the depot and end to the depot.
3. The demand at the outlet is known.
4. The demand at nodes cannot exceed the capacity of the vehicle.
5. The first node is considered as a depot.
6. The vehicle has a limited capacity.
7. Different types of products require different types of vehicles.
8. Rice and Pulse are selected as a product to be delivered.

We collected several data for our problem. The demand at the outlet is known the day before delivering.

Maximum capacity of the vehicle for product Rice and Pulses

= 6000 kg

Minimum demand for the product (Rice and Pulses) at outlets = 500 kg

Maximum demand for the product (Rice and Pulses) at outlets = 2000 kg

There are 87 outlets of Shawpno in Dhaka. We have prepared a dataset with all the information like latitude, longitude, addresses, zip code, the demand of one day for each location having the constraint of vehicle capacity in Excel. A sample of required data of 10 outlets is shown here for our scheduling problem using google sheet.

Display ID	Location ID	Latitude	Longitude	Location Address
D	Depot	23.767941	90.403939	Tejgaon Industrial Area, Dhaka
1	Shwapno Outlet 1	23.8639063	90.3970899	Plot-32/D&E, Nator Tower,RD-02, Sector-03, Uttara, Dhaka.
2	Shwapno Outlet 2	23.8139908	90.3237293	Plot # 27, Road # 02, Sector # 11, Uttara.
3	Shwapno Outlet 3	23.8818046	90.3885748	House No, 12 Road No, 12, Thana, Uttara, Sector, 10 District, Dhaka.
4	Shwapno Outlet 4	23.8457796	90.417862	Vit NO:(1-18),Kawla Bazar,Civil Aviation welfare market,Thana:Dakshinkhan,Dis:Dhaka-1229.
5	Shwapno Outlet 5	23.8339741	90.4153739	House NO:1/C, 1/D, Road NO:16, Nikunja-2, Post:Khilkhet-1229, Thana:Khilkhet, Dis:Dhaka.
6	Shwapno Outlet 6	23.764741	90.429108	House- 14 & 30-B, Main Road, Block-B, North Banasree, Rampura, Dhaka-1219
7	Shwapno Outlet 7	23.764608	90.42914	Block # K, South Banasree.
8	Shwapno Outlet 8	23.7290047	90.4295342	Sky view Plaza 3/2 Mugdapara Sabujbagh Dhaka.
9	Shwapno Outlet 9	23.7611984	90.4293065	H Avenue Road No-08, House-12,Rampura,Banasree,Dhaka- 1219.
10	Shwapno Outlet 10	23.8098247	90.3864708	Shop NO:05,Plot NO:60,RD#07, Banasree, Thana:Rampura,Dis:Dhaka-1219.

Figure 1: Depot and Delivery Locations

Vehicle ID	Start Location	End Location	Earliest Start Time	Latest End Time	Volume Limit	Weight Limit
V1	Depot	Depot	08:00	16:00		6000
V2	Depot	Depot	08:00	16:00		6000

Figure 2: Vehicle Information

Order ID	Volume	Weight	Order Location	Earliest Start Time	Latest Start Time	Service Time (min)
Order 1		2000	Shwapno Outlet 1	09:00	16:00	10
Order 2		500	Shwapno Outlet 2	09:00	16:00	10
Order 3		1500	Shwapno Outlet 3	09:00	16:00	10
Order 4		700	Shwapno Outlet 4	09:00	16:00	10
Order 5		800	Shwapno Outlet 5	09:00	16:00	10
Order 6		2000	Shwapno Outlet 6	09:00	16:00	10
Order 7		1200	Shwapno Outlet 7	09:00	16:00	10
Order 8		2000	Shwapno Outlet 8	09:00	16:00	10
Order 9		800	Shwapno Outlet 9	09:00	16:00	10
Order 10		500	Shwapno Outlet 10	09:00	16:00	10

Figure 3: Delivery information of Outlets

2.2 Case study

For Research purposes Shawpno transportation system was investigated. Shawpno has more than 120 outlets in Dhaka city. Dhaka city's road is full of congested, for this Shawpno faced difficulty in their delivery system to outlets. We identified they faced issue in their vehicle scheduling and routing. Resolving this issue, we considered the scheduling orders based on area and then based on scheduling, tried to improve their vehicle routing by using the application.

2.2.1 1st step- Scheduling

For scheduling, we gathered the required data: latitude, longitude, addresses, demand, vehicle capacity. All of these data were stored in an excel file. We made use of google sheet for scheduling. The vehicle routing feature on the google sheet was added using the ad-ons option. The input data stated in the data collection section was used to solve the scheduling problem. The scheduling made using this vehicle routing feature clustered the outlets according to the demand, location, available vehicle, and vehicle capacity. The road traffic condition was also considered in this scheduling, which made the sequencing more specific and authentic. This sequencing of the vehicle was used in the next step for navigating. The scheduling was done for ten outlets, and all of the outlets were covered using two vehicles. The scheduling result obtained using these inputs are shown here:

Vehicle ID	Stop	Order ID	Location Name	Activity	Arrival Time (Plan)	Departure Time (Plan)
V1	0	0	Depot	Start	08:45	08:45
V1	1	Order 2	Shwapno Outlet 2	Visit	09:00	09:10
V1	2	Order 10	Shwapno Outlet 10	Visit	09:21	09:31
V1	3	Order 5	Shwapno Outlet 5	Visit	09:44	09:54
V1	4	Order 3	Shwapno Outlet 3	Visit	10:06	10:16
V1	5	Order 1	Shwapno Outlet 1	Visit	10:23	10:33
V1	6	Order 4	Shwapno Outlet 4	Visit	10:39	10:49
V1	0	0	Depot	End	11:05	11:05
V2	0	0	Depot	Start	08:48	08:48
V2	1	Order 8	Shwapno Outlet 8	Visit	09:00	09:10
V2	2	Order 9	Shwapno Outlet 9	Visit	09:21	09:31
V2	3	Order 7	Shwapno Outlet 7	Visit	09:32	09:42
V2	4	Order 6	Shwapno Outlet 6	Visit	09:44	09:54
V2	0	0	Depot	End	10:02	10:02

Figure 4: Scheduled Outlets According to Vehicles

The output of the scheduling plan seemed like vehicle-1 started from the depot, served six outlets, and returned to the depot finally in the sequence of depot – outlet 2 – outlet 10 – outlet 5 – outlet 1 – outlet 3 – outlet 4 – depot. For vehicle-2, the sequencing is as follows: depot – outlet 6 – outlet 7 – outlet 9 – outlet 8 – depot. The visualization of scheduling is given below:

Figure 5: Visualization of Sequencing and Scheduling

This sequencing order was used to navigate the vehicle based on the real-time traffic condition in the next step. The scheduling approach covers the maximum outlets that a vehicle can attend, maintaining its capacity constraint based on location and demand at nodes. This approach will pick the minimum number of vehicles required for serving the nodes. So, it will reduce the number of vehicles also. The algorithm behind this scheduling solver tool is given below:

$$\sum_{i\in V_C}\sum_{k\in K} p_i\, y_i^k - \sum_{(i,j)\in A}\sum_{k\in K} c_{ij}^k\, x_{ij}^k - \sum_{j\in V_c}\sum_{k\in K} f^k\, x_{o^k,j}^k - \Pi\sum_{i\in V} u_i \quad \ldots\ldots\ldots\ldots(1)$$

Here, this equation (1) expresses the maximizing the total profit by subtracting travel cost of vehicles, fixed cost of vehicles, and penalty for violating time windows, respectively. In our problem, this equation is subjected to the following constraints:

$$\sum_{k\in K} y_i^k = 1\ \forall_i \in V_M \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$\sum_{p\in S, q\in V\setminus S} x_{pq}^k \geq y_i^k \quad \forall_i \in V_c, k\in K, S\subset V: o^k \in S, i \in V\setminus S \ \ldots\ldots\ldots\ldots(3)$$

$$\sum_{j\in V\setminus\{i\}} \omega_{ij}^k - \sum_{j\in V\setminus\{i\}} \omega_{ij}^k = q_i y_i^k \ \forall_i \in V_c, k \in K \ldots\ldots\ldots (4)$$

$$\sum_{i\in V_c} \omega_{i,r^k}^k = \sum_{j\in V_c} q_j y_j^k \ \forall k \in K \ldots\ldots\ldots\ldots (5)$$

$$\sum_{j\in V\setminus\{i\}} Z_{ji}^k - \sum_{j\in V\setminus\{i\}} Z_{ij}^k = \hat{q}_i y_i^k \ \forall_i \in V_c, k \in K \ldots\ldots\ldots (6)$$

$$\sum_{i\in V_c} Z_{o^k,j}^k = \sum_{i\in V_c} \hat{q}_i y_i^k \ \forall k \in K \ldots\ldots\ldots\ldots (7)$$

$$\omega_{ij}^k + Z_{ij}^k \leq Q^k \ \forall (i,j) \in A, k \in K \ldots\ldots\ldots (8)$$

$$\sum_{(i,j)\in A} d_{ij} x_{ij}^k \leq D^k \ \forall (i,j) \in A, k \in K \ldots\ldots\ldots (9)$$

Here equation (2) indicates that every customer must be visited once. Constraint (3) provides the connectivity between the vehicle(k) of the origin depot and the customers. Equation (4) and (5) provides the pickup commodity, whereas equation (6) and (7) provides the delivery commodity. Constraint (8) prohibits the excessing of vehicle capacity limits. Constraint (9) indicates the distance for each vehicle [23].

2.2.2 2nd step- Navigating

Navigating vehicles based on the instant traffic condition is done here. We have got the sequence of outlets to be visited by vehicle-1 and vehicle-2, respectively. But there are many ways to reach from one outlet to another. As the road traffic condition is not always the same, navigating the vehicles based on instant traffic conditions from one outlet to another is crucial to obtain an efficient and optimal output of routing.

The pseudocode for Dijkstra's algorithm is given below:

```
function Dijkstra (Graph, source):
    dist [source]:= 0
    for each vertex v in Graph:
        if v ≠ source
            dist[v]:= infinity
        add v to Q
while Q is not empty:
    v:= vertex in Q with min dist[v]
    remove v from Q
    for each neighbor u of v:
        alt := dist[v] + length(v, u)
        if alt < dist[u]:
            dist[u] := alt
  return dist[]
end function
```

To calculate the shortest distance between the vertices, we used the haversine formula which determines the great-circle distance between two points on a sphere given their longitudes and latitudes. To plot the route between the markers, we retrieve the shortest path and store it in another variable. Different tools from the google cloud platform like navigation based on real-time, on map click e.t.c were used to make the system taking decision automatically.

The final sample output of navigating vehicle is as follows:

Figure 6: Navigation of vehicle-1 from depot to outlets

A two-step procedure of scheduling and routing is done here to identify the optimal vehicle routing for super shop Shawpno. Our case study used the Dijkstra algorithm to find the shortest path between depot to the various outlet. To reach the destination, many nodes may arise from the depot. For the shortest travel distance between depot and outlets, appropriate weight was considered the distance between them. The calculation was done by considered adjacent nodes distance and chose the smallest one. So, for continuing to generate the path, identify all adjacent nodes related to the current nodes. For calculating their distance to other nodes to reach the destination, the nodes' weight was added to the current nodes. But only change the nodes if it was less than the previous one. The weighted was calculated from previous nodes to current nodes based on adjacent nodes. After completing the algorithm shortest route was found that is shown in figure (6). If any obstruction arises on the selected path, the edges of weight reevaluate and find another shortest path.

3. Result and Discussion

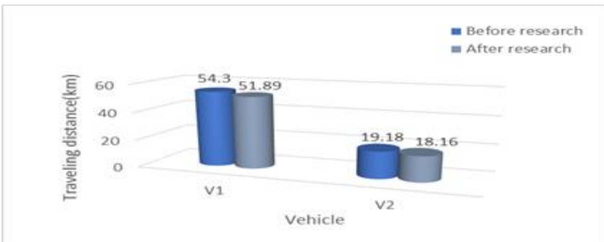

Figure 7: Comparison between before and after research

Before our research, the total traveling distance between selected outlets was 54.3 km for vehicle-1 and 19.18 km for vehicle-2. But after applying the algorithm, the traveling distance was reduced to 51.89 km for vehicle-1 and 18.16 km for vehicle-2. So, traveling efficiency is increased to 4.4% for vehicle-1 and 5.3% for vehicle-2.

The framework has been illustrated to update the shortest route during a journey:

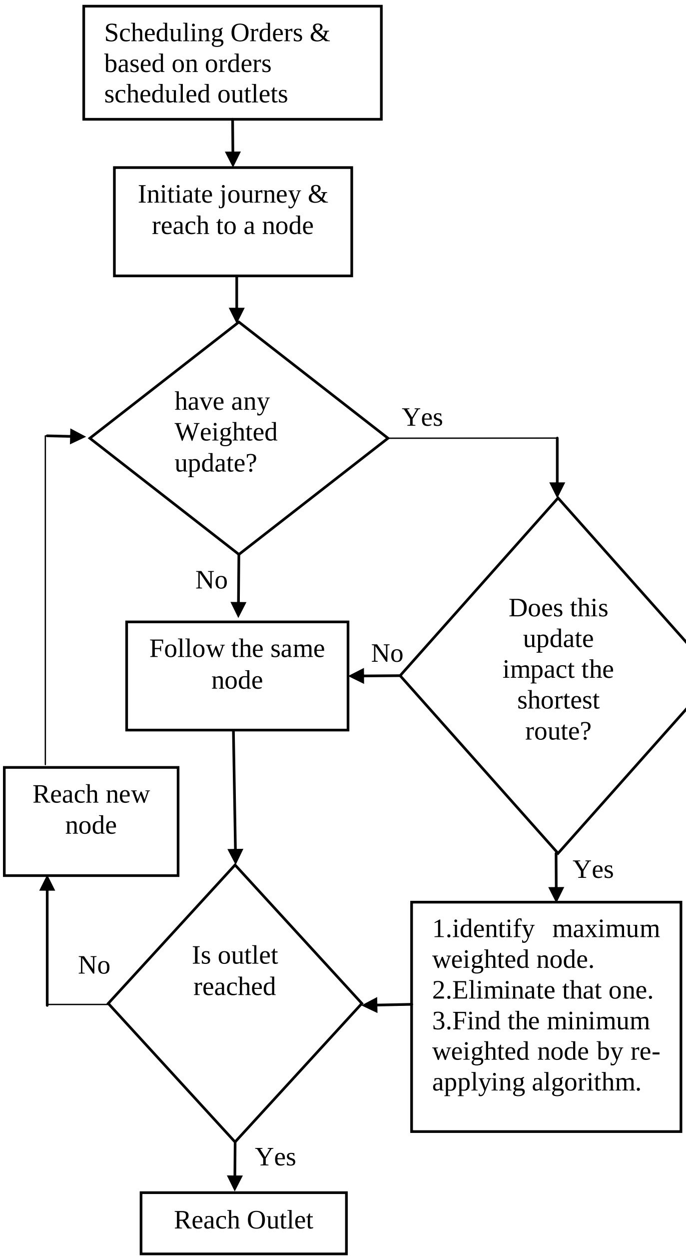

Figure 8: Framework of vehicle routing

Even though several papers have been developed on vehicle routing and order scheduling, both of them were considered and figured out a solution for super shop Shawano in our research. We scheduled the clustered orders using the vehicle routing features on google sheet, and then we achieved the shortest path using Dijkstra's algorithm. Also, to find the shortest path, traffic congestion for that route should be updated. We concluded that if any obstruction appears on the road, an alternative path is being shown. Thus, make the system intelligent because it responds to the present traffic condition and finds the shortest path by reevaluating the weighed distances of available nodes to reach the destination. The new track will be the shortest one, among others. Our case study picked ten orders based on schedule; then, we re-route those delivered paths according to our algorithms. The result shows us an optimal route to reach the outlets.

4. Conclusion

This research represents scheduling and an intelligent vehicle routing approach of Super shop Shawpno.

- The approach was applied to design scheduling and finding the shortest path between nodes.
- Based on real traffic congestion, this approach can find the alternate shortest path if any obstruction arises.
- The approach was sufficient to decrease traveling distance.
- Based on the result, it is expected that applying the process on the whole delivery system will have a good impact on the adequate transportation of the super shop Shawpno.
- Theoretically, the spreadsheet tool and application method's implementation has a good impact on optimizing vehicle routing because these are easy to use to find the most optimal output in a dynamic situation.
- In practical life, we can expect to apply and extend these methods in several sectors like RMG sectors, online shops, other retail chains, etc. that need vehicle routing improvement, reducing cost structure of a company, and improving customer satisfaction.

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NOMENCLATURE

V_D= Vertex set to contain the depots,
V_c= Vertex set to contain the customers,
p_i= Profit of servicing a customer,
q_i= Service amount for the customer,
K= Set of vehicles,
f^k = Fixed cost of using the vehicle,
Q^k= Capacity of the vehicle,
d_{ij}= Distance,
C_{ij}^k= Travel cost,
β, π= Operational constraint,
$x_{ij}^k, y_i^k, w_{ij}^k, Z_{ij}^k, t_i^k$ = Decision variable.