

PAPER • OPEN ACCESS

## A simulated annealing approach for redesigning a warehouse network problem

To cite this article: Rozieana Khairuddin *et al* 2017 *J. Phys.: Conf. Ser.* **890** 012109

View the [article online](#) for updates and enhancements.

### Related content

- [University Accreditation using Data Warehouse](#)  
A S Sinaga and A S Girsang
- [Protection and development planning of mud flat: A modelling approach and case study](#)  
Ling Sun and Zesheng Zhu
- [Promotion bureau warehouse system design. Case study in University of AA](#)  
N Parwati and M Qibtiyah

# A simulated annealing approach for redesigning a warehouse network problem

**Rozieana Khairuddin<sup>1</sup>, Zaitul Marlizawati Zainuddin<sup>2,3</sup> and Gan Jia Jiun<sup>4</sup>**

<sup>1</sup>Faculty of Industrial Sciences & Technology, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia

<sup>2</sup>Department of Mathematical Sciences Faculty of Sciences, Universiti Teknologi Malaysia 81310, Johor Darul Ta'azim, Malaysia

<sup>3</sup>UTM Centre for Industrial and Applied Mathematics & Department of Mathematical Sciences Faculty of Sciences, Universiti Teknologi Malaysia 81310, Johor Darul Ta'azim, Malaysia

<sup>4</sup>Centre for Transportation Research, Department of Civil Engineering, University of Malaya, 50603 Wilayah Persekutuan Kuala Lumpur, Malaysia

E-mail: zmarlizawati@utm.my

**Abstract.** Now a day, several companies consider downsizing their distribution networks in ways that involve consolidation or phase-out of some of their current warehousing facilities due to the increasing competition, mounting cost pressure and taking advantage on the economies of scale. Consequently, the changes on economic situation after a certain period of time require an adjustment on the network model in order to get the optimal cost under the current economic conditions. This paper aimed to develop a mixed-integer linear programming model for a two-echelon warehouse network redesign problem with capacitated plant and uncapacitated warehouses. The main contribution of this study is considering capacity constraint for existing warehouses. A Simulated Annealing algorithm is proposed to tackle with the proposed model. The numerical solution showed the model and method of solution proposed was practical.

## 1. Introduction

A warehouse is a building for storing of personal properties or goods and chattels. Warehouses are usually being used by manufacturers, wholesalers including the importers and exporters, transport businesses, and government society's i.e customs. Warehouses usually situated in industrial areas of cities, towns or villages as a bulky ordinary building where it composed an important part in the overall supply chain process. Besides, the overall supply chain process, logistics, environmental sustainability and information technology (IT) are further progressing the functions of the warehouses due to the ongoing globalization process.

The business landscape and the way of doing it has recently transformed by the globalization and development of the business scene. As stated by [5], supply chain management controls material flow among suppliers, plants, warehouses and customers efficiently such that the total cost in the supply chain can be minimized. Traditionally, planning, purchasing, manufacturing, distribution, and marketing organizations along the supply chain have operated independently, but now it is a strategy through which integration can be achieved [4]. A major number of recent researches in this area have been well established within operations research. The concurrent optimization of different functions



such as production and distribution yields an efficient platform which can help companies to achieve a variety of logistics objectives ranging from low cost to high responsiveness.

The works on this area is so limited even though there is a strong requirement for restructuring and reconfiguration of the current system. [2] proposed a multi-objective model to relocate a single facility. Capacity can be transferred from a source facility to a destination. However, the extension or reduction of the total network capacity is not considered, nor is uncertainty. Finally, a resulting mixed integer linear program (MILP) was solved using commercial software.

[1] improved the model for warehouse network redesign by considered delivery lead times and customer due dates for ordered product as well as capacity limitation of warehouses. Re-design decisions are strategic and require substantial capital investment. Additionally, these decisions have a great impact on the operational activities and, thus, on the total unit cost of the products. For these reasons, network re-design decisions must maintain their optimality or near optimality over the lifetime of the supply chain. The objective of this study is to develop the solution procedure for solving the warehouse redesign model with consolidation, elimination and addition of a new site.

## 2. Methodology

Prior to developing the mathematical model, we make the following underlying assumptions by slight modifying previous method by [3]: (1) the warehouses are private. (2) when a warehouse is consolidated into another warehouse, its whole capacity is relocated.

### 2.1. Indices and sets

$p$  = index for manufacturing plant;  $p \in P$ .

$k$  = index for customers;  $k \in K$ .

$i$  = index for existing warehouses and new candidate sites for relocation and consolidation;  $i \in A$ .

$A = E \cup N; (j, i) \in (E \times A)$ , where  $E$  = set for existing warehouses, and  $N$  = set for new candidate sites for relocation and consolidation.

### 2.2. Model parameters

$v_{pi}$  = unit production cost (including storage cost) at manufacturing plant  $p$  plus unit transshipment cost between manufacturing plant  $p$  and warehouse  $i$ ,

$s_{ik}$  = unit warehousing cost at warehouse  $i$  and unit transportation cost between warehouse  $i$  and customer  $k$ ,

$r_{ji}$  = cost of moving and relocating unit capacity  $j$  to consolidated site  $i$  ( $j \neq i$ ),

$c_j$  = throughput capacity of existing warehouse  $j$ ,

$q_p$  = production capacity of manufacturing plant  $p$ ,

$d_k$  = demand of customer  $k$ ,

$f_i^c$  = cost per unit capacity of warehouse  $i$ ,

$f_i^m$  = fixed cost of maintaining warehouse  $i$ , excluding capacity cost.

$f_i^s$  = cost saving resulted from the closure of existing warehouse  $i$ ,

### 2.3. Decision variables

$x_{ik}$  = volume of products shipped from warehouse  $i$  to customer  $k$ ,

$y_{pi}$  = volume of products supplied plant  $p$  to warehouse  $i$ ,

$$z_{ji} = \begin{cases} 1, & \text{if capacity of warehouse } j (j \in E) \text{ is relocated to site} \\ & i (i \in A, i \neq j) \text{ or if existing warehouse } j (j \in E, i = j) \text{ remains open} \\ 0, & \text{otherwise.} \end{cases}$$

$$w_i = \begin{cases} 1, & \text{if a new warehouse is established at site } i (i \in N), \\ 0, & \text{otherwise.} \end{cases}$$

#### 2.4. Mathematical formulation

$$\begin{aligned} \text{Min } & \sum_{p \in P} \sum_{i \in A} v_{pi} y_{pi} + \sum_{i \in A} \sum_{k \in C(i)} s_{ik} x_{ik} + \sum_{p \in P} \sum_{i \in A} r_{ji} z_{ji} + \sum_{i \in A} f_i^c \sum_{j \in E} c_j z_{ji} + \sum_{i \in E} f_i^m z_{ii} + \sum_{i \in N} f_i^m w_i \\ & - \sum_{j \in E} \left[ f_j^s \left( 1 - \sum_{i \in A} z_{jk} \right) + f_i^m \sum_{\{i \in E, i \neq j\}} z_{ji} \right] \end{aligned} \quad (1)$$

Subject to

$$\sum_{i \in A} y_{pi} \leq q_p \quad \forall p \in P, \quad (2)$$

$$\sum_{p \in P} y_{pi} \leq \sum_{k \in C(i)} x_{ik} \quad \forall i \in A, \quad (3)$$

$$\sum_{k \in C(i)} x_{ik} \leq \sum_{j \in E} c_j x_{ji} \quad \forall i \in A, \quad (4)$$

$$\sum_{i \in D(k)} x_{ik} = d_k \quad \forall k \in K, \quad (5)$$

$$\sum_{j \in E} z_{ji} \leq |E| z_{ii} \quad \forall i \in E, \quad (6)$$

$$\sum_{j \in E} z_{ji} \leq |E| w_i \quad \forall i \in N, \quad (7)$$

$$\sum_{i \in A} z_{ji} \leq 1 \quad \forall j \in E, \quad (8)$$

$$x_{ik} \geq 0 \quad \forall i \in A, k \in K, \quad (9)$$

$$y_{pi} \geq 0 \quad \forall p \in P, i \in A, \quad (10)$$

$$z_{ji}, w_i \in (0,1) \quad \forall j \in E, i \in A, \quad (11)$$

The objective function (1) minimizes total supply chain cost comprised of production, transportation, warehousing and relocation costs, while maximizing the cost savings resulting from the closure or consolidation of redundant warehouses. Constraint (2) guarantees that the aggregate volume of item dispatched to distribution centres or warehouses don't surpass the limit of an assembling plant providing such items. Constraint (3) insures that the total volume of product supplied by the manufacturing plant to each warehouse matches to the total volume of products

shipped from that warehouse to its customer. In other words, inbound shipping volume for each warehouse should be equivalent to its outbound shipping volume. Constraint (4) ensures that the total volume of products shipped to customers do not exceed the throughput capacity (after consolidation) of the warehouse serving them. Constraint (5) allows the customer demand to be satisfied. Constraint (6) expresses that the present assets (i.e capacity) of a current warehouse can't be merge into another current warehouse, unless such a consolidated warehouse stays open. Herein  $|E|$  stands for cardinality of set  $E$ . similarly, constraint (7) expresses that the limit of a current distribution centre or warehouse can't be migrated to another site, unless a warehouse is built up at the new site. Constraint (8) considers various options for an existing warehouse  $j$ . these option include: the warehouse remains open ( $z_{ji} = 1$ ), or its capacity is consolidated into another existing warehouse  $i \in E, i \neq j$  ( $z_{ji} = 1$ ), or its capacity is relocated to a new site  $i \in N$  ( $z_{ji} = 1$ ) , or the existing warehouse  $j$  is closed ( $z_{ji} = 0 \forall i \in A$ ). Constraint (9) and (10) ensure the nonnegativity variable of decision variables  $x_{ik}, y_{pi}$ . Constraint (11) states that  $z_{ji}$  and  $w_i$  are zero-one integer variables.

### 3. Results and Analysis

Simulated Annealing (SA) is a local search method developed by combining statistical mechanics and optimization principles. It has been recognized as a powerful tool for solving large number of optimization problems in a variety of application areas. Simulated Annealing uses stochastic approach to direct the search where the random design changes with a probabilistic acceptance criterion during the search. Below is the procedure if a basic SA heuristics were used throughout this study. Figure 1 illustrates the location of the 2 manufacturing plant, 10 warehouses and 40 customers in this study.

**Step 1** Select setting for the heuristic parameters and generate an initial solution and its cost. This solution is defined as the current solution

Choose two points randomly as the manufacturing plant from the 52 fixed points. Then apply Transportation Problem (TP) to allocate all warehouses to that plant. TP will give us two set of allocations. Find the cost of these allocations. Then calculate the new cost for each region. Next, use TP to relocate the other customers to warehouses. Calculate the total cost. Set the cost as  $F(x)$ . Select an initial temperature  $T_0 = 1000^\circ C$ ,  $T_{k+1} = T_k / 2$ .

**Step 2** Obtain a neighbouring solution of the current solution using a local search technique

For each allocation, find the neighbouring fixed points of the customers which are defines as the fixed points that lie within a certain radius from the warehouse taken to be  $r_i = d(i, j) / 2$  where  $d(i, j)$  is the distance between facility  $i$  and its furthest allocated customer. If there are more than one neighbouring points then moves the warehouse randomly to one of the points. But if there are no neighbouring points then the current warehouse will be kept as its current location.

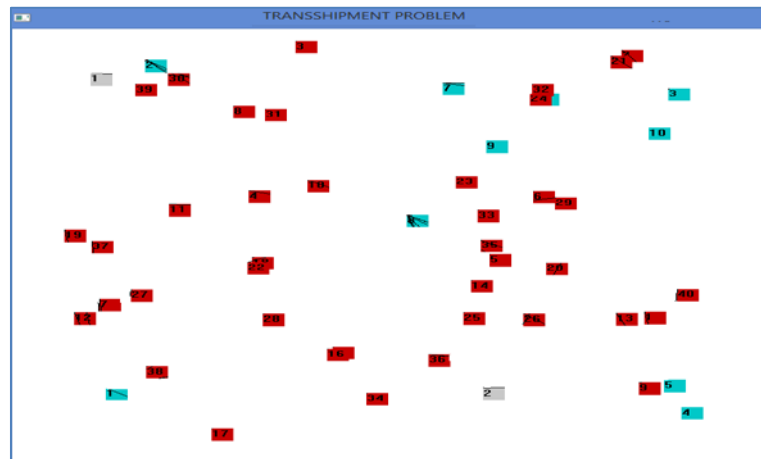
**Step 3** Obtain the cost of the neighbouring solution and compare it to the cost of the current solution

Then by using TP allocate all the customers to the new warehouse and find the cost for this allocation. Next use TP to allocate the customers to current warehouse that we get from the consolidation procedure. Calculate the total cost. Set the cost as  $F(x')$ . If  $F(x') < F(x)$  let  $F(x) = F(x')$ . Else check the probability acceptance  $P(\delta)$ . If random number  $< P(\delta)$  then accept this move and go to Step 2. Else reject this move, and allocate again from the current solution.

Step 4 (Update counters and parameters, and repeat steps 2-4, until an appropriate stopping criterion is reached.)

$$T_{k+1} = T_k / 2$$

Set iteration = iteration+1.



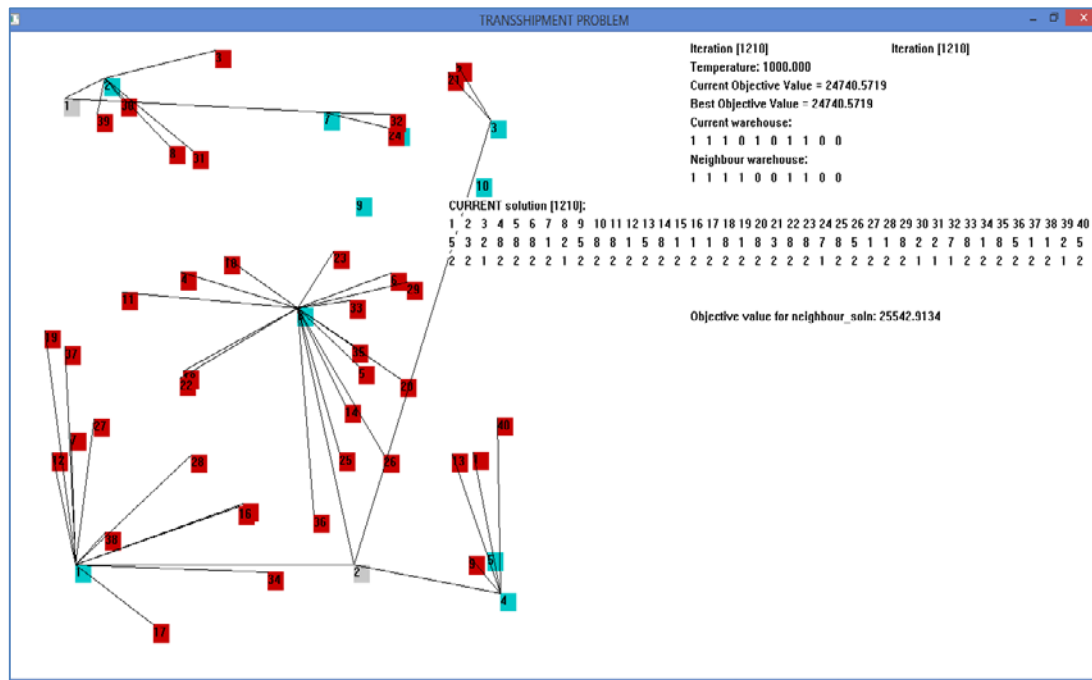
**Figure 1.** The location of the 2 manufacturing plant (grey), 10 warehouses (blue) and 40 customers (red).

### 3.1 Computational result

Table 1 provides the results that were obtained by applying basic SA implementation to warehouse redesigning problem network. The described solution approach is implemented by using Microsoft Visual Studio 2015 and ran for 10.50 seconds on an Intel Inside Core i5.40 GHz computer with 4 GB RAM.

**Table 1.** The results of the basic SA.

Open warehouse	Customers	Manufacturing plant
1	7, 12, 15, 16, 17, 19, 27, 28, 34, 37, 38	2
2	3, 8, 30, 31, 39	1
3	2, 21	2
5	1, 9, 13, 26, 36, 40	2
7	24, 32	1
8	4, 5, 6, 10, 11, 14, 18, 20, 22, 23, 25, 29, 33, 35	2



**Figure 2.** The results of the basic SA.

Figure 2 depicted the result after consolidation by using simulated annealing. Based upon the results, it can be seen that only warehouse 2 and 7 acquire the source from manufacturing plant 1. Meanwhile, warehouse 1, 3, 4, 7 and 8 acquire the source from manufacturing plant 2.

Besides, this model suggested that warehouse 10 consolidate with warehouse 3, warehouse 5 consolidate with warehouse 7 and warehouse 6 consolidate with warehouse 7. Meanwhile, warehouse 9 was suggested to be closed. This is similar with previous study by [3] which proposed that the reason was due to the fact that most of the warehouses were located near to each other.

#### 4. Conclusion

This paper developed a simulated annealing approach that intended to provide a least cost solution for a warehouse redesign problems. The model considered saving due to consolidation process where only a fewer number of warehouses actively serving their customers. There are several suggestions for future research such as an attempt to solve the problem on a larger number of warehouses and customers. Others parameters values of SA are also worth investigating for example the cooling schedule and stopping criterion since this can affect the efficiency of the annealing process.

#### References

- [1] Anaraki, Amir Hossein Zahedi, Razmi J and Mohammad Jeihoonian 2009 A Benders Decomposition Approach for Redesigning a Warehouse. *Proceedings of the 41st International Conference on Computers & Industrial Engineering* pp 56–61
- [2] Melachrinoudis E and Min H 2000 The dynamic relocation and phase-out of a hybrid, two-echelon plant/warehousing facility: a multiple objective approach *European Journal of Operational Research* 123 pp 1–15
- [3] Melachrinoudis E and Min H 2007 Redesigning a warehouse network *European Journal of Operational Research* 176 pp 210–229
- [4] Shapiro J F 2000 Modeling the supply chain *Pacific Grove: Duxbury Press*
- [5] Thomas D J and Griffin P M 1996 Coordinated supply chain management *European Journal of Operational Research* 94(1) pp 1–15.