STATISTICS, OPTIMIZATION AND INFORMATION COMPUTING
Stat., Optim. Inf. Comput., Vol. **x**, Month 202x, pp 0–10.
Published online in International Academic Press (www.IAPress.org)

Optimization of Standard Wood Cutting : A Case Study of a Wood Furniture Factory

Kannat Na Bangchang*, Kamonmanee Chuaysrinual, Tanapon Klangklaw, Kalyakorn Roekkamyee

Department of Mathematics and Statistics, Faculty of Science and Technology, Thammasat University, Thailand

Abstract Efficient use of raw timber is an important operational issue in furniture manufacturing because component-by-component cutting can create short residual pieces that are difficult to reuse. This study presents a one-dimensional cutting stock formulation based on Integer Linear Programming (ILP) for a proof-of-concept case study of a wood furniture factory. The raw material is a standard timber block of 11 × 11 × 200 cm, while the study focuses on longitudinal cutting of four component types: sofa legs, table legs, chair legs, and chair backrests. Because the chair-leg and chair-backrest cross-sections permit three pieces to occupy one 45-cm longitudinal layer, the pattern-generation procedure represents these components in groups of three. Constrained enumeration was then used to construct 75 candidate cutting patterns, after which an ILP model selected the number of times each pattern should be used to satisfy production demand while minimizing the number of standard timber units. For the January 2023 production instance, the optimized plan uses 44 standard timber units instead of 47 under the conventional plan, a reduction of 6.38%. Total geometric residual length decreases from 1,100 cm to 500 cm, a reduction of 54.55%. The difference between the two percentages indicates that the principal benefit of optimization is the improved utilization of residual lengths within each stock unit rather than a proportional reduction in the number of stock units. The study is intentionally presented as a proof-of-concept; the model does not explicitly represent saw kerf, grain orientation, defects, or timber-quality variation, and validation with longer-term production data is required before generalizing the findings.

Keywords Cutting Stock Problem, Integer Linear Programming, Wood Cutting, Cutting Patterns , Resource Allocation

DOI: 10.19139/soic-2310-5070-4602

1. Introduction

The wood furniture industry is a sector that consumes a substantial amount of timber resources. Standard cutting practices that lack proper planning can generate a significant amount of waste material, leading to increased production costs. A study of the production process in a case study wood furniture factory found that cutting wood separately for each component results in material loss. Related research indicates that applying the Cutting Stock Problem in combination with Integer Linear Programming (ILP) can effectively reduce waste and improve resource utilization efficiency. Therefore, this project aims to enhance the efficiency of standard wood cutting by developing an integer linear programming model to determine optimal cutting patterns.

Regarding the application of linear programming methods, Sarayut Malai proposed the use of integer linear programming for planning steel sheet cutting. The study found that it could reduce material usage by approximately 0.75% to 3.85% compared to the actual usage by contractors [1]. Similarly, Wacharaphum Benja-olarn developed a linear planning approach for construction material cutting using linear programming combined with the Best-Fit-Decreasing algorithm [2]. This approach reduced the material waste rate to only 1.24%, which is three times lower

*Correspondence to: Kannat Na Bangchang(Email: kannat@mathstat.sci.tu.ac.th). Department of Mathematics and Statistics, Faculty of Science and Technology, Thammasat University. 99 Klongnung, Klongluang, Pathumthani Province, Thailand (12120).

ISSN 2310-5070 (online) ISSN 2311-004X (print)

than the traditional method [2]. These findings demonstrate that optimization techniques using linear programming can effectively address material cutting problems.

In terms of computer program development for material cutting planning, Preecha Kriangkrok and Nussara Kriangkrok developed the Cutter 1.0 program to assist in solving one-dimensional cutting stock problems. The results showed that the program significantly reduced material waste compared to traditional cutting methods [3]. Moreover, computer programs offer convenience in solving complex planning problems.

For improving the efficiency of paper core cutting using linear programming, Suwit Songkroh, Sakchai Rakkarn, Attakorn Klankwamdee, and Thanakom Sakulthai developed a model capable of rapidly generating up to 83 cutting patterns. The application of linear programming resulted in an average waste rate of only 0.51%, reducing paper core waste by up to 87.9% per month [4]. This demonstrates the effectiveness of optimization techniques in decision-making and achieving optimal operational outcomes.

The development of mathematical models for cutting problems integrated with material requirement planning was studied by Panatda Kongsilp, Narathip Saengsai, and Kanokporn Sripathomsawat . Their objective was to minimize waste from standard raw material cutting by formulating a linear programming model that incorporates bill-of-material sequencing. This approach enhances material utilization efficiency and improves production system performance [5]. The use of integer linear equations provides optimal solutions under given constraints for cutting stock problems.

This research, therefore, aims to design and develop a program that enhances the efficiency of wood material cutting in furniture factories by applying linear programming techniques alongside user-friendly system design. The proposed system will simplify the calculation process, improve planning accuracy, and minimize material waste effectively.

Currently, improving efficiency in wood cutting processes can be further achieved through the integration of computer programs with linear programming. This approach not only reduces waste but also enhances accuracy and planning efficiency. For example, the study by Amit K. Jha, Govind S. Sharma, and Nitesh Kaushik titled "Modeling of Transport Problem in Linear Programming with Python (PuLP)" utilized Python and the PuLP library to develop a linear programming model for solving transportation problems. The program can determine the optimal quantity of goods transported from origins to destinations with minimum cost and allows real-time adjustments of supply and demand data [6]. This demonstrates the flexibility and capability of Python and PuLP as decision-support tools for resource allocation.

Similarly, the study by Kuhn, C. C. N., Calbert, G., Garanovich, I., and Weir titled "Integer Linear Programming Supporting Portfolio Design" applied ILP using Python and PuLP to solve investment portfolio optimization problems. The developed program calculates optimal asset allocation based on defined objective functions and allows dynamic adjustments of constraints such as budget and risk [7]. This study highlights that Python and PuLP not only provide accurate solutions to LP/ILP problems but can also be extended into practical decision-support applications.

Both studies demonstrate the applicability of linear programming using Python for real-world optimization problems. These approaches can be further extended to wood cutting planning in the furniture industry, enabling waste reduction, improved material utilization, and the development of user-friendly tools that facilitate efficient calculation and planning processes.

Although Integer Linear Programming has been extensively applied to cutting stock problems, most previous studies focus on generic industrial materials such as steel sheets, paper rolls, and construction materials. Limited research has investigated the integration of cutting stock optimization with a user-oriented decision support system specifically designed for small and medium-sized furniture manufacturers. The contribution of this study is therefore primarily applicational and computational rather than algorithmic. The study (i) formalizes the factory's standard-timber cutting problem as a 1D-CSP, (ii) provides an explicit reproducible rule for constructing the 75 candidate patterns from component dimensions and cross-sectional packing, (iii) solves the resulting ILP using Excel Solver and Python/PuLP, and (iv) demonstrates the resulting cutting plan using real production data from the case-study factory.

2. Literature Review

Optimization techniques have been extensively applied to cutting stock problems across various industries. According to the widely accepted classification proposed by Wäscher et al. (2007) [8], the standard wood cutting problem considered in this study belongs to the class of one-dimensional Cutting Stock Problems (1D-CSP), where standardized stock materials must be cut into smaller items while minimizing trim loss. This classification has become the standard taxonomy for cutting and packing optimization problems. Previous studies demonstrate that Integer Linear Programming can significantly reduce material waste. Malai (2012) applied ILP to steel plate cutting and reported improvements in material utilization. Similarly, Benja-olan (2013) combined linear programming with heuristic algorithms to achieve substantial waste reduction. In addition, computational tools have been developed to support cutting optimization. Kriangkrokot and Kriangkrokot (2010) introduced a heuristic-based program that improved cutting efficiency compared to traditional methods. Recent advancements emphasize the integration of optimization with programming tools. Studies utilizing Python and the PuLP library (e.g., Jha et al., 2023; Kuhn et al., 2023) demonstrate the flexibility of modern optimization frameworks in solving real-world problems. Despite these developments, limited research focuses specifically on wood furniture manufacturing. This study addresses this gap by integrating ILP with a practical decision-support system.

This research integrates specialized knowledge from multiple disciplines, particularly Operations Research (OR), Linear Programming (LP), and Computer Programming, which serve as the core foundations for analyzing and developing efficient standard wood cutting strategies to maximize resource utilization.

Operations Research (OR): This project applies OR concepts to analyze and solve the problem of inefficient use of standard wood materials. Mathematical modeling is employed to support decision-making processes aimed at achieving maximum efficiency. The approach involves problem formulation, model development, and the determination of optimal solutions. Linear Programming (LP): Linear programming is used as the primary tool for constructing the mathematical model. The objective is to minimize the number of standard wood pieces used, subject to constraints such as wood dimensions, production requirements, and the need to fulfill all component demands. This ensures systematic cutting planning and efficient resource utilization. Computer Programming: A software application named Smart Cutting Design was developed using the Python programming language to compute and analyze cutting patterns derived from the mathematical model. The program features a user-friendly interface built with CustomTkinter and supports data storage in JSON format, enhancing usability and efficiency for repeated operations. Standard wood cutting refers to the process of dividing standard-sized timber logs or wooden boards into smaller components according to specified dimensions required for furniture production, such as table legs, panels, chairs, or cabinet frames. Achieving maximum efficiency in wood cutting requires careful planning to ensure optimal material utilization while minimizing residual waste.

Cutting and packing problems constitute a major class of Operations Research problems concerned with allocating items to stock objects under geometric and demand constraints. Dyckhoff's typology [9] and the later improved typology of Wäscher, Haußner, and Schumann provide a systematic basis for distinguishing cutting and packing problem classes. The present problem is most appropriately treated as a one-dimensional cutting stock problem because each stock unit has a fixed longitudinal dimension and the optimization is performed on that dimension. Gilmore and Gomory introduced the classical linear-programming approach to the cutting-stock problem and showed why explicit enumeration of all possible cutting patterns can become computationally difficult [10, 11]. Their approach underlies column generation, in which new patterns are generated by solving a pricing or knapsack subproblem. For larger one-dimensional instances, branch-and-price and branch-and-cut-and-price methods have subsequently been developed to obtain exact integer solutions while avoiding explicit enumeration of a very large pattern set.

Another important extension concerns usable leftovers. Research on the one-dimensional cutting-stock problem with usable leftovers distinguishes between unavoidable waste and residual material that may retain economic value for future orders. This distinction is relevant to wood manufacturing because a residual piece that is too short for any component is effectively waste, whereas a sufficiently long leftover may be inventory. In the present case, the factory's reported residuals are treated as waste because the study states that the small residual pieces generated by the conventional cutting process could not be used for the component types under consideration.

Against this background, the gap addressed by the present study is not the invention of a new cutting-stock algorithm. Instead, it is the adaptation of a transparent, small-scale exact ILP framework to a furniture-factory setting in which component cross-sections influence the feasible longitudinal patterns. The source report also describes a user-oriented Smart Cutting Design application intended to translate optimization output into cutting instructions for operators. This application-oriented integration is useful for a small or medium-sized production environment where the number of feasible patterns is sufficiently small to permit complete enumeration.

In practice, most manufacturing facilities define "standard wood sizes" based on the dimensions of raw materials supplied by sawmills, such as $2.5 \times 10 \times 200$ cm or $3 \times 15 \times 250$ cm. Upon receiving a production order, the factory must plan the cutting process to produce all required components according to the specified designs. Each order typically involves varying quantities and dimensions, which increases the complexity of the planning process.

A common issue arises when cutting plans rely solely on the experience of operators. This approach may lead to inefficient cutting decisions, such as excessive use of raw materials or the generation of unusable residual pieces. Consequently, this results in both resource wastage and increased production costs.

In summary, this project represents an integration of knowledge in Operations Research, Linear Programming, and Programming to develop an optimal standard wood cutting approach. The primary objective is to minimize the use of raw materials and reduce waste generated during the production process. This contributes to cost reduction, efficient resource utilization, and the promotion of sustainable manufacturing practices in the furniture industry.

The development of the mathematical model in this study aims to determine optimal cutting patterns for standard wood materials. Specifically, the model seeks to minimize the number of standard wood units used while ensuring that all required furniture components are produced according to customer demand in the case study factory. The model is based on the principles of Integer Linear Programming (ILP), which is a key methodology within the field of Operations Research. Modern cutting stock optimization frequently employs exact optimization techniques such as column generation and branch-and-price methods for solving large-scale one-dimensional cutting stock problems [12].

The formulation of this model is grounded in real operational data collected from the factory. The researchers gathered information on standard wood dimensions used in production, as well as the dimensions of various furniture components required in each production batch. Key variables include the length, width, and thickness of different types of wood, along with the required quantities of each component, as detailed below: Furthermore, the model development process begins with the specification of cutting patterns, which are classified into feasible configurations under the constraints imposed by standard timber dimensions. Subsequently, Python programming is employed in conjunction with combinatorial enumeration with constraints to systematically generate feasible combinations of components from different groups, such that the total length does not exceed the predefined standard timber size. Exact algorithms for one-dimensional cutting stock problems have been extensively studied, including branch-and-bound and branch-and-price approaches capable of solving large industrial instances efficiently [13]. In this study, a total of 75 distinct cutting patterns were generated, making complete enumeration computationally practical.

To provide a clear and concrete illustration of the differences in cutting processes based on the number of dimensions considered, example diagrams of one-dimensional and two-dimensional cutting are presented, as shown in the figure. These illustrations serve as essential components in facilitating a comprehensive understanding of the conceptual framework and the principles underlying the determination of cutting patterns within the proposed model.

3. Methodology

Once the raw data have been properly structured into a suitable format for use as inputs to the model, the next step is to formulate a mathematical model to determine the most efficient cutting strategy. The formulation is presented as follows: The sets are defined in Eqs. 1–2, the model parameters are defined in Eqs. 3–6, and the decision variable is given in Eq. 7: This model is designed to ensure that the production of each furniture type yields a sufficient number of components to meet customer demand, while utilizing standard timber as efficiently as possible. Accordingly, the constraints are formulated to regulate the cutting process such that the required quantities of each component type are satisfied. Although the raw material is a three-dimensional timber block (11 × 11 × 200 cm) that is indicated in Table 1, the optimization model is formulated as a one-dimensional along the 200-cm direction because the 11 × 11 cm cross-section is fixed. The four component types and their longitudinal dimensions are: sofa leg = 35 cm, table leg = 45 cm, chair leg = 45 cm, and chair backrest = 45 cm. Chair legs and chair backrests have 3 × 6 cm cross-sections, allowing three pieces to occupy one 45-cm longitudinal layer within the 11 × 11 cm stock cross-section, that are reported in Table 2 . Thus, for pattern-generation purposes, three chair-leg/backrest pieces consume the same longitudinal layer as one 45-cm layer.

The model makes the following case-specific assumptions: (1) the stock length is exactly 200 cm; (2) cross-sectional dimensions are fixed; (3) the cutting direction is longitudinal; (4) chair legs and chair backrests are packed in groups of three within a longitudinal layer; (5) only patterns with at most 30 cm geometric residual length are retained in the 75-pattern candidate set; and (6) demand constraints may be satisfied with equality or overproduction because the source ILP uses constraints.

Practical cutting effects are not explicitly modeled. In particular, the source data do not specify a numerical saw-kerf width, grain-orientation restriction, or a defect/quality map for individual timber units. Therefore, the reported residual length is a geometric residual based on the stated dimensions, not an operational residual after kerf. This limitation is material: if a saw kerf of k cm per cut is relevant in practice, the pattern-generation rule should subtract the appropriate cumulative kerf from the usable 200-cm stock length before a pattern is accepted.

Therefore, the primary decision variable concerns the allocation of timber length, while width and thickness are incorporated during the pattern generation stage to ensure feasibility.Consequently, the optimization problem focuses on minimizing waste along the longitudinal dimension of the timber stock.

These constraints establish the relationship between the "number of selected cutting patterns" and the "quantity of wooden components produced," as defined in Eqs. 9–13.

3.1. Sets

Let the sets be defined as:

$$I = \{i_1, i_2, i_3, i_4\} \tag{1}$$

where:

- i_1 = sofa legs
- i_2 = table legs
- i_3 = chair legs
- i_4 = chair backrests

$$J = \{1, 2, \ldots, 75\} \tag{2}$$

represents the set of all possible cutting patterns.

3.2. Parameters

$$a_{ij} : \text{ number of pieces of type } i \text{ obtained from pattern } j, \quad \forall i \in I, j \in J \tag{3}$$

$$d_1 : \text{ demand for sofas} \tag{4}$$

$$d_2 : \text{ demand for tables} \tag{5}$$

$$d_3 : \text{ demand for chairs} \tag{6}$$

3.3. Decision Variables

Feasible cutting patterns were generated using constrained combinatorial enumeration implemented in Python. Similar pattern-generation concepts have been adopted in previous one-dimensional cutting stock studies [14].

Each pattern represents a combination of furniture components that can be cut from a single standard timber unit of length 200 cm.

All possible combinations were systematically enumerated and infeasible combinations exceeding 200 cm were removed.The procedure generated 75 unique cutting patterns that formed the candidate columns of the ILP model.

$$X_j: \text{ number of times cutting pattern } j \text{ is used}, \quad \forall j \in J \tag{7}$$

3.4. *Objective Function*

The objective is to minimize the total number of cuts (or standard wood pieces used)as formulated in Eq. 8:

$$\min \quad \sum_{j=1}^{75} X_j \tag{8}$$

3.5. *Constraints*

$$\sum_{j=1}^{75} a_{i_1,j} X_j \geq 4d_1 \tag{9}$$

$$\sum_{j=1}^{75} a_{i_2,j} X_j \geq 4d_2 \tag{10}$$

$$\sum_{j=1}^{75} a_{i_3,j} X_j \geq 4d_3 \tag{11}$$

$$\sum_{j=1}^{75} a_{i_4,j} X_j \geq 3d_3 \tag{12}$$

$$X_j \geq 0 \text{ and integer}, \quad \forall j \in J \tag{13}$$

Constraint (9): Since one sofa requires four wooden legs, this constraint ensures that the total number of sofa legs produced from all cutting patterns is at least four times the number of sofas to be manufactured.

Constraint (10): Similarly, as one table requires four legs, this constraint specifies that the total number of table legs obtained from the cutting process must be no less than four times the number of tables required.

Constraint (11): Given that one chair requires four legs, this constraint enforces that the total number of chair legs produced must be at least four times the number of chairs to be manufactured.

Constraint (12): Since each chair requires three backrest components, this constraint guarantees that the cutting patterns collectively produce a sufficient number of chair backrests to meet the required production quantity.

Constraint (13): In practice, timber cutting cannot be performed in fractional quantities. Therefore, the number of times each cutting pattern is used must be restricted to non-negative integers.

To obtain solutions for the developed mathematical model, this study initially employed Microsoft Excel to perform preliminary experiments. The Excel Solver add-in was utilized to solve the Linear Programming problem, allowing for verification of the model's validity and feasibility, and confirming that the results satisfy all specified constraints. Excel Solver was configured using the Simplex LP algorithm with integer restrictions imposed on decision variables. For the case study instance, the optimal solution was obtained in less than one second.

Subsequently, in the development of the Smart Cutting Design program, the proposed mathematical model was implemented in Python using the PuLP library [15], a widely used tool for solving Linear Programming (LP) and Integer Linear Programming (ILP) problems. PuLP enables systematic definition of decision variables, objective functions, and constraints, and efficiently computes the optimal solution automatically.

The model was first tested using Microsoft Excel Solver to verify feasibility and the logical consistency of the constraints. It was subsequently implemented in Python using PuLP as the optimization engine and integrated into the Smart Cutting Design application. Because the candidate set contains only 75 patterns, complete enumeration followed by an exact ILP solve is computationally practical for this case. For substantially larger pattern spaces, column generation or branch-and-price would be a more scalable alternative.

Table 1. Dimensions of Standard Wood

Item	Dimensions
Standard wood	Width: 11 cm Length: 11 cm Height: 200 cm

Table 2. Summary of Dimensions of Wooden Components Used in the Study

Component	Dimensions	Pieces per Product
Sofa legs	Width: 9.5 cm Length: 9.5 cm Height: 35 cm	4
Table legs	Width: 8.5 cm Length: 8.5 cm Height: 45 cm	4
Chair legs	Width: 3 cm Length: 6 cm Height: 45 cm	4
Chair backrests	Width: 3 cm Length: 6 cm Height: 45 cm	3

In addition, the model development process begins with defining cutting patterns, which are categorized into feasible configurations under the constraints of standard wood dimensions. Python programming, combined with combinatorial enumeration under constraints, is employed to generate feasible combinations of components such that the total length does not exceed the standard wood size. A total of 75 cutting patterns were generated.

To clearly illustrate the differences between cutting processes based on dimensional considerations, examples of one-dimensional and two-dimensional cutting patterns are presented (Figures 1 and 2). These figures serve as key components in understanding the conceptual framework and methodology for defining cutting patterns in the model.

To solve the developed mathematical model, Microsoft Excel Solver was initially used to obtain preliminary solutions. This step was conducted to verify the correctness and feasibility of the model using linear programming techniques.

Subsequently, the model was implemented in the Smart Cutting Design program using Python. The PuLP library, a widely used tool for solving Linear Programming (LP) and Integer Linear Programming (ILP) problems, was utilized. PuLP enables systematic definition of variables, objective functions, and constraints, and automatically computes the optimal solution.

The combined use of Excel Solver and PuLP allows for both validation of the model and efficient real-world implementation within the Smart Cutting Design system, ensuring accuracy in computation and clarity in result presentation.

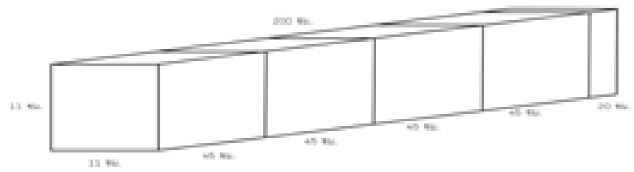

Figure 1. Example of a one-dimensional cutting pattern

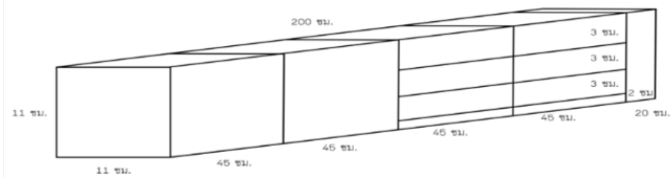

Figure 2. Example of a two-dimensional cutting pattern

4. Results

The experimental application of the Smart Cutting Design program to real order data from a wooden furniture manufacturing factory demonstrates a significant improvement in material utilization efficiency. The program employs Linear Programming techniques to determine and select cutting patterns that minimize material waste.

A case study based on order data from January 2023 illustrates this improvement. Prior to the implementation of the program, the factory required 47 standard timber units per production cycle, generating a total wood waste of 1,100 centimeters. After adopting the Smart Cutting Design program for cutting plan optimization, the number of required standard timber units was reduced to 44, while the total wood waste decreased to 500 centimeters.

These results are consistent with those presented in Table 3, which clearly compares the conventional approach and the proposed method in terms of both the number of standard timber units used and the amount of residual waste. In percentage terms, the results indicate a reduction in wood waste of 54.55% and a decrease in standard timber usage of 6.38

5. Discussion

The main mechanism behind the result is pattern mixing. Under the conventional practice, the factory cuts a single component category from a stock unit. For example, the source report states that a stock unit can produce five sofa legs, four table legs, twelve chair legs, or twelve chair backrests when each category is cut separately. The January order therefore leads to 32 stock units for sofa legs, 6 for table legs, 5 for chair legs, and 4 for backrests, or 47 units in total.

The optimized plan combines component categories within the same stock unit whenever the geometry permits. Pattern 07 is the clearest example: three sofa legs occupy 105 cm and two table legs occupy the remaining 90 cm, leaving only 5 cm. Patterns 12 and 18 use the cross-sectional capacity of the smaller 3×6 cm components so that six chair legs or six backrests can be accommodated in two 45-cm layers. This systematic mixing transforms residual length that would otherwise remain unusable into productive cutting capacity.

The 54.55% reduction in residual length being much larger than the 6.38% reduction in stock units is therefore not contradictory. Reducing stock units and reducing residual length are related but distinct objectives. A plan can use nearly the same number of stock units while placing components more efficiently inside those units. In this case, the optimization primarily removes small unusable offcuts from the interior of the 44 selected stock units. The large percentage change in waste is therefore a consequence of improved packing efficiency rather than a proportional reduction in raw-material units.

The model also illustrates an important distinction between geometric waste and operational waste. The reported 500 cm is calculated from pattern residual lengths and does not subtract saw kerf. If the cutting process consumes, for example, k cm per cut, each pattern's usable length should be reduced by the appropriate number of kerf intervals. Similarly, grain direction and defects may eliminate patterns that are geometrically feasible. The current results should therefore be interpreted as an idealized baseline for pattern planning rather than a complete three-dimensional production simulation.

From a methodological perspective, complete enumeration is justified for this small instance because the candidate set contains 75 patterns. However, the approach should not be interpreted as a scalable replacement for column generation. In larger furniture systems with many component types, variable stock lengths, inventory of reusable leftovers, multiple cross-sections, or sequencing constraints, the number of patterns can increase rapidly and a column-generation or branch-and-price framework would become more appropriate.

6. Conclusion

The experimental application of the Smart Cutting Design program using real order data from a wood furniture factory demonstrates a significant improvement in material utilization efficiency. The program applies Linear Programming principles to compute and select cutting patterns that minimize material waste.

A case study based on production orders in January 2023 shows that, prior to implementing the program, the factory required 47 standard wood pieces, generating a total waste of 1,100 centimeters per production cycle. After integrating the Smart Cutting Design program into the cutting planning process, the number of required standard wood pieces decreased to 44 pieces, and the total waste was reduced to 500 centimeters.

Assuming a unit timber cost of C monetary units, the reduction of three standard timber units per production cycle yields a direct material saving of 3C per production batch. Reduced timber consumption contributes to sustainable manufacturing by lowering demand for raw wood resources and reducing waste disposal requirements.

These results are consistent with the data presented in Table 3, which clearly compares the conventional and optimized approaches in terms of both the number of standard wood pieces used and the amount of material waste generated. In percentage terms, the results indicate a 54.55% reduction in wood waste and a 6.38% reduction in the number of standard wood pieces required.

Table 3. Optimal cutting patterns

Pattern	Sofa legs	Table legs	Chair legs	Backrests	Used(times)	Residual unit (cm)
01	5	0	0	0	14	25
07	3	2	0	0	12	5
12	3	0	6	0	10	5
18	3	0	0	6	8	5

Table 4. Example comparison of the number of standard wood pieces used and wood waste in January 2023 before and after applying the Smart Cutting Design program

Item	Before	After	Reduction (%)
Standard wood (pieces)	47	44	6.38
Wood waste (cm)	1,100	500	54.55

The selected patterns are transparent and directly interpretable. Pattern 01 produces five sofa legs and leaves 25 cm. Pattern 07 produces three sofa legs and two table legs and leaves 5 cm. Pattern 12 produces three sofa legs and six chair legs and leaves 5 cm. Pattern 18 produces three sofa legs and six chair backrests and leaves 5 cm. The last two patterns are feasible because six chair legs or six backrests correspond to two 45-cm longitudinal layers, with three 3×6 cm pieces in each layer. Multiplying each pattern by its selected frequency gives 160 sofa legs, 24 table legs, 60 chair legs, and 48 chair backrests. Thus the sofa, table, and chair-leg requirements are met exactly, while the backrest requirement is exceeded by three pieces. The total number of stock units is 14+12+10+8 = 44. The total geometric residual is 14(25)+12(5)+10(5)+8(5)=500 cm, that is reported in Table 4.

Furthermore, to demonstrate the practical applicability of the program in a real industrial setting, consider the example of production orders in January 2023. The factory required the production of 40 sofas, 6 tables, and 15 chairs. The program calculated that a total of 44 standard wood pieces were required and identified the optimal cutting patterns for this production cycle as follows:

Pattern 01: 14 pieces Pattern 07: 12 pieces Pattern 12: 10 pieces Pattern 18: 8 pieces

This information enables operators to plan wood usage systematically and accurately, while significantly reducing the likelihood of human error associated with manual calculations.

From this case study, it can be concluded that the Smart Cutting Design program not only improves the accuracy of cutting pattern calculations but also effectively reduces material waste and promotes efficient resource utilization. These improvements contribute to cost reduction and enhanced production efficiency.

Due to data availability limitations, only January 2023 production data were available for analysis. Therefore, the study should be regarded as a proof-of-concept implementation. Future studies should evaluate performance using longer-term production records.

The results confirm that the developed program has strong potential for real-world implementation in the wood furniture industry and can significantly enhance the quality and effectiveness of production planning processes.

Acknowledgement

This research on “Enhancing the Efficiency of Standard Timber Cutting: A Case Study of a Wooden Furniture Factory” was successfully completed with the financial support of the Thammasat University Research Unit in Statistical Theory and Applications. The authors would also like to express their sincere gratitude to the Department of Mathematics and Statistics, Faculty of Science and Technology, Thammasat University, for their academic support. Furthermore, the authors gratefully acknowledge the management team and staff of the case-study wooden furniture factory for providing valuable data and facilitating the data collection process.

REFERENCES

1. S. Malai, *Planning of steel plate cutting using integer linear programming*, (Research report). Lampang: Lampang Rajabhat University. (in Thai), 2012.
2. W. Benja-olan, *Development of linear construction material cutting plans to reduce waste in construction projects*, (Research report). Nakhon Ratchasima: Suranaree University of Technology. (in Thai), 2013.
3. P. Kriangkrokot, and N. Kriangkrokot, *Computer program for one-dimensional cutting stock problem management using heuristic methods*, (Research report). Ubon Ratchathani: Ubon Ratchathani University. (in Thai), 2010.
4. S. Songkroa, S. Rakkarn, A. Klankhwamdee, and T. SakuThai *Efficiency improvement in paper core cutting using linear programming*, (Research report). Bangkok: Kasem Bundit University. (in Thai), 2017.
5. P. Kongsilp, N. Saengsai, and K. Sripathomsawat, *Development of a mathematical model for cutting stock problems integrated with material requirements planning* , (Research report). Bangkok: King Mongkut’s University of Technology North Bangkok. (in Thai), 2012.
6. K. Amit, S. Govind, and K. Nitesh, *Modeling of transport problem in linear programming with Python (PuLP)*, (Research report). India: Suresh Gyan Vihar University, 2023.
7. C. C. Kuhn, G. Calbert, I. Garanovich and T. Weir, *Integer linear programming supporting portfolio design*, (Research report). Defence Science and Technology Group, AustralianDepartment of Defence, Canberra, Australia, 2023.
8. G. Wäscher, H. Haußner, and H. Schumann, *An improved typology of cutting and packing problems*, European Journal of Operational Research, 183(3), 1109–1130, 2007.
9. H. Dyckhoff, *A typology of cutting and packing problems*, European Journal of Operational Research, 44(2), 145–159, 1990.
10. P. C. Gilmore and R. E. Gomory, *A linear programming approach to the cutting-stock problem*, Operations Research, 9(6), 849–859, 1961.
11. P. C. Gilmore and R. E. Gomory, *A linear programming approach to the cutting stock problem—Part II*, Operations Research, 11(6), 863–888, 1963.
12. K. C. Poldi and M. N. Arenales, *Heuristics for the one-dimensional cutting stock problem with limited multiple stock lengths*, Computers & Operations Research, 36(6), 2074–2081, 2009.

13. G. Belov and G. Scheithauer, *A branch-and-cut-and-price algorithm for one-dimensional stock cutting and two-dimensional two-stage cutting*, European Journal of Operational Research, 171(1), 85–106, 2006.
14. Y. Cui and X. Zhao, *An exact method for the one-dimensional cutting stock problem with usable leftovers*, European Journal of Operational Research, 224(2), 245–250, 2013.
15. I. Dunning, S. Mitchell, and M. O'Sullivan, *PuLP: A linear programming toolkit for Python*, Department of Engineering Science, University of Auckland, 2011.