

Agent Based Plant Allocation and Transfer Routing of Products in Case of Emergency

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In this paper, two problems, plant allocation problem and that of transfer routing from plants to customers, are considered simultaneously. Especially, adaptation scheme for emergency cases are checked. To solve these problems, decentralized agent based optimization procedures are used. In our study, oil production and products transfer in Saudi Arabia are treated. Through numerical experiments, practicability of the proposed method is verified.

1. Introduction

In recent years, the system optimization technologies are studied briskly and applied widely to production and distribution problems. These advancements are supported both by the progress of computer technologies and that of the optimization technologies for large scale system.[1] This research deals with an optimization problem for oil production planning and its transfer control in case of emergency. When an emergency occurs, it becomes necessary to determine once again the appropriate allocation of plants and transfer routes from plants to customers. To the purposes, a decentralized agent method for optimizing both the allocation of plural oil plants and the transfer route of oil products in a wide area are studied. Optimization of oil production and products distribution system are taken up as the aimed problem of real scale. In order to optimize the arrangement of oil production plants, delivery routes of a product are taken into consideration simultaneously.

2. Problem Description

To treat the problem, 48 nodes representing consumer places are arranged in Saudi Arabia Fig.1 and 3 production plants are set up on the corresponding nodes. The delivery route of a product shall be constituted by the adjoining node sequence. The tracks made with a uniform velocity are belonged to each plant.

[Emergency cases]

In this research, there are two kinds of emergency

cases. One is plant damage or building a new plant to cover consumer's demands for plants in work. The other is the interruption of transfer to some reason such as the destruction of a proper transfer rout to consumer cities.

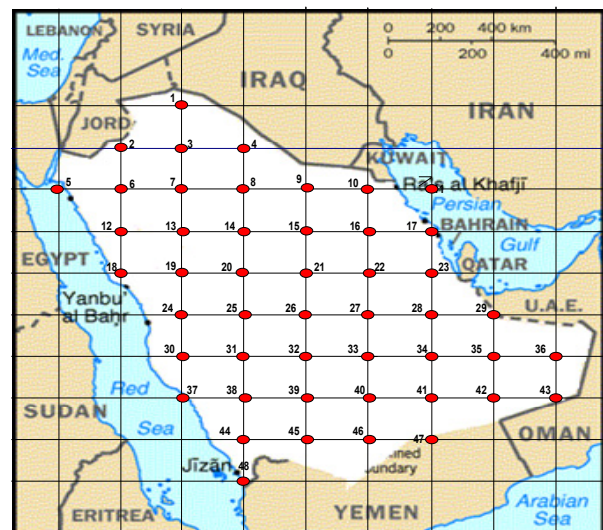


Fig.1 Saudi Arabia Node map

3. Mathematical description

In our treatment, the time required for movement between nodes is made one unit period and all tracks are assumed to have a uniform velocity. The mathematical models for track operations are

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described in the following. Decision variables are $[0,1]$ variables representing moving from one node to the adjacent node whose attributes are track number, corresponding to nodes, time and plant number. In the following, these definitions will be described mathematically together with restrictive conditions and objective functions for optimization.

3.1 Notation for variables

Variables, parameters and functions used in our paper are summarized as follows.

C : city number ($C=1, \dots, 48$), $S_C(t)$: Volume of inventories, $D_C(t)$: amount of demands, $R_C(t)$: amount of consumption, p : Plant number, Ω_p : Plants Quantity of production, X_α : search track (main agent) of plant arrangement, X_β : transportation track of an oil product (sub agent), a_β : freight per track, b_β : loading of a track (if $b=1$), $l_{p \cdot c}$: distance from plant to city, $f_\alpha(l_{i \cdot j})$: arrangement cost of a plant, $f_\beta(l_{i \cdot j})$: transfer cost between a city and a plant, I_α : evaluation function for optimum plants arrangement, I_β : evaluation function for optimization of sub agent's transportation (conveyance route length), ΔW_α : amount of pheromone of a main agent, ΔW_β : amount of pheromone of a sub agent, ρ_α : evaporating ratio of pheromone of a main agent, ρ_β : evaporating ratio of a sub agent, Q : penalty cost reflecting the number of consumption nodes which is not delivered,

3.2 Restrictive Conditions

Conditions for continuation are as follows.

$$\sum_{j \in N_i} x_{i,j,t}^{k,m} = 0, \quad \sum_{j \in N_i} x_{i,j,t}^{k,m} = 1 \quad (1)$$

Where N_i denotes a set of adjacent nodes of node $\#i$. As shown here, decision variable is x that express the movement of a track between adjacent nodes in unit time. Variable $x_{\beta,i,j,t}^{k,m}$ takes 1 when a track $\#k$ belonging to the plant $\#m$ moves from node $\#i$ to node $\#j$ at time period t .

Condition for shipment from a plant is as follows. Where, Ω_m , $N(m)$ and a are the quantity of production

$$H_m = g(\Omega_m - a \sum_{k,j \in N(m)} x_{\beta,n(m),j,t}^{k,m,l}) \quad (2)$$

of a plant $\#m$, a set of nodes corresponding to plant $\#m$ and the capacity of a truck.

Condition for inventory volume at consumer place is given by

$$S_C^{Min} < S_C < S_C^{Max} \quad (3)$$

Where, S_C^{Min} , S_C^{Max} and $R_{C,t}$ are minimum volume of stock, maximum volume of stock and current stock at a consumer node.

3.3 Objective functions for plants arrangement

Delivery cost is used for the objective function in plants arrangement problem. Namely, the objective function I_α is defined by equation (4).

$$I_\alpha = \sum_{i,j,m,t} f_{\alpha,i,j} x_{\alpha,i,j,t}^{k,m} + \gamma_1 Q \rightarrow Min \quad (4)$$

In equation (4), penalty cost Q depending on the number of consumption nodes which is not delivered is added to the transfer cost.

3.4 Objective function for transfer routing

Objective function for transfer routing is defined by

$$W = H^e + H^o + \gamma_2 H^v + \mu H_m \quad (5)$$

Where, H^e , H^o , H^v and H_m show the transfer costs of approaching, returning, penalty value for inventory volume at consumers and penalty for excessive loading of a truck. Except H_m , these are defined as follows.

$$H^e = \sum_{i,j,k,m,t,b=1} f_\beta^e(l_{i,j}) x_{\beta,i,j,t}^{k,m,b} \quad (6)$$

$$H^o = \sum_{i,j,m,t,b=0} f_\beta^o(l_{i,j}) x_{\beta,i,j,t}^{k,m,b} \quad (7)$$

$$H^v = f(\Delta S) \quad , \quad \Delta S = f \sum_i (S_{Ci} - S_i^{Min}) \quad (8)$$

Where, f^e and f^o show the cost per unit distance for movement in approach and return respectively. $f(y)$ is a nonlinear function whose value takes positive large one if the sign of y becomes negative. As for the parameters in equation (6), $f_{\beta,i,j}^b$ is the delivery cost between nodes i, j .

Where, b denotes parameter showing approach or return route of a track. The value of b is one when a track is on an approach route and is zero for return.

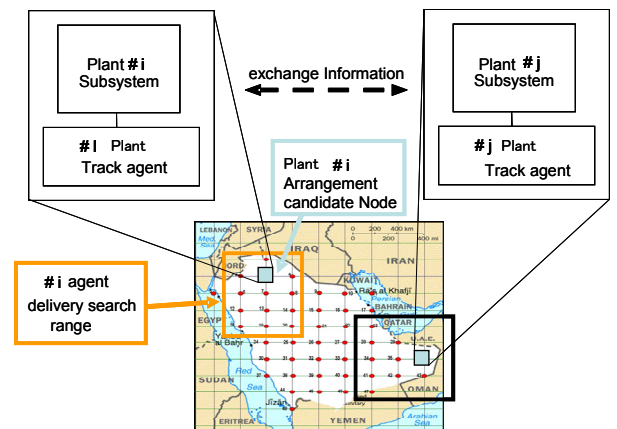


Fig.2 planning plant location and transfer routes by decentralized agents

4. Algorithm for optimization

In our method the decentralized agent method is adopted for the optimization. [2]-[4] As shown in Figure 1, agents corresponding to plant accompanied by tracks autonomously search their locations and distribution area including transfer routes.

4.1 Search algorithm for optimal plant allocation

Step1. input number of plants.

Step2. generate the node of a plant location.

The Plant node number is not allowed to overlap the node number of other plants.

Step3. search delivery route for a track randomly.

These serve as a primary solution candidate.

Step4. sprinkle pheromone ΔW_α on delivery nodes employing the following relation.

$$Ph_k^\alpha = \Delta W_\alpha \quad (9)$$

Ph_k^α : amount of accumulated pheromone.

Step5. calculate evaluation of primary solution.

Step6. search again the delivery course of a track randomly, This serves as a secondary solution candidate.

Step7. compare pheromone information for primary and secondary solution

$$Ph_k^{\alpha,2} \geq \sum_{k' \neq k} Ph_k^{\alpha,1} \quad (10)$$

If the amount of pheromone for a secondary solution is larger, then go to Step 9, else go to Step8.

Step8. calculate probability of adoption of a secondary solution candidate, $R_\alpha(k)$

$$R_\alpha(k) = \max \left[\exp \left[\frac{r_\alpha(k)}{T_{R_\alpha}} \right], R_o \right] \quad (11)_1$$

$$r_\alpha(k) = Ph_k^{\alpha,2} - \sum_{k' \neq k} Ph_k^{\alpha,1} \quad (11)_2$$

If it becomes $r_\alpha(k) < 0$, return to Step6. with probability $R_\alpha(k)$. Otherwise, go to Step9.

Step9. pheromone is sprinkled on nodes of a secondary solution.

Step10. compare cost of the primary solution and that of the secondary. If the secondary solution is better than the primary solution, go to Step12. If not good, go to step 11.

Step11. calculate probability of adoption of the secondary solution even if its cost is not good.

$$P_\alpha(k) = \exp \left[\frac{I_\alpha^1(k) - I_\alpha^2(k)}{T_P} \right] \quad (12)$$

When not improved, go to step 12 with probability $P_\alpha(k)$. Otherwise, return to step6.

Step12. Secondary solution is exchange with primary solution.

Step13. Convergence condition is investigated to finish the iterations. When convergence is not

attained, returns to Step6.

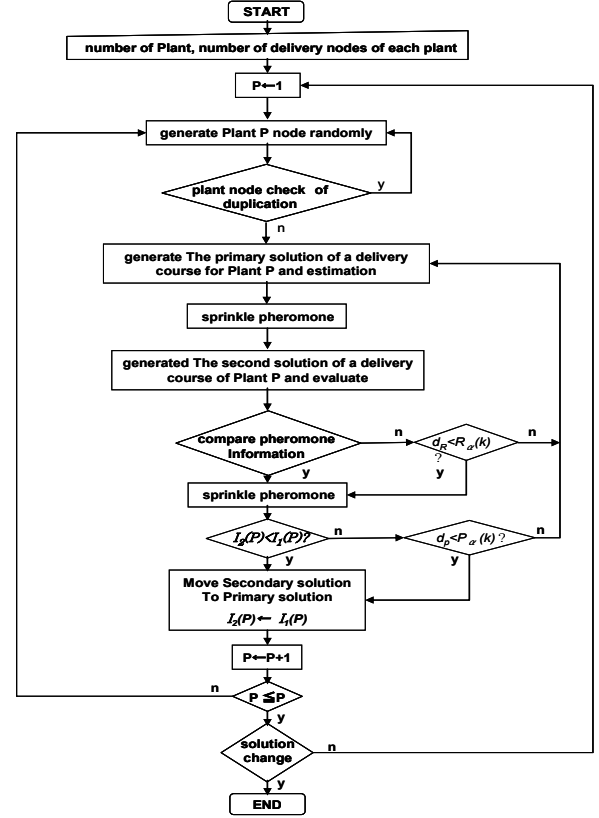


Fig.3 Main algorithm for Plant allocation search

Fig.3 shows Main algorithm for allocation search

4.2 Algorithm for transfer routing

In transfer routing after plant allocation Algorithm is

over plan node number and plant transfer area nodes, or in emergency case the arc cant be used are passing to transfer routing Algorithm.

Step1. Input plants node number, delivery node numbers.

Step2. Create the track primary solution in random, and calculate Evaluation.

Step3. Sprinkle pheromone ΔW_β on delivery nodes.

$$Ph_k^\beta = \Delta W_\beta \quad (13)$$

Ph_k^β the amount of accumulation pheromones.

Step4. Create the track Secondary solution, calculate Evaluation.

Step5. Compare pheromone information for primary and secondary solution

$$Ph_k^{\beta,2} \geq \sum_{k' \neq k} Ph_k^{\beta,1} \quad (14)$$

If the amount of pheromones of a secondary solution is large then go to Step 7, else go to Step6.

Step6. Probability it calculates.

$$R_{\beta}(k) = \max \left[\exp \left[\frac{r_{\beta}(k)}{T_{R_{\beta}}} \right], R_o \right] \quad (15)_1$$

$$r_{\beta}(k) = Ph_k^{\beta,2} - \sum_{k' \neq k} Ph_k^{\beta,1} \quad (15)_2$$

$r_{\beta}(k) < 0$ If it becomes, it will return Step6. By probability $R_{\beta}(k)$. Otherwise, it progresses to Step9.

Step7. a pheromone is sprinkled on a secondary solution node.

Step8. Compare the Cost of a primary solution and Secondary solution. If Secondary solution Cost is better than the primary solution, it will progress to Step6. If bad, it will progress to next.

Step9. When not improved, it returns to Step6 by probability

$$P_{\beta}(k) = \exp \left[\frac{I_{\beta}^1(k) - I_{\beta}^2(k)}{T_p} \right] \quad (16)$$

$P_{\beta}(k)$ Otherwise, it progresses to Step10.

Step10. replace a Secondary solution and primary solution .

Step11. Convergence situation of a solution is investigated. When convergence is not enough, it returns to Step6. It will end, if it is converging.

Fig.4 shows algorithm for customers routing

5. Experimental conditions

Numerical experiment was conducted in order to verify the effect of the algorithm stated above. The problem of plants arrangements and distribution from plants to consumers was solved simultaneously. In the experiment, the number of plants was set as 3. The production data of oil plants are given together with data of customers in Table 1. Parameters for decentralized agents stated above are given as shown in Table 2.

The result of the plant arrangement node and cost which used and searched for this algorithm is shown in Table 3.

Table 1. Plants production and customers number

Plant	producing	No of track	customers
1	11	1	48 nodes 76 arcs
2	21	1	
3	16	1	

Table 2. Constant in algorithm

ρ	ΔW	T_p	T_R
0.3	4.0	12.0	18.0

6 Experimental results

Using the algorithm and conditions described in the preceding sections, numerical experiments were carried out.

6.1 Plant allocation design

Plants allocation search is made by decentralized agent algorithm explained in the above sections. The transition of evaluation function, cost, is shown in Figure 2. In the figure, three examples of calculated customer cities by plant #1 is shown with excess of iterations. According to the change in cost, numbers of customers converge to its final solution. The delivery zone from each plant in the target area which is the converged solution is shown in Fig. 3. In Table 3, calculated numbers of customers for 3 plants are shown together with their costs. As shown in the table, calculated number of customers (nodes) of a plant coincides with production rate of the corresponding plant. Costs in the table mean summation of arcs on each transfer route.

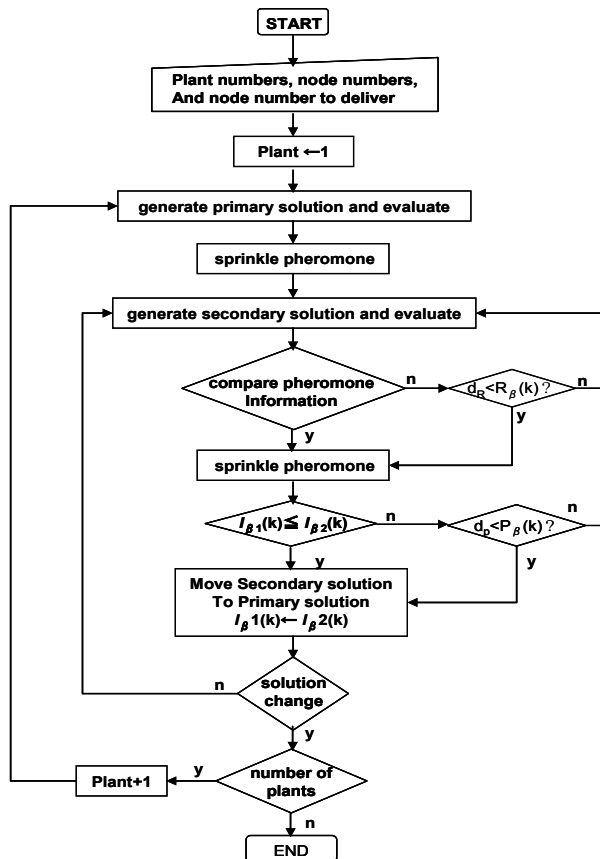


Fig .4 sub algorithm for customers route search

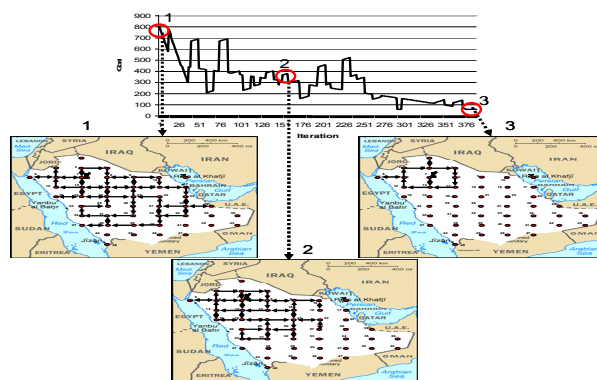


Fig.5 Transition of Cost during search procedure
Thus, the solution corresponding to the plant capability and the demand in a consumer place is obtained.

Table 3 Numerical experiment result (cost and the optimal solution)

	Production of plant	optimal solution	
		Node	Cost
Plant 1	11	11	14
Plant 2	21	21	26
Plant 3	16	16	18

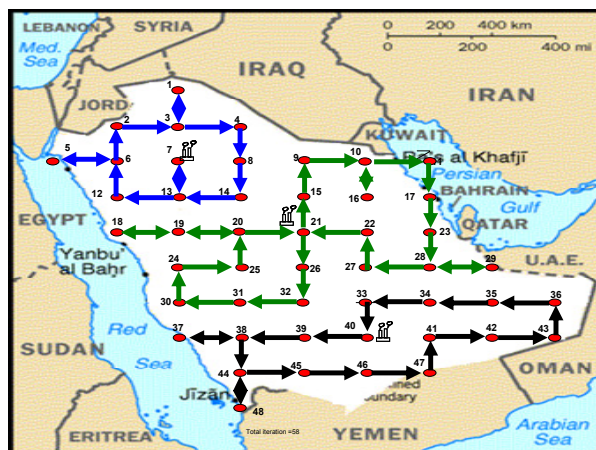


Fig.6 Simulation result

To check the validity of the proposed algorithm, pheromone consumption on the selected transfer route is checked. Fig.7 shows the accumulated amount of pheromone corresponding to plant #1 at nodes #7 and #19. As is shown in figure 3, node #7 is served by plant #1. on the other hand, node #19 is not served.

As shown in figures 7,8 and 9, accumulated amount of pheromone increased with iterations. figure 7 shows changes in pheromone accumulation of #1 plants at nodes

#7 and #19. The amount at node #7 are increasing with iterations. Contrary to this, the amount of pheromone at node #19 is decreasing with iterations. Similar results are shown in figures 8 and 9. Finally, the amount of pheromone accumulation becomes to its maximum value at the nodes corresponding to its appropriate locations.

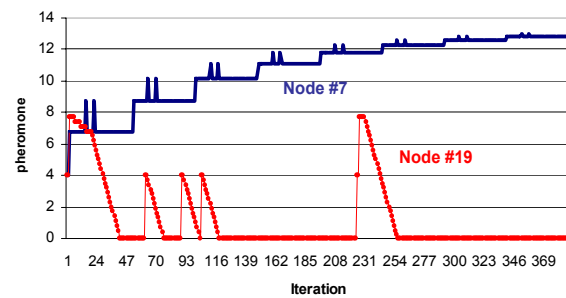


Fig.7 Change of pheromone accumulation
(Plant #1)

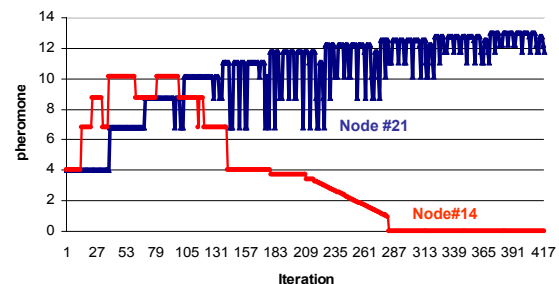


Fig.8 Change of pheromone accumulation
(Plant #2)

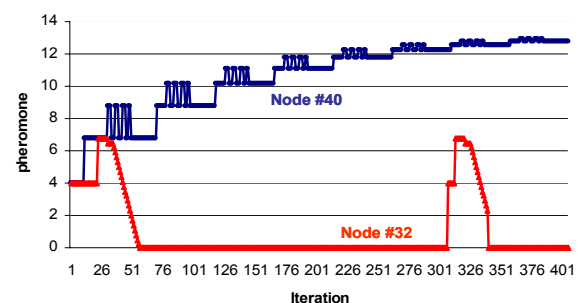


Fig.9 Change of pheromone accumulation
(Plant #3)

5.2 Results for emergency cases

As for emergency, case of route destruction is considered. As shown in Figure 5, arc between node #8 and #14 is destructed. As the results, the other transfer route except this arc should be determined. Using the proposed method, surrogate transfer route was determined as such shown in Figure 6.

As shown in figure 6, new arc is created between nodes #7 and #8. Addition to this, transfer direction is changed to fulfill the minimization of transfer distance. As the result, total traveling distance of the surrogate route is the same before the destruction of transfer route.

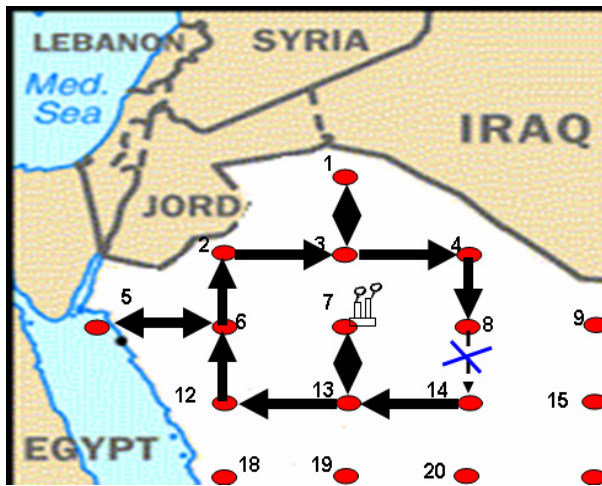


Fig.10 Emergency case of route destruction

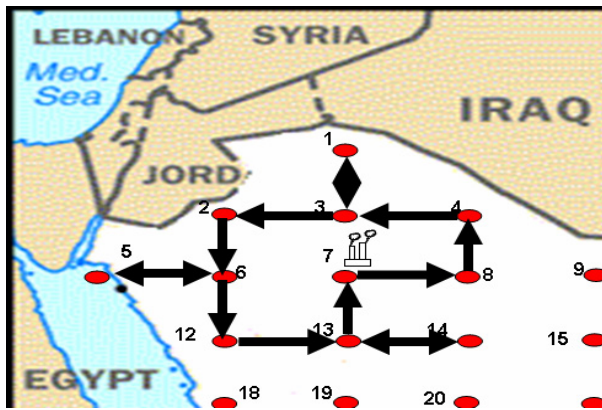


Fig.11 Finding of surrogate transfer route

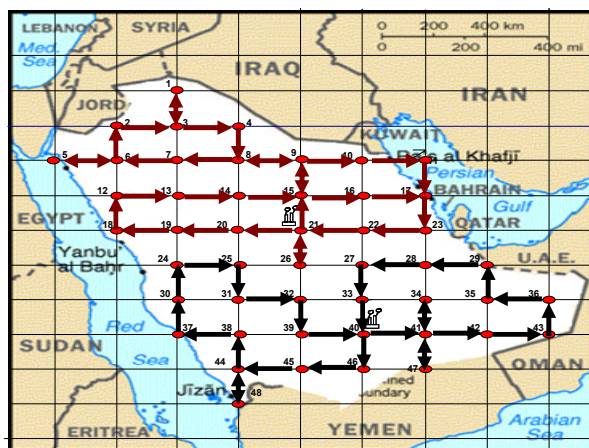


Fig. 12 Solution in case #1 Plats is shut down

6. Conclusion

This research examined the subject about the arrangement of oil production plants, where to locate and to what consumer places the oil products are to be delivered, and how to employ the distribution routes. In the proposed method, a delivery tracks was set up as a distributed agents, and it tried for these agents to search for an appropriate solution autonomously.

Using the developed program for planning, the arrangement of three plants and the delivery problem to 48 cities were set up supposing cities in Saudi Arabia, and the solution was calculated.

Consequently, the very suitable solution could be found and the validity of the proposed method has been checked. The proposed method is expected to extend for more advanced problems about optimization of both production base planning and logistics in a wide area.

Based on the result, further research will be made to solve the problem of seven plants of a real scale, and 48 cities under the various conditions.

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