

## **New Strategy for Warehouse Optimization – Lean warehousing**

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### **Abstract**

Co-ordination of warehouse operations efficiently is critical in the supply chain management of all manufacturing industry. Lean tools and techniques are widely used in optimization problems where this study also the get the assistance of Lean techniques to optimize the warehouse operations. According to Lean thinking it can be decided that the efficiency of warehouse operations depends on the layout arrangement, material handling techniques and media of transportation. Therefore, this study attempts to optimize warehouse layout: by allocating an economical place to each type of item while minimizing the honeycombing. However, due to the computational complexity of finding an optimal allocation within reasonable time frame, this is mathematically termed as NP-hard type problems. It has been found in the literature that the heuristic approaches are highly attractive than the traditional approaches for this instances. The Simulated Annealing heuristic was used to determine the optimal allocation of each category once the initial solution is generated by greedy approach. Generating a shortest route to collect all the items of a respective order is also an objective of this study. The route was decided based on the item's rank in the delivery route, distance in between two consecutive types of items and the weight. The improved layout was tested on several case studies and simulation results show that improved layout is beneficial in terms of travel distance (reduced by 30% ) and resource utilization.

Keyword: Supply chain management, Lean warehousing, Honeycombing

### **1. Introduction**

Current trend in the manufacturing sector is to make the supply chain (SC) more efficient and effective since it spans all the activities from material extraction stage to dispatching of finished goods. Among SC functions (figure 1), the warehouse operations play a main role in supply chain management since it bounds with the shipment of goods from plant to customer while ensuring the safety of products. The present records imply that the cost of warehouse operations is comparatively high due to the existence of many non value added activities. Therefore, the requirement arises to lean the warehouse operation in terms of cost and time by eliminating non value adding activities and optimizing value adding activities. A Value Stream Mapping (VSM) is one of the best elements in Lean since it shows the collection of all actions (value added & non value added) that are required to bring a product through the main flows, starting with raw material and ending with the customer [6], [7]. The VSM identifies the whole warehouse operation consists of sub processes such as order receiving, storing, picking and shipping. A 1988 study in the United Kingdom revealed that 55% of all operating costs in a typical warehouse can be attributed to order picking as shown in figure 2 [1]. Although the manufacturer's objective is to keep the production cost in a minimum level, numbers of non value adding activities create additional costs in overall production.

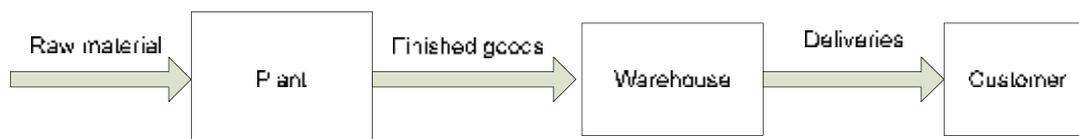


Figure 1 : Supply chain

Moreover, the customer requirement is getting the desired goods on time with low price and in good condition. Therefore, in order to meet with the customer and manufacturer perspective, the warehouse operations are optimized.

Generally, warehouse layout design models attempts to achieve warehouse optimization objectives. Therefore, in order to eliminate the inefficiencies in warehouse functions and make them reliable in terms of cost, the importance of warehouse layout design arises. The objectives of the layout design in this study are to use the warehouse space efficiently while providing most economical storage location for each item type to minimize the handling cost.

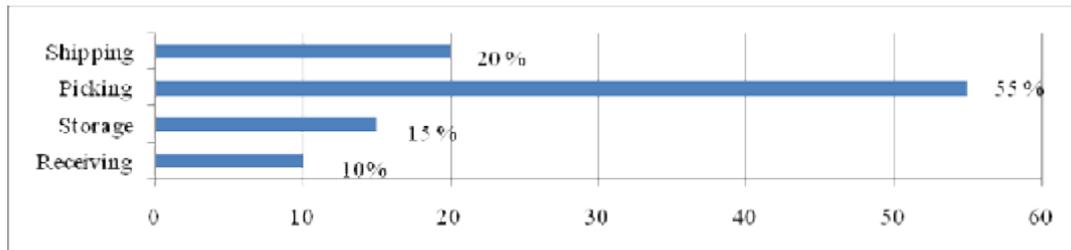


Figure 2: Percentage of annual operating expense

It has been found in the literature that warehouse configurations are governed by certain policies and principles. The implied storage policies are: randomize storage, dedicated storage, and class based storage. In random location, inventory is allocated in a certain location where it is unoccupied at the moment. This is beneficial in terms of space whereas inefficient in handling. The dedicated storage policy assigns material to predetermined location based on throughput and storage requirement. The class based storage is a mix of random and dedicated, where storing is done based on some criterion such as demand, product type, size etc.[2]. However, the proposed layout of this study is based on an integration of both dedicated and class based storage policies.

The implied storage area principles defined in the literature are popularity, similarity, size, characteristics, utilization, accessibility etc [1]. However, this study is based on popularity, accessibility and size since they are dominating factors of each product. Those dominating factors are considered in an integrated manner since consideration of single factor will not be a prudent solution to current problem. For instance, referring to the size; the heavy, bulky and hard to handle goods are stored in close proximity to the shipping point. On the other hand side, based on popularity condition, high demanded items is locating up front and other items are in back. Finally, it is realized that the both factors should be considered simultaneously to end up with economical warehouse configuration. The space management was done by allocating required space for each item category based on past data while minimizing honeycombing where the wasted space that results when a partial row or stack cannot be utilized. Once the proper location of the respective item is determined, generating a route to pick the demand of respective vehicle is other challenge in this study. This route is generated by considering the rank of the item in the path and distances.

However, finding an optimal location for each category is computationally very complex in practical situation. Mathematically, this type of problems termed as NP – hard problems. Heuristics such as Genetic Algorithm (GA), SA, TS are highly attractive for a complex problem to find a better solution within a reasonably lesser computational time. Previous researchers have introduced different heuristics for combinatorial optimization problems. These issues prevent of using traditional algorithms therefore in this research meta-heuristic and evolutionary techniques are adapted to find near optimal results within considerable time frame.

## 2. Warehouse optimization

### 2.1 Problem definition

The manufacturing firm produces varieties of  $n$  types of products ( $n = 1,2,3,\dots$ ) where  $n \in \mathbb{R}$ , differs in characteristics such as size, demand, weight ( $s_i, d_i, w_i$ ). Once it comes out from the manufacturing process it needs to be stored until the dispatching stage. Meanwhile, numbers of sub processes (figure 2) are functioning within the warehouse to transfer goods from plant to customer. However, based on the stored place of the particular item, the storing, picking and shipping cost is determined. According to the present records in (Tompkins et al), a higher cost is scored by the picking operations. This is reasoned by the location of the particular item and the order picking

route. In this study, forklift is selected as the material handling equipment and the handling amount per time is  $q_i$  where  $i$  represents the product number. The travelling cost of the forklift is  $c$  for unit distance and the maximum holding weight is  $W$ . Therefore, the defined handling cost of item  $i$  is  $c / q_i$ . Therefore, in order to minimize the cost of those non value adding activities, economical layout is proposed with following benefits.

1. Providing a most economical storage in relation to retrieving time, use of space.
2. Providing maximum flexibility in order to meet changing storage and handling requirements
3. Providing economical path to collect orders of customers

## 2.2 Methodology

The proposed method consists of two stages and first stage folded into three sections (figure 3). In stage one, the layout of the warehouse is determined and it follows the generation of the shortest path in the second stage. The computation starts with the particular information of each item (average demand, frequency of shipment and number of carrying item per trip) is needed as shown in table 1. In section1, comparisons are carried out between two storage philosophies and in section 2, the initial solution (initial configuration) is generated integrating storage principles such as popularity, demand, and size of the particular item. In section 3, the solution is improved by Simulated Annealing.

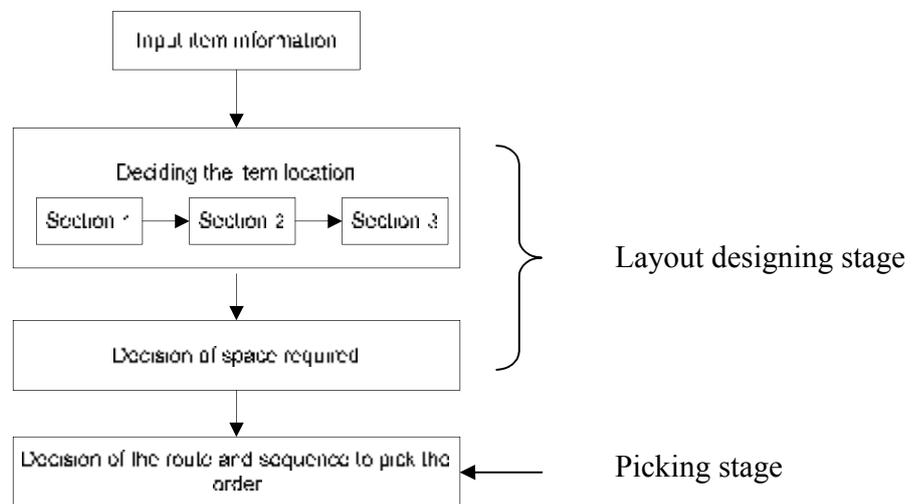


Figure: 3 Stages of proposed method

### 2.2.1 Decision of item location

#### Section 1

Two major material storage policies are compared at the initial stage of this study i.e. Dedicated and Random (figure 4 and 5) in order to select the most suitable one with our objectives. According to the past records and current practice, picking and shipping consumes a lot from the total production cost. In order to eliminate the inefficiencies of them, dedicated placing is selected as layout configuration. In dedicated placing storage, each good is stored in a specific location and allocated region won't be loaded with any other though the space is empty whereas in random-location there exists a feasibility of storing in any place.

#### Section 2

The section 2 is carried out under the dedicated placing philosophy. The layout arrangement is decided as shown in figure 4. The initial solution considers the location where the item is going to be placed based on several factors such as average demand, unit travelling cost and frequency of demand. It is obvious that giving priority to one aspect may not lead to an effective layout since each item has different characteristics. For instance, an item that has high unit travelling cost and low demand, then it won't be prudent to place it by considering single aspect. If the cost is considered, then the item is placed closer to shipping point, but the demand considered, it is pointless to locate them near to shipping point. Therefore, proposing a layout by integrating several factors will lead to better

configuration. In order to finalize the location of each item, a weighted factor is calculated and then sorted out in ascending order. Section 2, the location is decided considering factors such as total demand and unit travelling cost.

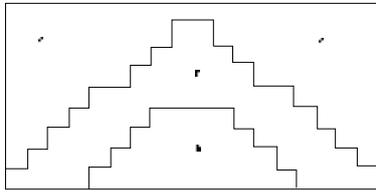


Figure 4: Dedicated placing

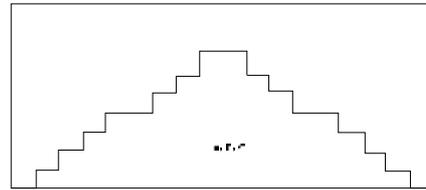


Figure 5: Random placing

Step 1: Input all task information, Input average distance to each storing location, define  $\alpha, \beta$ .

Step 2: Calculate the weighted factor for each item  
 $F = (\alpha * Total\ demand) + (\beta * Total\ travelling\ cost)$

Step 3: Make them in a descending order by F factor and locate item from the shipping point

Step 4: Calculate the associate cost (Average distance \* no. of shipment)  
 (Average distance is calculated according to the dimension in figure 6)

Figure 6: Outline of the initial solution

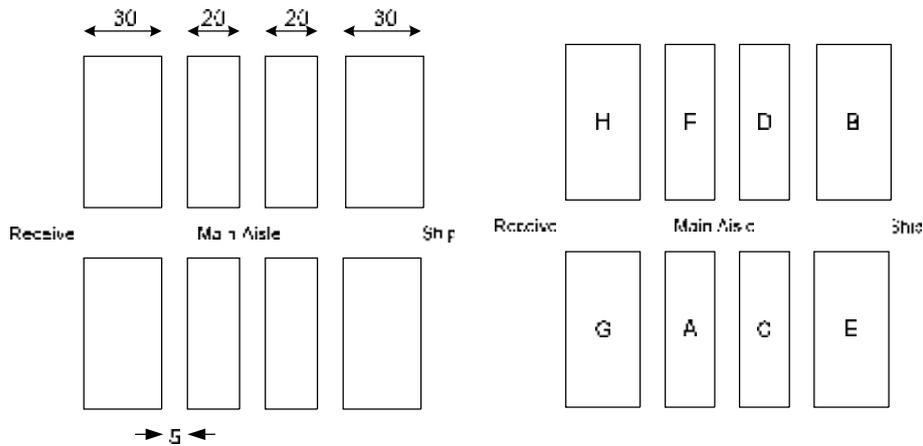


Figure 7: Layout of the warehouse (follows dedicated placing)

### Section 3

The initial solution obtained in section 2 is improved by Simulated Annealing technique. SA is developed analogous to physical process of annealing with high diversification search where diversification can be controlled by varying the cooling rate. Moreover, SA accepts the candidate solution probabilistically by the metropolis acceptance criterion, provides a procedure to find sufficiently good solution over the solution space. As shown in figure 8, the initial solution generated by the greedy approach and interchange move operator is used in neighborhood search mechanism. If the current neighborhood solution is feasible and satisfies: (Current solution < Best solution) or probability  $\exp(\text{best solution} - \text{current solution}) / T > \text{random}[0,1]$ , then the current solution is taken as the best solution. In this way, local search continues until the termination criterion. It has been found that the as temperature decreases the best layout being found.

### 2.3 Route generating stage

The picking sequence is determined with correspondence to the delivery amount of respective delivery vehicle. Moreover, we assume that a single customer requires single item only. Since the products are loaded by following the last in first out strategy(LIFO), picking task is also done according to this scenario. Beforehand to deciding the route, it is required to decide the maximum amount of each item that can be carried out by a fork lift (Table 1). If the order of the respective customer can be catered by round move of a forklift, then it is done without any further thinking. However, if forklift can carry more weight once it is loaded with a single demand, then tries to accommodate other orders considering the position of that correspondence customer in the route , item weight and number of items.

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Step 1: Generate an initial solution by greedy approach.
Step 2: Initialize parameters, Initial temperature T start = T, Set cooling rate, ending
        Temperature(Tend), iter = 0.
Step 3: Do neighborhood search (exchange operator).
Step 4: Calculate the current associate cost of travelling.
Step 5: If the best neighbor is feasible and satisfy aspiration criterion (current
        solution < best solution) OR
        (exp(best solution - current solution) / T ) > rand [0,1].
        Update the best solution
    Else
        Continue the neighborhood search (go to Step 3)
    end
Step 6: Modify the temperature and iterations.
Step 9: If Temp < Tend | iter is terminated.
Step 10: If the termination criterion satisfied. Stop.
    
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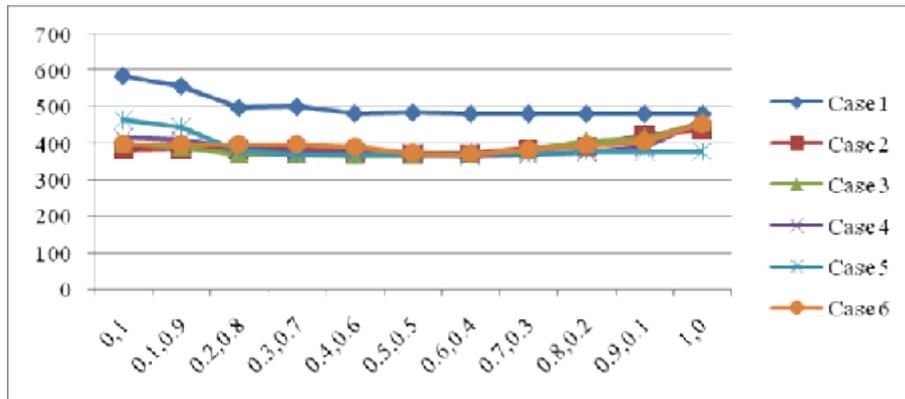
Figure 8 : Pseudocode of SA heuristic

### 3. Simulation and results

The study of warehouse optimization was carried out based on the average demand of each item as stated in table 1. Two factors such as demand and unit travelling cost were considered at the stage of initial solution generation and decision was drawn in weighted manner. The two parameters which were assigned to demand and travelling cost is  $\alpha$  and  $\beta$  respectively. Numbers of case studies were carried out to select most appropriate  $\alpha$  and  $\beta$  value and results of few case studies were graphically shown in figure 8. Results reveals that the most probable combination of  $\alpha$  and  $\beta$  is 0.6 and 0.4. Further, for deduced value  $\alpha$  and  $\beta$ , the initial solution (total travel distance for particular configuration) is optimized by SA technique. As reported in table 4, it can be concluded that SA can improve the solution quality in terms of total transporting distance. Moreover, it was convinced that the proposed layout shows significant reduction of travel distance compared to the traditional method. The traditional way of retrieving is done based on the single demand of a single vehicle. However, the propose method attempts to carry out more than single demand considering distance, and weight of the respective item. Table 3 shows the result obtained in several case studies which carried out to test the novel picking method.

Table : 1 Typical sets of manufacturing item data

Item no.	Average demand	Number of carrying items/ shipment	Frequency demand
1	40	1	7
2	100	4	3
3	800	2	4
4	30	7	5



Summary result of  $\alpha, \beta$  for 20 case studies

$\alpha, \beta$	%
0.5,0.5	20
0.6,0.4	70
0.7,0.3	10

Figure 9: Variation of initial solution with  $\alpha$  and  $\beta$  values

Table 2: Improvement of initial solution (distance) by SA heuristic ( $\alpha = 0.6$  and  $\beta = 0.4$ )

Case No.	Initial	SA solution	% Improvement
1	480	450	6.25
2	372	350	5.91
3	364	343	5.76
4	370	320	13.5

Table 3 : Comparison between previous and present system

Case No. & size	Retrieval distance (units)	
	Traditional	Proposed
1- 10	200	160
2- 15	552	402
3- 20	500	420
4- 25	650	600

#### 4. Conclusions

In this paper warehouse functions were optimized with the help of Lean tools and techniques. Warehouse layout design models designed to achieve warehouse optimization objectives. Based on dedicated based and class based storage policy and considering the characteristics of each item, an economical layout arrangement is proposed. SA heuristic was used to find an optimal place for each item type. Results show that the proposed locations are significant in terms of travel distance and cost. Moreover, unnecessary movements were significantly reduced by shipping more than one product at a time. It can be concluded that the approach used to decide the item location and the shipping system is beneficial in Lean warehousing since it could achieve 30% reduction from overall travel distance.

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