Research in Economics and Management
ISSN 2470-4407 (Print) ISSN 2470-4393 (Online)
Vol. 9, No. 3, 2024
www.scholink.org/ojs/index.php/rem

*Original Paper*

# Presenting a Mixed Meta-Heuristic Method with the Aim of Optimizing Logistics for Production Planning in Industrial Units

Mohammad Taleghani[1*]

[1] Associate Professor, Department of Industrial Management, Rasht Branch, Islamic Azad University (IAU), Rasht, Iran

[*] Mohammad Taleghani, Department of Industrial Management, Rasht Branch, Islamic Azad University (IAU), Rasht, Iran

Received: June 17, 2024 Accepted: July 1, 2024 Online Published: July 26, 2024

doi:10.22158/rem.v9n3p12 URL: http://dx.doi.org/10.22158/rem.v9n3p12

***Abstract***

*With the aim of strategic optimization in the design of logistics networks to improve the efficiency of the business space, the author of this paper developed a method called integrative hybrid search and by imposing suitable conditions on the general model, it was applied to various real-world problems of business, production and They used the operation. However, during a planning horizon for a design, various changes usually occur that are assumed to be fixed in such strategic or static considerations. Therefore, in this study, the previous methods have been expanded as much as possible so that we can make a reliable and more reliable and operational decision by considering the dynamic conditions and focusing on the role of warehouse inventory system management in the planning horizon. Finally, it is possible to show the importance of multi-objective programming and the validity of the proposed method in comparison with commercial software through numerical tests and quantitative tests.*

***Keywords***

*multi-objective logistics planning, inventory system management, large-scale combinatorial optimization, integrative combinatorial search*

## 1. Introduction

Logistics optimization is increasingly accepted as a key issue in dynamic supply chain management to improve the efficiency of the business environment under global competition and agile manufacturing. Although many studies have been conducted in the field of operations research related to integrative hybrid optimization (e.g., Campbell, 2022), we need to make more careful and deliberate efforts to deal with complex real-world business problems. In this aspect, we face various logistics optimization problems for dynamic strategic decision making.

In connection with integrated production planning, it is necessary to pay attention to the various deviations assumed in the strategic or static model. By considering such dynamic conditions, we can make more reliable and operational decisions. Therefore, in this study, we have extended our previous approach, named integrative hybrid search, to deal with multi-objective planning problems and incorporate warehouse or distribution center (DC) inventory system management into the design optimization of logistics core networks.

After presenting a general formula and its algorithm, the validity of the proposed method is shown through numerical experiments.

### *1.1 Statement of the Problem*

#### 1.1.1 Basic Assumptions

Many studies in operations research focus on developing new algorithms and testing their capabilities through simple benchmarking and/or proving theoretic facts about speed, accuracy, and problem magnitude. However, easy applications of these results often greatly increase the problem size in real-world problems, thereby creating such a problem that it is nearly impossible to solve the resulting problem with any currently available software.

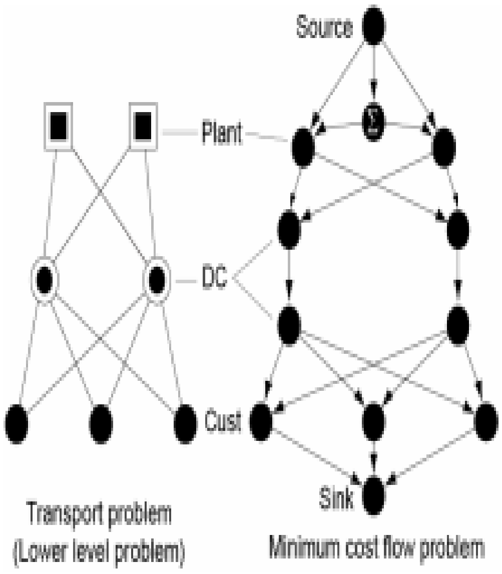
Under such an understanding, to deal with the specific problem in complex and complex conditions, we paid attention to various logistics optimization problems subject to conditions such as realistic discounting of transportation cost, flexibility to demand deviations, multi-item delivery, etc. (Shimizu & Wada, 2020; Wada, Shimizu, & Yu, 2019; Shimizu, Matsuda, & Wada, 2024; Wada, Yamazaki, & Shimizu, 2018). The combinatorial search used in those studies decomposes the original problem into high- and low-level subproblems and applies an appropriate method to each subproblem.

The high-level subproblem determines DC locations by complex and dynamic search. Integrative hybrid search (TS; Glover, 2023) is a meta-heuristic algorithm based on a local search technique with a memory-oriented structure. The TS repeats the local search iteratively to move from a current solution x to a possible best solution x’ in the neighborhood of x. To avoid a solution cycle, TS uses an initial list that prohibits moving to any solution for some time, even if it improves the current solution.

On the other hand, the low-level subproblem determines the network paths under the given high-level decision. This refers to a linear program that may be transformed into a Minimum Cost Flow (MCF) problem. In practice, this transformation is done by adding virtual nodes and edges to the physical configuration as shown in Figure 1. Then the resulting MCF problem can be solved with the graph algorithm, which is especially known for fast solving algorithm such as CS2 (Goldberg, 2021).

Now, back to the top level, neighboring locations must be evaluated according to a complex and dynamic search algorithm. These procedures will be repeated until a certain convergence criterion is met. Figure 2 shows this solution method schematically. The probability of selecting the local search operation summarized in Table 1 is decided based on the following ideas. It makes sense that search types such as

"Add" and/or "Subtract" may be used more often in the initial phase of the search, while "Swap" is more appropriate in the later phase when the number of open DCs is close to optimal. Letting probabilities be the basis for decision-making, we developed an idea to do it more efficiently using long-term memory, or a history of past search processes. That is, the probability of each operation increases by a certain amount if it brings the update of the solution. Conversely, these values are reset when the trial solution has not improved by the prescribed consecutive time and/or a practical solution has not been obtained.



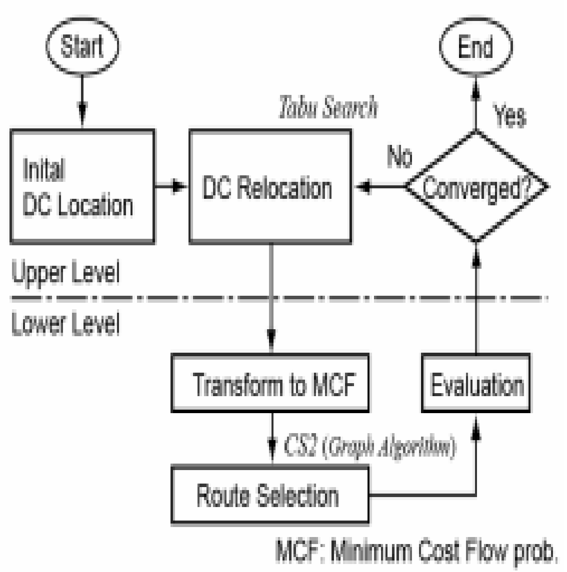


Fig.1 Transformation of network to MCF graph

Fig.2 Schematic procedure of hybrid tabu search

**Table 1. Employed Neighborhood Search Operations**

| Search type | Selection probability | Neighborhood operation |
|---|---|---|
| Add | $p_{add}$ | Let closed DC open. |
| Subtract | $p_{subtract}$ | Let open DC close. |
| Swap | $p_{swap}$ | Let closed DC open and open DC close. |

## 2. Methodology

### *2.1 Multi-objective Model in the Horizon of Strategic Planning*

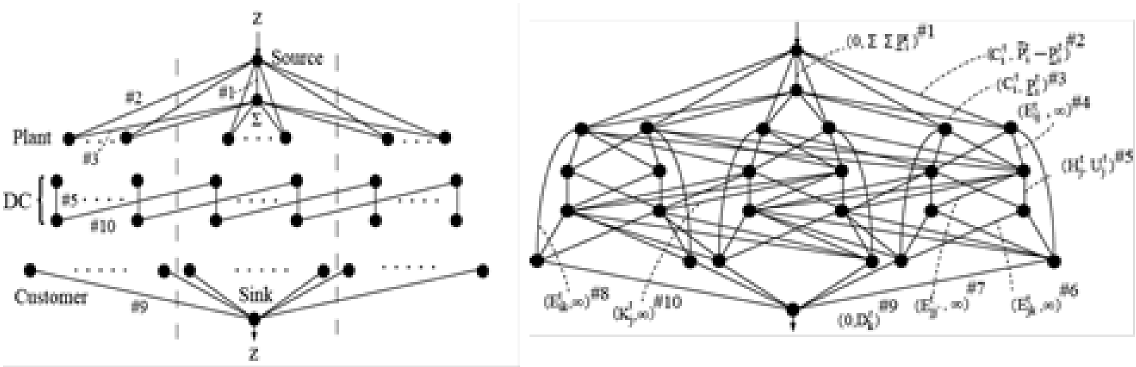
We have extended static or single-term expansion to deal with multi-objective problems in a practical way. By using the existing DC inventory to draw down periods (inventory system management), we can expect to have significant effects on strategic decision-making.

After that, we have mathematically formulated the problem as a mixed integer programming problem as stated below. The objective function consists of the total transportation cost between each facility, the total production cost in the factory and the total operating cost in each facility, the total DC holding cost in the planning horizon, and the total fixed cost for open space.

On the other hand, constraints require responding to the demand of each customer in each period. Capacity limit per DC per period. Upper and lower bounds on the ability to produce each computational item per cycle and the material balance per DC per cycle. In addition, non-negative conditions are imposed on material flow and binary conditions on open/close selection. Finally, the model has problem size as: the number of integer variables J, continuous variables T (IJ+J2+JK+IK+J) and constraints T(2I+2J+K) denoted by I, J, K Is. and T represent the number of plants, DCs, customers and conditions, respectively.

### *2.2 Integrative Hybrid Search for Multi-objective Transport*

Under the multi-objective condition, the lower-level subproblem of integrative combinatorial search must determine the network paths for each epoch. It refers to a linear program whose coefficient matrix becomes block-diagonal in almost every term and expands rapidly with the number of terms known in the above expression.



(a) (b)

Fig.3 Transformation procedure to aggregate MCF graph for three-term problem: (a)Add edges for inventory, and(b) Final stage

**Table 2. Labeling on the Edge**

| Edge ID | Cost | Capacity | Description |
|---|---|---|---|
| #1 | 0 | $\sum_{t\in T}\sum_{i\in I} \underline{P}_i^t$ | source－∑ |
| #2 | $C_i^t$ | $P_i^t$ - $\underline{P}_i^t$ | source－plant *i* (period *t*) |
| #3 | $C_i^t$ | $\underline{P}_i^t$ | ∑－plant *i* (period *t*) |
| #4 | $E_{ij}^t$ | ∞ | plant *i*－DC *j* (period *t*) |
| #5 | $H_j^t$ | $U_j^t$ | between doubled nodes representing DC |
| #6 | $E_{jj'}^t$ | ∞ | DC *j*－DC *j'* (period *t*) |
| #7 | $E_{jk}^t$ | ∞ | DC *j*－customer *k* (period *t*) |
| #8 | $E_{ik}^t$ | ∞ | plant *i*－customer *k* (period *t*) |
| #9 | *D* | $D_k^t$ | customer *k*－sink (period *t*) |
| #10 | $K_j^t$ | ∞ | stock at DC *j* (period *t*) |

Noticing a special topological structure associated with the minimum cost flow problem, however, we can present a smart procedure to transform the bulk original problem into a compact form as follows:

Step 1: Every period, place the nodes that stand for plant, DC (doubled), and customer. Next, virtual nodes termed source, ∑, and sink are placed at the top and the bottom, respectively. Then connect the nodes between source and ∑ (#1), source and plant (#2), ∑ and plant (#3), up and down DC nodes (#5), and customer and sink (#9). This results in the graph as depicted in Figure 3 (a).

Step 2: Letting $z$ be the total amount of customer demand over planning horizon, $z=\sum_{t\in T}\sum_{k\in K} D_k^t$, flow this amount into the source, and flow out from the sink.

Step 3: To constrain the amounts of flow, set the capacities on the edges identified by #1, #2, #3, #5 and #9 as each in “Capacity column” in Table 2. Apparently, there never induce any costs on edge #1 and #9 for the connections.

Step 4: To allow the stock at DC, add the edges from down-DC node to up-DC node in the next period (#10) as shown in Fig.3 (a). For the labeling, see the “#10” row of the table.

Step 5: Connect the edges between plant and DC (#4), DC and DC (#6), DC and customer (#7) and plant and customer (#8) every period.

Step 6: Finally, place the appropriate label on each edge.

From all of these, we have the final graph as shown in Fig.3 (b) that makes it possible to still apply the graph algorithm like CS2 (Goldberg, 1997). Consequently, we can solve the extensively expanded problem extremely fast compared with the linear programs.

## 3. Result

### *3.1 Numerical Test (Quantitative)*

#### 3.1.1 Preliminary Tests

In long-term planning, a strategic or conceptual decision is often made based on average values rather than a dynamic model. This is equivalent to saying that we are trying to obtain only a vision of a static or single-objective problem whose parameters fluctuate over the planning horizon as demand in reality. To verify the advantage of considering the dynamic model that uses stocks in DC, we first compared the results between the single-objective (average) model and the multi-objective model using small-size benchmark problems. In Table 3, we summarize the results obtained in terms of demand deviation. Hence, we know that the dynamic model can derive decisions with a lower total cost (the value of the average model is shown as a rate relative to the multi-period model of one hundred). In particular, it is noteworthy that the average model includes an infeasible solution to demand deviations, while the multiperiod model always copes with the situation through inventory management. For example, as shown in Figure 4, proper production planning is carried out and the stock in DC is used to meet customer demands that have changed beyond the production capability of the factory.

**Table 3. Effect of Dynamic Model**

| Properties of problem (rate) | | | | Cost |
|---|---|---|---|---|
| Plant | DC | Cust | Term | Averaged |
| 1 | 10 | 20 | 5 | 107.9 |
| 1 | 15 | 25 | 10 | N/A |
| 1 | 20 | 30 | 20 | 138.2 |

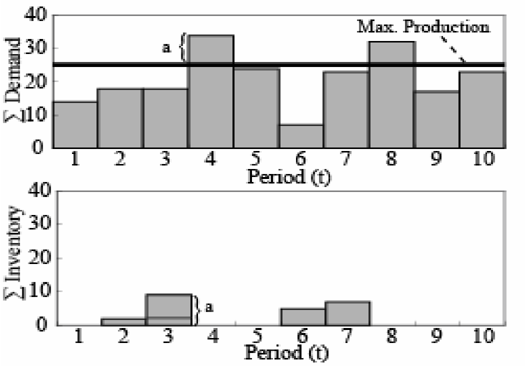


**Figure 4. Role of Inventory in Multi-term Planning**

**Table 4. Computation Environment for Numerical Experiments**

| Method | CPU type | Memory | OS |
|---|---|---|---|
| CPLEX | Pentium4 3.0 GHz | 512 MB | Windows XP |
| This work | Pentium4 3.0 GHz | 512 MB | Debian 3.0 |

### *3.2 Evaluation and Analysis of the Proposed Algorithm*

From the current topics, it is interesting to check the effectiveness of the proposed method in terms of problem size. Each result of the proposed method is averaged in five experiments. In Table 4, we summarize the computational environment for the present numerical experiments.

Figure 5 compared the CPU times over the number of planning horizons between the proposed method and CPLEX 9.0 (the parameters determining the problem size are set as I=2, J=25, and K=30, and several problem sizes are shown there.). There, we can observe that the CPU time of the proposed method increases almost linearly while exponentially for CPLEX.

**Table 5. Comparison with Commercial Software**

| Term | CPU time [s] | | Rate* |
|---|---|---|---|
| | CPLEX | Hybrid | |
| 1 | 0.91 | 0.14 | 1.0000 |
| 5 | 10.50 | 0.84 | 1.0000 |
| 10 | 33.66 | 1.82 | 1.0000 |

| | | | |
|---|---|---|---|
| 25 | 138.83 | 5.88 | 1.0000 |
| 50 | 904.26 | 17.42 | 1.0000 |
| 75 | 1648.20 | 27.12 | 1.0000 |
| 100 | 3782.88 | 34.23 | 1.0000 |

As shown in Table 5, the proposed method can achieve the same CPLEX (hypothetical optimal) results with much shorter CPU times for every problem in the range we can compare. For each, the gap between the MIP and its LP reduction problem remained roughly constant, say 8-10%, but the load rate (CPU time) increased significantly (but not as quickly) with this term.

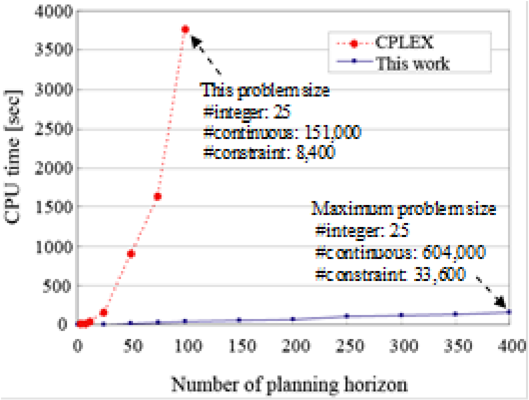


Fig.5 Comparison of CPU time with commercial software

Objective function value of Hybrid /CPLEX

From these numerical experiments and quantitative calculations, the proposed method is expected to achieve a high approximation speed even for larger problems and is promising for real-world applications in business and production space.

## 4. Discussion

This paper is concerned with a multi-objective logistics optimization problem by extending a two-level method called integrative combinatorial search previously developed by the author. For this purpose, the author has devised a systematic method to transform the mathematical planning model into a manageable compact graph model for the inventory system in the strategic planning horizon. This enables us to solve a long-term logistics network optimization problem that no other method has ever tackled. Numerical experiments and mathematical calculations showed that such an inventory control system can have an economic effect and robustness against demand deviations. Also, the validity of the proposed method was shown in comparison with commercial software.

**Acknowledgment**

In this article, I sincerely thank and appreciate all graduate students who were with the author in the process of implementing this research.

## References

Campbell, J. F. (2022). Integer programming formulations of discrete hub location problems. *European Journal of Operational Research*, *72*, 387-405.

Glover, F. (2023). Tabu search: Part I.. *ORSA Journal on Computing*, *1*, 190-206.

Goldberg, A. V. (2021). An Efficient Implementation of a Scaling Minimum-cost Flow Algorithm. *J. Algorithm*, *22*, 1-29.

Shimizu, Y., & Wada, T. (2024). *Logistic Optimization for Site Location and Route Selection under Capacity Constraints Using Hybrid Tabu Search, Proc. 8th Int. Symp. on Computer- Aided Process Systems Engineering* (pp. 612-617). Kunming, China.

Shimizu, Y., Matsuda, S., & Wada, T. (2020). *A Flexible Design of Logistic Network against Uncertain Demands through Hybrid Meta-Heuristic Method, Proc. 16th Europe. Symp. on Computer-Aided Process Engineering* (pp. 2051-2056). Garmisch Partenkirchen, Germany.

Wada, T., Shimizu, Y., & Jae-Kyu Yoo. (2019). *Entire Supply Chain Optimization in Terms of Hybrid in Approach, Proc. 15th Europe. Symp. on Computer-Aided Process Engineering* (pp. 1591-1596). Barcelona, Spain.

Wada, T., Yamazaki, Y., & Shimizu, Y. (2018). Logistic Optimization Using Hybrid Meta-heuristic Approach. *Transaction of the Japan Society of Mechanical Engineers* (C-727, 73, pp.919-926).