Optimization of Space Utilization of Storage Rack System for a Garment Industry using Linear Integer Programming

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Abstract: **The garment industry in India faces multiple problems with respective to achieve performance measure such as quality, throughput, cycle time, FGI (Finished Goods Inventory). In order to achieve these performance measures, an optimization model needs to be created with a focus on single or multiple objectives. In the current work, the focus is on obtaining optimal solution with an objective of minimize storage space. This can be obtained by using Integer Linear Programming technique. The objective is to minimize the volume left by means of allocation of various combination of packets of materials in such a way that the constraints of each rack space is considered. Different strategies for allocating various packets of materials were generated and using these strategies, optimal solutions was obtained.**

Key words: Optimization, Integer Linear Programming, Garment Industry, Operations Research, Inventory Management, ABC Analysis.

1. INTRODUCTION

Managing of Inventory takes place at various stages which include raw material inventory stage, WIP (Work In Progress) stage and FGI (Finish Good Inventory) Stage. Managing involves creating an optimal strategy to ensure that objective function which is needed is either minimized or maximized. Currently in the company there is no set practices for allocating materials to the rack based on optimization of storage space. Hence there is a need to create an optimal strategy. In order to achieve, an objective function is used to minimize usage of raw material storage space of the rack system by allocating material in the rack accordingly. To obtain a better understanding about the methodology it is necessary to understand about the raw material storage system.

It was observed the storage for raw materials was randomly done and there seemed to be a lot of space not being utilized properly simply due to the inconsistency in racks and also the carton boxes in which the raw materials were placed. It was also noticed that the best results under the

given circumstances was yet to be achieved. The racks were not being properly utilized. The current storage method was not optimized.

Initially the whole area for raw material storage was observed and the way the packing and combination of different raw materials placed were seen. Also the racks and the boxes were seen and dimensions were taken. It was seen that the boxes were randomly placed based on availability and the racks were also spaced in appropriately.

It is seen from Fig 1 that raw materials are stored in racks in containers according to their types, however there is no set strategy for allocation of materials in order to optimize rack space. To understand about allocating materials to the rack it is necessary to know the dimension of the rack and dimension of the material package. The dimension of the rack would be considered as part of constraint. Typically when allocating a set of different packaged material to a rack, dimension of the packaged material would be considered to stack and the material were stacked length or breadth wise. Thus when stacking different packets of materials there can be a set of combination which can evolve when onset of material is stacked according to their and other according to their breadth. This allocating strategy is shown in Table 1. Based on these strategies an optimal set of strategies can be found to minimize volume left for a storage rack system.

2. LITERATURE REVIEW

Allocation problems have been dealt in various books and literature. Taha [1] explains various methods of allocating products, materials in his book on operations research. Rajendran [2] in his paper addresses on how to allocate different bar materials for the required length put forward by the construction site. The paper focuses on different case studies in which one of them focuses on minimization

of scrap for cutting reinforcement bars to various lengths. There are different types of bars. The bars come in with a particular length which needs to be cut to various lengths based on the requirements put forward by the construction sites.

In order to minimize the scrap, they have found out the different possible patterns of cutting and have assumed the decision variable to be number of possible different methods of cutting. The objective function is minimization of scraps subjected to the constraints of availability of bars.

The current paper addresses the problem in a similar however the objective function in our case is to minimize the volume left when we are allocating different boxes based on different strategies in order to minimize the volume left.

Additionally ABC classification was applied and allocation was accordingly done based on these classification.

3. PROBLEM DESCRIPTION:

As mentioned earlier in the introduction section, the rack space is not optimally utilized and packaged material are allocated based on a random basis or wherever there is space availability. Hence there is a need for systematic and scientific way of allocation with the objective of optimal utilization of rack space.

In addition to the above mentioned the classification of materials weren't applied and this adds to further problems.

For the solution of the above-identified problems, ABC classification and an OPERATION'S RESEARCH model using Integer linear programming method, which is done for optimization, were recommended for the same

4. PROBLEM OBJECTIVE

The objective of this study is to allocate materials optimally based on the current scenario (No ABC classification), ABC Classification, AB and C classification and then comparing all these combinations and suggesting best practices.
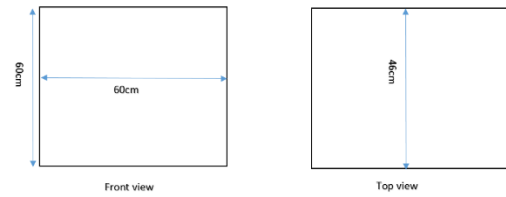

Figure1: Raw Material Storage

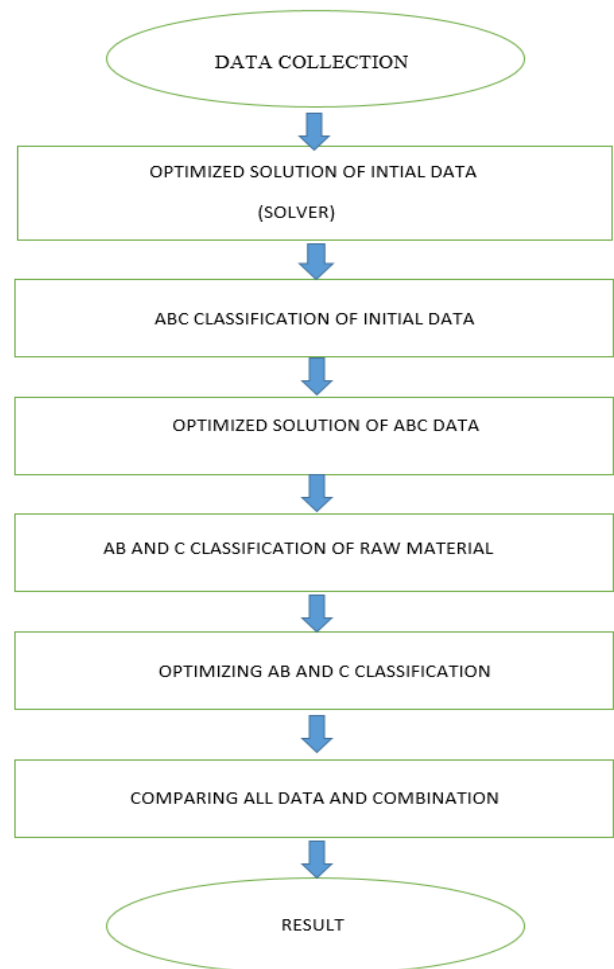Figure 2 : Rack Dimensions

5. METHODOLOGY:

Figure 3 : Methodology

5.1 ANALYSING THE RAW MATERIAL STORAGE AWAREA

Figure 4: Raw Materials

Material	Quantity(pcs.)	Value(Rs.)	Pieces/Packet(pcs.)	Boxes / Material(pcs.)	Packet dimensions(cm)
Button	2249582	3616272	864	2603	19*15*3
Pu Patch	176515	690734	500	353	36*26*3
Rivet	471095	643283	5000	942	22*19*3
Stud	57768	150976	5000	58	22*19*3
Tag	672342	2012751	1000	672	36*26*3
Leather Patch	35221	347296	500	70	36*26*3
Carry Bag	83650	356510	1000	17	51*42*10
Zip	434966	2641242	1000	435	20*25*3
Label	1547692	863435	500	3095	20*20*3
Number of racks in avialable : 152					
Number of racks in use : 132					
Rack Dimensions(cm) : 60*46*60					

5.2 INTEGER LINEAR PROGRAMMING AND ABC ANALYSIS

5.3 INTEGER LINEAR PROGRAMMING

Linear Programming (LP) is a mathematical procedure for determining optimal allocation of scarce resources. It is a special case of mathematical programming (mathematical optimization). Linear programming deals with a class of programming problems where both the objective function to be optimized is linear and all relations among the variables corresponding to resources are linear.

Any LP problem consists of an objective function and a set of constraints. A function is a thing that does something.

In the problem stated by the company it was the rack space for material allocation which was required to be optimized.

1. The decision variables are the various strategies used in allocating the boxes based on the rack dimensions

2. The objective function is to minimize the volume left based on the allocation strategy

3. The constraints are the total number of boxes available for various products (Calculated based on availability and there should be minimum availability)

Based on the various strategy, the calculation below shows the coefficients to be used for the constraints. Figure 5 shows an excel table sheet on how coefficients are allocated for each strategy and a particular product. It should be noted from the calculation below that based on the strategy allocated and the rack dimension the coefficients are calculated. The below figure is example of solver table without ABC Classification.

PRODUCTS	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
P_1	A_1	A_2	A_3	A_4	A_5			A_8		A_{10}		A_{12}	A_{13}					A_{18}		A_{20}
P_2			B_3			B_6		B_8							B_{15}	B_{16}			B_{19}	
P_3						C_6										C_{16}				
P_4				D_5					D_9		D_{11}	D_{12}								
P_5				E_4														E_{18}		
P_6		F_2	F_3				F_7						F_{13}	F_{14}	F_{15}			F_{19}		
P_7			G_4													G_{16}	G_{17}			
P_8			H_3				H_7				H_{11}		H_{13}	H_{14}					H_{19}	H_{20}
P_9									J_9	J_{10}							J_{17}			
VOLUME LEFT	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}	V_{16}	V_{17}	V_{18}	V_{19}	V_{20}

Figure 5: Strategy allocations

Where

Z = Total volume left after allocation

A_1 = Number of packets for a rack for part P_1 using strategy X_1

A_2 = Number of packets for a rack for part P_1 using strategy X_2

A_3 = Number of packets for a rack for part P_1 using strategy X_3

A_4 = Number of packets for a rack for part P_1 using strategy X_4

A_5 = Number of packets for a rack for part P_1 using strategy X_5

A_8 = Number of packets for a rack for part P_1 using strategy X_8

A_{10} = Number of packets for a rack for part P_1 using strategy X_{10}

A_{12} = Number of packets for a rack for part P_1 using strategy X_{12}

A_{13} = Number of packets for a rack for part P_1 using strategy X_{13}

A_{18} = Number of packets for a rack for part P_1 using strategy X_{18}

A_{20} = Number of packets for a rack for part P_1 using strategy X_{20}

B_3 = Number of packets for a rack for part P_2 using strategy X_3

B_6 = Number of packets for a rack for part P_2 using strategy X_6

B_8 = Number of packets for a rack for part P_2 using strategy X_8

B_{15} = Number of packets for a rack for part P_2 using strategy X_{15}

B_{16} = Number of packets for a rack for part P_2 using strategy X_{16}

B_{19} = Number of packets for a rack for part P_2 using strategy X_{19}

C_6 = Number of packets for a rack for part P_3 using strategy X_6

C_{16} = Number of packets for a rack for part P_3 using strategy X_{16}

D_5 = Number of packets for a rack for part P_4 using strategy X_5

D_9 = Number of packets for a rack for part P_4 using strategy X_9

D_{11} = Number of packets for a rack for part P_4 using strategy X_{12}

D_{12} = Number of packets for a rack for part P_4 using strategy X_{12}

E_4 = Number of packets for a rack for part P_5 using strategy X_4

E_{18} = Number of packets for a rack for part P_5 using strategy X_{18}

F_2 = Number of packets for a rack for part P_6 using strategy X_2

F_3 = Number of packets for a rack for part P_6 using strategy X_3

F_7= Number of packets for a rack for part P_6 using strategy X_7

F_{13}= Number of packets for a rack for part P_6 using strategy X_{13}

F_{14}= Number of packets for a rack for part P_6 using strategy X_{14}

F_{15}= Number of packets for a rack for part P_6 using strategy X_{15}

F_{19}= Number of packets for a rack for part P_6 using strategy X_{19}

G_4= Number of packets for a rack for part P_7 using strategy X_4

G_{16}= Number of packets for a rack for part P_7 using strategy X_{16}

G_{17}= Number of packets for a rack for part P_7 using strategy X_{17}

H_3= Number of packets for a rack for part P_8 using strategy X_3

H_7= Number of packets for a rack for part P_8 using strategy X_7

H_{11}= Number of packets for a rack for part P_8 using strategy X_{11}

H_{13}= Number of packets for a rack for part P_8 using strategy X_{13}

H_{14}= Number of packets for a rack for part P_8 using strategy X_{14}

H_{19}= Number of packets for a rack for part P_8 using strategy X_{19}

H_{20}= Number of packets for a rack for part P_8 using strategy X_{20}

J_9= Number of packets for a rack for part P_9 using strategy X_9

J_{10}= Number of packets for a rack for part P_9 using strategy X_{10}

J_{17}= Number of packets for a rack for part P_9 using strategy X_{17}

OBJECTIVE FUNCTIONS

Min Z = $V_1X_1+V_2X_2+V_3X_3+V_4X_4+V_5X_5+V_6X_6+V_7X_7+V_8X_8+V_9X_9+V_{10}X_{10}$

$Min\ Z = \sum_{e=1}^{n} V_i X_i$

S.T CONSTRAINTS

$\sum_{e=1}^{n} A_i X_i \geq$ Total number of boxes for part P1

$\sum_{e=1}^{n} B_i X_i \geq$ Total number of boxes for part P2

$\sum_{e=1}^{n} C_i X_i \geq$ Total number of boxes for part P3

$\sum_{e=1}^{n} D_i X_i \geq$ Total number of boxes for part P4

$\sum_{e=1}^{n} E_i X_i \geq$ Total number of boxes for part P5

$\sum_{e=1}^{n} F_i X_i \geq$ Total number of boxes for part P6

$\sum_{e=1}^{n} G_i X_i \geq$ Total number of boxes for part P7

$\sum_{e=1}^{n} H_i X_i \geq$ Total number of boxes for part P8

$\sum_{e=1}^{n} J_i X_i \geq$ Total number of boxes for part P9

5.4 CALCULATION

Number of racks available: 152

Number of racks in use: 132

Rack Dimensions (cm): 60*46*60 (L*B*H)

The values and combinations were obtained by the following calculation.

X_1-Strategy for allocating Buttons Only

Number of packets of Buttons (A_1)= 3*4*19= 228 packets

The number of buttons are calculated based on rack dimensions and the button box dimension

Volume left = 16*46*60 = 44160 cm^3

X_2 - Strategy for allocating Buttons, Rivets

Number of packets of Buttons = 19*2*3= 114 packets

Number of packets of Rivets = 19*2*2= 76 packets

The number of buttons and rivets are calculated based on rack dimensions and the button box dimension

Volume left = (10*46*60) + (44*8*60) = 48720 cm^3

In a similar way coefficients can be calculated for the remaining set of strategy

5.5 OBJECTIVE FUNCTIONS & CONSTRAINTS

Min Z=$V_1X_1+V_2X_2+V_3X_3+V_4X_4+V_5X_5+V_6X_6+V_7X_7+V_8X_8+V_9X_9+V_{10}X_{10}$

Min Z $= \sum_{e=1}^{n} V_i X_i$

S.T CONSTRAINTS WITHOUT ABC CLASSIFICATION

For buttons:

$\sum_{e=1}^{n} A_i X_i \geq$ Total number of boxes for buttons

$228x_1+114x_2+57x_3+57x_4+114x_5+76x_7+114x_8+114x_{10}+171x_{12}+114x_{13}+57x_{18}+114x_{20} \geq 2603$

For zip:

$\sum_{e=1}^{n} B_i X_i \geq$ Total number of boxes for zip

$19x_3+19x_6+38x_8+19x_{15}+19x_{16}+19x \geq 435$

For tag:

$\sum_{e=1}^{n} C_i X_i \geq$ Total number of boxes for tag

$38x_6+19x_{16} \geq 672$

For label:

$\sum_{e=1}^{n} D_i X_i \geq$ Total number of boxes for label

$38x_5+76x_9+76x_{11}+38x_{12} \geq 3095$

For PU patch:

$\sum_{e=1}^{n} E_i X_i \geq$ Total number of boxes for PU patch

$19x_4+38x_{18} \geq 353$

For Revit:

$\sum_{e=1}^{n} F_i X_i \geq$ Total number of boxes for Revit

$76x_2-38x_3+76x_7+38x_{13}+76x_{14}+114x_{15}+38x_{19} \geq 942$

For leather patch:

$\sum_{e=1}^{n} G_i X_i \geq$ Total number of boxes for leather patch

$19x_4 + 19x_{16} + 19x_{17} \geq 70$

For stud:

$\sum_{e=1}^{n} H_i X_i \geq$ Total number of boxes for stud

$38x_3 + 76x_7 + 76x_{11} + 38x_{13} + 76x_{14} + 76x_{19} + 76x_{20} \geq 58$

For carry bag:

$\sum_{e=1}^{n} J_i X_i \geq$ Total number of boxes for carry bag

$5x_9 + 5x_{10} + 5x_{17} \geq 17$

WITH ABC CLASSIFICATION

For AB classified materials

For buttons:

$\sum_{e=1}^{n} A_i X_i \geq$ Total number of boxes for buttons

$228x_1 + 114x_2 + 114x_3 + 171x_4 + 57x_5 + 38x_6 + 57x_8 + 114x_{10} \geq 2603$

For zip:

$\sum_{e=1}^{n} B_i X_i \geq$ Total number of boxes for zip

$38x_3 + 38x_7 + 19x_{10} \geq 435$

For tag:

$\sum_{e=1}^{n} C_i X_i \geq$ Total number of boxes for tag

$19x_6 + 38x_8 + 38x_9 \geq 672$

For label:

$\sum_{e=1}^{n} D_i X_i \geq$ Total number of boxes for label

$76x_2 + 38x_4 + 114x_5 + 76x_7 + 38x_9 + 38x_{10} \geq 3095$

For C classified materials

For PU patch:

$\sum_{e=1}^{n} E_i X_i \geq$ Total number of boxes for PU patch

$19x_3 + 19x_4 + 19x_5 + 19x_6 + 19x_7 \geq 353$

For Revit:

$\sum_{e=1}^{n} F_i X_i \geq$ Total number of boxes for Revit

$76x_1 + 76x_3 + 38x_7 + 38x_8 + 38x_{10} \geq 942$

For leather patch:

$\sum_{e=1}^{n} G_i X_i \geq$ Total number of boxes for leather patch

$19x_2 + 19x_5 + 19x_8 \geq 70$

For stud:

$\sum_{e=1}^{n} H_i X_i \geq$ Total number of boxes for stud

$76x_1 + 76x_4 + 38x_7 + 38x_8 + 38x_9 \geq 58$

For carry bag:

$\sum_{e=1}^{n} J_i X_i \geq$ Total number of boxes for carry bag

$5x_2 + 5x_6 + 5x_9 + 5x_{10} \geq 17$

5.6 RESULT

Solving the obtained data through solver

Solver was used to find out the best combination among the materials in terms of rack space to optimize space.

Calculation was done in two methods

1. Without ABC Classification
2. With ABC Classification.

SOLVER TABLE (WITHOUT ABC CLASSIFICATION)

Figure 6 : Solver results without ABC classification

By using this technique 20 racks were saved.

SOLVER TABLE (WITH ABC CLASSIFICATION)
Solver table for AB classified materials

Figure 7 : Solver results with ABC classification for AB classified material

Solver table for C classified materials

Figure 8 : Solver results with ABC classification for C classified material

By using this technique we saved 2 more racks.

CONCLUSION:

After implementing the ABC classification and applying the optimized solution for allocation of materials in the rack it was observed that the method recommended and applied would bring down the number of racks in use. The optimized solution would help to allocate materials in a planned order which would be feasible in use.

The table below shows the number of racks in use in before and after implementation of ABC and AB &C classifications

Table 1: Results

CLASSIFICATION TYPE	NUMBER OF RACKS
INITIALLY IN USE	132
WITHOUT ANY CLASSIFICATION	112
ABC CLASSIFICATION	110

It is seen that by means of applying optimization technique 20 rack space is saved. It was also seen that ABC classification uses the least number of racks after optimization. Thus ABC classification with the optimization technique applied for storage is to be adopted in order to achieve the best results.

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