

A Cutting Plan of One-Dimensional Materials to Reduce Loss with Matlab Software

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Abstract

This study aims to address the One-Dimensional Cutting Stock Problem (1D-CSP) by developing an optimized approach for designing cutting plans for one-dimensional construction materials with the primary goal of minimizing material waste during the cutting process. The methodology involves the implementation of a Matlab algorithm based on linear programming principles and uses data derived from previous studies to formulate efficient cut-off plans. The investigation entails an analysis of the collected data from relevant studies, focusing on total material consumption and loss within the cutting plans. The study begins by considering foundational variables, which encompass the length of the standard linear inventory, the required lengths for each type, and the overall quantity of required lengths. These parameters are then processed using Matlab software to establish a solution through linear programming. The comparative analysis involves evaluating the collected data to demonstrate the advantages of the proposed model. This comparison encompasses the assessment of standard linear inventory utilization, material utilization effectiveness, and the residual waste generated during the cutting process. In comparison to the first relevant research, the developed method yields a material cutting plan with a loss rate of 1.21%, requiring less than one standard linear material inventory—improving upon the original result of 1.24%. Similarly, when compared to the second relevant study involving ten cases, the developed method generates a material cutting plan with a loss rate of 6.45%, utilizing fewer than three standard linear materials.

Keywords

One Dimensional Cutting Stock Problem (1D-CSP), Cutting Plan, Cutting loss, linear programming, Matlab software

1. Introduction

Today's businesses are highly competitive, and cutting production costs is one way to gain a competitive advantage. Cutting production costs to a minimum while maintaining or increasing production efficiency and effectiveness is another way to gain a competitive advantage. Reduced depreciation and material costs should also be prioritized because the cost of raw materials is typically the highest. As a result, it is clear that if we are successful in lowering costs and developing effective strategies, the overall cost of doing business can be reduced (Vacharapoom 2013). Furthermore, the general manufacturing industry requires one-dimensional linear materials, which result in a large number of losses in the cutting process as well as a constant increase in labor costs and inflation, which raises the cost of raw materials. And then there is the issue of waste from production, which is waste from creating a linear material cutting plan. As a result, this issue must be addressed immediately. There are also issues with the impact of COVID-19, the US-China trade war, and the Russian-Ukrainian state war, all of which have significantly impacted the industrial cost of steel required. As a result, one of the most direct solutions to the problem is the cost-effective use of one-dimensional linear materials with minimal loss. Another advantage is that it reduces environmental problems by reducing waste and scrap from construction materials.

In addition to the rebar examples mentioned above, many other materials are also utilized in construction. One-dimensional construction materials constitute a primary group of materials with usage characteristics that result in trimming losses, making them one of the sources of the highest waste. This Cutting Stock Problem (CSP) or Bin Packing Problem (BPP) (Naratip 2007), occurs in a variety of manufacturing industries. A model has been created to solve the problem, and several algorithms have been proposed. However, there is still research to be conducted in order to create a linear cutting solution model tailored for specific construction projects, along with the development of a suitable solution corresponding to the constructed model.

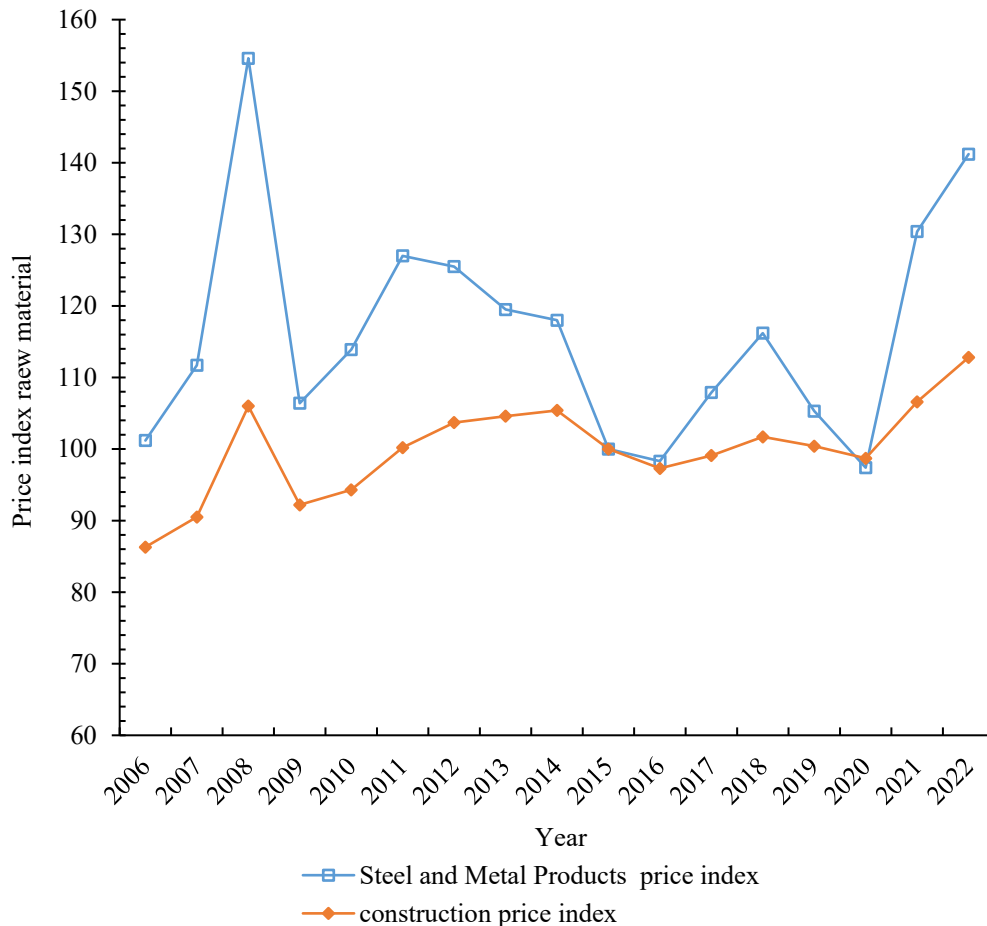


Figure 1. A statistical chart comparing the price of construction materials overall to the price of iron and steel

The challenge of cutting one-dimensional linear materials arises in various industries, particularly when dealing with single-criterion lengths such as steel rods, aluminum rods, steel pipes, PVC pipes, wooden rods, and others (Vacharapoom 2013). The issue is that raw material or one-dimensional material must be cut to the required length. Material cutting must be planned in order to use the fewest raw materials and produce the least waste. The goal is to minimize waste and maximize financial savings. In practice, it is discovered that there will be a variety of requirements in the material's details, namely the length, number required, and type of one-dimensional linear material that must be cut differently.

The researcher has drawn insights from previous studies, resulting in a research design that encompasses the following areas: A cutting plan of one-dimensional construction materials to reduce loss in construction projects (Vacharapoom, 2013) and investigating cutting-related challenges Heuristic Approaches for One Dimensional Cutting Stock Problems (Nuch Sara and Preecha 2009) through Matlab software to discover the optimal solution for the linear one-dimensional material segmentation issue. In order to draw comparisons with various techniques explored in prior research, researchers developed one-dimensional linear cutting schemes grounded in the principles of Linear Programming. Furthermore, the methodology used to generate one-dimensional linear material cutting plans using the developed

Matlab software can serve as both an educational resource and a problem-solving tool for manufacturers that are charged with developing cutting plans for one-dimensional linear materials (Niluka and Sium 2017).

2. Methodology

This study develops a one-dimensional linear material cutting plan using Matlab software principles. It addresses the broader linear material cutting problem, analyzes results, and compares conventional consumption practices with enhanced cutting efficiency strategies. The emphasis is on minimizing cutting margins. This is shown in picture 2.

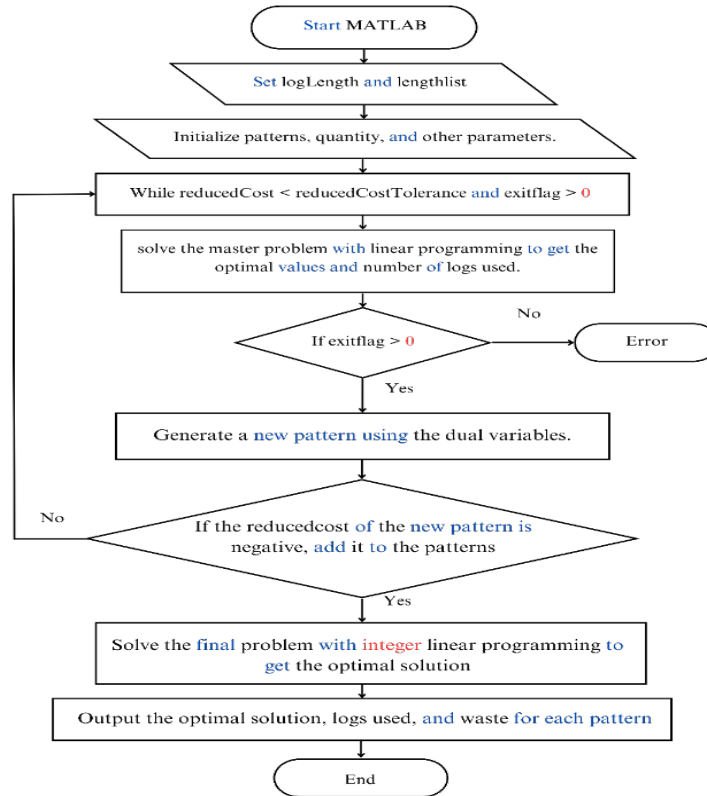


Figure 2. Control flow chart for one-dimensional linear material cutting using Matlab software.

2.1 Mathematical modelling

A linear program's problem model is a mathematical representation of all the data needed to solve the problem. This model comprises three integral constituents: the objective equation, the constraints, and the variables constrained to non-negative values. The concept of a one-dimensional linear material cutting axis involves the process of cutting a material along a single line. Furthermore, the cutting length must be considered, as well as standard length of rebar such as a 6-meter (L) length of material; this material must be cut to the required length and quantity while minimizing waste by cutting or using the most cost-effective method. The quantity of raw materials requiring cutting is unrestricted, and no material loss occurs during each cutting operation. $i = 1, 2, 3, \dots, n$. The process of column generation, or reconstructing the cutting method, can be achieved through the formulation of a linear program.

Objective:

$$\text{Min } Z = \sum_{i=1}^n f_i$$

Subject to:

$$\begin{aligned} a_{11} f_1 + a_{12} f_2 + \dots + a_{1n} X_n &\geq b_1 \\ a_{21} f_1 + a_{22} f_2 + \dots + a_{2n} X_n &\geq b_2 \\ a_{m1} f_1 + a_{22} f_2 + \dots + a_{mn} X_n &\geq b_m \end{aligned}$$

In the conditions of

$$x_1, x_2, \dots, x_n \geq 0$$

where Z represents the objective equation.

f_i = Frequency of cutting pattern at x_j

L = Standard length of rebar

x_j = Cutting pattern by $j = 1, 2, \dots, n$

l_i = Length of raw material

h_i = Length of residue of x_j

a_{ij} = Residue from the cutting plan of x_j

b_i = Required quantity for each length of l_i

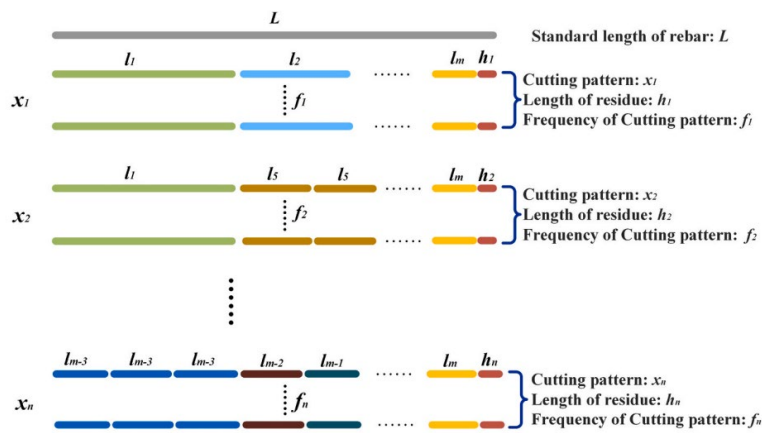


Figure 3. The scenario of a one-dimensional linear material cutting problem

Drawing from mathematical equations, the challenge of one-dimensional linear material cutting has given rise to numerous pre-designed programs. These programs help in devising longitudinal cutting plans, resulting in a reduction in scrap materials. Compared to manual planning, these automated approaches have been reported to enhance efficiency and lower wastage by approximately 1 to 10% (Naratip 2007).

The effectiveness and efficiency of one-dimensional linear material cutting depend on various constraints associated with the cutting process) These constraints encompass pertinent data, the standard length of linear inventory (L_s), the required length (l_i), the required quantity (b_i), and the plan for the one-dimensional linear material cutting. The cutting problem was addressed by referencing data from research sources that included one case study (Vacharapoom, 2013) and ten case studies by (Nuchsaara and Preecha 2017). The Matlab software was used as a solution to the problem of cutting one-dimensional linear materials into different dimensions.

Matlab is a software application designed for numerical computation and high-efficiency visualization. The acronym "Matlab" stands for Matrix Laboratory and is trademarked by MathWorks Inc. The Matlab program's functionality revolves around the fundamental principles of matrix manipulation and computation. Matlab software offers an interactive mode similar to programming languages like QBasic as well as a compiled mode akin to languages like C and Pascal. Problem-solving data, such as numbers or strings, is stored in rows and columns, or arrays, which are matrices like scalar numbers.

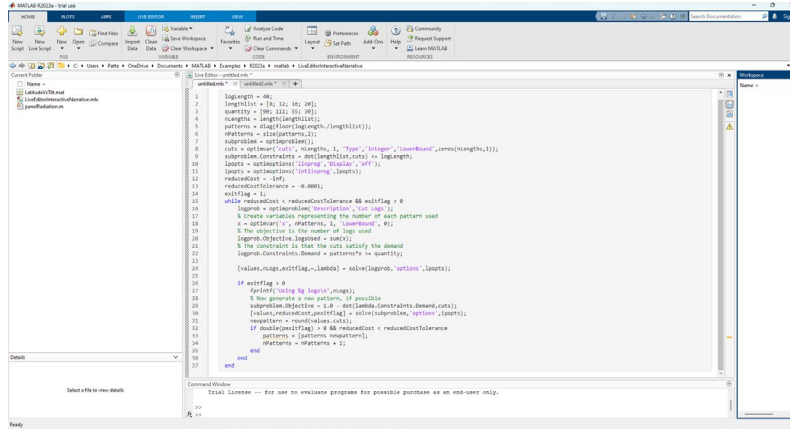


Figure 4. MATLAB software interface and Coding for solving one-dimensional linear cutting problems

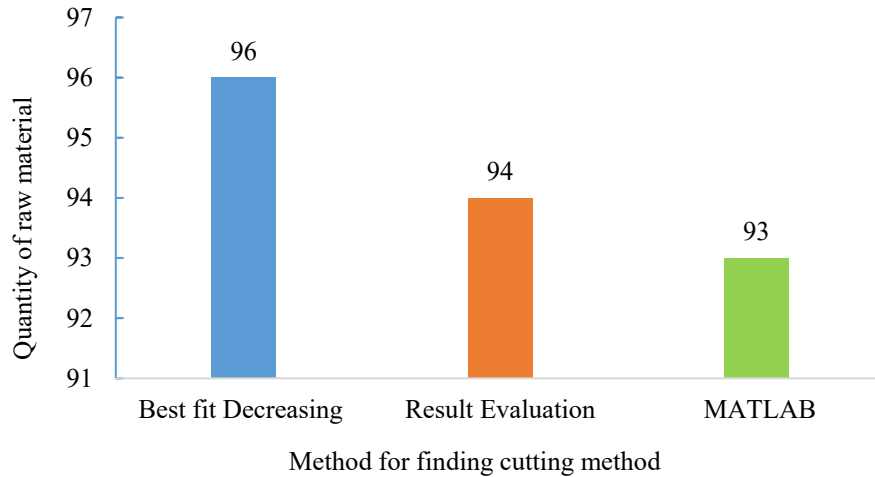
3. Results and Discussion

The findings of a research study titled "A cutting plan of one-dimensional construction materials to reduce loss in construction projects" (Vacharapoom 2013). The results of the analysis, which was facilitated by Matlab software and used a standard linear raw material of 10 meters in length, are explained in Figure 5 : These findings are related to the resolution of one-dimensional linear cutting problems in the context of the same problems.

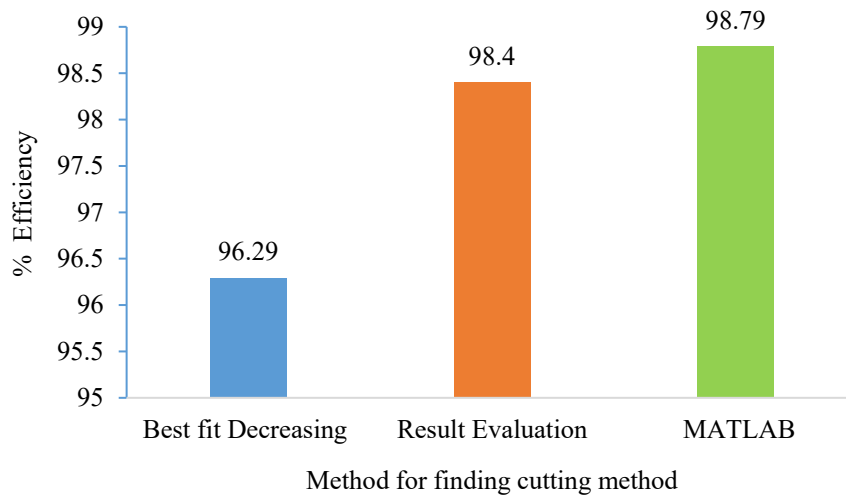
i	l_i	b_i	Cutting patterns (from 10 m. raw material)																$\sum_{i=1}^n f_i + x_j$
			X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	
1	0.95	25			2					1			1		1	1			25
2	1.4	18										2				2	1		18
3	1.75	14				2				1			1					2	14
4	1.8	23	5									2							23
5	1.88	7													1				7
6	2.67	22			1			1		1									22
7	2.88	10						1											10
8	3.05	36												2		1	1		36
9	3.2	4														1			4
10	3.75	15												1					15
11	5	26		2															26
12	5.4	19			1							1	1				1		19
13	6.35	7					1												7
14	7	23						1	1										23
15	7.19	12									1								12
f_i			1	13	5	3	5	10	12	1	4	5	5	15	7	2	4	1	93
h_i			1	0	0.03	0.15	0.33	0.12	0.14	0.3	0.05	0.05	0.05	0.15	0.17	0	0.15	0.1	
h_Sum			1	0	0.15	0.45	1.65	1.2	1.68	0.3	0.2	0.25	0.25	2.25	1.19	0	0.6	0.1	11.27

Figure 5. Table for MATLAB one-dimensional linear material cutting plan

Based on the data presented in Figure 5, a comparative chart could be developed to analyze the experimental findings from one-dimensional linear material cutting problems. This comparison will be drawn between the results collected from the same problems, as shown in Figures 6 and 7.



Figures 6 . Chart comparing results of one-dimensional linear standard inventory



Figures 7 . Efficiency results comparison chart

The development of a one-dimensional material cutting plan was concluded with a standard inventory of 94 pieces. The efficiency of standard linear inventory was 98.4%, total scrap was 1.60%, and the method of using Matlab software was used. It was concluded that the development of a one-dimensional material cutting plan was achieved with a standard inventory of 93 pieces, an efficiency in using standard linear inventory of 98.79%, and a total scrap of 1.21%. The difference in the amount of standard linear material used is less than 1 piece, representing a cutting efficiency difference of more than 0.39%. 3.2 The findings of a research study titled "Heuristic Approaches for One Dimensional Cutting Stock Problems" (Nuchsa and Preecha 2009).

This research examined 10 cutting problems in this one-dimensional linear material cutting process and divided the case studies into three sub-case studies. There are three different standard linear lengths (Ls) of material. In problems 1–2, a standard linear length (Ls) of 1 meter was employed. For problems 3-6, the chosen standard linear length (Ls) was 6 meters. Additionally, problems 7–10 were tackled using a standard linear length (Ls) of 12 meters. The process of determining solutions through heuristic methods involved considering the lengths of different pieces (Li), measured in centimeters. The "Max. Length" approach was employed, wherein the longest length within the Candidate List was selected as the initial cut. Subsequently, the outcomes of the cutting process were compiled, encompassing the count

of raw materials, the efficiency of cutting, and the combined and averaged cutting residue. These aggregated results were then compared with the outcomes obtained using Matlab software for further analysis.

Table 1 . How to generate cutting plots in Matlab and compare research findings

Problem	Matlab		Max.Length		Min.Length		Random		Greedy Random	
	f_i	%	f_i	%	f_i	%	f_i	%	f_i	%
1	16	92.06	16	92.06	20	73.65	19	77.53	18	81.83
2	22	99.05	23	94.74	28	77.82	25	87.16	24	90.73
3	69	87.8	70	86.77	80	75.73	75	80.78	72	84.14
4	86	97.77	86	97.77	103	81.63	95	88.51	90	93.43
5	93	95.95	93	95.95	116	76.93	106	84.18	101	88.6
6	690	77.7	690	77.17	724	73.55	706	75.42	698	76.29
7	167	78.25	167	78.25	184	71.02	171	76.42	169	77.33
8	184	87.93	184	87.93	209	77.41	197	82.13	183	88.41
9	169	99.04	170	98.46	246	68.04	208	80.47	196	85.4
10	299	94.04	299	94.04	384	73.23	337	83.44	323	87.06

Note: Cutting efficiency (%) equals the total length of standard inventory used multiplied by 100.

Table 1 shows a comparison between the research that used a heuristic approach to solve one-dimensional linear material cutting problems and the method that used a Matlab software to build a one-dimensional linear material cutting plan, as shown in Figure 8.

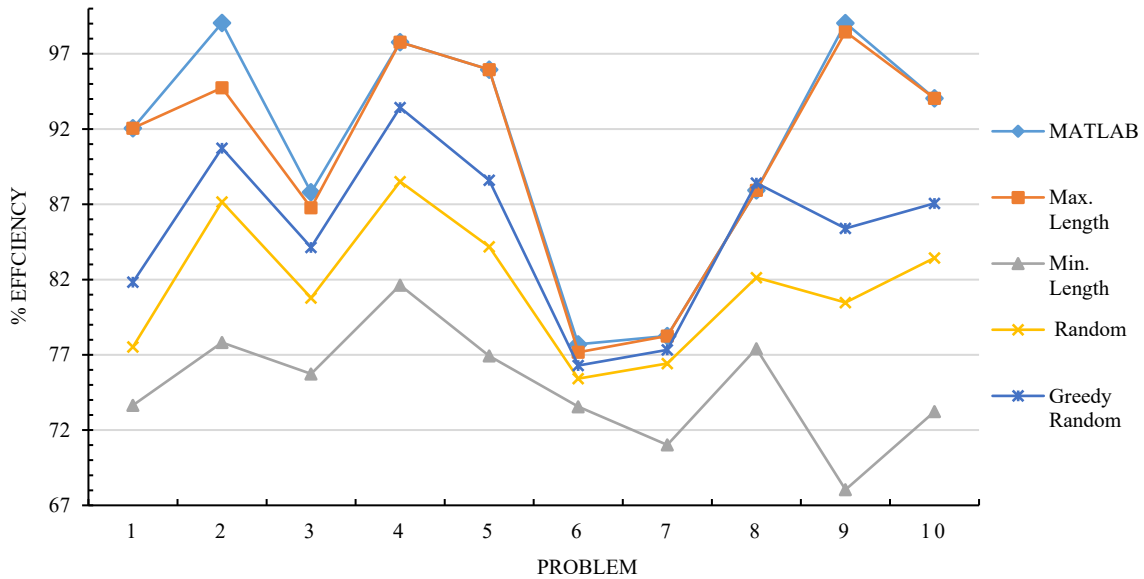


Figure 8 . One-dimensional material linear cutting efficiency comparison chart

Figure 8 provides a visual representation of the efficiency comparison in material cutting across all ten case studies (Problems). The heuristic methods utilized for solving material cutting challenges involve Max. Length, Min. Length, Random, and Greedy Random. When compared to the heuristic method, the approach of a one-dimensional linear material cutting plan using Matlab software is more effective in terms of using a reduced standard linear material inventory and achieving enhanced cutting efficiency. However, the results for Max. Length heuristics are the same in

case studies 1, 4, 5, 6, 7, 8, 10 but are more effective than in case studies 2, 3, 9. For a comprehensive view of these comparable results, see Table 2.

Table 2. Comparison of the best Matlab results for one-dimensional linear material cutting problems

Problem	Matlab		Max.Length		difference	
	f_i	%	f_i	%	f_i	%
2	22	99.05	23	94.74	1	4.31
4	69	87.8	70	86.77	1	1.03
6	690	77.7	690	77.17	0	0.53
9	169	99.04	170	98.46	1	0.58

Table 2 presents the test results that establish a comparison between heuristic methods and the approach of constructing one-dimensional linear solutions using a Matlab .

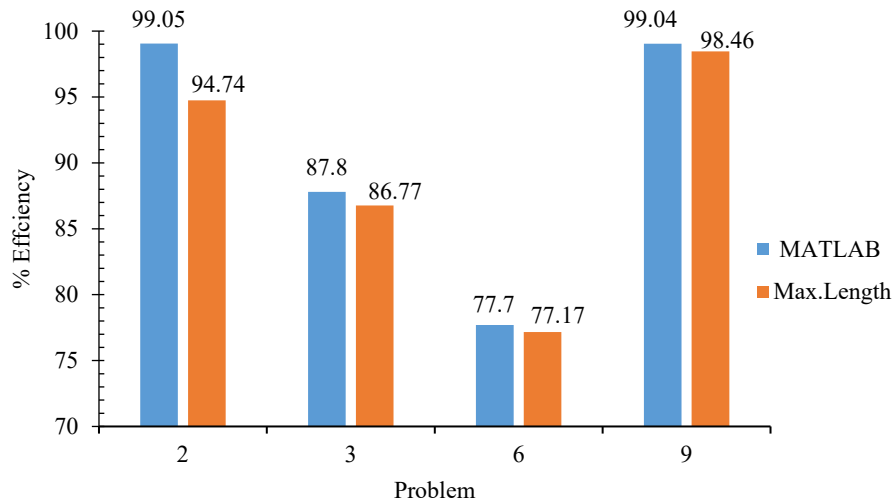


Figure 9. Comparison of cutting efficiency percentage

The Matlab software problem-solving strategy outperformed the heuristic method in all ten cases (Problems), particularly in the cases of Min. Length, Random, and Greedy Random. While the results were similar to the Max. Length heuristic in case studies 1, 4, 5, 6, 7, 8, and 10, it outperformed the heuristic in case studies 2, 3, and 9 due to the more efficient use of the standard linear inventory. The improvement increased overall efficiency by 6.45 percent.

4. Conclusion and Discussion

The goal of the research was to develop a one-dimensional linear material cutting plan to reduce losses during the cutting process. This was accomplished using a Matlab software and included a thorough investigation of 11 case studies. These comprised one case study from the research titled "A cutting plan of one-dimensional construction materials to reduce loss in construction projects" (Vacharapoom 2013) and an additional 10 case studies drawn from research exploring "Heuristic Approaches for One Dimensional Cutting Stock Problems" (Nuchasara and Preecha, 2009) "The primary goal of this study is to delve into the realm of one-dimensional linear material cutting. Through this investigation, the aim is to comprehensively understand the outcomes of one-dimensional linear material cutting, focusing on factors such as achieved results, minimized usage of standard linear materials, optimized cutting efficiency, and reduced waste in the cutting process. These objectives are pursued by employing computational techniques, particularly Linear Programming with the aid of the Matlab, to analyze the problem, find solutions, and generate cutting plans.

The conclusions drawn from the utilization of Matlab software are as follows: Employing Matlab for solving cutting problems and formulating one-dimensional linear material cutting plans leads to heightened efficiency in the one-dimensional material cutting process. This approach not only minimizes scrap but also contributes to an overall increase in efficiency. As a result, it can be concluded that the construction of one-dimensional linear cutting plots using MATLAB can be used to solve the problem of one-dimensional linear cutting in order to achieve the best efficiency and reduce scrap of the material cutting process.

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