overtime, hiring and firing, and inventory. The change in workforce level by hiring and firing allows changes in production rates. Abu Bakar et al., 2016 develop a linear programming model for multi-period with the aim to minimize production cost and workforce cost. The practicality of the proposed model is illustrated and applied for a vegetable oil manufacturer, which produces a wide range of products. Nour et al., 2017 present a MILP model to maximize profit for a manufacturer of porcelain tableware. The electricity cost is included as one of the elements in the objective function.

The above-mentioned research on APP discusses a single objective and ignores the inherent of other objective functions, such as minimizing environmental impact, smoothing workforce level, maximizing product quality, or meeting high service level. As a result, APP is considered as a multiple criteria decision-making problem. The environmental effects of carbon dioxide (CO_2) emissions are of significant interest by researcher and practitioners since it makes up the largest share of the greenhouse gases emissions (GHGs). The concentration of GHGs from manufacturing process significantly contributes to global warming and climate change. In response to this threat, manufacturers have adopted the importance of environmental protection on the basis that it is an ability to gain and maintain competitive advantage in the future. This leads to the integration of environmental objective into their vision and core values. One of environmental dimensions is input-oriented factors, such as consumption of energy or natural resources. According to Statistics Canada, the electricity consumption from the production process accounts for 76.4% in the year of 2016 (Statistics Canada, 2016). Energy consumption is a major source of environmental pollutions and is increasing, while fossil energy resources are limited. Bettoni & Zanoni, 2012 imply that not only government but also a firm must consider environmental and energy policies. The upper limit of GHGs and wastes, occurred during production process, is set as an ethical boundary. A firm has to pay extra taxes due to its emission ratio. It is stated that the efforts in saving energy consumption is especially vital to production planning, and is one of ways to reduce negative impacts to environment and minimize wastes. Therefore, this dimension is attached in decision making process when developing aggregate production planning. The focus on multi-objective optimization is necessary to simultaneously optimize two or more conflicting objectives subject to certain constraints. Mirzapour Al-e-hashem et al., 2013 develop a stochastic programming to solve APP problem in a green supply chain with multi-period multi-product multi-site. Modarres & Izadpanahi, 2016 consider carbon footprint and energy consumption as major dimensions to assess the environment performance of an organization. A multi-objective linear program model to minimize operational cost, energy cost, and carbon emissions is formulated for a smelting manufacturer producing various kinds of products.

Together with growing environmental awareness, researchers and managers also pay attention to social factors. Social concerns are usually evaluated under the form of employee job security and morale-motivation, employee health, work family balance, and customer satisfaction (Türkay et al., 2016). All of these factors have a significant impact to overall performance of a company. For example, the loyalty of workforce to the company is decreased when the company has a high percentage of layoffs. Wang & Liang, 2004 present a multi-objective linear programming (MOLP) model for solving multi-product and multi-period problem in a fuzzy environment. Excessive or lower use of the number of hiring and firing workers may be limited by regulations and may create severe labor problem. Therefore, the purpose of this study is to increase social welfare through minimizing total production cost and the number of labor levels through the planning horizon. Following this interest, Ripon Kumar & Md, 2013 propose Generic algorithm to solve this model in the deterministic state. The resulting optimization is a set of Pareto optimal solutions that show the relationship between cost and social criteria. Mirzapour Al-e-hashem et al., 2011 formulate a MOLP model that aims to maximize customer satisfaction by minimizing sum of the maximum amount of shortages. However, it is insufficient and inefficient to address the sustainable development in manufacturing process. According to the National Council of Advanced Manufacturing, sustainable manufacturing (SM) is defined as the use of technologies and processes for manufacturing products that minimizes environmental impact, and conserves energy and natural resources, while maintaining the safety, reliability, and economic competitiveness of product and services. The concept of sustainable manufacturing design has emerged as important issues and exciting field, and has become the focus of recent research due to the increasing awareness from the customers. In the scholar provided by Türkay et al., 2016, a methodological approach to incorporate sustainability consideration, including economic, carbon footprint, energy consumption, and social factors, is presented in the multi-objective model. The effect of carbon cap, overtime limit, and service level on total cost is analyzed through the use of a refrigerator manufacturers. However, this study takes in account the deterministic state. It can be seen that this assumption may be valid when customer demand, on-hand resources, or other related factors show a smooth pattern or a consistent state.

In practical business environments, the production planners usually deal with a situation of shorter life cycles product, unstable workforce condition, limited production capacity, and variable demand. The use of traditional deterministic models cannot be suitable to solve the problem in this situation, and hence may lead to considerable errors and imprecise decisions. This implies the dynamic and uncertain characteristics of APP and the need to integrate uncertainties when developing an aggregate production plan. The input data or parameters, such as demand and cost are generally imprecise due to incomplete or unobtainable information (Wang & Liang, 2004). Therefore, these parameters can be defined as random, fuzzy, or interval numbers. One of the popular and powerful approaches to consider aforementioned uncertainty is to make use of fuzzy programming (Baykasoglu & Gocken, 2010). This approach is applied for a multi-objective integer linear programming (MOLP) model, including environmental social aspects along with economic criterions in this study. The proposed model is evaluated based on a case example from the garment industry. The resulting numerical example shows its ability to minimize the changes of workforce level, overtime, and shortage.

The remainder of the paper is organized as follows: The essential information for the case example in garment industry is introduced in Section 2. Based on this example, a MOLP is formulated in Section 3. The findings of the numerical analysis are presented and explained in Section 4. The paper ends with a conclusion of results in Section 5.

2. Problem description

Garment industry is one of the major sectors in Vietnam, which creates lots of job opportunity. The sector contributes to 10 – 15% of the annual gross domestic product (GDP) and is the outcome of the investment initiative. The production capacity is expected to increase by averaging around 12% - 14% per year from 2016 – 2020. Vietnam is one of choices for outsourcing garment manufacturing. As mentioned in the report of Institute of labor science and social affairs, there are about 6,000 garment export - oriented factories with the increasing shipment to major market, such as the US, EU, and Japan. The workforce is diversity with 3.5 million workers, while the population is about 90 million people.

In this case, ABC is a garment manufacturing in Mekong Delta Region, Vietnam. In recent years, the demand requirements for products have made the manufacturer necessary to continuously invest equipment and technology. However, the company realizes that the productivity in the production line and ability to adapt to customer demand are low due to the inefficient allocation of workers and on-hand inventory. The fluctuation in demand makes the workforce and inventory level unstable between periods. Some workers are idle, while the others are overload at some periods. It is worth noting that garment manufacturers face labor shortage due to an increase degree of labor mobility to other companies. This results in the increasing of cost of labor and operating, accounting for 72% of the overall cost. Therefore, the fundamental consideration of the company is to optimize the production plan through the simultaneous determination of production, inventory level, subcontracting, shortage, overtime hours, workforce level, and energy consumption over a finite time horizon. The company tries to achieve a balance whereby they need inventory to meet customer demand, but not so much that they have excess.

The company produces three products to fulfil customer demand. The data related to the company is collected in the planning horizon of 6 periods. The regular daily working time of a worker is 8 hours. The daily limit of overtime is 15% of regular time for a worker. According to labor laws and contracts, the changes of workforce level (hiring and firing workers) must be lower than 10%. There is no initial and final backlog. Detailed values are provided in Table 1.

Table 1: Experimental data for the numerical example

	Product type 1	Product type 2	Product type 3
Initial inventory level	459	350	400
Initial workforce level	18	20	19
Cycle time/product (hour)	0.058	0.05	0.06

3. Model formulation

In this section, a multi-objective integer fuzzy linear programming model is constructed based on the above numerical example. The mathematical model is composed of three conflicting objective functions, including total operating cost, energy consumption, and number of workers fired over a planning period. The problem involves the determination of the most effective production plan by adjusting output rates, hiring and layoffs, inventory levels, overtime work, subcontracting, and other controllable variables.

3.1. Assumption

The mathematical model is developed based on the following assumptions:
- A manufacturer supplies multi-product to satisfy customer demand for multi-period.
- All customer demand for all product types must be satisfied at the ending of each period. The level of inventory is assumed to be zero at the ending of each period.
- Customer demand and related cost including production cost, inventory holding cost, firing and hiring cost, subcontracting cost, and stock out cost are assumed to be uncertain.
- A number of workers depend on production quantity in each period.
- Customer demand and cost are assumed to be triangular fuzzy numbers.

3.2. Indexes and parameters

We briefly review the mathematical formulation of the model. The sets, indices, and variables, embedded in the model, are presented in this section.

* Indexes

p: Type of product (p = 1…m)
t: Periods of planning (t = 1…n)

* Parameters

F'_{tp}: Forecasted demand of product *p* in period *t* (unit/month)
T: Working hours per day (hours/day)
D: Number of working days per period (day/period)
Cr: Cost of regular time paid for a worker per hour (VND/worker)
Co: Cost of overtime paid for a worker per hour (VND/worker)
Ch': Cost of hiring a worker (VND/worker)
Cl': Cost of firing a worker (VND/worker)
Cp'_p: Cost of producing per unit of product *p* (VND/unit)
Ci'_p: Cost of carrying per unit of product *p* (VND/unit)
Cc'_p: Subcontracting cost per unit of product *p* (VND/unit)
Cs'_p: Stock out cost per unit of product *p* (VND/unit)
EP_p: Amount of electricity consumption to produce one unit of product *p* (KWh/unit)
EI_p: Amount of electricity consumption to carry one unit of product *p* (KWh/unit)
EC_p: Amount of electricity consumption to subcontract one unit of product *p* (KWh/unit)
Lo: Upper limit of overtime per worker each period *t* (hours/worker)
TT_p: Production cycle time for product *p* (hours/unit)
I_{0p}: Inventory level at the beginning of period for the product *p* (unit)
W_{0p}: Workforce level at the beginning of period for product *p* (worker)
Lc_p: Maximum subcontracting quantity for product *p* in period *t* (unit)
k_p: Number of units produced by one worker per day (unit)
$\propto'$: Service level
β: Percentage of total workers fired at each period *t*

3.3. Decision variables

W_{tp}: Number of workers for product *p* in period t (worker)
L_{tp}: Number of workers fired for product *p* in period *t* (worker)
H_{tp}: Number of workers hired for product *p* in period *t* (worker)
P_{tp}: Number of units of product *p* produced in period *t* (unit)
I_{tp}: Number of units of product *p* hold in period *t* (unit)
C_{tp}: Number of units of product *p* subcontracted in period *t* (unit)
S_{tp}: Number of units of product *p* stocked out in period *t* (unit)
O_{tp}: Amount of overtime for product *p* in period *t* (hours)
OP_{tp}: Number of units of product *p* overtime in period *t* (unit)

3.4. Mathematical model

** Objective functions*

- *Minimization of cost:* The objective function (1) minimizes the sum of cost of firing workers, cost of hiring workers, wage of workers, cost of holding inventory, cost of producing product in regular time and overtime, cost of stocking out, and cost of overtime, respectively.

$$Min\,Z_1 = \sum_{t=1}^{n}\sum_{p=1}^{m} Cl' \times L_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Ch' \times H_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Cr \times T \times D \times W_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Ci'_p \times I_{tp}$$
$$+ \sum_{t=1}^{n}\sum_{p=1}^{m} Cp'_p \times (P_{tp} + OP_{tp}) + \sum_{t=1}^{n}\sum_{p=1}^{m} Cc'_p \times C_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Cs'_p \times S_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Co \times O_{tp} \quad (1)$$

- *Minimization of electric consumption*: The objective function (2) minimizes the sum of electricity consumption from producing, holding and subcontracting products.

$$Min\,Z_2 = \sum_{t=1}^{n}\sum_{p=1}^{m} EP_p \times \left(P_{tp} + OP_{tp}\right) + \sum_{t=1}^{n}\sum_{p=1}^{m} El_p \times I_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} EC_p \times C_{tp} \quad (2)$$

- *Minimization of number of fired workers:* the third objective function (3) can be constructed as presented in

$$Min\,Z_3 = \sum_{t=1}^{n}\sum_{p=1}^{m} L_{tp} \quad (3)$$

* *Constraints:* The production plan must satisfy the following constraints:

$$k_p \times D \times W_{tp} + OP_{tp} \geq P_{tp} \qquad \forall\, p,t \quad (4)$$
$$k_p \times D \times W_{tp} \geq OP_{tp} \qquad \forall\, p,t \quad (5)$$
$$P_{tp} \times TT_p \leq T \times D \qquad \forall\, p,t \quad (6)$$
$$OP_{tp} \leq O_{tp} / TT_p \qquad \forall\, p,t \quad (7)$$
$$\sum_{p=1}^{n} O_{tp} \leq Lo \times W_{tp} \qquad \forall\, p,t \quad (8)$$
$$W_{0p} + H_{tp} - L_{tp} = W_{tp} \qquad \forall\, p,t=1 \quad (9)$$
$$W_{(t-1)p} + H_{tp} - L_{tp} = W_{tp} \qquad \forall\, p,t>1 \quad (10)$$
$$L_{tp} \leq \beta \times W_{tp} \qquad \forall\, p,t \quad (11)$$
$$F'_{tp} = P_{tp} + S_{tp} + I_{0p} + C_{tp} + OP_{tp} - I_{tp} \qquad \forall\, p,t=1 \quad (12)$$
$$F'_{tp} = P_{tp} + S_{tp} + I_{(t-1)p} + C_{tp} + OP_{tp} - I_{tp} - S_{(t-1)p} \qquad \forall\, p,t>1 \quad (13)$$

$$(1-\alpha)\times F'_{tp} \geq S_{tp} \qquad \forall\, p,t \qquad (14)$$

$$I_{tp} = 0 \qquad \forall\, p, t=6 \qquad (15)$$

$$S_{tp} = 0 \qquad \forall\, p, t=6 \qquad (16)$$

$$C_{tp} \leq Lc_{p} \qquad \forall\, p,t \qquad (17)$$

$$L_{tp} = 0 \qquad \forall\, p, t, W_{tp} \geq W_{(t-1)p} \qquad (18)$$

$$H_{tp} = 0 \qquad \forall\, p, t, W_{tp} \leq W_{(t-1)p} \qquad (19)$$

$$W_{tp}, L_{tp}, H_{tp}, P_{tp}, I_{tp}, C_{tp}, S_{tp}, OP_{tp} \geq 0, Integer \qquad \forall\, p,t \qquad (20)$$

$$O_{tp} \geq 0, \in R \qquad \forall\, p,t \qquad (21)$$

The production level in regular time and overtime are identified in the constraint (4) and (5). Constraints (6) states that regular time cannot not be greater than available hours in each period. Constraints (7) presents amount of products by using overtime. Overtime working is allowed during high demand period, but results in physical and psychological strain on worker health. Therefore, the limit of overtime production is given in Constraint (8). This means that the total overtime cannot exceed total allowable overtime in each period for each product type. Constraints (9) and (10) set the number of workers for producing each product type in each period. In order to avoid the lower workforce motivation level, the maximum number of workers fired at each period must be considered when planning. Constraints (11) assures that this number cannot exceed 10% of workforce level in that period. Constraints (12) and (13) assure the balance between the production quantity and inventory in regular time at each period. Stock-out occurs when on-hand inventory and production capacity are not sufficient to meet customer demand. However, this results in lost customer and an increase in cost, and hence constraint (14) considers the customer satisfaction. The desired service level (∝) is defined as the fraction of the demand satisfied at each period. Constraints (15) and (16) ensures that there is no inventory and shortage level at the ending period. Constraints (17) restricts the maximum number of products to be subcontracted at each period. Constraints (18) and (19) present that hiring or firing workers occurs, but not both happen at the same period. Nonnegativity, integer and real of decision variables are defined in Constraint (20) and (21)

As mentioned earlier, the customer demand and some related cost are considered under the uncertainty environment, thus the triangular fuzzy parameters of the proposed model are stated, as follows:

- Modeling the imprecise data using triangular fuzzy numbers:

$$F'_{tp} = \left(F1_{tp}, F2_{tp}, F3_{tp}\right) \qquad Ch'_{tp} = \left(Ch1_{tp}, Ch2_{tp}, Ch3_{tp}\right)$$

$$Cl'_{tp} = \left(Cl1_{tp}, Cl2_{tp}, Cl3_{tp}\right) \qquad Cp'_{tp} = \left(Cp1_{tp}, Cp2_{tp}, Cp3_{tp}\right)$$

$$Ci'_{tp} = \left(Ci1_{tp}, Ci2_{tp}, Ci3_{tp}\right) \qquad Cc'_{tp} = \left(Cc1_{tp}, Cc2_{tp}, Cc3_{tp}\right)$$

$$Cs'_{tp} = \left(Cs1_{tp}, Cs2_{tp}, Cs3_{tp}\right) \qquad \alpha' = \left(\alpha 1, \alpha 2, \alpha 3\right)$$

- Converting the multi objectives fuzzy linear model to an equivalent crisp one: The customer demand and some related cost in the objective function and constraints are triangular fuzzy numbers. In this way, three values, including pessimistic, most likely, and optimistic value, is formulated based on the ranking approach provided by Jiménez et al., 2007. Here, the value for δ is feasibility degree.

$$P_{tp} \geq \frac{\delta}{2}\times\frac{F2_{tp}+F3_{tp}}{2} + (1-\frac{\delta}{2})\times\frac{F1_{tp}+F2_{tp}}{2} + I_{tp} + I_{0p} - C_{tp} - S_{tp} - OP_{tp} \qquad \forall\, p, t=1$$

$$P_{tp} \leq (1-\frac{\delta}{2})\times\frac{F2_{tp}+F3_{tp}}{2} + \frac{\delta}{2}\times\frac{F1_{tp}+F2_{tp}}{2} + I_{tp} + I_{0p} - C_{tp} - S_{tp} - OP_{tp} \qquad \forall\, p, t=1$$

$$P_{tp} \geq \frac{\delta}{2}\times\frac{F2_{tp}+F3_{tp}}{2} + (1-\frac{\delta}{2})\times\frac{F1_{tp}+F2_{tp}}{2} + I_{tp} + I_{(t-1)p} - C_{tp} - S_{tp} - OP_{tp} + S_{(t-1)p} \quad \forall\, p, t>1$$

$$P_{tp} \le (1-\frac{\delta}{2}) \times \frac{F2_{tp}+F3_{tp}}{2} + \frac{\delta}{2} \times \frac{F1_{tp}+F2_{tp}}{2} + I_{tp} + I_{(t-1)p} - C_{tp} - S_{tp} - OP_{tp} + S_{(t-1)p} \quad \forall\, p, t>1 \tag{22}$$

$$\left((1-\delta)\times\frac{\alpha_2+\alpha_3}{2}+\delta\times\frac{\alpha_1+\alpha_2}{2}\right)\times\left((1-\delta)\times\frac{F2_{tp}+F3_{tp}}{2}+\delta\times\frac{F1_{tp}+F2_{tp}}{2}\right)\ge S_{tp} \quad \forall\, p,t \tag{23}$$

$$\begin{aligned}
Z_{11} &= \sum_{t=1}^{n} Cl1 \times L_{tp} + \sum_{t=1}^{n} Ch1 \times H_{tp} + \sum_{t=1}^{n} Cr \times T \times D \times W_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Ci1 \times I_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Cp1 \times (P_{tp} + OP_{tp}) \\
&\quad + \sum_{t=1}^{n}\sum_{p=1}^{m} Cc1_p \times C_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Cs1_p \times S_{tp} + \sum_{t=1}^{n} Co \times O_{tp} \\
Z_{12} &= \sum_{t=1}^{n} Cl2 \times L_{tp} + \sum_{t=1}^{n} Ch2 \times H_{tp} + \sum_{t=1}^{n} Cr \times T \times D \times W_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Ci2 \times I_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Cp2 \times (P_{tp} + OP_{tp}) \\
&\quad + \sum_{t=1}^{n}\sum_{p=1}^{m} Cc2_p \times C_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Cs2_p \times S_{tp} + \sum_{t=1}^{n} Co \times O_{tp} \\
Z_{13} &= \sum_{t=1}^{n} Cl3 \times L_{tp} + \sum_{t=1}^{n} Ch3 \times H_{tp} + \sum_{t=1}^{n} Cr \times T \times D \times W_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Ci3 \times I_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Cp3 \times (P_{tp} + OP_{tp}) \\
&\quad + \sum_{t=1}^{n}\sum_{p=1}^{m} Cc3_p \times C_{tp} + \sum_{t=1}^{n}\sum_{p=1}^{m} Cs3_p \times S_{tp} + \sum_{t=1}^{n} Co \times O_{tp}
\end{aligned} \tag{24}$$

- Solving the resulting multi objective crisp linear programming model using fuzzy goal programming approach:

In order to transform a multi-objective to a single objective, the model is solved using the approach provided by Bellman & Zadeh, 1970. This approach is used by various researchers and shows its ability to generate an optimal solution (Ekel et al., 2007; Madadi & Wong, 2014). Then, the model is derived as follows:

Max φ (25)

Subject to:

$\varphi \le \mu_{EV_\gamma}\left(\tilde{Z}_1(x)\right)$

Equations (4) – (11);
(15) – (23);

$0 \le \varphi \le 1;$

$x \ge 0$

4. Computational results & Discussion

The simple numerical example is introduced to illustrate the performance of the model in the previous section. This proposed model is coded and solved using the IBM ILOG CPLEX optimization studio software, Version 12.4, and is run on Core i3 processor, 2GB RAM within 30 seconds. The values for γ and δ are assumed to be 0.3 and 0.8, respectively. These values are assigned by decision makers and can be changed to obtain the satisfactory results. In this paper, we are interested in how production plan impacts the decision makers in terms of sustainability. Therefore, the three different scenarios, including total cost, energy consumption, and workforce motivation level for the six-period planning, are shown in Table 2.

The optimum solution is determined by comparing values and selecting the minimum among them. The resulting table 2 shows the comparison between the three scenarios. Each scenario, corresponding to a production plan, is solved separately by using the same set of constraints. This plan involves the number of products, workforce level, and inventory level. It can be seen that any improvement in one objective can result in the others being worse. For example, the decision makers optimize workforce motivation level, a potentially common practice, may increase their total cost, by as much as 19%. Scenario S1 can contribute to cost-saving, while scenario S3 has at least number of fired workers. The amount of in-house production is found to be 22,776 and 26,780 in scenario S1 and S2, respectively. For scenario S1, the company can stock up inventory on hand to handle uncertainty situation in the market. Stock out can make the company lose customers to competitors. Therefore, shortage can be eliminated in scenario S1 with the better balance between inventory level and subcontracting quantity. This shows the desirable achievement for customer service level. However, in scenario S2, the significant number of customer demand cannot be satisfied with unexpected customer demand. Overtime working can be used to respond to variation in demand. This has influence on the length of working week, and can be a source of disruption for workers. In the three scenarios, overtime working is totally avoided.

Table 2. A payoff of cost, energy consumption, and workforce motivation level

	Scenario 1 (S1)	Scenario 2 (S2)	Scenario 3 (S3)
	Cost minimization	Energy consumption minimization	Workforce motivation level
Production quantity	22,776	26,780	28,392
Inventory level	3,291	69	3,122
Total subcontracting quantity	1,776	6,158	4,325
Total shortage	0	2,261	1,390
Total overtime hours	758.676	340.8	420.128
Number of hired workers	0	37	15
Number of fired workers	12	11	0
Total cost	4,325,356,025	5,100,295,100	5,147,890,915
Total energy consumption	2,696,514	2,439,276	2,683,201

Ideally, the production plan should be such that it minimizes the total cost, energy consumption, and number of fired workers. Here, the optimum scenario S4, observed in Table 3, appears to be the most promising scenario due to the good balance between the three objectives. The total cost of this scenario is 4.4% higher than that of scenario S1. The energy consumption of scenario S4 is 3.1% higher than that of scenario S2, but this difference is not too large.

Table 3. Results obtained for multi-objective functions (S4)

1st objective	Minimize total cost	4,515,776,680
2nd objective	Minimize electrical consumption	2,514,602
3rd objective	Minimize number of fired workers	3
φ		0.75

The quantity of production, inventory, subcontracting, shortage, and workforce level at each period for scenario S4 is presented Table 4 and Table 5, respectively. Based on the results obtained in Table 4, the stable workforce level can be maintained for the planning period because the number of fired workers for all products is low compared to scenario S1 and S2. This can contribute to improve employee job security and morale-motivation significantly. As mentioned in section 2, keeping little inventory level and reducing shortage are one of the company objectives. Therefore, the use of scenario S4, as seen in Table 5, provides a great opportunity for saving energy consumption and total cost, since the lowest inventory level among scenarios can be achieved. Moreover, this production plan also creates better customer satisfaction due to low shortage compared to scenario S1 and S2.

Table 4. Workforce level for different products in each period

Period	Product type 1			Product type 2			Product type 3		
	W	H	L	W	H	L	W	H	L
1	18	0	0	19	0	1	19	0	0
2	18	0	0	18	0	1	19	0	0
3	18	0	0	17	0	1	19	0	0
4	18	0	0	17	0	0	19	0	0
5	18	0	0	17	0	0	19	0	0
6	18	0	0	17	0	0	19	0	0

Table 5. Results corresponding to production, inventory, subcontracting, shortage, and overtime at each period

Product	Period	Production quantity	Inventory level	Subcontracting quantity	Shortage	Overtime
1	1	1,404	0	350	0	16.94
1	2	1,404	0	350	0	25.87
1	3	1,404	0	350	0	23.55
1	4	1,404	0	0	0	48.20
1	5	1,404	0	350	0	37.76
1	6	1,404	0	350	0	35.73
2	1	1,976	276	0	0	0
2	2	1,872	218	0	0	0
2	3	1,768	59	0	0	0
2	4	1,768	85	53	0	0
2	5	1,768	0	0	0	0
2	6	1,768	0	157	0	0
3	1	988	0	350	0	38.52
3	2	988	0	350	0	50.82
3	3	988	0	350	0	49.62
3	4	988	0	350	0	54.42
3	5	988	0	350	0	52.5
3	6	988	0	350	0	52.92
		25,272	**638**	**4,060**	**0**	**486.836**

5. Conclusion

Aggregate production planning provides the detailed production plan for the decision makers to achieve the firm's strategic objectives. The use of various mathematical programming formulations is proposed for aggregate production planning with the more intensive consideration of cost. However, other criteria are also taken into account by managers.

This study presents a novel approach for aggregate production planning problem. The approach makes use fuzzy programming and optimization modeling. Three-objective mathematical model is formulated and solved using multi-objective solving method, allowing the design of production plan with the consideration of economic, environmental and social aspects. The numerical example is used to illustrate the approach, and the calculation procedures used to determine the production plan with favorable cost, energy consumption, and workforce motivation level. The results indicate that the proposed model can provide a promising production plan to easily apply it in practice for the decision makers.

The use of hiring and firing strategy at each period can result in lower workforce morale at any period of planning. Therefore, it is necessary to conduct a study with a more intensive social consideration, such as employee job security, employee health, and work family balance. Moreover, the primary area for future research should involve environmental factors, such as GHGs per unit product manufactured or consumed.

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Biographies

Nguyen Truong Thi is a lecturer of Industrial Management in the Department of Industrial Management at Can Tho University. He holds a ME degree in Logistics and Supply Chain Systems Engineering from Sirindhorn International Institute of Technology, Thammasat University, Thailand. His primary research interests lie in the development and application of quantitative methods for use in the design and control of production and supply-chain systems.

Tran T. M. Dung received the B.S. degree in Chemical Engineering from Can Tho University, Vietnam in 2006, the M.S. degree in Industrial Engineering and Engineering Management from National Tsing Hua University, Taiwan in 2010. Currently, she is a lecturer and head of Industrial Management Department at Can Tho University. Her research interests include production and operations management, multiple criteria decision making, and lean manufacturing.

Vo Thi Kim Cuc is an undergraduate student in Industrial Management at Department of Industrial Management, Can Tho University. Her research interests focus on aggregate production planning, supply chain management, and sustainability manufacturing.