IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-10, Oct 2018 E-ISSN: 2347-2693

One Dimensional Cutting Stock Problem (1D-CSP): A New approach for Sustainable Trim Loss

P. L. Powar[1*], Siby Samuel[2]

[1*]Dept. of Mathematics & Computer Science, Rani Durgavati University, Jabalpur, M.P., India
[2]Department of Computer Science, St. Aloysius College, Jabalpur, M.P., India

[*]*Corresponding Author: pvjrdvv@rediffmail.com*

Available online at: www.ijcseonline.org

Accepted: 16/Oct/2018, Published: 31/Oct/2018

Abstract- Given the stock lengths $U_j, j = 1,2, \dots, n$, this paper computes the total trim loss of One-dimensional-cutting stock problem (1D-CSP) by considering the cutting plan of at most two order lengths at a time of the required order lengths $l_1, l_2, \dots, l_n$. The Total Trim Loss (TTL) is computed by fixing a variable t as the percentage of the Pre-Defined Sustainable Trim Loss(PDSTL) on the given stock by the industry.

In view of the past experience, it has been noticed that the trim loss up to 3% is viable for the smooth running of the industry. Hence, we consider 3 as the upper bound of the pre-defined sustainable trim t. Considering the variable $t: 0.5 \leq t \leq 3$ with the stepping of 0.5 as the nodal points in the domain, we have first computed the corresponding TTL and plotted these points in the range. With this information, Lagrange Interpolation method has been applied to predict the TTL at any arbitrary point $(0.5 \leq t \leq 3)$.

Keywords: Pre-Defined Sustainable Trim Loss, Sustainable Trim Loss, Lagrange interpolation approximation, Total Trim Loss

I. INTRODUCTION

Industries are facing many problems nowadays with focus to 'optimal' solution. One such problem in concern is Cutting Stock Problem (CSP). It is referred as cutting required items from a fixed size called stock of bars, sheets etc. with an aim to minimize the waste of raw material. Therefore the optimization in CSP plays a significant role in the cost-effective functioning of the industries.

Methods of optimization was primarily initiated and proposed by Gilmore and Gomory in 1960, 1963 and 1965 (see[6], [7] and [8] which was found to be unfeasible due to large number of arrangements of cutting patterns. And later many heuristic methods have been developed with a purpose to minimize the waste. We now consider the current findings in this field-

A process flowchart technique was proposed by Erjavec et al. in 2009 [5] in which the authors compared as-was and as-is states using a simulation model and provided an estimate of the trim loss along with other production costs. In 2010, Alem et al. [1] framed two-stage stochastic nonlinear program in which the objective was to minimize the probable cost acquired at both the stages due to waste and holding of orders. Dikili et al. in 2011 [4] proposed a generalized method for optimization of One-Dimensional Cutting Stock Problem (1DCSP), in which the authors considered the feasible cutting arrangements by eliminating majority of the possible inefficient cutting plans thus rendering the problem solvable for practical applications. Suliman (2012) [12] combined lot sizing with cutting stock problem and considered lot sizing for each period and then best cutting patterns were generated and also considered available capacity, scheduling periods and purchase cost burden index. CSP with Setup cost was introduced by Mobasher et al. in 2013 [10], in which the authors had considered different cost factors for the material and the number of setups with objective to minimize the total production cost. Araujo et al. (2014) [2] proposed a heuristic method based on the concept of genetic algorithm using randomly and practically generated instances obtained from chemical-fiber company with an aim to minimize the number of objects and the number of different cutting patterns. In 2015 Arenales et al. [3] considers cutting stock / leftover problem (CSLP) in which the stock leftovers are not considered as waste in the current period whereas used to meet the new demands in next period. In 2017 Rodrigo et al.[12] suggested Modified Brach and Bound algorithm for 1DCSP and derived Cartesian coordinate points for the developed algorithm. In 2018 Ibrahim et al. [9] proposed a two stage extension of 1DCSP in which the demands of the order lengths on finished rolls was done through two successive cutting processes, in which stock leftover in the former were used as input for the next cutting plan, with the aim to minimize the number of stock used.

In this paper we have a developed a mathematical model to organize the cutting plan which consists of cutting of at most two order lengths at a time of the required n order lengths $l_1, l_2, \ldots, l_n$ from the given m stock $U_1, U_2, \ldots, U_m$. At each stage of cutting, the stock used is checked against the sustainable trim loss computed, since the perception of sustainable trim loss plays a vital role in monitoring the total trim.

Lagrange Approximation is a well-known approximation method which we have introduced in our method to interpolate the values approximately for the given set of points (x_i, y_i). The x_i corresponds to sustainable trim loss and y_i corresponds to total trim loss being computed considering a range of pre-defined sustainable trim percent that is acceptable by the industry. Using the above approximation method on any generated arbitrary set of data, the value of the approximate trim loss can be predicted in accordance with the proposed cutting plan.

This paper is organized as follows: Section II describes the problem definition and mathematical formulation, Section III briefs the algorithm of the model, Section IV elaborates the practical approach of the model on the actual data obtained from a Transmission tower industry, Section V deals with a comparative study of this model with a model being developed by Powar et al. [11], Section VI gives the study of finding the feasibility of sustainable trim loss using approximation method and the succeeding section VII concludes the study.

II.PROBLEM DEFINITION AND MATHEMATICAL FORMULATION

It is considered that for every customer order, sufficiently large stocks of material of different lengths are available. The model is demonstrated for 1DCSP and our study is focused on Transmission tower manufacturing Industry. We propose cutting plan with cutting at most two order lengths at a time considering the working space restraint and manpower constraint of sorting the scrape.

We are now set to define our problem exclusively as follows:

Given notations are-

$l_i -$ the order lengths; $i = 1,2, \ldots, n$ (arranged in descending order with respect to length; $l_1 \geq l_2 \geq l_3$ ...),

$d_i -$ required number of pieces of order length l_i,

$U_j -$ stock lengths; $j = 1, 2, \ldots, m$; the lower bound and upper bound of stock varies from 7mts to 14 mts respectively; m depends on the cutting process for a particular dataset.

t_j – refers the trim loss corresponding to the stock U_j used to cut the corresponding combinations of order length.

t_s^l - computed sustainable trim loss based on PDSTL by the industry,

$U_{ij} -$ combinations of order length l_i and l_j to be cut come stock U_j ; $i, j \in BLK(n)$ when $BLK(n)$ is block of integers ; $1,2, \ldots, n$

$p_{ij} -$ pieces of order length l_i being cut from the stock U_j,

A. *Sustainable trim loss* t_s^l

Sustainable trim loss is computed depending on the PDSTL of the industry. The profit sustainability of the industry depends on, up to what range we can allow the raw material, convert to scrape after the cutting plan.

Note: The scrape (trim loss t) affordable by the industry is up to 3% for its smooth and profitable functioning.

Given the stock length U_j, the sustainable trim loss t_s^l is computed as-

$$L_j = \frac{t}{100} * U_j \; ; \; j = 1,2, \ldots, m; \; t \leq 3 \qquad (2.1)$$

We finally define

$$t_s^l = \frac{\sum_{j=1}^{m} L_j}{m} \qquad (2.2)$$

which is desired sustainable trim loss.

Now we design a mathematical model keeping in view the practical approach of cutting process in Tower industry which is as follows: .

Objective: To minimize the trim loss when a combination U_{ij} of an order lengths l_i and l_j is cut from a given stock U_j. We define the model as:

$$min \sum_{j=1}^{k} t_j \quad \text{(minimization of trim loss)} \qquad (2.3)$$

$$t_j \geq 0 \quad \forall j$$

subject to the condition

$$U_{ij} = \max_j \{ U_{ij} = \alpha l_i + \beta l_j ; i = 1, j = 2, \ldots, n \; ; i < j; \; \alpha, \beta \text{ are non-negative numbers} \} \qquad (2.4)$$

Note: i is assumed to be 1, because the order length l_1 being the largest among all order length is considered to be cut at the initial stages.

$$\sum_{j=1}^{k} p_{ij} = d_i \quad \text{(demand constraint)} \qquad (2.5)$$

where

$$p_{ij} = \begin{cases} =0, \text{ if the order length } l_i \text{ is not cut from the stock length } U_j \\ >0 \text{ (integer), if the order length } l_i \text{ is cut from the stock length } U_j \end{cases}$$

$$t_j = min(U_j - U_{ij}) \leq t_s^l ; \quad \text{for some values of } j. \qquad (2.6)$$

Note: t_s^l is computed sustainable trim loss (cf. (2.1) and (2.2))

At the outset the combinations are obtained by combining the order length l_1 and with rest of the order lengths i.e., $l_j \; where \; j = 2,3, \ldots n$. The order length l_1 (being

the largest in the order list) is considered to be cut at the initial stage of the cutting process and assumed that smaller lengths can be adjusted easily later in the cutting plan.
So we define: $U_{1j} = \alpha l_1 + \beta l_j$ for $1 \neq j$; α, β are non-negative integers; $j = 2,3 \ldots, n$. Now select the combination of the order lengths with the maximum value which is within the range of $u = 7\ mtrs\ and\ U = 14mtrs$.
Remark:

- The lower bound of the stock feasible by the industry is 7 meters as the stock less than this is not feasible by the supplier
- The upper bound of the stock cannot exceed 14 meter, due to the limitations of transportation.

i.e., $\$ = \{U_{1j} : u \leq U_{1j} \leq U\}$
Now select the stock length to cut the combination such that
$\min\left(U_j - U_{1j}\right) \leq t_s^l$ (2.7)
is assumed to be the first stock length U_1 from which α, β times the l_1 and l_j respectively can be cut.

B. Cutting Plan
Combinations U_{1j} are prepared amongst the order length l_1 and l_j; $j = 2,3, \ldots, n$, then select $7 \leq \max\left(U_{ij}\right) \leq 14$ for some values of j
Then, select from given U_j the appropriate stock length such that it satisfies (2.7)

Now get the corresponding order lengths l_1 and l_j along with the analogous required number of pieces d_1 and d_j for the combination U_{1j}. There may be three cases to be considered for further cutting plan:

1. The number of the required pieces d_1 and d_j of the order lengths l_1 and l_j respectively are completely cut for fixed j when the required piece of both order lengths are same.
2. The required pieces d_1 of order length l_1 is less than required number d_j of order length l_j, therefore in this case the cutting process of l_1 is completed and for l_j order length, $d_j - d_1$ required number of pieces are left to cut.
3. When the required number of pieces d_1 of order length l_1 is more that l_j, then the cutting process of l_j is completed and for l_1 order length, $d_1 - d_j$ required number of pieces are left for cutting.

One of the case will exists from above three cases, for all values of j under the condition (2.7).

Coming across the first condition, we will be left with remaining $(n-2)$ order lengths whose combinations are again made with order lengths arranged in descending order for generating the cutting pattern keeping in mind the sustainable trim loss
$.t_j = [U_j - (\max_j \{ U_{ij} = \alpha l_i + \beta l_j ; i = 1, j = 2, \ldots, n ; i < j\})] \leq t_s^l$ (2.8)
Refer (2.1) and (2.2) for t_s^l

Considering the second condition, the order length l_1 is completely cut, therefore the order length l_1 along with its required number of pieces d_1 are removed from the order list with remaining $n-1$ orders to be processed. Again the combinations are made with $n-1$ order list and the process is continued to satisfy (2.8).

In case of third condition the order length l_j is completely exhausted, therefore the order length l_j along with required number of pieces d_j are eliminated from the order list left with $n-1$ order list with l_1 as the largest order length. The process is continued till all the order lengths with required number of pieces are exhausted.
At the end of the cutting process we may come across with the following situations viz.,

1. the combination U_{1j} made does not satisfy (2.8), then consider $\beta = 0$.
2. only few pieces of single order length is left, then choose stock length U_j such that the waste is minimum although it may not satisfy (2.8).

III. ALGORITHM

1. Read the order length l_i and the required number of pieces d_i and arrange them in descending order; $= 1,2, \ldots, n$.
2. Read the available stock length U_j.
3. for t=0.5 to 3
4. do while $(n > 0)$
5. for $i = 1\ to\ n-1$
6. for $j = 2\ to\ n$
7. calculate $U_{ij} = \alpha l_1 + \beta l_j$; α, β are positive integers
8. goto 4 for $j \leq n$
9. goto 3 for $i \leq n-1$
10. select $U_{ij} = \max_j \left(U_{ij} : u \leq U_{ij} \leq U \right)$
11. check U_{ij} in U_j list and fetch $U_{ij} \geq U_j$
12. then calculate $t_s^p = \frac{t * U_j}{100}$
13. if $t_j = min(U_j - U_{ij} \leq t_s^p)$

Note: Proceed for cutting plan;

14. select $U_{ij} \geq U_j$
15. check l_i, l_j with corresponding d_i, d_j analogous to U_{ij}

Note: for l_i, d_i ; $i = 1$; for almost all cases.

16. if $d_1 = d_j$
17. remove $l_i, l_j\ and\ d_i, d_j$ from the order list.
18. $n = n - 2$
19. if $d_1 < d_j$
20. remove $l_1\ and\ d_1$ and update $d_j = d_j - d_1$
21. $n - -$
22. if $d_1 > d_j$
23. remove $l_j\ and\ d_j$ and update $d_1 = d_1 - d_j$

24. $n--$
25. if $U_{ij} \leq u$
26. select $U_j = 700$ to cut U_{ij}
27. calculate $gt_j = gt_j + t_j$
28. go to line no 4 till $l_i = 0,\ d_i = 0$
29. print U_j, gt_j
30. check for t then go to line no 3.

IV. Illustrative Example

A practical demonstration of the above algorithm has been illustrated on the data set being used by Powar et al. (2013) [11] which is a real time Transmission tower industry data. This industry accepts up to 2% scrape for smooth running with moderate profit. The order lengths and stocks have been considered in centimeters.

Note: Sustainable trim loss in industries is acceptable upto 3%.

TABLE 4.1: Required Order lengths

i	*Order lengths l_i (in cms)*	*Required No. of pieces d_i(in cms)*	*i*	*Order lengths l_i (in cms)*	*Required No. of pieces d_i(in cms)*
1	890	36	6	550	39
2	800	13	7	460	21
3	750	24	8	400	47
4	660	16	9	310	40
5	640	23	10	230	32

Table 4.2: Details of available stock length and sustainable trim loss

j	*Stock lengths U_j (in cms)*	j	*Stock lengths U_j (in cms)*	Sustainable trim loss at 2% t_s^l *(in cms)*
1	700	8	1050	21.00
2	750	9	1100	
3	800	10	1150	
4	850	11	1200	
5	900	12	1250	
6	950	13	1300	
7	1000	14	1350	
		15	1400	

At the onset compute sustainable trim loss t_s^l at 2%, referring (2.1) and (2.2) for the stock lengths (Table 4.2).

$$t_s^l = 21$$

Arrange the order list l_1 along with d_i in descending order. The first iteration starts with determining the combination $U_{1j} = \alpha l_1 + \beta l_j$ that satisfies (2.4). Then check its feasibility for particular U_j with sustainable trim loss that satisfies (2.8). First combination that satisfies (2.8) is $U_{1,10}$ with corresponding order lengths $l_1 = 890$ and $l_{10} = 230$; $\alpha = 1, \beta = 2$, is being cut using the stock $U_j = 1350$. The number of pieces of U_j used to cut $d_1 = 36$ of l_1 and $d_{10} = 32$ of l_{10} is 16, then this iteration continues to check various cases from section 2.1 It satisfies the condition $d_1 > d_{10}$. Therefore, the required number of pieces of $l_{10} = 230$ is completely cut, thereby eliminating l_{10}, d_{10} from the order list with $d_1 = 20$ corresponding to l_1 left to cut.

Again arrange the order list in descending order preparing for second iteration with combination U_{1j}, comprising of $l_1 = 890$ and $l_7 = 460$ (considering to cut the bigger order lengths at the initial steps) with $d_1 = 20, d_7 = 21$ ($d_1 = 20$ is left after the first iteration); $\alpha = \beta = 1$. This combination is cut using the stock $U_j = 1350$ which satisfies (2.8). In this iteration l_1 is completely cut and is removed along with d_1 from the order list and l_7 left with $d_7 = 1$. The process is continued with iterations of making combinations and cutting plans that satisfies (2.8) until all $l_i = d_i = 0$. Table 4.3 refers to the cutting plan at 2% sustainable trim loss.

Table 4.3. Cutting plan at 2% sustainable trim loss

S.No	Order lengths in cm	Pieces to cut	Stock used *(in cms)*	No. of stock used	Trim loss in cms	Used stock length in cms
1	890	36	1350	16	0	21600
	230	32				
2	890	20	1350	20	0	27000
	460	21				
3	800	13	1350	13	0	17550
	550	39				
4	750	24	1300	24	0	31200
	550	26				
5	660	16	1300	16	20	20800
	640	23				
6	640	7	1100	1	0	1100
	460	1				
7	640	6	950	6	0	5700
	310	40				
8	550	2	1350	2	0	2700
	400	47				
9	400	43	1350	11	220	14850
	310	34				
10	400	32	1200	10	0	12000
11	400	2	1150	1	40	1150
	310	1				
Total trim loss / total stock used					260	155650
Trim loss %						0.1670

The trim loss % computed on given required number of order lengths is 0.1670. The total trim loss may vary for different data sets. Table 4.4 refers to the total stock length used to cut the required number of order lengths described in Table 4.1.

Table 4.4: Total stock length used

U_j (in cms)	Total pieces of U_j	l_i (in cms)	No. of pieces d_i cut
1350	62	890	36
		230	32
		460	20
		800	13
		550	15
		400	15
		310	33

1300	40	750	24
		550	24
		660	16
		640	16
1200	10	400	30
1110	1	400	2
		310	1
1100	1	640	1
		460	1
950	6	640	6
		310	6

V. COMPARATIVE STUDY

We made a relative study of this anticipated model with the model been defined by Powar et al. (2013) [13]. They computed sustainable trim loss based on the weighted mean of the order length. The cutting pattern generated was based on two criteria, first the required numbers of pieces of order lengths are integral multiples of each other and second the required pieces of order lengths are in prime number. The assessments of both the models are done on the basis of total stock length, cutting dimensions, sustainable trim loss, and total trim loss.

Table 5.1: Cutting Plan as derived by Powar [13]

S.No	Order Lengths (in cm)	Required no. of pieces cut	Stock used	Trim loss (in cm)	Total stock length (in cms)
1	230	32	1150	480	1150 x 16 = 18400
	660	16			
2	750	24	750	0	750 x 24 = 18000
3	800	13	800	0	800 x 13 = 10400
4	310	36	1200	0	1200 x 36 = 43200
	890	36			
5	310	4	1250	10	1250 x 1 = 1250
6	400	39	950	0	950 x 39 = 37050
	550	39			
7	400	8	800	0	80 x 4 = 3200
8	460	21	1100	0	1100 x 21 = 23100
	640	21			
9	640	2	1300	20	1300 x 1 = 1300
Total trim loss / stock length				510	155900
Total trim loss %					0.33%

Based on the analysis, it was inferred that on the given data set, refer Table (4.1) and (4.2), trim loss computed using the proposed model is better than the model been suggested by Powar [11], since the total trim loss (TTL) calculated by [11] is 0.33% and the TTL calculated by the proposed model is 0.1670%. The authors of the proposed model also deduced that the computation of sustainable trim loss in the proposed model is more feasible as it has produced fewer scrape than being computed using the weighted mean of the given order lengths [11].

VI. Finding feasibility of sustainable trim loss using approximation method

Approximation methods are of great concern in cutting stock problem domain to understand the variance of the trim loss with in the expected range of sustainable trim loss of the industry ($\leq 3\%$). There are many approximation methods available, but Lagrange approximation method has practical significance, when given data points y_i corresponding to the points x_i, where no two values of x_i are equal and the intervals between the points may not be regular.
Given a set of $k+1$ data points

$$(x_0, y_0), \ldots, (x_i, y_i), \ldots, (x_k, y_k)$$

where no two x_i are the same, the interpolation polynomial in the Lagrange form is a linear combination

$$L(x) = \sum_{i=0}^{k} y_i l_i(x)$$

of Lagrange basis polynomials

$$l_i(x) = \prod_{\substack{0 \leq m \leq k \\ m \neq i}} \frac{x - x_m}{x_i - x_m}$$

$$= \frac{(x - x_0)}{(x_i - x_0)} \cdots \frac{(x - x_{i-1})}{x_i - x_{i-1}} \frac{(x - x_{i+1})}{(x_i - x_{i+1})} \; ; \; 0 \leq i \leq k$$

Given the initial assumption that no two $x_i s$ are the same, $x_i - x_m \neq 0 : i \neq m.$ (6.1)
Hence the use of this approximation in cutting stock problem domain is viable due to (6.1)

6.1 Application

For a given data set refer (Table 4.2), the sustainable trim loss (STL) is computed using (2.1) and (2.2) based on the pre-defined sustainable trim loss (PDSTL) by the industry. For the smooth functioning of the industry, PDSTL is accepted up to 3%. Initially, the sustainable trim loss has been computed from 0.5% say Δ_0 having minimum scrape to 3% say Δ_n having maximum scrape. Therefore, we consider a closed interval $[\Delta_0, \Delta_n]$ on STL with difference of 0.5 between consecutive points, let it be defined by ρ such that:

$$\rho = \Delta_0 < \Delta_1 < \cdots < \Delta_n \quad (6.2)$$

Corresponding to each $\Delta_i (i = 0, \ldots, n)$, the total trim loss say Δ_i^t is computed referring section 3.

Therefore we obtain the following total trim loss Δ_i^t on the corresponding Δ_i.

Table 6.1

S.No	PDSTL in %	Sustainable trims Δ_i	Total trim in % Δ_i^t
1	0.5	5.25	0.07074
2	1	10.5	0.07074
3	1.5	15.8	0.07074
4	2	21	0.16704
5	2.5	26.3	0.16704
6	3	31.5	0.16704

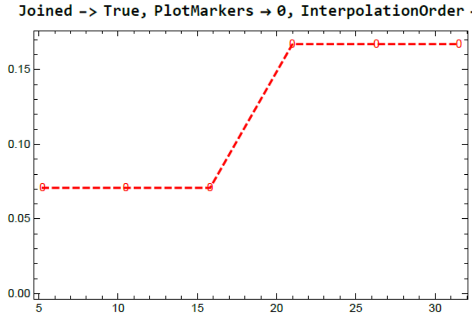
The sustainable trims Δ_i generated satisfies (6.2), such that

$$\rho = \Delta_0(5.25) < \Delta_1(10.5) < \Delta_2(15.8) < \Delta_3(21) < \Delta_4(26.3) < \Delta_5(31.5)$$

Based on the study, we comprehend that the total trim loss remain constant for PDSTL that range from 0.5% to 1.5%, later from 2% above, there is increase in trim loss, refer Table 6.1 and this increase we observed to be constant till 3%, which is assumed to be the maximum PDSTL.

```
x = {5.25, 10.5, 15.8, 21, 26.3, 31.5};
y = {0.07074, 0.07074, 0.07074, 0.16704, 0.16704, 0.16704};

ListPlot[Transpose[{x, y}], PlotStyle → {Red, Dashed}, Frame → True,
 Joined -> True, PlotMarkers → 0, InterpolationOrder → 1, PlotRange → All]
```



Graph 6.1

The graph depicts the change that occurs when the pre-defined sustainable trim loss increment from 1.5% to 2%. Further the authors used Lagrange approximation to apprehend points of gradual increase of total trim loss that lie between 1.5% and 2%, refer Table 6.2.

Table 6.2

S.No	PDSTL in %	Sustainable trims Δ_i	Total trim in % Δ_i^t
1	0.5	5.25	0.07074
2	1	10.5	0.07074
3	1.5	15.8	0.07074
4	1.6	16.8	0.08728
5	1.7	17.8	0.10766
6	1.8	18.9	0.12917
7	1.9	19.9	0.14961
8	2	21	0.16704
9	2.5	26.3	0.16704
10	3	31.5	0.16704

It was been observed that at every point of STL lying between 1.5% to2% has a gradual increase in TTL. This observation can help the Industry to predict the total trim loss and also to understand the range of sustainable trim loss at any arbitrary point within the range of PDSTL which can be used to predict the STL for the smooth functioning of the industry.

VII. CONCLUSION

From the study we infer that PDSTL plays a very significant role in determining the feasibility of the cutting patterns of the required number of order lengths from a given stock length. Using 2% PDSTL the model proposed t_s^p using which STL and TTL were computed. Further, with the application of approximation method we observed that this concept will be useful for the industries to select the appropriate cutting plan by varying the conditions on the sustainable trim.

REFERENCES

[1]. Alem Douglas José, Munari Pedro Augusto, Arenales Marcos Nereu, Ferreira Paulo Augusto Valente, "On the cutting stock problem under stochastic demand", Annals of Operations Research, vol. 179 (1), pp. 169-186, 2010.

[2]. Araujo Silvio Alexandre de, Poldi Kelly Cristina, Smith Jim, "A Genetic Algorithm for the One-Dimensional Cutting Stock Problem with Setups", Pesquisa Operacional, vol. 34(2) pp. 165-187, 2014.

[3]. Arenales, M. N., Cherri, A. C., Nascimento, D. N. do, & Vianna, A., "A New Mathematical Model for the Cutting Stock/Leftover Problem", Pesquisa Operacional, vol. 35(3), pp. 509–522, 2015.

[4]. Dikili Ahmet Cemil, Barlas Baris, "A Generalized approach to the solution of One-Dimensional Stock-Cutting Problem for Small Shipyards", Journal of Marine Science and Technology, vol. 19, no. 4, pp. 368-376, 2011.

[5]. Erjavec, J., Miro Gradišar, Trkman Peter, "Renovation of the Cutting Stock Process", International Journal of Production Research, vol. 47(14), pp. 3979-3996, 2009.

[6]. Gilmore, P. C. and Gomory, R. E., "A linear programming approach to the cutting-stock problem", Operations Research, vol. 9, pp. 849-859, 1961.

[7]. Gilmore, P. C. and Gomory, R. E., "A linear programming approach to the cutting-stock problem Part II", Operations Research, vol. 11, pp. 863-888, 1963.

[8]. Gilmore, P. C. and Gomory, R. E., "Multi-stage cutting-stock problems of two or more dimensions", Operations Research, vol. 13, pp. 94-120, 1965.

[9]. Ibrahim Muter, Zeynep Sezer "Algorithms for the One-Dimensional Two-Stage Cutting Stock Problem", European Journal of Operational Research, vol 271(1), pp. 20-32, 2018.

[10]. Mobasher A.,Ekici A., "Solution approaches for the cutting stock problem with setup cost", Journal Computers and Operations Research, vol. 40(1), pp. 225-235, 2013.

[11]. Powar P.L., Jain V., Saraf M., Vishwakarma R., "One-Dimensional Cutting Stock Problem with First Order Sustainable Trim: A Practical Approach," International Journal of Computer Science Engineering and Information Technology Research, vol. 3(3), pp. 227-240, 2013.

[12]. Rodrigo N., Shashikala S., "One-Dimensional Cutting Stock Problem with Cartesian Coordinate Points", International Journal of Systems Science and Applied Mathematics, vol 2(5), pp: 99-104, 2017.
[13]. Suliman S. M. A., "An Algorithm for Solving Lot Sizing and Cutting Stock Problem within Aluminum Fabrication Industry", Proceedings of the International Conference on Industrial Engineering and Operations Management Istanbul, Turkey, July 3 –6, pp. 783-789, 2012.

Author Profiles

P. L. Powar received her M.Sc. and Ph.D. in Mathematics form Rani Durgavati University, Jabalpur, India. Currently, she is a Professor in Department of Mathematics and Computer Science, Rani Durgavati University, Jabalpur, India. Her research areas are Cutting Stock Problem, Spline Approximation Theory, Finite Element Methods, Software Engineering and Topology.

Siby Samuel received her M.Phil(Computer Science) from Rani Durgavati University, Jabalpur, India. Presently persuing Ph.D. in Computer Science. Her research domain is Cutting Stock Problem.