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ESTABLISHING ASSOCIATION BETWEEN THE ORDERED PIECE AND A PIECE SELECTION BASIS FOR RECTANGLE PACKING HEURISTIC

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In this paper reworked rectangle-packing algorithm suggested by Cheok-AYC Nee is used to generate different 120 feasible patterns. Simulated tests were conducted for classification of items and sheets into three different categories (and so are objects) as *regular* when length/width ratio is uniformly distributed (1.25 ± 0.25), *standard* (length/width ratio is uniformly distributed (3 ± 0.3) and *tapered* (length/width ratio is uniformly distributed (6 ± 1). Different nature of items was placed on different nature of sheets. Heuristics which gives maximum utilization/minimum trim loss is selected and find out direct relation with the sequencing patterns i.e., area, perimeter, length, width and length/width ratio and the nature of items/ object. Recommendation developed for the best heuristic under different condition. It is observed that as the L/B ratio of sheet increases, the average utilization factor of sheet will decrease.

Keywords: Rectangle Packing, Heuristics Algorithm, Greedy Approach, NP-Complete Problems, Sheet Layout, Industrial Applications.

1. Introduction

Rectangle-packing problem involves many industrial applications. For example, in shipping industry, various size boxes have to be loaded as many as possible in a larger container. In wood or glass industries, rectangular components have to be cut from large sheets of material. In very large scale integration (VLSI) floor planning, various chips have to be laid on the chip board, and so on. In the rectangle-packing problem, rectangular parts are placed onto a rectangular stock sheet, which is bigger in size in comparison to items with the aim of minimizing the unused space. This problem belongs to NP-complete problems class where computation time for an exact solution increases with *N* and becomes rapidly prohibitive in cost as *N* increases [1]. The solution approach to these problems lies in reducing the exhaustive search of all possible arrangements of nesting the parts and subsequently checking upon the execution time. Usually, various heuristic rules are proposed to generate different patterns, which are generally the priority rules used to allocate patterns to the stock sheet sequentially. In this paper revised heuristic algorithm [2] is used to generate different pattern to sequence items both in ascending and in descending order on the basis of breadth, length, perimeter, area and aspect ratio (length/width ratio). These sequenced items are then placed one-by-one onto the object from bottom-lower corner (sheet reference point) till the solution continues to be feasible. Both length-wise and breadth-wise orientations of the object and then first item placed onto it have been considered.

Simulated tests were conducted for classification of items and sheets into three different categories (and so are objects) as *regular* when length/width ratio is uniformly distributed (1.25 ± 0.25), *standard* (length/width ratio is uniformly distributed (3 ± 0.3) and *tapered* (length/width ratio is uniformly distributed (6 ± 1). Different nature of items was placed on different nature of sheets. Heuristics which gives maximum utilization/minimum trim loss is selected and find out direct relation with the sequencing patterns i.e., area, perimeter, length, width and length/width ratio and the nature of items/object. Recommendation developed for the best heuristic under different condition.

2. Related Work

2.1 Generation of Rectangular Sheet and Items:

Industrial practice and literature survey substantiate for varied distribution of length and breadth of the rectangular parts. This is because of numeral manufacturers in a job in wide-ranging industrial application areas. In the VLSI applications the rectangular parts are generally skinny (aspect ratio of length/width is large); whereas in furniture industry majority parts are regular (lengths and widths are of comparable dimensions). In sheet metal industry, a major portion of ordered pieces are generally rectangular in nature. In the simulation study, accordingly the items are classified into three different categories (and so are objects) as *regular* when length/width ratio is uniformly distributed (1.25 ± 0.25), *standard* (length/width ratio is uniformly distributed

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(3 ± 0.3) and *tapered* (length/width ratio is uniformly distributed (6 ± 1). An Object is also considered in three variations: regular, standard and tapered.

Some researchers have suggested the uniform distribution [2] and others have suggested beta distribution [3] as shape distribution for length and width of rectangular parts. In the present study it is assumed that since the normal distribution comes close to fitting the actual observed frequency distributions of many phenomena, including human characteristics (weights, heights, IQs), outputs from physical processes (dimensions and yields) and other measures of interest related to industrial problems [4]. Accordingly, it is assumed that:

- Breadth of each item is normally distributed with a presumed mean and the standard deviation as 1/4th of it.
- Length of each item is related to breadth as regular, standard and tapered.

3. PROPOSED WORK

3.1 Heuristic for Nesting Rectangle Parts:

Rectangle packing problem is optimization problem that is concerned with finding a good arrangement of multiple items in larger containing regions with aim of minimizing unused space. In order to reduce the exhaustive search of all the possible arrangements of nesting of rectangular parts and to reduce the execution time of PC, various heuristic rules are proposed by which the sequence of the pattern location on the stock sheet is generated.

Heuristic allocates patterns to the stock sheet sequentially based on the priority rules. In past different authors used different heuristic [2, 3, 5]. In present study 120 rules are investigated on the basis of possible orientation of stock sheet as well as items, all the possible orders for sequencing and pivot point.

Heuristic Algorithm for Rectangle Packing

Used algorithm has following constraints

- Stock sheet does not contain any defective area.
- Items must lie within stock sheet i.e. all the item must satisfy stock sheet length and width constraints.
- Items do not overlap to each other.
- Object sheet and items rotate by 90 degree.
- Area of stock sheet must be greater than area of sum of all items.
- Ordered pieces will be rectangular in shape;
- Packing arrangements are non-guillotine and orthogonal.

Outlines of Heuristic Algorithm for Rectangle Packing are:

- The items are first sequenced. The criteria for sequencing is based on the all-possible aspects related to a rectangle e.g., length, width, area, perimeter, length/width ratio. The lists are sorted in increasing order and in decreasing order.
- The item thus picked first is placed horizontally and then vertically at the lower left corner of the object, referred to as its reference *point*. *Sheet Utilization Ratio* is defined as the sum total area of all items placed on the stock sheet to total stock sheet area. The item placed at reference point of the object gives rise to two *pivot points*. Pivot points are the top-left and bottom-right corner of the ordered piece placed and the top-left and bottom-right corners of enclosing rectangle that encloses all ordered pieces placed so far. Essentially, pivot points are the only probable positions where next item in sequence can be placed. The next item is then placed at each of the pivot points, both length-wise and breadth-wise for all feasible results. Orientations that result in minimum wastage are retained. New pivot points are defined and used ones are deleted. In the algorithm, pivot points are sequenced in the following three ways:
  - minimum radial distance (PPD)
  - minimum *x*-distance, in case of tie, point with minimum *y*-distance is to be served first (PPL)
  - minimum *y*-distance, in case of tie, point with minimum *x*-distance is to be served first (PPB)
- This process is repeated until every rectangle has been placed.
- The object is also placed in both the orientations.

Sequencing of items on the basis of various bases has been abbreviated as per the following scheme:

Possible Orientation of Object:

- Length-wise (OL)
- Breadth-wise (OB);

Possible Orientation of First Item placed on the Object:

- Length-wise (IL)
- Breadth-wise (IB);

Possible Sequencing Patterns:

- Increasing (I)
- Decreasing (D);

Different Basis for Sequencing of Items Considered:

- Length (SL),
- Breadth (SB),
- Area (SA),
- Perimeter (SP) and
- Aspect Ratio (SAR);

Different Sequencings of Pivot Points considered along

- Diagonal/Radial (PPD),
- Length (PPL) and
- Breadth (PPB).

Thus **OL-IL-I-SL-PPD** stands for pattern obtained when **O**bject is oriented **L**ength-wise; first-**I**tem placed on the reference point is also oriented **L**ength-wise; items are sorted in **I**ncreasing order and are **S**equenced on the basis of **L**ength; **P**ivot **P**oints are arranged in increasing order along the **D**iagonal of the object. Total number of feasible layouts possible are = 2 × 2 × 2 × 5 × 3 = 120;

4. RESULT AND DISCUSSION

Nine set of items and sheets combination are identified to find out direct relation with the sequencing patterns i.e., area, perimeter, length, width and length/width ratio and the nature of items/ object. Length of each rectangular part is related to breadth as regular, standard and tapered. When the items/sheets having length to breadth (L/B) ratio between 1 to1.5 are referred as 'Regular', between 2.7 to 3.3 are referred as 'Standard' and between 5 to7 are referred as 'Tapered'.

The nine sets of patterns investigated in the present work are

a) When the items L/B ratio lie between 1 to 1.5 and stock sheet L/B ratio lie between 1 to1.5.

b) When the items L/B ratio lie between 1 to 1.5 and stock sheet L/B ratio lie between 2.7 to 3.3.

c) When the items L/B ratio lie between 1 to 1.5 and stock sheet L/B ratio lie between 5 to7.

d) When the items L/B ratio lie between 2.7 to 3.3 and stock sheet L/B ratio lie between 1 to1.5.

e) When the items L/B ratio lie between 2.7 to 3.3 and stock sheet L/B ratio lie between 2.7 to 3.3.

f) When the items L/B ratio lie between 2.7 to 3.3 and stock sheet L/B ratio lie between 5 to7.

g) When the items L/B ratio lie between 5 to 7 and stock sheet L/B ratio lie between 1 to1.5.

h) When the items L/B ratio lie between 5 to 7 and stock sheet L/B ratio lie between 2.7 to 3.3.

i) When the items L/B ratio lie between 5 to 7 and stock sheet L/B ratio lie between 5 to7.

For each combination of items and stock sheet five set of samples are generated where breadth of the each rectangular part is normally distributed with mean $\mu = 20$ and standard deviation $\sigma = 5$. Length of the items is calculated by breadth X L/B ratio of items. Table 1-3 show the length and breadth of regular, standard and tapered items. Table 4 represent length and breadth of different type of sheets and Table 5 represent the quantity of different items. By processing the data of five sets, an average value of utilization is calculated for each combination. Results of the simulated tests are given in Table (7 & 8). Table 6 represents the performance of different heuristics for sample 2 of regular items which is placed on regular sheet and maximum utilization factor 96.9% is obtained by heuristic OB-IL-D-SB-PPL, OB-IL-D-SB-PPB and OB-IL-D-SB-PPD. Bold values in the Tables identify the maximum average utilization factor.

Table 1
Different Five Data Sets for Regular Items

Sample 1		*Sample 2*		*Sample 3*		*Sample 4*		*Sample 5*	
L	*B*	*L*	*B*	*L*	*B*	*L*	*B*	*L*	*B*
7	6	18	14	19	15	12	10	18	12
11	11	22	15	23	17	15	12	13	13
16	13	23	17	27	18	18	14	21	14
19	14	25	18	21	19	15	15	22	15
26	18	20	19	21	20	21	17	23	16
23	19	25	20	26	21	24	18	23	17
20	20	26	21	27	22	25	19	28	20
29	21	25	22	29	23	29	20	24	21
29	22	29	23	28	24	40	27	23	22
25	23	25	24	27	25	42	29	32	23
35	24	35	25	32	29	32	30	31	25

Table 2
Different Five Data Sets for Standard Items

Sample 1		*Sample 2*		*Sample 3*		*Sample 4*		*Sample 5*	
L	*B*	*L*	*B*	*L*	*B*	*L*	*B*	*L*	*B*
19	6	43	14	41	15	29	10	34	12
30	11	43	15	51	17	39	12	36	13
42	13	53	17	50	18	43	14	43	14
39	14	57	18	52	19	47	15	48	15
52	18	61	19	55	20	56	17	46	16
54	19	62	20	58	21	55	18	50	17
58	20	64	21	71	22	53	19	60	20
60	21	66	22	75	23	64	20	62	21
65	22	63	23	71	24	82	27	69	22
69	23	66	24	72	25	91	29	72	23
76	24	71	25	85	29	90	30	69	25

Table 3
Different Five Data Sets for Tapered Items

Sample 1		*Sample 2*		*Sample 3*		*Sample 4*		*Sample 5*	
L	*B*	*L*	*B*	*L*	*B*	*L*	*B*	*L*	*B*
35	6	79	14	79	15	69	10	66	12
70	11	79	15	101	17	77	12	78	13
76	13	96	17	114	18	85	14	98	14
89	14	122	18	133	19	103	15	79	15
107	18	114	19	136	20	117	17	84	16
117	19	108	20	137	21	93	18	109	17
133	20	113	21	125	22	100	19	130	20
130	21	137	22	141	23	127	20	121	21
121	22	133	23	167	24	161	27	119	22
139	23	148	24	157	25	173	29	159	23
145	24	152	25	159	29	159	30	172	25

Table 4
Length and Breadth of Different Type of Sheet

	L	*B*
REGULAR	225	150
STANDARD	330	110
TAPERED	490	70

Table 5
Quantity Vector for Different Type of Items

QUANTITY	11	8	15	13	14	13	10	14	9	13	9

It concludes from the Table 1, 2, 3, 4, 5, 6 and 7:

a) When regular items are placed on regular sheet then OB-IL has average maximum utilization (89.7%).

b) When standard items are placed on regular sheet then OB-IL has average maximum utilization (90.4%).

c) When tapered items are placed on regular sheet then OB-IL has average maximum utilization (88.8%).

d) When the regular items are placed on the standard sheet then OB-IL has average maximum utilization (88.7%).

e) When the standard items are placed on the standard sheet then OL-IL has average maximum utilization (90.4%).

f) When the tapered items are placed on the standard sheet then OL-IL has average maximum utilization (88.7%).

g) When the regular items are placed on the tapered sheet then OB-IB has average maximum utilization (86.7%).

Table 6
Performance of Different Heuristics for Sample 2
(Regular Items Placed on Regular Sheet)

			OL-IL		*OB-IL*		*OL-IB*		*OB-IB*	
#	*ORDER*	*SPP*	*TPP*	*UF (%)*	*TPP*	*UF (%)*	*TPP*	*UF (%)*	*TPP*	*UF (%)*
I.	D-SA	PPL	53	96.7	53	96.7	45	87	49	92.5
II.	D-SA	PPB	53	96.7	53	96.7	45	87	49	92.5
III.	D-SA	PPD	53	96.7	53	96.7	45	87	49	92.5
IV.	D-SAR	PPL	65	90.4	62	85.9	64	89.9	63	86.9
V.	D-SAR	PPB	63	86.4	62	85.9	64	89.9	63	86.9
VI.	D-SAR	PPD	65	90.4	62	85.9	64	89.9	63	86.9
VII.	D-SB	PPL	51	94.5	52	**96.9**	50	93	50	94.4
VIII.	D-SB	PPB	51	94.5	52	**96.9**	50	93	50	94.4
IX.	D-SB	PPD	51	94.5	52	**96.9**	50	93	50	94.4
X.	D-SL	PPL	53	95.2	49	92.7	48	88.6	50	92.8
XI.	D-SL	PPB	53	95.2	53	95.9	48	88.6	50	92.8
XII.	D-SL	PPD	53	95.2	49	92.7	48	88.6	50	92.8
XIII.	D-SP	PPL	53	96.7	53	96.7	45	87	49	92.5
XIV.	D-SP	PPB	53	96.7	53	96.7	45	87	49	92.5
XV.	D-SP	PPD	53	96.7	53	96.7	45	87	49	92.5
XVI.	I-SA	PPL	73	84.3	75	87.4	71	81.3	74	85.8
XVII.	I-SA	PPB	73	84.3	75	87.4	71	81.3	74	85.8
XVIII.	I-SA	PPD	73	84.3	75	87.4	71	81.3	74	85.8
XIX.	I-SAR	PPL	62	92	67	93.5	62	92	67	93.5
XX.	I-SAR	PPB	62	92	67	93.5	62	92	67	93.5
XXI.	I-SAR	PPD	62	92	67	93.5	62	92	67	93.5
XXII.	I-SB	PPL	72	82.5	75	87.4	72	82.8	71	81.3
XXIII.	I-SB	PPB	72	82.5	75	87.4	72	82.8	72	82.8
XXIV.	I-SB	PPD	72	82.5	75	87.4	72	82.8	72	82.8
XXV.	I-SL	PPL	70	84.1	66	80.1	69	84.6	71	87.4
XXVI.	I-SL	PPB	70	84.1	66	80.1	69	84.6	72	89.6
XXVII.	I-SL	PPD	70	84.1	66	80.1	69	84.6	71	87.4
XXVIII.	I-SP	PPL	73	84.3	75	87.4	71	81.3	74	85.8
XXIX.	I-SP	PPB	73	84.3	75	87.4	71	81.3	74	85.8
XXX.	I-SP	PPD	73	84.3	75	87.4	71	81.3	74	85.8

Table 7
Average Utilization Factor (which have Combination of Sheet and Item Orientation under Different Nature of Sheets and Items.)

Nature of Items	*Nature of Sheet*	*Average UF% (of five sets of the data)*			
		OL-IL	*OB-IL*	*OL-IB*	*OB-IB*
Regular	Regular	89.2	**89.7**	87.4	89.4
	Standard	86.4	**88.7**	88.4	88.4
	Tapered	85.5	86.3	83.4	**86.7**
Standard	Regular	89.9	**90.4**	89.6	88.6
	Standard	**90.4**	89.8	90.3	88.5
	Tapered	87.8	88.3	**89.1**	88.4
Tapered	Regular	87.1	**88.8**	87.6	87.1
	Standard	**88.7**	86.6	87.5	85.6
	Tapered	**86.7**	35	36.1	85.4

h) When the standard items are placed on the tapered sheet then OL-IB has average maximum utilization (89.1%).

i) When the tapered items are placed on the tapered sheet then OL-IL has average maximum utilization (86.7%).

It concludes from the Table 8:

a) When regular items placed on regular sheet then D-SB-PPL, D-SB-PPB and D-SB-PPD have average maximum utilization (95.3%).

b) When regular items placed on standard sheet then D-SB-PPL, D-SB-PPB and D-SB-PPD have average maximum utilization (93.2%).

c) When regular items placed on tapered sheet then D-SL-PPL, D-SL-PPB, D-SL-PPD, D-SP-PPL D-SP-PPB and D-SP-PPD has average maximum utilization (91.5%).

d) When the standard items are placed on the regular sheet then D-SA-PPL and D-SB-PPL has average maximum utilization (94.6%).

e) When the standard items are placed on the standard sheet then D-SA-PPL, D-SA-PPB, D-SA-PPD, D-SB-PPL, D-SB-PPB and D-SB-PPD has average maximum utilization (95.9%).

f) When the standard items are placed on the tapered sheet then D-SL-PPL, D-SL-PPB, D-SL-PPD, D-SA-PPL, D-SA-PPB and D-SA-PPD has average maximum utilization (94.2%).

g) When the tapered items are placed on the regular sheet then D-SL-PPL, D-SL-PPB, D-SL-PPD, D-SP-PPL, D-SP-PPB and D-SP-PPD has average maximum utilization (95.2%).

h) When the tapered items are placed on the standard sheet then D-SB-PPL, D-SB-PPB and D-SB-PPD has average maximum utilization (93.2%).

i) When the tapered items are placed on the tapered sheet then D-SAR-PPL, D-SAR-PPB and D-SAR-PPD has average maximum utilization (73.7%).

Table 8
Average Utilization Factor (UF%) of Different Sequencing Pattern and Different Sequencings of Pivot Points of Five Sets of Data

Nature of Item		*Regular*			*Standard*			*Tapered*		
Nature of Sheet		*Regular*	*Standard*	*Tapered*	*Regular*	*Standard*	*Tapered*	*Regular*	*Standard*	*Tapered*
PPL	D-SA	94.7	92.6	91.2	**94.6**	**95.9**	**94.2**	94.6	91.9	53.9
PPB	D-SA	94.7	92.5	91.2	94.2	**95.9**	**94.2**	94.6	91.9	53.9
PPD	D-SA	94.7	92.6	91.2	94.2	**95.9**	**94.2**	94.6	91.9	53.9
PPL	D-SAR	91.5	89.4	89.1	92.8	91.4	90.8	92.2	92.7	**73.7**
PPB	D-SAR	91.3	89.6	89	92.7	91.5	91.2	92.5	92.7	**73.7**
PPD	D-SAR	91.5	89.5	89.1	92.8	91.6	90.8	92.2	92.7	**73.7**
PPL	D-SB	**95.3**	**93.2**	90.4	**94.6**	**95.9**	93.9	94.5	**93.2**	54.7
PPB	D-SB	**95.3**	**93.2**	90.4	94.2	**95.9**	93.9	94.5	**93.2**	54.7
PPD	D-SB	**95.3**	**93.2**	90.4	94.2	**95.9**	93.9	94.5	**93.2**	54.7
PPL	D-SL	94.9	92.5	**91.5**	93.4	95.1	**94.2**	**95.2**	91.4	53.9
PPB	D-SL	95	92.5	**91.5**	93.4	95.1	**94.2**	**95.2**	91.4	53.9
PPD	D-SL	94.9	92.5	**91.5**	93.4	95.1	**94.2**	**95.2**	91.4	53.9
PPL	D-SP	94.7	92.6	**91.5**	94	95.5	93.9	**95.2**	91.4	53.9
PPB	D-SP	94.7	92.5	**91.5**	93.8	95.5	93.9	**95.2**	91.4	53.9
PPD	D-SP	94.7	92.6	**91.5**	93.8	95.5	93.9	**95.2**	91.4	53.9
PPL	I-SA	81.7	81.7	77.8	84.5	83.2	82.5	78.9	80	63.1
PPB	I-SA	81.6	82.0	77	84.3	83.2	82.3	79.5	79.7	63.1
PPD	I-SA	81.7	81.7	77.8	84.5	83.2	82.3	78.8	80	63.1
PPL	I-SAR	89.2	89.7	87.4	90	89.8	88	89	90.3	64.8
PPB	I-SAR	89.7	89.2	87.4	90	89.8	88.1	89	90.3	64.5
PPD	I-SAR	89.4	89.2	87.6	90.1	89.8	88	89	90.3	64.8
PPL	I-SB	81.8	81.7	79.5	84.5	83.2	82.5	78.7	80.2	63.6
PPB	I-SB	81.7	82.7	79.6	84.3	83.2	82.3	78.7	79.9	63.6
PPD	I-SB	81.8	81.9	79.5	84.5	83.2	82.3	78.7	80.2	63.6
PPL	I-SL	83.6	83.5	78.2	84.4	82.7	81.7	78.9	80	63.1
PPB	I-SL	83.8	83.8	78.4	84.4	83.2	81.7	79.5	79.7	63.1
PPD	I-SL	83.6	83.5	78.2	84.4	83.2	81.7	78.8	80	63.1
PPL	I-SP	81.5	82.2	78.2	84.4	83.9	82.5	78.9	80	63.1
PPB	I-SP	81.5	82.5	77.9	84.4	83.9	82.5	79.5	79.7	63.1
PPD	I-SP	81.5	82.2	78.7	84.4	83.9	82.5	78.8	80	63.1

Now recommendations on selection of best heuristic for various combinations are summarised in Table 9. From Table 7 it is concluded that as the L/B ratio of sheet increases, the average utilization factor decreases, it is not depend on the L/B ratio of the items.

Table 9
Selection of Heuristic

Nature of Sheet	*Nature of Items*						
Regular	Regular	OB-IL-D-SB-PPL	OB-IL-D-SB-PPD	OB-IL-D-SB-PPD			
	Standard	OB-IL-D-SA-PPL	OB-IL-D-SB-PPL				
	Tapered	OB-IL-D-SL-PPL	OB-IL-D-SL-PPB	OB-IL-D-SL-PPD	OB-IL-D-SP-PPL	OB-IL-D-SP-PPB	OB-IL-D-SP-PPD
Standard	Regular	OB-IL-D-SB-PPL	OB-IL-D-SB-PPB	OB-IL-D-SB-PPD			
	Standard	OL-IL-D-SA-PPL	OL-IL-D-SA-PPD	OL-IL-D-SA-PPD	OL-IL-D-SB-PPL	OL-IL-D-SB-PPB	OL-IL-D-SB-PPD
	Tapered	OL-IL-D-SB-PPL	OL-IL-D-SB-PPB	OL-IL-D-SB-PPD			
Tapered	Regular	OB-IB-D-SL-PPL	OB-IB-D-SL-PPB	OB-IB-D-SL-PPD	OB-IB-D-SP-PPL	OB-IB-D-SP-PPB	OB-IB-D-SP-PPD
	Standard	OL-IB-D-SL-PPL	OL-IB-D-SL-PPB	OL-IB-D-SL-PPD	OL-IB-D-SA-PPL	OL-IB-D-SA-PPD	OL-IB-D-SA-PPD
	Tapered	OL-IL-D-SAR-PPL	OL-IL-D-SAR-PPB	OL-IL-D-SAR-PPD			

5. CONCLUSION AND FUTURE WORK

In the present study revised heuristic algorithm are used to generate 120 feasible patterns on the basis of orientation of first item, orientation of sheet, sequencing of items and pivot points. Items and sheet are classified into three categories (regular, standard and tapered) on the basis of L/B ratio of item/sheet. Different natures of items are placed on different nature of sheets. Here nine sets of patterns investigated on the basis of different nature of items and sheets. For each combination of items and sheets five sets of pattern randomly generated. By processing the data of five sets average values of utilization is calculated for each combination and conclude that it is not necessary that for each combination 120 feasible patterns are generated, heuristic which give minimum trim loss will be used. The experimental results demonstrate

- As the L/B ratio of ***sheet*** increases, the average utilization factor decrease and does not depend upon the L/B ratio of the item.
- When the regular items are placed on regular sheet then heuristic OB-IL-D-SB-PPD give the maximum utilization.
- When the standard items are placed on regular sheet then heuristic OB-IL-D-SA-PPL and OB-IL-D-SB-PPL gives the maximum utilization.
- When the standard items are placed on regular sheet then heuristics OB-IL-D-SL-PPL, OB-IL-D-SL-PPB, OB-IL-D-SL-PPD, OB-IL-D-SP-PPL, OB-IL-D-SP-PPB and OB-IL-D-SP-PPD gives the maximum utilization.
- When the regular items are placed on standard sheet then heuristic OB-IL-D-SB-PPB give the maximum utilization.
- When the standard items are placed on standard sheet then heuristics OL-IL-D-SA-PPL, OL-IL-D-SA-PPD, OL-IL-D-SA-PPL and OL-IL-D-SA-PPD gives the maximum utilization.
- When the tapered items are placed on standard sheet then heuristics OL-IL-D-SB-PPL, OL-IL-D-SB-PPB and OL-IL-D-SB-PPD gives the maximum utilization.
- When the regular items are placed on tapered sheet then heuristic OB-IB-D-SL-PPB give the maximum utilization.
- When the standard items are placed on tapered sheet then heuristics OL-IB-D-SL-PPL, OL-IB-D-SL-PPB and OL-IB-D-SL-PPD gives the maximum utilization.
- When the tapered items are placed on tapered sheet then heuristics OL-IL-D-SAR-PPL, OL-IL-D-SAR-PPB and OL-IL-D-SAR-PPD gives the maximum utilization.

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