Sustainable Aggregate Production Planning for Seasonal Products in Thailand

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A R T I C L E I N F O

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A B S T R A C T

The goal of this research is to develop a sustainable production plan that will provide a well-balanced profit to the company, good income for workers, job security without laying-off any workers, a safe workplace with less toxic chemicals usage, and a healthy environment. This study examines various factors, such as working days and daily wages, using a mathematical model to assess differences, benefits, and drawbacks. In response, the proposed multi-objective linear programming (MOLP) model is designed to optimize three interconnected company goals: total profit, social impact, and environmental responsibility. This research intends to contribute to a paradigm shift towards sustainable supply chain management (SSCM) by presenting a mathematical model that simultaneously addresses these objectives. This holistic view model offers a practical solution for striking a balance between these conflicting objectives of employees, supporting environmental sustainability, and ensuring that they feel secure in their jobs while the business turns a healthy profit.

1. INTRODUCTION

In an era, there are huge amounts of products manufactured each month, serving customer demand which significantly impacts the economy. The symbiotic relationship between profit and sustainability takes center stage, urging industries to recalibrate their strategies. In a world where excess production contributes significantly to environmental degradation. The well-plan production planning should not create waste, due to the wasteful resources, material costs, and opportunity costs. Environmental effects are not only resource usage but also emission pollution. To achieve sustainability in production planning, the holistic view from the supervisor or management level should be perfectly planned from the initial state of the project. The main objectives are linked to each other. For instance, when the business decides to use safer raw materials, it may cost more, but positive effect on workers' health and the company's reputation. In Southeast Asia Countries, there are a significant number of industries that rely heavily on manual labor. The mathematical model in this research will be presented to optimize the goals simultaneously: total profit, social, and environmental impact, while giving importance to the workers' income and the job stability of all employees. The company cannot lay off any employees, especially in low season. Still, they will manufacture and stock for selling in the peak period instead, as the mixed aggregate strategy production. This research has 3 main objectives as follows;

• Economically, mathematical models aim to maximize the company's total profit while considering various costs such as filler costs, packaging costs, inventory holding costs, wages, etc.

• Socially, focus on the well-being of all people in the factory by eliminating harmful materials from the production line. Additionally, ensuring reasonable wages that allow a comfortable life and job security through a well-planned production strategy.

• Environmentally, the result will promote sustainability by maximizing the recycled materials for packaging, as well as controlling the production line to reduce waste.

2. LITERATURE REVIEW

An increasing number of businesses are attempting to incorporate sustainable supply chains and production practices [1]. Production planning optimization involves coordinating and integrating all the business operations, from raw materials selection and preparation to the distribution of products to the customers. Generally, sustainable manufacturing prioritizes the concurrent

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optimization of social issues, environmental performance, and economic considerations [2]. Social issues are related to labor employment, community, and health security. While environmental is about resources, emissions, energy, and waste. Over the past few decades, environmental awareness has grown. Environmental issues like global warming, the use of toxic substances, and the depletion of non-renewable resources are becoming more widely recognized [3]. Factories have focused more on reuse initiatives in recent years, which reduce waste by recovering used goods [4]. Improvements in environmental efficiency will be more beneficial than ever as the costs of materials, energy, and waste increase [5]. Sustainability is highly discussed in science and industry [6]. The severity of the waste generation and scarcity issues is rising. Reverse logistics, recycling, reusing, and remanufacturing of products are among the environmental challenges that countries throughout the world are taking increasingly seriously [7]. "The integration of sustainability concerns to the decisions of the supply chain, in an attempt to improve and enhance the economic, environmental, and social performances" is the general definition of sustainable supply chain management [8]. Unsustainable production and consumption are the primary causes of environmental harm, particularly in developed nations. [9]. More creative goods were exported by developing nations than by developed ones. Thailand produced 6.1 million US dollars in 2015, making it the seventh-largest exporter of creative goods among developing countries [10]. One of the biggest and most divisive environmental threats today is global climate change. Air, water, and greenhouse gas pollution have made it necessary to create and enhance environmental management techniques [11]. It has been discovered that supply chains benefit from effective planning and cooperation in areas such as energy conservation, material recycling, and trash reduction [12]. Resources are costly and become harder to find as demand and population grow [13]. The traditional definition of supply chain management is the coordination of financial, logical, and physical flows within and between networks of intra- and inter-organizational relationships in order to jointly add value and satisfy customers [14]. The collaborated process by which many corporate organizations, including manufacturers, distributors, suppliers, and retailers, work together to procure raw materials, transform them into specific end products, and then distribute these finished goods to retailers is known as the supply chain. [15]. When the company's strategies change, target customers and demand will be different, because there are trade-offs involved, this movement needs to be carefully thought out. Lately, growing consciousness regarding environmental and social issues has compelled enterprises to take into account the environmental and social consequences of their operations [16]. Stricter environmental and occupational safety and health regulations reduce non-renewable resources and increase consumer preference. [17]. Green purchasing has a significant impact on a company's business performance and environmental protection strategies, making it an essential component of sustainable firm development [18].

For product quantity, forecasting and planning the production level is a crucial responsibility of the management, and understanding how to predict lot size precisely and procurement quantity is important. A medium-term capacity planning technique called aggregate production planning (APP) is used to calculate costs, production schedules, labor, and production plans in order to satisfy client expectations. A term of 12 to 24 months is typically covered by the aggregate plan [19–20]. It aims to determine the production quantity and inventory level in an aggregate term. Several parameters are included in each APP model, including market demand, labor costs, subcontracting costs, production rate, backorder cost, maximum labor level, maximum capital level, and product capacity [21]. Naturally, businesses can remove many costs, if they produce equal or close to market demand. The supply chain's overall economics is characterized by low costs, large profits, and strong competition [22]. Supply chain profits should be allocated reasonably and fairly to motivate stakeholder cooperation and thus avoid internal conflict [23]. Addressing complex societal issues and overcoming obstacles like homelessness, violence, drug abuse, and poverty are all part of societal entrepreneurship [24]. Building a sustainable business is not just about profits; it is about fair compensation to workers and nurturing the environment nearby.

The research gap in previous works is that there are limited research works related to production planning to minimize the use of toxic chemicals, maximize the use of sustainable materials, avoid workers' lay-off, consider workers' temporary leave from work, and analyze the effects of increasing labor cost on the profit.

3. METHODOLOGY

The goal of this study, in terms of business, is to maximize the total profit and minimize the social and environmental negative effects by substituting the amount of material used in manufacturing lines such as recycled packaging boxes and fillers with safer ones. In this study, all data are collected from a real case, and run all results on Microsoft Excel's Solver Option. To develop the efficiency of the production line to serve customer demand, and also utilize the number of employees. The block diagram as shown in Figure 1 represents the research methodology and illustrates the steps involved in developing the mathematical sustainable production planning model.

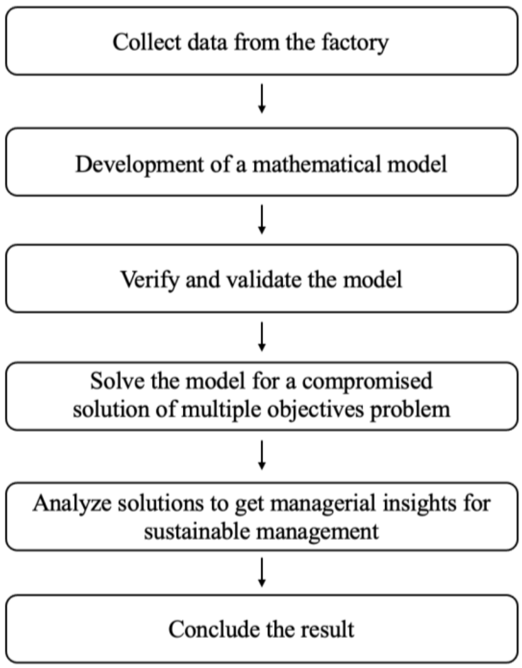

Fig. 1. Research Block Diagram

3.1 Concepts and Assumptions of Mathematical Model

3.1.1 Assumptions

This model is developed based on these assumptions.

1. No layoff since the workers will lose their job and create social problems. It results in a bad reputation for the company, so recruitment of new workers is difficult.
2. Allow workers to take leave for 1 period (month) since some workers have to go back to their hometown to cultivate and harvest their rice fields in May and November, respectively.
3. The products (shoes mainly schoolboy and girl shoes) have seasonal demand.
4. There are multiple products with different characteristics. Some models of shoes can use recycled packaging materials as an option and some models are designed to use recycled packaging materials.
5. The number of working days in each month is not equal and known.
6. Overtime is permitted but limited, it will be used when regular productivity is insufficient.

3.1.2 Input data

The model requires several important data such as labor productivity, working day, customer demand in each period, materials and manufacturing costs, unit cost of filler and box type, wage of worker, etc.

3.1.3 Output

This model generates optimal decisions related to the production quantity of each product in each period (in regular time and overtime), worker hiring, various expenses, inventory level, total profit, and weight average satisfaction.

3.1.4 Managerial insights

The company can analyze costs in each production plan, investigate the chemical and sustainable box use, and determine future company expenses and profit when the minimum wage increases.

3.1.5 Constraints

Production-worker relationship:

$$\sum_p Q_{pt} \leq LPw_t n_t \quad \forall t \tag{1}$$

(Assuming processing times for all products are equal)
Workers balance:

$$w_t = w_{t-1} - wl_t - wr_t + wh_t + wl_{t-1} \quad \forall t \tag{2}$$

Maximum hiring limit for workers:

$$wh_t \leq wh_{max} \quad \forall t \tag{3}$$

Filler used:

$$F \sum_p \sum_t (Q_{pt} + Q1_{pt}) = \sum_f F_f \tag{4}$$

Inventory balance:

$$I_{pt} = I_{pt-1} + Q_{pt} + Q1_{pt} - D_{pt} \quad \forall p,t \tag{5}$$

Safety stock:

$$I_{pt} \geq ss_{pt} \quad \forall p,t \tag{6}$$

Overtime production limit:

$$\sum_p Q1_{pt} \leq OT \sum_p Q_{pt} \quad \forall t \tag{7}$$

Box type:

$$QB_{standard} = \sum_t Q_{light,t} + B_{standard} \sum_t Q_{smart,t} \tag{8}$$

$$QB_{sustainable} = \sum_t Q_{zero,t} + B_{sustainable} \sum_t Q_{smart,t} \tag{9}$$

$$B_{standard} + B_{sustainable} = 1 \tag{10}$$

Total other material and manufacturing costs:

$$T_{OM} = \sum_p \sum_t (Q_{pt} + Q1_{pt}) CO_p \tag{11}$$

Total inventory holding cost:

$$T_{INV} = \sum_p \sum_t I_{pt}\, h \tag{12}$$

Total hiring cost:

$$T_{CH} = \sum_t wh_t Ch \tag{13}$$

Total labor cost during regular time:

$$T_{WI} = \sum_t W_{hr} sr\, n_t w_t \tag{14}$$

Total labor cost during overtime:

$$T_{OI} = \frac{W_{hr} so \sum_p \sum_t Q1_{pt}}{LP} \tag{15}$$

Total filler cost:

$$T_{FI} = \sum_f F_f \, CF_f \tag{16}$$

Total packaging cost:

$$T_{PI} = \sum_b CB_b QB_b \tag{17}$$

Total amount of sustainable boxes:

$$TB = QB_{sustainable} \tag{18}$$

Total toxic value of chemicals:

$$TX = \sum_f T_f F_f \tag{19}$$

Total cost:

$$T_C = T_{CH} + T_{WI} + T_{OI} + T_{FI} + T_{PI} + T_{INV} + T_{OM} \tag{20}$$

Total revenue:

$$T_R = \sum_p \sum_t D_{pt} P_p \tag{21}$$

Total profit:

$$T_P = T_R - T_C \tag{22}$$

Satisfaction of profit:

$$TP_{sat} = 1 - \frac{(TP_{max} - TP)}{(TP_{max} - TP_{min})} \tag{23}$$

Satisfaction of sustainable box:

$$TB_{sat} = 1 - \frac{(TB_{max} - TB)}{(TB_{max} - TB_{min})} \tag{24}$$

Satisfaction of toxic value for chemicals:

$$TX_{sat} = \frac{(TX_{max} - TX)}{(TX_{max} - TX_{min})} \tag{25}$$

3.1.6 Objective Function

Maximize weighted average satisfaction:

$$\text{Maximize } WS = \alpha_{TP} TP_{sat} + \alpha_{TB} TB_{sat} + \alpha_{TX} TX_{sat} \tag{26}$$

$$\alpha_{TP} + \alpha_{TB} + \alpha_{TX} = 1 \tag{27}$$

3.1.7 Explanation of Constraints and Objective Function

Constraint (1) expresses that production quantity is dependent on the number of workers and the number of working days. Worker balance constraint (2) allows workers to take leave for one month and come back to work, consider worker resignation based on historical data, and do not allow laying off. Constraint (3) sets a maximum hiring limit in each period to let the human resource section recruit workers easily. Constraint (4) allows the use of two fillers where one is more expensive but better for worker health. Inventory balance and required safety stock are controlled by constraints (5) and (6). The limit of overtime work is controlled by constraint (7) since it is more costly than regular time work. Constraints (8) and (9) allow the SMART series product to use a sustainable (recycled materials) box or standard (new materials) box by setting the value $B_{standard}$ and $B_{sustainable}$ according to constraint (10). Note that $B_{standard}$ and $B_{sustainable}$ are parameters that the value must be set by the planner. They are not decision variables to avoid a nonlinear function.

The total cost has 7 elements as shown in constraint (20). Each element of the total cost is expressed by constraints (11-17). Total revenue and total profit are calculated by constraints (21) and (22). The total amount of sustainable boxes and total toxic value of chemicals are represented by constraints (18) and (19). The three objectives, which are total profit, total amount of sustainable boxes, and total toxic value of chemicals have different units and magnitude. Trading off among them is inconvenient since one with a high magnitude may dominate others with a low magnitude. Therefore, all objectives are normalized to satisfaction levels with a common scale from 0.0 to 1.0 using constraints (23-25). Three objectives are combined into a single objective using the weighted average satisfaction as shown in equation (26). The sum of weights must be equal to 1.0 according to equation (27).

3.1.8 Sales Data

This is the historical sales data of the company from the previous 3 years (2021-2023), which is classified into each month. There are 3 series of our products. LIGHT has come with a reasonable price, SMART has the highest demand and ZERO is the limited edition, producing only 1,000 units per month. From Figure 2, the peak period of this seasonal product is in March-April every year, the reason is that most Thai schools are open the first semester in the middle of May. Therefore, the distributor and wholesaler have to purchase those products around that period, to serve the customer's needs. But on the other hand, after the peak, sales are decreasing due to students already purchasing shoes for going to school. The off-season is around August, after that the sales amount will get better.

3.1.9 Working Days (Thailand)

For the working days, some factories mandate that their employees work five days a week, while some require six (as shown in Table 1). The difference between these two strategies will be about 4 days per month. Regarding production scheduling, sales have been rising since November; however, there are numerous holidays in December, which will have an impact on the volume of shoes produced. The peak period occurs in April every year as well, but there are the fewest working days during this time of year.

Table 1. Working Days (Thailand)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2024	25	25	26	21	25	24	24	26	25	25	26	23
	22	20	21	18	20	19	20	21	21	21	21	19

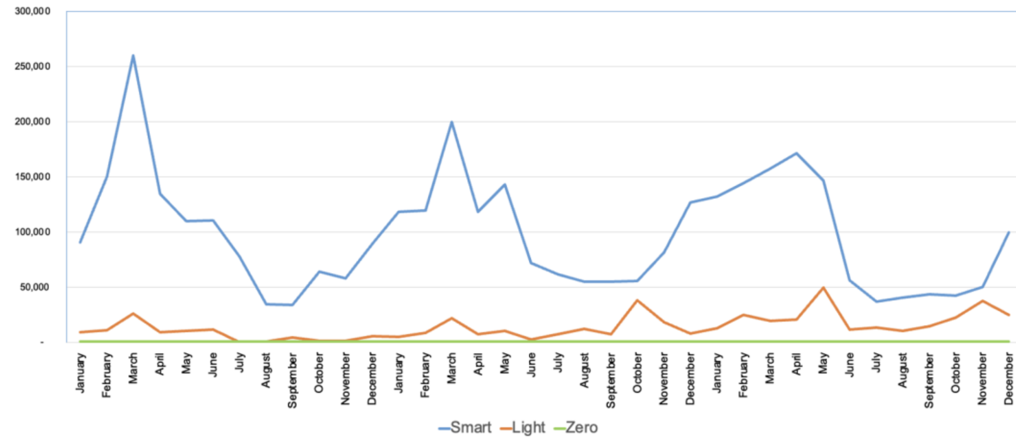

Fig. 2. Historical Sales Data.

3.1.10 Number of Workers

Southeast Asians and Thais typically consume rice at every meal. In addition, rice plays a significant role in the country's economy. It is the second most valuable agricultural export product of Thailand, accounting for 15% of the agricultural GDP. Every year, during May and November, a group of workers, primarily hailing from the northeastern region of Thailand, embark on a journey back to their hometowns to plant and harvest products. The rate of employees who leave or resign is about 5 percent each from the total, while in the other periods, the turnover rate is approximately 3%.

3.1.11 Data of Toxic Value and Costs

There are two types of filler with different toxic values and costs per unit, filler type one has a lower cost but a higher toxic value. In terms of cost, filler types 1 and 2 have unit costs of 7 and 30 THB per kilogram, respectively. Conversely, the toxic scores are 0.035 and 0.01, the higher the score, the worse the health of the workers and the pollution. Based on a survey of employees who are exposed to these chemicals, the satisfaction with the expensive but safer chemical is 3.5 times of another chemical. Thus, the toxic score of the cheap but more toxic is set at 3.25 times of the other.

3.1.12 Standard and Sustainable Packaging Costs

There are two kinds of packaging, the sustainable box is made from recyclable materials and uses less ink. The standard packaging cost is 10 THB per unit, while the sustainable packaging cost is 17 THB.

3.1.13 Products Details

LIGHT, SMART, and ZERO products are the three series under this research. ZERO will be made with sustainable materials and limited sales of only 1,000 pairs per month. SMART is the series that has the highest demand, with over 1 million pairs annually. LIGHT is the most affordable option in terms of cost. For packaging, LIGHT will be used by the standard box only, ZERO will go with the sustainable box, and SMART will be chosen to use either standard or sustainable materials by the mathematical model. About the filler type, all products will use only one type. This research will compute every situation before analyzing the benefits and drawbacks. Material details are shown in Figure 3.

	LIGHT	SMART	ZERO
PRICE (THB)	199	349	999
BOX PACKAGING	STANDARD BOX	STANDARD BOX / SUSTAINABLE BOX	SUSTAINABLE BOX
FILLER TYPE	SAME TYPE (1 OR 2) IN ALL PRODUCTS		

Fig. 3. Product Details.

This study separates the model into 12 scenarios, as shown in Figure 4. Grouped by days of work, type of box used for SMART product, and the amount of worker wage per day. Each scenario will be divided by weight for 10 sub-models. There will be 120 models in total, the objective is to see the advantages and disadvantages of each situation. Each sub-model has a different objective weight, salary, material used, and working days each week.

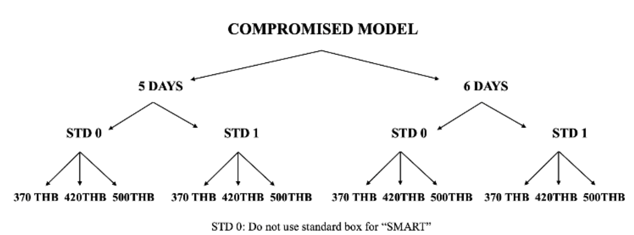

Fig. 4. Scenario in This Study

4. RESULT AND DISCUSSION

4.1 Total Profit Comparison

Tables 2 and 3 will represent the gross profit of all sub-models. As expected, when standard packaging is applied, the profit is higher than when sustainable packaging is used.

The annual maximum profit will be 70,520,339 THB with the condition of working 6 days per week, using the standard box instead of the sustainability box, and the daily wage at 370 THB per day, also with the condition that the management level give priority at 0.75 or higher with the profit allocation. On the other side, if the company decided to work five days a week, use the sustainability box, pay 500 THB every day, and prioritize profit satisfaction with less than three-fourths of the total, these conditions would make the business make a yearly minimum profit of 50,735,116 THB.

Table 2. Total Profit When Using Sustainable Packaging

α_{TP} - α_{TB} - α_{TX}	Profit					
	Both Smart and Zero Use Sustainable Boxes					
	5 day			6 day		
	370THB	420THB	500THB	370THB	420THB	500THB
0.40-0.20-0.40	59,418,819	56,077,437	50,735,116	60,464,190	56,982,648	51,633,210
0.40-0.40-0.20	59,418,819	56,077,437	50,735,116	60,464,190	56,982,648	51,633,210
0.50-0.25-0.25	59,418,819	56,077,437	50,735,116	60,464,190	56,982,648	51,633,210
0.60-0.05-0.35	59,418,819	56,077,437	50,735,116	60,464,190	56,982,648	51,633,210
0.60-0.10-0.30	59,418,819	56,077,437	50,735,116	60,464,190	56,982,648	51,633,210
0.70-0.15-0.15	59,418,819	56,077,437	50,735,116	60,464,190	56,982,648	51,633,210
0.75-0.05-0.20	59,418,819	56,077,437	50,735,116	60,464,190	56,982,648	51,633,210
0.75-0.20-0.05	61,905,675	58,564,293	53,221,972	62,951,046	59,469,505	54,120,067
0.85-0.10-0.05	61,905,675	58,564,293	53,221,972	62,951,046	59,469,505	54,120,067
0.90-0.05-0.05	61,905,675	58,564,293	53,221,972	62,951,046	59,469,505	54,120,067

4.2 Comparison of Production for Working 5 and 6 days a Week

Results are presented in Tables 4 and 5, production quantities during regular time and overtime are highlighted in yellow boxes. It shows that inventory level, demand, and number of workers required are related. The company has set a safety stock equivalent to 15% of customer demand for that product in each period. From those plans, the summation of shoes produced is 1,351,552 pairs. The difference is in the production during regular time and overtime. At the regular time, 5 days working can produce 1,167,334 shoes in a year, while working 6 days a week can manufacture only 1,215,902. But during overtime, working 5 and 6 days in a single week can make 184,218 and 135,650 per year, respectively. The total production of these 2 cases is at 1,351,552 pairs. At any plan, the inventory level needs to be more than safety stock for all periods. As shown in Tables 2 and 3, working six days a week offers a higher company's profit, which accounts for the decrease in productivity during overtime, and shortens the initial inventory preparation duration.

Table 3. Total Profit When Using Standard Packaging

α_{TP} - α_{TB} - α_{TX}	Profit					
	Only Zero Use Sustainable Boxes					
	5 day			6 day		
	370THB	420THB	500THB	370THB	420THB	500THB
0.40-0.20-0.40	66,988,112	63,646,730	58,304,409	68,033,483	64,551,941	59,202,504
0.40-0.40-0.20	66,988,112	63,646,730	58,304,409	68,033,483	64,551,941	59,202,504
0.50-0.25-0.25	66,988,112	63,646,730	58,304,409	68,033,483	64,551,941	59,202,504
0.60-0.05-0.35	66,988,112	63,646,730	58,304,409	68,033,483	64,551,941	59,202,504
0.60-0.10-0.30	66,988,112	63,646,730	58,304,409	68,033,483	64,551,941	59,202,504
0.70-0.15-0.15	66,988,112	63,646,730	58,304,409	68,033,483	64,551,941	59,202,504
0.75-0.05-0.20	66,988,112	63,646,730	58,304,409	68,033,483	64,551,941	59,202,504
0.75-0.20-0.05	69,474,968	66,133,586	60,791,265	70,520,339	67,038,798	61,689,360
0.85-0.10-0.05	69,474,968	66,133,586	60,791,265	70,520,339	67,038,798	61,689,360
0.90-0.05-0.05	69,474,968	66,133,586	60,791,265	70,520,339	67,038,798	61,689,360

Table 4 Production Plan for Working 5 Days a Week

Month	t		9	10	11	12	1	2	3	4	5	6	7	8	
Workday	Nt		21	21	21	19	22	20	21	18	20	19	20	21	
Demand Light			14,948	23,038	37,947	24,954	13,470	25,265	19,917	21,214	49,651	11,817	13,505	10,825	
Demand Smart			44,124	42,530	50,242	99,738	132,396	144,276	157,904	171,801	146,834	56,776	37,506	41,044	
Demand Zero			1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	
Production (regular time)	Qpt														
Light			100,355	63,476	63,227	397	-	-	-	-	0	6,142	13,758	10,423	
Smart			743	42,291	42,027	103,097	124,257	115,838	125,773	111,253	114,271	43,267	34,616	41,575	1,167,334
Zero			1,050	1,000	1,000	1,000	500	1,000	500	500	1,000	1,000	1,000	1,000	
Production (overtime)	Q1pt														
Light			-	-	-	397	-	-	-	-	-	-	-	-	
Smart			-	-	9,372	25,726	30,689	29,209	31,068	27,438	28,818	-	-	-	184,218
Zero			-	-	-	-	500	-	500	500	-	-	-	-	
Inventory Light		10,000	95,407	135,845	161,125	136,965	123,495	98,230	78,313	57,099	7,448	1,773	2,026	1,624	899,346
Inventory Smart		50,000	6,619	6,379	7,536	36,621	59,172	59,943	58,879	25,770	22,025	8,516	5,626	6,157	303,244
Inventory Zero		100	150	150	150	150	150	150	150	150	150	150	150	150	1,800
Safety Stock Light	SSpt-L		2,242	3,456	5,692	3,743	2,021	3,790	2,988	3,182	7,448	1,773	2,026	1,624	
Safety Stock Smart	SSpt-S		6,619	6,380	7,536	14,961	19,859	21,641	23,686	25,770	22,025	8,516	5,626	6,157	
Safety Stock Zero	SSpt-Z		150	150	150	150	150	150	150	150	150	150	150	150	

Table 5. Production Plan for Working 6 Days a Week

Month	t		9	10	11	12	1	2	3	4	5	6	7	8	
Workday	Nt		25	25	26	23	25	25	26	21	25	24	24	26	
Demand Light			14,948	23,038	37,947	24,954	13,470	25,265	19,917	21,214	49,651	11,817	13,505	10,825	
Demand Smart			44,124	42,530	50,242	99,738	132,396	144,276	157,904	171,801	146,834	56,776	37,506	41,044	
Demand Zero			1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	
Production (regular time)	Qpt														
Light			7,190	79,929	75,115	14,349	-	15,323	1,906	-	16,811	6,142	13,758	10,423	
Smart			743	42,291	51,399	107,571	136,886	125,840	149,393	118,417	111,409	43,267	34,615	41,575	1,215,902
Zero			1,050	1,000	1,000	1,000	1,000	1,000	1,000	1,000	500	1,000	1,000	1,000	
Production (overtime)	Q1pt														
Light			-	-	-	-	-	15,323	1,906	-	-	-	-	-	
Smart			≥ -	-	-	-	-	20,218	36,169	29,854	31,680	-	-	-	135,650
Zero			-	-	-	-	-	-	-	-	500	-	-	-	
Inventory Light		10,000	2,242	59,134	96,301	85,696	72,226	77,607	61,502	40,288	7,448	1,773	2,026	1,624	507,865
Inventory Smart		50,000	0≤ 6,619	6,379	7,536	15,369	19,859	21,641	49,299	25,770	22,025	8,516	5,626	6,157	194,798
Inventory Zero		100	150	150	150	150	150	150	150	150	150	150	150	150	1,800
Safety Stock Light	SSpt-L		2,242	3,456	5,692	3,743	2,021	3,790	2,988	3,182	7,448	1,773	2,026	1,624	
Safety Stock Smart	SSpt-S		6,619	6,380	7,536	14,961	19,859	21,641	23,686	25,770	22,025	8,516	5,626	6,157	
Safety Stock Zero	SSpt-Z		150	150	150	150	150	150	150	150	150	150	150	150	

According to the schedule we presented in the off-season, we want production to be stockpiled. Those finished goods will be stocked for sale during the peak period or before the schools start the semester. Additionally, workers still have enough money when they can work during their off-peak hours. In order to minimize the inventory holding costs, the corporation aims to maintain things in stock for the shortest amount of time, which should be followed with the 6 days a week working plan.

4.3 Comparison of Workers Required

The number of workers in any period, as shown in Tables 6 and 7, working five and six days a week. Normally, the employee turnover rate is roughly 3% throughout the other periods, compared to about 5% for each employee who leaves or resigns from the total in May and November. Knowing customer demand allows the company to plan production according to the number of workers required, if fewer workers than currently needed, we may be able to hire additional staff.

When compared to these alternative plans, show the average number of workers working 5 and 6 days a week at 228 and 215, assuming the initial workforce is distributed equally at 190. The company will require a larger workforce in case they have fewer working days in the same period. An increase in the average number of workers will inevitably increase the number of workers hired in Tables 6 and 7, which have indicated the annual hiring total at 120 and 99 people. Production must be hastened for programs that operate five days a week, which will also result in the requirement to hire additional staff regularly.

Table 6. Number of Workers in 5 Days a Week Plan

Month		9	10	11	12	1	2	3	4	5	6	7	8	
Number of workers	190	199	208	207	225	232	239	246	254	232	236	230	224	228
Number of workers leave		0	0	8	0	0	0	0	0	11	0	0	0	
Number of workers resigned		6	6	8	5	8	8	8	7	11	7	6	6	
Number of workers hiring		15	15	15	15	15	15	15	15	0	0	0	0	120

Table 7. Number of Workers in 6 Days a Week Plan

Month		9	10	11	12	1	2	3	4	5	6	7	8	
Number of workers	190	193	202	201	219	226	233	240	233	211	215	209	203	215
Number of workers leave		0	0	8	0	0	0	0	0	11	0	0	0	
Number of workers resigned		6	6	8	5	8	8	8	7	11	7	6	6	
Number of workers hiring		9	15	15	15	15	15	15	0	0	0	0	0	99

4.4 Comparison of Total Sustainable Box Used

Table 8 shows the number of sustainable boxes used when the policy is to use sustainable boxes for both SMART and Zero product series. On the contrary, Table 9 is for the policy that the sustainable box is used only for the ZERO product series. It is seen from Table 8 that when sustainable boxes are used for both products the number of sustainable boxes required is much higher at 1,093,378 units a year when compared with 12,050 units a year in Table 9. The policy to use sustainable boxes or not for the SMART product series affects sustainability issues significantly.

However, sustainable boxes are more expensive than standard boxes. The policy to use sustainable boxes for both SMART and ZERO product series results in a total cost of boxed of 21,169,167 THB annually when compared with 13,599,574 THB annually when sustainable boxes are used only for ZERO products.

Table 8. Total Sustainable Boxes Use for SMART & ZERO

α_{TP} - α_{TB} - α_{TX}	Sustainable Box Use					
	Both Smart and Zero Use Sustainable Boxes					
	5 day			6 day		
	370THB	420THB	500THB	370THB	420THB	500THB
0.40-0.20-0.40	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378
0.40-0.40-0.20	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378
0.50-0.25-0.25	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378
0.60-0.05-0.35	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378
0.60-0.10-0.30	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378
0.70-0.15-0.15	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378
0.75-0.05-0.20	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378
0.75-0.20-0.05	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378
0.85-0.10-0.05	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378
0.90-0.05-0.05	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378	1,093,378

Table 9. Total Sustainable Boxes Use for ZERO

α_{TP} - α_{TB} - α_{TX}	Sustainable Box Use					
	Only Zero Use Sustainable Boxes					
	5 day			6 day		
	370THB	420THB	500THB	370THB	420THB	500THB
0.40-0.20-0.40	12,050	12,050	12,050	12,050	12,050	12,050
0.40-0.40-0.20	12,050	12,050	12,050	12,050	12,050	12,050
0.50-0.25-0.25	12,050	12,050	12,050	12,050	12,050	12,050
0.60-0.05-0.35	12,050	12,050	12,050	12,050	12,050	12,050
0.60-0.10-0.30	12,050	12,050	12,050	12,050	12,050	12,050
0.70-0.15-0.15	12,050	12,050	12,050	12,050	12,050	12,050
0.75-0.05-0.20	12,050	12,050	12,050	12,050	12,050	12,050
0.75-0.20-0.05	12,050	12,050	12,050	12,050	12,050	12,050
0.85-0.10-0.05	12,050	12,050	12,050	12,050	12,050	12,050
0.90-0.05-0.05	12,050	12,050	12,050	12,050	12,050	12,050

4.5 Total Toxic Value Comparison

Table 10 shows that the total toxic value of chemicals is affected by the weight of three objectives. When the weight of poisonous value of chemicals (α_{TX}) is very low (0.05), the optimal result suggests using a cheap filler which is not good for the health of workers and the total toxic score is high (3,784.35). However, when the weight of toxic value of chemicals (α_{TX}) is not too low (0.15 or more), a better-quality filler should be used which is safer to the workers and the total toxic value is lower (1,081.24).

When the total toxic score is 1,081.24, the annual filler cost is 3,243,725 THB. On the other hand, the company has a cost of 756,869 THB if the total toxic score is 3,784.35. The difference is almost 2.5 million THB annually. It is important to highlight that the optimal solution from the model suggests using a better filler that is safer for worker health when the management sets not too low weight for the objective concerning the health issue (α_{TX}).

Table 10. Total Toxic Value of Chemicals

α_{TP} - α_{TB} - α_{TX}	Total Chemical Value					
	Both Smart and Zero Use Sustainable Boxes					
	5 day			6 day		
	370THB	420THB	500THB	370THB	420THB	500THB
0.40-0.20-0.40	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24
0.40-0.40-0.20	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24
0.50-0.25-0.25	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24
0.60-0.05-0.35	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24
0.60-0.10-0.30	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24
0.70-0.15-0.15	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24
0.75-0.05-0.20	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24	1,081.24
0.75-0.20-0.05	3,784.35	3,784.35	3,784.35	3,784.35	3,784.35	3,784.35
0.85-0.10-0.05	3,784.35	3,784.35	3,784.35	3,784.35	3,784.35	3,784.35
0.90-0.05-0.05	3,784.35	3,784.35	3,784.35	3,784.35	3,784.35	3,784.35

4.6 Weighted Average Satisfaction Comparison

The weighted average satisfaction is calculated from the summation of multiplication between weights and satisfactions of profit, sustainable box, and toxic value of chemicals.

The worst cases of weighted average satisfaction are highlighted in Table 11, which are 0.44, 0.45, and 0.47. The reason why the weighted average satisfaction of these cases is bad is because the satisfaction of the sustainable box is perfect (1.0) in both SMART and ZERO use sustainable boxed scenarios, but the weight given to this objective (α_{TB}) is almost zero (at 0.05). Therefore, the weighted average satisfaction is extremely low. See the detailed analysis in Table 12.

Table 11. Weight Average Satisfaction for Both SMART and ZERO Use Sustainable Boxes

α_{TP} - α_{TB} - α_{TX}	Sustainable Box Use					
	Both Smart and Zero Use Sustainable Boxes					
	5 day			6 day		
	370THB	420THB	500THB	370THB	420THB	500THB
0.40-0.20-0.40	0.85	0.81	0.74	0.87	0.82	0.75
0.40-0.40-0.20	0.65	0.61	0.54	0.67	0.62	0.55
0.50-0.25-0.25	0.82	0.76	0.68	0.84	0.78	0.69
0.60-0.05-0.35	0.78	0.72	0.61	0.80	0.73	0.63
0.60-0.10-0.30	0.78	0.72	0.61	0.80	0.73	0.63
0.70-0.15-0.15	0.75	0.67	0.55	0.77	0.69	0.57
0.75-0.05-0.20	0.73	0.65	0.51	0.75	0.67	0.54
0.75-0.20-0.05	0.74	0.66	0.52	0.76	0.68	0.55
0.85-0.10-0.05	0.71	0.62	0.47	0.74	0.64	0.49
0.90-0.05-0.05	0.70	0.60	0.44	0.73	0.62	0.47

Table 12. Weight Average Satisfaction for Only ZERO Use Sustainable Boxes

α_{TP} - α_{TB} - α_{TX}	Sustainable Box Use					
	Only Zero Use Sustainable Boxes					
	5 day			6 day		
	370THB	420THB	500THB	370THB	420THB	500THB
0.40-0.20-0.40	0.75	0.71	0.64	0.77	0.72	0.65
0.40-0.40-0.20	0.55	0.51	0.44	0.57	0.52	0.45
0.50-0.25-0.25	0.69	0.64	0.55	0.71	0.65	0.56
0.60-0.05-0.35	0.88	0.81	0.71	0.90	0.83	0.73
0.60-0.10-0.30	0.83	0.76	0.66	0.85	0.78	0.68
0.70-0.15-0.15	0.77	0.69	0.57	0.79	0.71	0.59
0.75-0.05-0.20	0.86	0.78	0.65	0.89	0.80	0.67
0.75-0.20-0.05	0.72	0.64	0.51	0.75	0.66	0.53
0.85-0.10-0.05	0.82	0.73	0.58	0.85	0.75	0.60
0.90-0.05-0.05	0.87	0.77	0.61	0.90	0.80	0.64

The weighted average satisfactions in Table 12 are higher than those in Table 11 for most cases due to the lower packaging cost, and since Table 12 assumes that sustainable boxes are used for only ZERO product series which results in less satisfaction for sustainable boxes but more satisfaction for profit. The weights of the three objectives under consideration are relatively high for the profit and relatively low for the sustainable boxes. Therefore, the weighted average satisfaction tends to be higher in Table 12 than in Table 11.

Table 13 shows the data in the scenario using a sustainable box for SMART and ZERO while working 5 days a week, giving the wage at 500 THB per day, and the α_{TP} which is at 0.9. Table 14 shows detailed information on a case in Table 12 where the weighted average satisfaction is low (0.45) while Table 15 represents a case where the weighted average satisfaction is high (0.9). It is seen that when the weight and satisfaction of the same objective are high at the same time, the weighted average satisfaction is comparatively large.

Table 13. The Satisfaction Under Condition STD0 / 5 Days / 500 THB / 0.90-0.05-0.05

Total profit	Tp	53,221,971.88	THB	
Total profit (max)	Tp	70,520,339.17	THB	
Total profit (min)	Tp	40,000,000.00	THB	
Satisfaction of profit		0.43		0.90
Total sustainable box use		1,093,377.60	box	
Total sustainable box use (max)		1,093,377.60	box	
Total sustainable box use (min)		12,000.00	box	
Satisfaction of total sustainable box used		1.00		0.05
Total toxic chemical value		3,784.35		
Total toxic chemical value (max)		3,784.35		
Total toxic chemical value (min)		1,081.24		
Satisfaction of toxic value		0.00		0.05
		Weight average satistaction		0.44

Table 14. The Satisfaction Under Condition STD1 / 6 Days / 500 THB / 0.40-0.40-0.20

Total profit	Tp	59,202,503.56	THB	
Total profit (max)	Tp	70,520,339.17	THB	
Total profit (min)	Tp	40,000,000.00	THB	
Satisfaction of profit		0.63		0.40
Total sustainable box use		12,050.00	box	
Total sustainable box use (max)		1,093,377.60	box	
Total sustainable box use (min)		12,000.00	box	
Satisfaction of total sustainable box used		0.00		0.40
Total toxic chemical value		1,081.24		
Total toxic chemical value (max)		3,784.35		
Total toxic chemical value (min)		1,081.24		
Satisfaction of toxic value		1.00		0.20
		Weight average satistaction		0.45

Table 15. The Satisfaction Under Condition STD1 / 6 Days / 370 THB / 0.60-0.05-0.35

Total profit	Tp	68,033,482.85	THB	
Total profit (max)	Tp	70,520,339.17	THB	
Total profit (min)	Tp	40,000,000.00	THB	
Satisfaction of profit		0.92		0.60
Total sustainable box use		12,050.00	box	
Total sustainable box use (max)		1,093,377.60	box	
Total sustainable box use (min)		12,000.00	box	
Satisfaction of total sustainable box used		0.00		0.05
Total toxic chemical value		1,081.24		
Total toxic chemical value (max)		3,784.35		
Total toxic chemical value (min)		1,081.24		
Satisfaction of toxic value		1.00		0.35
		Weight average satistaction		0.90

4.7 Hiring Cost, Inventory Holding Cost, and labor Cost

Costs excluding material costs, when the labor cost is 370 THB/day, are presented in Table 16. It shows that working 6 days a week can slightly help the company save costs in terms of total hiring cost, inventory holding cost, and overtime cost while the regular time labor cost is higher. However, the total cost of working 6 days a week is cheaper about 1 million THB per year. Note that all workers are paid on a daily not a monthly basis.

Table 16. Total Cost Excluding Material Costs (370 THB/day)

		Working 5 days	Working 6 days
Total hiring cost	Tch	372,000	297,000
Total inventory holding cost	Tinv	6,789,060	4,018,313
Labor cost during regular time	Twi	20,543,387	23,447,001
Labor cost during overtime	Toi	4,182,837	3,080,051
		31,887,284	30,842,365

4.8 Average Worker's Income Per Person Per Year

Table 17 presents the plan that allows each worker to receive more money in one year on average. The total wage from different working days per week is divided by the average number of workers (228 and 215) under the plan of working 5 and 6 days per week, respectively. The average worker's annual salary for working 5 days and 6 days a week is 108,448.35 and 123,381.61 THB, respectively. Regarding these plans, in one year the worker can earn more money if the factory runs 6 days a week.

Table 17. Average Annual Labor Wage When Working 5 Days or 6 Days a Week

		Working 5 days	Working 6 days
Labor cost during regular time	Twi	20,543,387	23,447,001
Labor cost during overtime	Toi	4,182,837	3,080,051
		24,726,224	26,527,052
Average workers		228	215
Average workers income per year		108,448.35	123,381.64

4.9 Average Worker's Income Per Person Per Day

To determine how much money an employee will receive in a day, the division of average annual income and number of working days in a year is equal to daily workers' income. To work 5 days a week, employees can receive slightly higher than 6 days a week (446 and 418 THB) as shown in Table 18. Therefore, if the factory decided to operate 5 days a week, workers would receive a higher daily wage, but lower total wage annually. Note that the wage is the total regular and overtime wage that the worker receives.

Table 18. Average Daily Wage Per Person

		Working 5 days	Working 6 days
Average workers income per year		108,448.35	123,381.64
Working days/year	Nt	243	295
Average workers income per day		446.29	418.24

4.10 Average Worker's Income Per Person Per Hour

Comparing the income and costs under various overtime production, number of workers, and working days in earlier chapters is too tricky. This is the calculation part for the hourly income rate per person per hour. Thai's minimum wage is 363 THB per day (8 hours), updated in August 2024, but this calculation is assumed at 370 THB per day, which is slightly higher. The overtime wage is 150% of the regular time wage. For working 5 and 6 days a week, the average wage for both regular and overtime is 52.96 and 51.06 THB/hour respectively as shown in Tables 19 and 20.

Table 19. Average Hourly Income for Working 5 Days a Week

6 days/week																
Month	t		9	10	11	12	1	2	3	4	5	6	7	8		
Workday	Nt		25	25	26	23	25	25	26	21	25	24	24	26		
Hour			200	200	208	184	200	200	208	168	200	192	192	208		
Number of workers	Wt	190	192.6449972	202	201	219	226	233	240	233	211	215	209	203	2,581	215
Sum OT production			-	-	-	-	-	35,541	38,075	29,854	32,180	-	-	-	135,650	
Average OT per day			0.087													
OT count (hour)			2.10													
Hourly income rate			51.06	THB/hr												

Table 20. Average Hourly Income for Working 6 Days a Week

5 days/week																
Month	t		9	10	11	12	1	2	3	4	5	6	7	8		
Workday	Nt		21	21	21	19	22	20	21	18	20	19	20	21		
Hour			168	168	168	152	176	160	168	144	160	152	160	168		
Number of workers	Wt	190	199	208	207	225	232	239	246	254	232	236	230	224	2,747	228
Sum OT production			-	-	9,372	26,123	31,189	29,209	31,568	27,938	28,818	-	-	-	184,218	
Average OT per day			0.136													
OT count (hour)			3.27													
Hourly income rate			52.96	THB/hr												

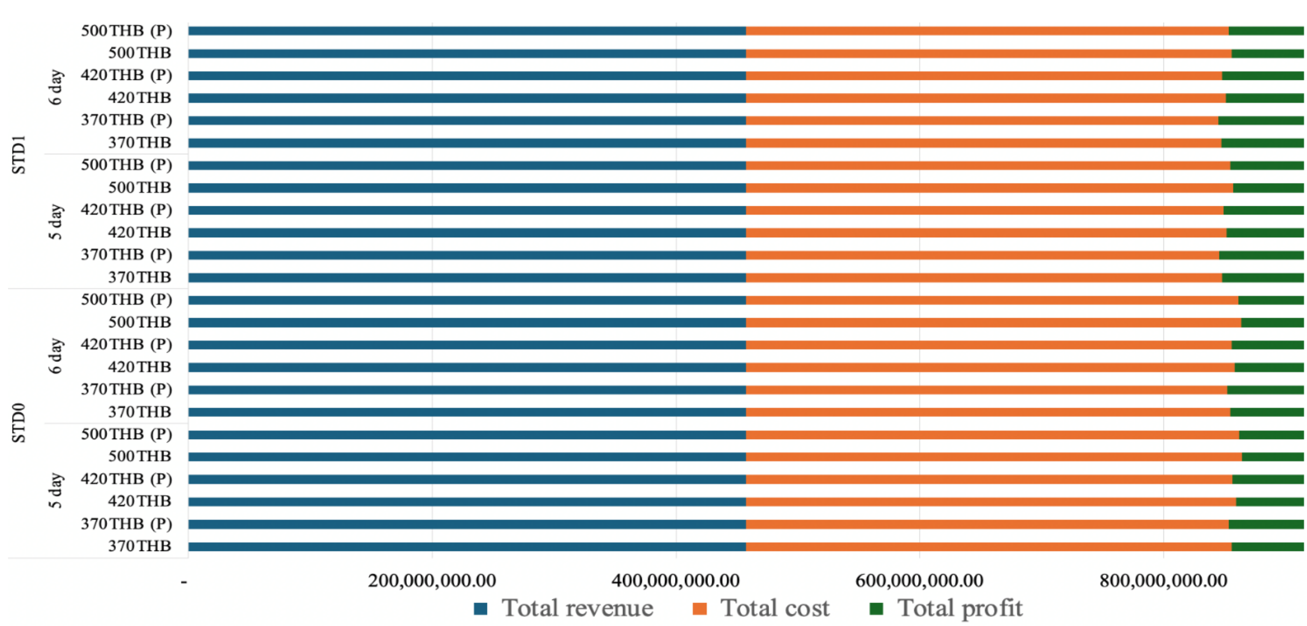

Fig. 5. Total Profit, Revenue, and Cost.

4.11 Total Profit, Revenue, and Cost Per Scenario

In this study, the production line operates based on consumer demand; thus, the revenue is the same in every situation (as shown in Figure 5 at 457,716,328 THB). However, the difference is in packaging cost, filler cost, and labor wage. Therefore, the total profit will be different, it can be seen that the total profit per year of the factory is variable depending on the scenarios. However, the total profit is not much different and there is no scenario that the profit is unacceptable to the factory owner.

4.12 Financial Impact of Changing the Minimum Wage

According to Thai law, the minimum wage is currently 363 THB per day. However, as shown in Table 21, the lowest pay that employees could receive in this study is 370 THB. The minimum wage might rise one day under rates of inflation, legislation, and political party policy. This production indicates that an increase of 50 THB per day will result from the minimum wage being changed from 370 THB to 420 THB, within working 5 days per week condition. In terms of percentage, it is at 13.51%. Similarly, when the daily wage is adjusted from 420 to 500 THB, equal to an increase of 19.04 percent.

Table 21. Comparison of Total Wages

	5 day		
	370THB	420THB	500THB
Labor wage during regular time	20,543,387.21	23,319,520.61	27,609,500.00
Labor cost during overtime	4,182,837.14	4,748,085.40	5,709,420.40
Total labor wage	24,726,224.35	28,067,606.02	33,318,920.40

Table 22 shows that when the daily wage is increased from 370 to 420, and 500 THB of working 5 days a week and have $\alpha_{TP}, \alpha_{TB}, \alpha_{TX}$ at 0.50,0.25,0.25 respectively. The total labor wage has increased significantly from 24.7 to 28.1 and 33.3 million THB. However, for the shoe factory under consideration, the labor cost is less than 10% of the total cost. Table 22 shows the total cost is increased by only 2.2% when the daily wage is increased from 370 to 500 THB.

Table 22. Comparison of Total Costs

	5 day		
	370THB	420THB	500THB
Inventory holding cost	6,789,059.74	6,789,059.74	6,891,454.21
Hiring cost	371,387.55	371,387.55	360,000.00
Labor wage during regular time	20,543,387.21	23,319,520.61	27,609,500.00
Labor cost during overtime	4,182,837.14	4,748,085.40	5,709,420.40
Other material and manufacturing cost	341,997,945.50	341,997,945.50	341,997,945.50
Filler cost	3,243,725.64	3,243,725.64	3,243,725.64
Packaging cost	21,169,166.70	21,169,166.70	21,169,166.70
Total cost	398,297,509.48	401,638,891.15	406,981,212.44

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study looked into how different production factors affected sustainability, worker income, and profit. According to the results, there is a 20 million THB difference between the highest and lowest profits, which are approximately 70 and 50 million THB, respectively. However, there are differences between these scenarios in terms of working days, worker pay, filler type, and packaging box. Working six days a week can increase profit; employees' yearly income is reduced as a result. Similarly, using sustainable packaging materials is beneficial for the environment but increases production costs. There is no one-size-fits-all answer that will give the business the upper hand in achieving all its goals simultaneously; every alternative goal must be a trade-off against the others. For example, when the company decides to change the packaging to a sustainable box and use the filler type to the safer one, this company will achieve in terms of social and environmental impacts but in terms of profit, it will get worse because of the higher cost.

This research considers the impact on production costs of raising Thailand's minimum wage. The research indicated that although there was a rise of 13.51% and 18.71% when the daily minimum income changed from 370 THB to 420 THB and 500 THB respectively. This increase in the daily minimum wage at these rates seems to be a big problem for the company. However, this results in a small increase in total production costs, ranging from 0.84% to 1.33% in this study. This implies that the government might be able to raise the minimum wage without placing a heavy financial burden on the shoe factory under consideration. The study does, however, stress the importance of giving long-term effects careful thought.

5.2 Summary of Theoretical and Practical Contributions

The case study company has already applied the idea of not firing any employees in practice. The shoes in the "Zero" series are currently conceptual designs, the idea is to determine whether producing shoes from recycled or sustainable materials will be able to build a solid reputation for the company or not.

Our concept in this research is to adapt to the reality of the situation.

- Allow our workers to take time off to cultivate and harvest their rice fields.
- Make a production plan that provides workers with a good income and avoids using highly toxic chemicals for the health of employees.
- The factory has prepared for potential future inflation as well as wage increases mandated by the government.
- Consider the advantages and disadvantages of working five or six days a week.
- Provide job security to all workers (no layoffs).
- Be responsible for the environment and surroundings.

5.3 Limitations and Further Studies

Under this research, there are some limitations about the workers when their incomes are increased, they get a sense of job stability, the likelihood of staying with the company longer, and blind tests to gauge employee satisfaction when the company tries to protect their health from the harmful substances. Not only that, but also the emotions of the customers when a company is launching the sustainability campaign, and how it will affect the company's sales and marketing. Other businesses can apply this idea and mathematical models, but they will need to modify the data and some specifics to fit their unique situations and circumstance.

NOMENCLATURE

The mathematical model of this research and the data of this case study. Indices, parameters, and decision variables are defined as follows:

Indices

p Set of products {LIGHT, SMART, ZERO}

t Set of periods {Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec}

f Set of fillers {1, 2}

b Set of box type {standard, sustainable}

Parameters

LP Labor production rate (pairs/person*day)

W_{hr} Regular working hours per day (hour)

n_t Working days in period t (day)

D_{pt} Demand of product p in period t (pair)

P_p Price of product p (THB/pair)

CF_f Unit cost of filler f (THB/kg)

CB_b Unit cost of box type b (THB/pair)

Ch Unit hiring cost (THB/person)

CO_p Other materials and manufacturing cost of the product p (THB/pair)

F Amount of filler needed per pair (kg/pair)

h Unit inventory holding cost (THB/pair-period)

sr Wage of worker during regular working hour (THB/hour)

so Wage of worker during overtime (THB/hour)

ss_{pt} Safety stock of product p at the end of period t (pair)

B_b 1 if product "SMART" use box type b, 0 otherwise

wr_t Number of workers resigned at the beginning of period t (person)

wl_t Number of workers who take leave (for one period) at the beginning of period t (person)

wh_{max} Maximum number of workers that can be hired in each period (person)

T_f Toxic value of filler f (unitless)

OT Maximum proportion of overtime production per regular time production (unitless)

TP_{max} Maximum total profit satisfaction calculation (THB)

TP_{min} Minimum total profit satisfaction calculation (THB)

TB_{max} Maximum total number of sustainable boxes satisfaction calculation (unit)

TB_{min} Minimum total number of sustainable boxes satisfaction calculation (unit)

TX_{max} Maximum total toxic value from chemicals satisfaction calculation (unitless)

TX_{min} Minimum total toxic value from chemicals satisfaction calculation (unitless)

α_{TP} Weight of profit

α_{TB} Weight of sustainable box

α_{TX} Weight of toxic value of chemicals

Decision Variables

w_t Available number of workers during period t (person)

Q_{pt} Production quantity of product p in period t during regular time (pair)

$Q1_{pt}$ Production quantity of product p in period t during overtime (pair)

I_{pt} Inventory of product p at the end of period t (pair)

wh_t Number of workers hired at the beginning of period t (person)

F_f Amount of filler type f used (kg)

QB_b Total number of box type b used (unit)

TP_{sat} Satisfaction level of total profit (unitless)

TB_{sat} Satisfaction level of sustainable box (unitless)

TX_{sat} Satisfaction level of toxic value (unitless)

WS Weighted average satisfaction (unitless)

T_C Total cost (THB)

T_P Total profit (THB)

T_R Total revenue (THB)

T_{CH} Total hiring cost (THB)

T_{FI} Total filler cost (THB)

T_{OM} Total other material and manufacturing cost (THB)

T_{WI} Total labor cost during regular time (THB)

T_{PI} Total packaging cost (THB)

T_{OI} Total labor cost during overtime (THB)

T_{INV} Total inventory holding cost (THB)

TB Total amount of sustainable box (unit)

TX Total toxic value of chemicals (unitless)

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