International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 07 | July 2021 www.irjet.net p-ISSN: 2395-0072

Harmonic Search Algorithm for Multi-Level Inventory Problem with Supplier Selection

V.V.D. Sahithi[1], M. Srinivasa Rao[2], C.S.P. Rao[3]

[1]Research Scholar, JNTU Hyderabad, India
[2]Professor, JNTU Hyderabad, India
[3]Director, NIT, Warangal, India

Abstract - *An Industry's Inventory metrics will decide the Performance of supply chain. Inventory costs mainly include different costs like setup cost, Transportation, warehousing costs etc. Inventory optimization is not only an important task but also difficult task. so, to obtain Optimum inventory in a system there are lots of traditional, heuristic, and meta heuristic techniques were proposed in the literature. But most of the techniques failed in finding the optimum solution for Multi-level Problem. So, in this paper we are proposing a Harmonic Search optimization algorithm for multi-level supplier selection problem and then Comparing this algorithm with heuristic Wagner Whitin Algorithm and traditional Lot for Lot Technique. According to the results our Harmonic Search Algorithm outperformed the other methods in case of solution efficiency*

Key Words: Inventory Optimization, Lot sizing, Multi-Level Inventory, Supplier Selection.

1.INTRODUCTION

Inventory Optimization plays a major role in the Success of any industry. Because of the rapid change in the customer requirements, competitive pressure for cost reduction Inventory Optimization came into limelight. There are different issues in inventory management like supplier selection, capacity constraints, storage constraints, transportation constraint etc. So many researchers are working on different heuristic and meta heuristic techniques for solving these inventory issues. Most of these algorithms are giving better solutions for simple single level problems. But for multi-level inventory problems most of the techniques are not working properly because of the complexity of the problem. Many heuristics, meta heuristic and traditional techniques failed to obtain optimum solution for Multi-level Problem [1-15].

Inventory cost involves two components like fixed cost and variable cost. Fixed cost mainly depends on the component cost and number of components or items purchased. Variable cost depends on the way how we are ordering the items. It is the sum of ordering cost and holding cost. If we change our ordering quantities, our variable cost will change. So, if we optimize variable cost Inventory cost will also be optimized. So, in our problem we need to find optimum variable cost for different suppliers and the least inventory cost will decide the best supplier.

The work Proposed in this paper focuses on the application of Harmonic Search algorithm for multi-level problem with supplier selection. And the results of this harmonic search algorithm are compared with the results obtained from the Wagner Whitin algorithm and Lot for Lot technique. By comparing the results, we can say that our proposed harmonic Search algorithm outperformed all the other methods in case of optimization of inventory cost.

In this current journal paper, authors have considered general product structure of a multi-level problem with 3 different suppliers. Section (2) describes the problem statement and mathematical modelling for that problem. Section (3) is about algorithm and its implementation. Section (4) is about computational results. Finally, section (5) is conclusion.

2. PROBLEM DEFINITION AND MATHEMATICAL FORMULATION

Multi-level Lot sizing problem types of product structures are mainly divided into 3. They are assembly product structure, Absorbent Product Structure and General Product Structure. According to the number of Levels of the product structure problems are divided into small (up to 4 levels), medium (4 to 8 levels) and large level (more than 8 levels) problems.

In our Present work we considered Assembly type of product structure with small number of levels for Multi level supplier selection Problem . Here 3 suppliers were Considered for the proposed problem and according to the simulation results we are going to find out the best supplier among the available suppliers [16-23].For supplier selection different techniques like Lot for Lot(LFL),Wagner Whitin algorithm(WW),Harmonic Search(HS) algorithm were applied to solve this proposed problem.

The mathematical formulation for Proposed multi-level problem is as follows:

$$Minimize \sum_{k1=1}^{N}\sum_{t=1}^{T1} HC_{k1} \times l_{k1,t} + K_{k1} \times a_{k1,t} \quad (2.1)$$

Constraints of the Problem

$$l_{k1,t} = l_{k1,t} + P_{k1,t} - D_{k1,t} \quad (2.2)$$

$$\sum_{k1=1}^{N1} C_{k1,m1} \times P_{m1,t+l_{m1}} \quad (2.3)$$

$$P_{k1,t} = a_{k1,t} \times D_{k1,t} + \sum_{s=t+1}^{T}\left(a_{k1,s+1}\, D_{k1,s} \prod_{u=k1+1}^{s}(1 - a_{k1,u})\right) \quad (2.4)$$

$$P_{k1,t} - M a_{k1,t} \le 0 \quad a_{k1,t} \epsilon \{0,1\} \quad (2.5)$$

$$P_{k1,t} \ge 0 \quad l_{k1,t} \ge 0 \quad (2.6)$$

Where

K1 = Index Of Item
$C_{k1,m}$ = No. of k1 items required for producing item m1
H_{Ck1} = Inventory holding cost to produce 1 unit of k1
K_{k1} = Setup cost for producing 1 unit of item k
l_{k1} = Lead time
$l_{k1,t}$ = k1 inventory level at the end of the period t
$a_{k1,t}$ = 0/1(binary values)
$D_{k1,t}$ = Item k1 Demand in period t
$P_{k1,t}$ = Producing Item I in t period
N1 = Total items
T = Planning Horizon Length

Binary $a_{k1,t}$ values decide whether the item is ordered in that period or not. If the value is "1" it represents the item is ordered in that period. If the value is "0" item is not ordered in that period.
Γ-1 (k1), Γ(k1) are used to present immediate predecessor/ successor

3. Harmonic Search Algorithm

This is a Meta heuristic optimization technique which was inspired from jazz musician's improvement of harmony. Zong Woo Geem et al. proposed this algorithm in 2001.Following is the Pseudo code explanation for implementation of Harmonic search algorithm. This Heuristic technique was applied to many complex optimization problems to find optimum solution.

Pseudo code

Step 1: Input parameters and algorithm related parameter declaration tic (tic for computational time calculations in MATLAB)

Step 2: Initialization of solution

Step 3: improvement of solution

```
it = 1:MaxIt  % Maximum iterations 1 to Maximum iterations
% steps involved in the creation of new harmonies
    for k=1:n
% new solutions creation
      if rand<=HMCR
         use Harmony Memory create new solution
       if rand<= PAR(Pitch Adjustment rate)
         % Create new solution accordingly
       End
          Else
              Create random harmony
    end
  end
  Evaluate all the new solutions
  Merge new solutions with old solutions
  Harmony_memory =[ Harmony memory  NEW harmony];
  Sort all the solutions
  Truncate unwanted solutions
  Update - Best Solution
  Update – Simulation time (toc)
end
```

4. Experimental investigation and Computational Results

In this Section, we presented 6 computational experiments with 6,9 items problems with 10,12,15 period planning horizon & 3 suppliers were taken into consideration for supplier selection. Here for all the experiments Lot for Lot technique, Wagner-Whitin Algorithm and Harmonic search algorithm are applied to find out optimum cost in each supplier case. These experiments were conducted in a PC with a 3.3GHZ CPU and 32GB RAM and 64bit operating system. All the Experiments were conducted in MATLAB R2018a.We run each program for 50 times to find out the results.

All the problems are considered from Yi Han, et al. [2009], and we added different suppliers for the same problem [20] & implemented LFL, WW, HS algorithms on those problems. All the Product Structures and Input values like Demand, Product structure, ordering cost and holding cost are taken from reference Literature. Following is the Ordering cost information for different suppliers. Table1 gives the information about different suppliers setup/ordering cost values. Table 2-5 gives the information about the computational experiments, figures 1-3shows the comparison of performance of different methods. Figure 4 compares optimum cost in case of different suppliers

Table -1: Setup costs of different items in the product structure in case of different suppliers.

Item Number	Setup Cost		
	Supplier 1	Supplier 2	Supplier 3
1	130	120	110
2	120	110	100
3	25	50	50
4	30	40	20
5	30	40	30
6	40	30	50
7	130	100	110
8	120	120	100
9	25	20	40

Table -2: Simulation results of different problems in case of Supplier-1

Supplier -1			
Problem Size	Lot for Lot	WW algorithm	HS algorithm
6×10	3750	1707	1493
6×12	4500	2123	1895
6×15	5625	2909	2546
9×10	6500	2807	2043
9×12	7,800	3498	2522
9×15	9,750	4834	3448

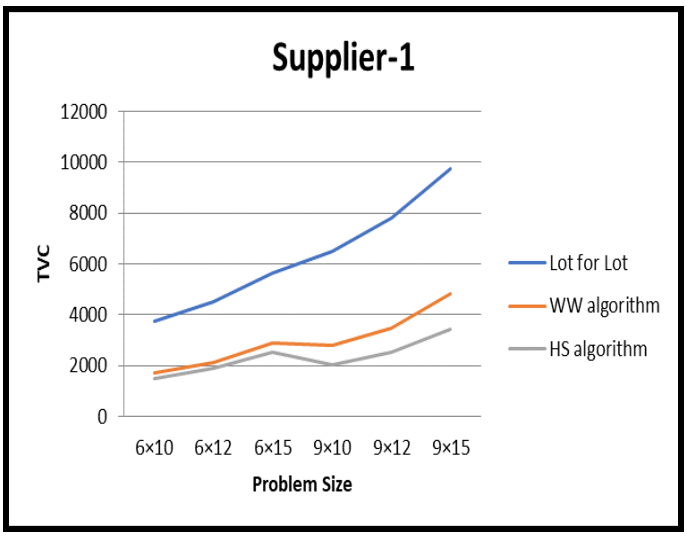

Chart -1: Different Methods Simulation results comparison in case of Supplier-1

Table -3: Simulation results of different problems in case of Supplier-2

Supplier -2			
Problem Size	Lot for Lot	WW algorithm	HS algorithm
6×10	3900	1767	1523
6×12	4680	2198	1940
6×15	5,850	3014	2606
9×10	6,300	2727	2003
9×12	7,560	3398	2482
9×15	9,450	4694	3405

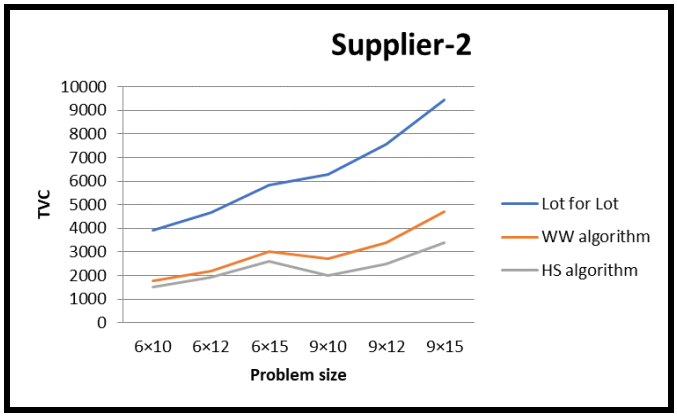

Chart -2: Different Methods Simulation results comparison in case of Supplier-1

Table -4: Simulation results of different problems in case of Supplier-3

Supplier -3			
Problem Size	Lot for Lot	WW algorithm	HS algorithm
6×10	3600	1647	1455
6×12	4320	2048	1892
6×15	5,400	2804	2478
9×10	6,100	2647	1963
9×12	7,320	3298	2442
9×15	9,150	4554	3345

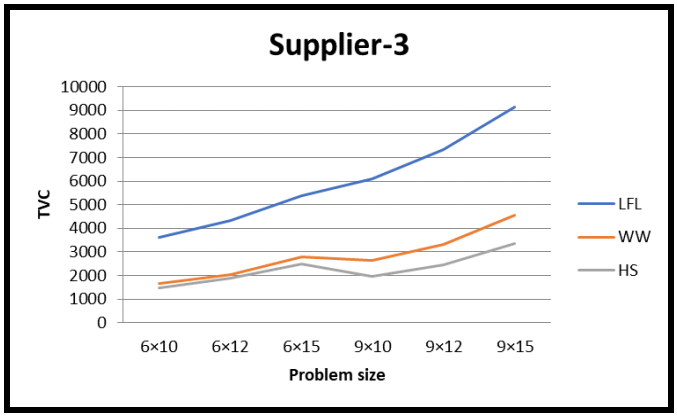

Chart-3: Different Methods Simulation results comparison in case of Supplier-1

Table -5: Comparison of 3 suppliers using HS algorithm simulation Results.

	Supplier -1	Supplier -2	Supplier -3
6×10	1493	1523	1455
6×12	1895	1940	1892
6×15	2546	2606	2478
9×10	2043	2003	1963
9×12	2522	2482	2442
9×15	3448	3405	3345

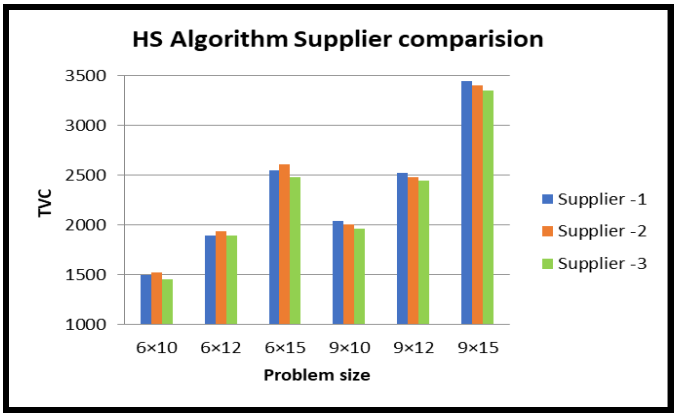

Chart-4: Simulation Results Comparison of different suppliers with HSA

5. Conclusions

In this research Multi level Lot sizing problems were solved using different techniques like LFL, WW, HS algorithms and the results were compared for the selection of best supplier.

- Experimental results clearly say that Harmonic Search algorithm is giving best optimum solution when compared to other Methods.
- WW algorithm is giving better solution when compared to LFL technique.
- Suppler -3 is Selected as the best supplier, because in all the test cases the total variable cost is minimum in case of supplier -3 when compared with other suppliers.

REFERENCES

[1] D. 1. Dellaert, N. & Jeunet, J. & Jonard, N., 2000. "A genetic algorithm to solve the general multi-level lot-sizing problem with time-varying costs," International Journal of Production Economics, Elsevier, vol. 68(3), pages 241-257, December.

[2] 2. W. Hernandez and G. A. Suer, "Genetic algorithms in lot sizing decisions," Proceedings of the 1999 Congress on Evolutionary Computation-CEC99 (Cat. No. 99TH8406), Washington, DC, USA, 1999, pp. 2280-2286 Vol. 3, doi: 10.1109/CEC.1999.785558.

[3] 3. Klorklear Wajanawichakon & Rapeepan Pitakaso (2011) Solving large unconstrainted multi level lot-sizing problem by a binary particle swarm optimization, International Journal of Management Science and Engineering Management, 6:2, 133-140, DOI: 10.1080/17509653.2011.10671156

[4] 4.Wagner, H. M. and T. M. Whitin, "Dynamic Version of the Economic Lot Size Model," Management Science, Vol. 5, 1958.

[5] 5. Silver, E. and Meal, H. (1973). A heuristic for selecting lot size requirements for the case of a deterministic time-varying demand rate and discrete opportunities for replenishment. Production and Inventory Management, 14(2):64–74.

[6] 6. Kuik, R. & Salomon, M., 1990. "Multi-level lot-sizing problem: Evaluation of a simulated-annealing heuristic," European Journal of Operational Research, Elsevier, vol. 45(1), pages 25-37, March.

[7] 7. W. Hernandez and G. A. Suer, "Genetic algorithms in lot sizing decisions," Proceedings of the 1999 Congress on Evolutionary Computation-CEC99 (Cat. No. 99TH8406), Washington, DC, USA, 1999, pp. 2280-2286 Vol. 3, doi: 10.1109/CEC.1999.785558.

[8] 8. Dellaert, N. and Jeunet, J. (2000). A genetic algorithm to solve the general multi-level lot sizing problem with timevarying costs. International Journal of Production Economics, 68(3):241–257.

[9] 9. Klorklear Wajanawichakon & Rapeepan Pitakaso (2011) Solving large unconstrainted multi level lot-sizing problem by a binary particle swarm optimization, International Journal of Management Science and Engineering Management, 6:2, 133-140, DOI: 10.1080/17509653.2011.10671156

[10] 10. Alfares, Hesham & Turnadi, Rio. (2016). General Model for Single-item Lot-sizing with Multiple Suppliers, Quantity Discounts, and Backordering. Procedia CIRP. 56. 199-202. 10.1016/j.procir.2016.10.054.

[11] 11. Hrouga, Mustapha & Godichaud, Matthieu & Amodeo, Lionel. (2016). Heuristics for multi-product capacitated disassembly lot sizing with lost sales. IFAC-PapersOnLine. 49. 628-633. 10.1016/j.ifacol.2016.07.749.

[12] 12. You, Meng & Xiao, Yiyong & Zhang, Siyue & Zhou, Shenghan & Yang, Pei & Pan, Xing. (2019). Modeling the Capacitated Multi-Level Lot-Sizing Problem under Time-Varying Environments and a Fix-and-Optimize Solution Approach. Entropy. 21. 377. 10.3390/e21040377.

[13] 13. Seyed Ashkan Hoseini Shekarabi, Abolfazl Gharaei & Mostafa Karimi (2019) Modelling and optimal lot-sizing of integrated multi-level multi-wholesaler supply chains under the shortage and limited warehouse space: generalised outer approximation, International Journal of Systems Science: Operations & Logistics, 6:3, 237-257, DOI: 10.1080/23302674.2018.1435835

[14] 14. Sahithi V.V.D., Rao C.S.P., Srinivasa Rao M. (2020) An Extensive Study of Multi-level Inventory Lot Sizing Optimization Problem. In: Voruganti H., Kumar K., Krishna P., Jin X. (eds) Advances in Applied Mechanical Engineering. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-15-1201-8_126

[15] 15. P. Afentakis, B. Gavish, V. Karmarkar, Computationally efficient optimal solutions to the lot-sizing problem in multi-stage assembly systems, Management Science 30 (1984) 222–239.

[16] 16. H. Tempelmeier, M. Derstroff, A lagrangean-based heuristic for dynamic multilevel multiitem constrained

lotsizing with setup times, Management Science 42 (1996) 738–757.

[17] 17. R. Pitakaso, C. Almeder, K.F. Doerner, R.F. Hartl, A MAX–MIN ant system for unconstrained multi-level lot-sizing problems, Computers and Operations Research 34 (2007) 2533–2552.

[18] 18. Mishra.S.K , Sahithi, V.V.D , Rao. C. (2016). A hybrid binary particle swarm optimization for large capacitated multi item multi level lot sizing (CMIMLLS) problem. IOP Conference Series: Materials Science and Engineering. 149. 012040. 10.1088/1757-899X/149/1/012040.

[19] 19. Xiao, Y.; Kaku, I.; Zhao, Q.; Zhang, R. A variable neighborhood search based approach for uncapacitated multilevel lot-sizing problems. Comput. Ind. Eng. 2011, 60, 218–227.

[20] 20. Yi Han, Jiafu Tang, Iko Kaku, Lifeng Mu,Solving uncapacitated multilevel lot-sizing problems using a particle swarm optimization with flexible inertial weight,Computers & Mathematics with Applications,Volume 57, Issues 11–12,2009,Pages 1748-1755,ISSN 0898-1221,https://doi.org/10.1016/j.camwa.2008.10.024.

[21] 21.Woo Z, Hoon J, Loganathan GV. A New Heuristic Optimization Algorithm: Harmony Search. SIMULATION. 2001;76(2):60-68. doi:10.1177/003754970107600201

[22] 22.. Mehrabian, A.R. & Lucas, Cameron. (2006). A novel numerical optimization algorithm inspired from weed colonization. Ecological Informatics. 1. 355-366. 10.1016/j.ecoinf.2006.07.003.

[23] 23. J. Xie, J.F. Dong, Heuristic genetic algorithm for general capacitated lot-sizing problems, Computer and Mathematics with Applications 44 (2002) 263–276.

BIOGRAPHIES

V.V.D Sahithi, Research Scholar, JNTU Hyderabad, India

Dr. M. Srinivasa Rao, Professor, JNTU Hyderabad, India

Dr. C.S.P RAO, Director, NIT, Warangal, India