Resource Optimization and Profit Maximization in Small-Scale Laundry Enterprise Using the Simplex Method

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Abstract

Linear Programming is a fundamental mathematical technique employed in solving optimization problems across business and management domains. Among its methods, the Simplex Method stands out as a systematic procedure for determining the optimal allocation of limited resources to maximize profit or minimize cost. This synthesis paper examines the application of the Simplex Method to the "Clothes in Baskets Laundry Shop Problem," a real-world case study involving a small-scale service enterprise. The study aimed to identify the most profitable combination of laundry services subject to constraints in washer and dryer machine-time availability. Through the formulation of objective functions, operational constraints, slack variables, and successive simplex tableau iterations, the problem was solved systematically to convergence. Results indicate that exclusively processing 8 kg regular laundry loads generates the maximum achievable daily profit of ₱13,716. The paper underscores the significance of Linear Programming as a practical decision-support tool for enhancing operational efficiency, resource management, and profitability in small and medium-sized enterprises.

Keywords: Linear Programming; Simplex Method; profit maximization; resource optimization; laundry operations; small-scale enterprise; operations research

1. Introduction

Businesses across industries face the persistent challenge of managing constrained resources while sustaining profitability and operational efficiency. In service-oriented sectors such as laundry operations, proprietors must determine which combination of services yields the highest return without exceeding machine capacities or available operating time. These practical concerns have elevated mathematical optimization techniques to the status of indispensable tools in modern business management.

Linear Programming (LP) is among the most widely applied optimization frameworks. As described by Render, Stair, and Hanna (2009), LP is a quantitative approach used to optimize an objective function subject to a set of constraints. Its applications span production planning, transportation logistics, agricultural resource allocation, and service operations wherever resource scarcity demands systematic decision-making.

The Simplex Method, developed by George B. Dantzig in 1947, is an iterative procedure for solving LP problems. Starting from an initial feasible solution, the method evaluates adjacent corner-point solutions, systematically improving the objective value until optimality is confirmed. Simplex tableaux, pivot operations, and the $C_j - Z_j$ criterion serve as computational tools guiding this iterative process.

This synthesis paper applies the Simplex Method to a laundry shop optimization problem. Specifically, it determines the most profitable daily service mix for Clothes in Baskets Laundry Shop given fixed machine-time constraints. The study demonstrates the practical value of operations research in improving efficiency and profitability for small and medium-sized enterprises (SMEs).

2. Review of Related Literature

Linear Programming is recognized as one of the most significant mathematical tools in operations research and business decision-making. Render et al. (2009) describe LP as a quantitative methodology for maximizing or minimizing an objective function under given constraints, enabling organizations to allocate scarce resources efficiently and improve both productivity and profitability.

Dantzig (1963) formalized the Simplex Method as a systematic procedure that evaluates feasible corner-point solutions iteratively. By employing simplex tableaux, pivot operations, and substitution rates, the algorithm progressively improves a solution until the optimum is reached, satisfying all constraints at each step.

Hillier and Lieberman (2015) highlighted the method's versatility in production and manufacturing contexts, noting that LP models enable organizations to identify profit-maximizing product mixes within resource limits. Taha (2017) similarly affirmed that LP-based optimization contributes to superior managerial decisions across transportation, inventory management, workforce scheduling, and diverse service industries.

Winston (2004) extended this perspective to service-oriented businesses including restaurants, hospitals, and personal-service establishments, arguing that optimization models improve operational efficiency by identifying the most resource-effective service combinations. Mohd Baki and Cheng (2021) corroborated this view in an SME context, demonstrating that LP helps small businesses determine the optimal service mix under constraints of labor, materials, and capacity. Their framework is directly applicable to laundry operations that must manage machine schedules, wash-load cycles, detergent allocation, and labor hours.

Jain et al. (2021) further validated LP's effectiveness in small-scale mechanical industries, showing profit maximization under labor, materials, and production-time constraints. Oliveira, Costa, and Ravagnani (2017) developed a Mixed Integer Linear Programming (MILP) model for production planning in the drying sector of an industrial laundry, demonstrating that optimal LP planning dramatically improves equipment utilization and profit, a finding directly relevant to small-scale operations seeking to optimize washer and dryer schedules.

Adriantantri and Indriani (2021) demonstrated LP-based resource allocation strategies for SME profitability, providing a practical template for employee scheduling, inventory allocation, and daily service-capacity planning in laundry settings. Firmansyah et al. (2020) applied the Simplex Method to minimize production costs under resource constraints, concluding that LP-derived solutions can reduce monthly expenditures below conventional levels and serve as scientifically grounded benchmarks for operational decisions, a cost-minimization lens that complements the profit-maximization focus of the present study.

Collectively, the literature affirms that mathematical optimization techniques are effective and accessible tools for strategic planning, operational efficiency, and profitability enhancement in both large organizations and small businesses. Their application to a laundry-shop context is both theoretically sound and practically motivated.

3. Research Method

This study employed a quantitative research approach, applying Linear Programming and the Simplex Method to determine the optimal daily service combination that maximizes profit for Clothes in Baskets Laundry Shop.

3.1 Data Collection

Primary data were gathered through a structured personal interview with Mr. Alessandro Basman, owner of Clothes in Baskets Laundry Shop. Information collected included the available laundry services, washing and drying times per service, daily operating hours, machine capacities, selling prices, and itemized operational costs (water, electricity, LPG, and detergent). Secondary data were obtained from the shop's daily operational records.

3.2 Problem Scope

The study focused on three standard laundry service categories: 5 kg, 8 kg, and 10 kg loads. The shop operates from 7:00 AM to 7:00 PM, yielding 720 minutes of daily machine time per unit. With six washing machines and six dryers, total daily machine-time capacity is $6 \times 720 = 4{,}320$ machine-minutes for each equipment class.

3.3 Decision Variables

Three decision variables were defined:

x_1 = number of 5 kg laundry loads processed per day
x_2 = number of 8 kg laundry loads processed per day
x_3 = number of 10 kg laundry loads processed per day

3.4 Objective Function

The objective function aimed to maximize daily net profit:

$$\textbf{Maximize: } Z = 107x_1 + 127x_2 + 142x_3$$

3.5 Constraints

Subject to the following operational constraints:

Washing machine time: $38x_1 + 40x_2 + 50x_3 \leq 4{,}320$

Dryer time: $30x_1 + 30x_2 + 30x_3 \leq 4{,}320 \Rightarrow x_1 + x_2 + x_3 \leq 144$

Non-negativity: $x_1, x_2, x_3 \geq 0$

Slack variables s_1 (unused washing machine time) and s_2 (unused dryer time) were introduced to convert the inequality constraints into standard equality form for simplex computation. The Simplex Method was then applied iteratively using tableau operations until all $C_j - Z_j$ values were zero or negative, signaling an optimal solution.

4. Results and Discussion

4.1 Business Profile and Operational Data

Table 1 summarizes the existing laundry services, processing times, and selling prices for Clothes in Baskets Laundry Shop.

Table 1. Laundry Services, Processing Times, and Selling Prices

Service Type	Washing Time (min)	Drying Time (min)	Selling Price (PHP)
5 kg Load	38	30	₱165
8 kg Load	40	30	₱185

10 kg Load	50	30	₱210

4.2 Determination of Net Profit per Load

Operational costs were itemized per service type. Table 2 presents the cost breakdown, and Table 3 shows the resulting net profit per load after deducting total costs from the selling price.

Table 2. Operational Cost Breakdown per Load (PHP)

Cost Component	**5 kg**	**8 kg**	**10 kg**
Water	₱18	₱18	₱18
Electricity	₱10	₱10	₱10
Dryer LPG	₱20	₱20	₱20
Detergent & Conditioner	₱10	₱10	₱20
Total Cost	₱58	₱58	₱68

Table 3. Net Profit per Load (PHP)

Service Type	**Selling Price**	**Total Cost**	**Net Profit**
5 kg	₱165	₱58	₱107
8 kg	₱185	₱58	₱127
10 kg	₱210	₱68	₱142

4.3 Linear Programming Model Formulation

The complete LP model is stated as follows:

$$\textbf{Maximize: } Z = 107x_1 + 127x_2 + 142x_3$$

Subject to:

$$38x_1 + 40x_2 + 50x_3 \leq 4{,}320 \text{ (washing machine time)}$$

$$x_1 + x_2 + x_3 \leq 144 \text{ (dryer time)}$$

$$x_1, x_2, x_3 \geq 0 \text{ (non-negativity)}$$

Standard form (with slack variables s_1 and s_2):

$$38x_1 + 40x_2 + 50x_3 + s_1 = 4{,}320$$

$$x_1 + x_2 + x_3 + s_2 = 144$$

$$Z - 107x_1 - 127x_2 - 142x_3 = 0$$

4.4 Simplex Method Solution

Initial Simplex Tableau

Table 4 presents the initial simplex tableau with slack variables in the basis.

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Table 4. Initial Simplex Tableau

Cj	Solution Mix	x_1 (107)	x_2 (127)	x_3 (142)	s_1 (0)	s_2 (0)	RHS
₱0	s_1	38	40	50	1	0	4,320
₱0	s_2	1	1	1	0	1	144
	Zj	0	0	0	0	0	0
	Cj−Zj	107	127	142	0	0	

First Iteration

The highest Cj−Zj value is 142, so x_3 enters the basis. The minimum ratio test yields 4,320 ÷ 50 = 86.4 < 144 ÷ 1 = 144; therefore, s_1 leaves. Dividing Row 1 by the pivot element (50) and updating Row 2 produces the tableau in Table 5.

Table 5. Simplex Tableau — First Iteration

Cj	Solution Mix	x_1	x_2	x_3	s_1	s_2	RHS
₱142	x_3	0.76	0.80	1	0.02	0	86.4
₱0	s_2	0.24	0.20	0	−0.02	1	57.6
	Zj	107.92	113.60	142	2.84	0	12,268.80
	Cj−Zj	−0.92	13.40	0	−2.84	0	

Second Iteration (Optimal)

The remaining positive Cj−Zj value is 13.40, so x_2 enters. Ratio test: 86.4 ÷ 0.80 = 108 < 57.6 ÷ 0.20 = 288; x_3 leaves. Dividing Row 1 by 0.80 and updating Row 2 yields the final tableau (Table 6), in which all Cj−Zj values are zero or negative, confirming optimality.

Table 6. Final Simplex Tableau (Optimal Solution)

Cj	Solution Mix	x_1	x_2	x_3	s_1	s_2	RHS
₱127	x_2	0.95	1	1.25	0.025	0	108
₱0	s_2	0.05	0	−0.25	−0.025	1	36
	Zj	120.65	127	158.75	3.175	0	13,716
	Cj−Zj	−13.65	0	−16.75	−3.175	0	

4.5 Verification Using QM for Windows

To validate the manually derived simplex solution, the problem was solved independently using QM for Windows (Version 5.0), a widely adopted decision-science software package developed by Howard J. Weiss. QM for Windows provides a dedicated Linear Programming module capable of solving LP problems of varying complexity and generating complete simplex tableau output, ranging analysis, and sensitivity reports.

Step-by-Step Procedure

The following steps were performed to replicate the laundry shop optimization problem in QM for Windows:

Step 1 — Launch & Module Selection. Open QM for Windows and select Module → Linear Programming from the main menu.
Step 2 — New Problem Setup. Click File → New. In the dialog box, set the following parameters: Number of Constraints = 2; Number of Variables = 3; Objective = Maximize; Problem Title = "Clothes in Baskets Laundry Shop."
Step 3 — Enter the Objective Function Coefficients. In the objective function row, input the net profit coefficients: X1 = 107, X2 = 127, X3 = 142.
Step 4 — Enter the Constraint Coefficients. For Constraint 1 (washing machine time): X1 = 38, X2 = 40, X3 = 50; Direction = ≤; RHS = 4320. For Constraint 2 (dryer time): X1 = 1, X2 = 1, X3 = 1; Direction = ≤; RHS = 144.
Step 5 — Solve. Click Solve. QM for Windows executes the Simplex algorithm and displays the Solution, Ranging, and Iterations results screens.
Step 6 — Retrieve Results. Navigate to the Iterations tab to review the full simplex tableau history and confirm the pivot sequence. Navigate to the Solution tab to record the optimal variable values and objective function value.

QM for Windows Output Summary

Table 8 presents the solution output generated by QM for Windows. The software confirmed the optimal solution in two iterations, consistent with the manual simplex procedure.

Table 8. QM for Windows Solution Output

Variable / Output	QM for Windows Result	Manual Simplex Result	Match?
x_1 (5 kg loads)	0	0	✓
x_2 (8 kg loads)	108	108	✓
x_3 (10 kg loads)	0	0	✓
Optimal Profit Z*	₱13,716	₱13,716	✓
Slack s_1 (Washer)	0 min	0 min	✓
Slack s_2 (Dryer)	36 loads	36 loads	✓
Iterations to Optimum	2	2	✓

The QM for Windows output is in complete agreement with the manually derived solution across all decision variables, slack values, and the optimal objective value. This computational verification confirms the accuracy of the two-iteration simplex procedure and eliminates the possibility of arithmetic error in the manual tableau operations. The shadow price for the washing machine constraint, reported by QM for Windows as ₱3.175 per machine-minute, likewise corroborates the dual variable interpretation discussed in Section 6.

4.6 Optimal Solution Summary

Table 9. Optimal Solution

Decision Variable	Description	Optimal Value
x_1	5 kg loads per day	0
x_2	8 kg loads per day	108
x_3	10 kg loads per day	0
Z*	Maximum Daily Profit (PHP)	₱13,716

The optimal solution prescribes processing exactly 108 loads of 8 kg regular laundry per day, yielding a maximum daily profit of ₱13,716. Both 5 kg and 10 kg loads are excluded from the optimal mix: despite generating higher absolute profit per unit, the 10 kg load consumes disproportionately more washing machine time (50 minutes versus 40 minutes for the 8 kg load), producing a lower profit-per-machine-minute ratio. The 5 kg load also fails to compensate for its lower unit profit relative to the binding constraint.

Resource utilization analysis confirms that washing machine time is fully consumed ($40 \times 108 = 4{,}320$ minutes), establishing it as the sole binding constraint. Dryer capacity retains an excess of 36 load-slots ($s_2 = 36$), indicating that machine-time expansion rather than additional dryers represents the more valuable capital investment. This finding highlights an asymmetric resource bottleneck that the laundry owner may leverage in future capacity planning.

5. Application of the Simplex Method

The Simplex Method was applied by first converting the inequality constraints into equations via slack variables, enabling representation in standard tableau form. The procedure then proceeded through a series of well-defined computational steps: identification of the entering variable (highest positive $C_j - Z_j$), application of the minimum ratio test to determine the leaving variable, pivot row normalization, and row transformation to zero out the entering variable's column in all other rows.

The method required two iterations to reach optimality. In the first iteration, x_3 (10 kg loads) entered the basis, improving total profit to ₱12,268.80. However, the positive residual $C_j - Z_j$ for x_2 indicated that a further improvement was achievable. In the second iteration, x_2 (8 kg loads) replaced x_3, and all $C_j - Z_j$ values became non-positive, confirming that the optimal basis had been reached.

The key insight from the simplex iterations is that the 8 kg load offers a superior profit-per-machine-minute efficiency over the 10 kg load. Although the latter generates ₱142 per load compared to ₱127 for the 8 kg service, the additional ten minutes of washing time per 10 kg load renders it less efficient under the prevailing machine-time constraint. The Simplex Method identified this trade-off automatically through the $C_j - Z_j$ criterion, demonstrating its power as an objective decision-support tool.

6. Analysis of Results

The findings demonstrate a counterintuitive but well-established principle in operations research: profitability under constraints depends not on absolute unit profit, but on the ratio of unit profit to resource consumption. Although the 10 kg load commands the highest per-load margin (₱142), its elevated washing time (50 minutes) yields a profit rate of ₱2.84 per machine-minute—inferior to the 8 kg load's rate of ₱3.175 per machine-minute. The Simplex Method's dual variable framework (reflected in the s_1 shadow price of ₱3.175) quantifies this relationship precisely.

The identification of washing machine time as the binding constraint has direct managerial implications. Each additional machine-minute of washing capacity is worth approximately ₱3.175 in daily profit, providing a concrete basis for evaluating whether the capital cost of an additional washing machine would be offset by the incremental revenue it enables. Dryer capacity, by contrast, has zero shadow price in the optimal solution, meaning that acquiring additional dryers would yield no profit improvement under the current service mix.

The study also reaffirms the broader applicability of LP models in service-sector SMEs. As the literature consistently shows, optimization models move strategic decisions from intuition-driven to evidence-based, reducing waste and improving both short-term efficiency and long-term sustainability of small business operations.

7. Conclusion

This synthesis paper demonstrated the practical utility of the Simplex Method in solving a real-world business optimization problem for a small-scale laundry enterprise. Through a two-iteration simplex procedure involving tableau formation, pivot operations, and the Cj−Zj optimality criterion, the study systematically identified the maximum-profit service mix under machine-time constraints.

The optimal solution processing 108 loads of 8 kg regular laundry per day yields a maximum daily profit of ₱13,716. Washing machine time was confirmed as the sole binding constraint, while dryer capacity remained under-utilized with 36 load-slots in excess. The result underscores that profit maximization in resource-constrained environments requires attention to resource efficiency rather than unit margin alone.

These findings validate the Simplex Method as a rigorous, accessible, and practically actionable tool for SME decision-making. Its application is not limited to manufacturing but extends naturally to service industries where machine capacity, labor, and time constitute the key limiting factors.

8. Recommendations

Based on the findings, the following recommendations are offered to the business owner and future researchers:

- Prioritize marketing and promotional initiatives for the 8 kg laundry service, as it generates the highest profit efficiency relative to machine-time consumption. To drive demand, the following promotional activities are suggested: free delivery for customers who choose the 8 kg load; free fabric conditioner added at no extra charge for every 8 kg wash; free pick-up for 8 kg loads booked in advance; and priority scheduling where 8 kg customers get preferred time slots for faster turnaround.
- Implement structured scheduling and workflow management to sustain full washing machine utilization across all operating hours.
- Evaluate the feasibility of investing in additional washing machines, given that machine time is the sole binding constraint and carries a shadow price of ₱3.175 per machine-minute.
- Monitor customer demand patterns on a seasonal and weekly basis to ensure the recommended service mix remains operationally viable and responsive to market fluctuations.
- Future researchers are encouraged to extend the model by incorporating additional decision variables such as labor costs, delivery services, folding time, and stochastic demand to develop a more comprehensive and robust optimization framework.

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