Vol. 9, No. 2, 2022, Pages 182-195

JIEMS

Journal of Industrial Engineering and Management Studies

journal homepage: www.jiems.icms.ac.ir

Optimizing boehmite production process using goal programming approach (Case study: Iranian West Mineral Applied Research Center)

Mohammad Aali[1], Shahram Saeidi *[1]

[1] Department of Industrial Engineering, Islamic Azad University, Tabriz Branch, Tabriz, Iran.

Received: Aug 2021-14/ Revised: Mar 2022-14/ Accepted: Aug 2022-30

Abstract

In this research, a goal programming model is proposed for optimizing the production of Boehmite in the Iranian West Minerals Applied Research Center (IWMARC). This product can be produced using internal or external methods and currently is produced traditionally, and the production process is not optimal. This research optimizes the production process using the linear goal programming technique. A multi-objective model is proposed containing 20 goal constraints of effective parameters concerning production, sales, raw materials usage, water and energy consumption, customer needs, and workforce components. The main objectives are ranked using the AHP method, and the model is implemented in Lingo 11 software. The computational results show that due to the impact of the price of foreign raw materials and the limitations caused by its use, as well as the good efficiency of the gasification method in the internal(domestic) method, the domestic method can effectively tackle the major and minor objectives of the production system of in IWMARC and achieve 16 goals out of 20 goals with zero or positive (more than the expected level) deviations. Besides, changing the technical and production specifications according to customer needs can increase profitability up to 3.75 times the current amount (375%) and decrease inventory cost by 32%.

Keywords: goal programming; AHP, production planning; Iranian West Minerals Applied Research Center; boehmite.

Paper Type: Original Research

1. Introduction

Manufacturing and service activities are the basis of a country's economic system. The conversion of raw materials, capital, information, labor, and other resources into more value-added goods and services forms the basis of a production system. Production planning is one of the main tasks of factory managers and determines how much production should be done in each planning period based on estimating the demand for goods. Classical and traditional optimization methods have been widely used in solving optimization problems. They fail to solve complex problems because they do not have the necessary efficiency in solving problems with many variables and a complex or multi-objective goal function (Marcenaro et al., 2010).

In the present age, managers and shareholders are not just looking to increase profits, and in addition, they want to achieve other goals such as customer satisfaction, good market position, high market share, and other issues. Goal programming is an efficient way to solve such models that can meet the needs of system planning to an acceptable level if the goals are diverse and conflicting (Charnes et al., 1993), (Nixon et al., 2014). This method minimizes the deviations between the desired goals and the existing goals and prioritizes them according to their importance (Momeni, 2014).

Each production planning issue seeks to determine the optimal amount of production, level of the workforce, and inventory control of the warehouse level with the lowest cost during the planning horizon. In industries with mixed production plans, determining the optimal amount of manufacturing of each product is one of the most crucial decision-making issues, and the task of managers in allocating available resources is susceptible. The optimal use of these resources will lead to the growth and survival of the company.

The IWMARC is currently facing several goals and limitations, but no scientific research has been taken to optimize the production planning in this industry so far, and the current production planning method is traditional and not optimized. Besides, the literature review revealed that the GP technique has not ever been used in this industry worldwide. This fact raised the authors' attention to answer the critical question to identify a practical and comprehensive method for optimizing the production process of Boehmite in IWMARC. So, the present study is performed on the Boehmite production in this company for reducing overhead costs, optimal use of raw

*Corresponding Author: sh_saeidi@iaut.ac.ir

DOI: 10.22116/jiems.2022.299779.1454

materials, production based on market needs, and increasing equipment efficiency. For this purpose, the production process is identified in detail, and a goal programming approach model is developed. The research results are described in the following sections.
The manuscript structure is as follows: The second section is devoted to studying literature review and previous work. The proposed method is introduced in the third section, and in the fourth section, the simulation and computational results are presented and discussed. The fifth section contains the general conclusion of the research.

2. Literature review

Anandarja and Ahren (2007) conducted a study to show investment priority in the railway company using the GP method to achieve the optimal combination of investment at different levels. The results showed that if the investment is based on economic principles or quantitative factors, it is better to invest first on plan A and then on plan B besides plan C. However, using the GP method, the best-recommended option is Plan C, which can achieve 100% of the goals at half the investment cost.
Akoz and Petrovic (2007) investigated the application of fuzzy GP in batch process scheduling and loading. The purpose of this research is to optimize an integrated loading and planning as a multi-criteria optimization problem, including short-term goals, such as maximizing efficiency and minimizing the work in the process; and long-term goals such as balancing the level of inventory and achieving the financial goals imposed by the level of the high production planning. Another study on perishable production planning is conducted by Leung and NG (2007) to determine the number of productions manufactured from raw materials, the number of semi-processed products, and the number of semi-processed products. Leung (2007) proposed a non-linear GP model for optimizing trip distribution problems and developed a Genetic Algorithm for solving the model.
Asadpoor et al. (2007) designed a GP model to determine the optimal cultivation pattern in Dashtnaz plain of Sari city. According to their model, there are potential and actual possibilities to manage the region's agricultural sector so that the net income of each farm per hectare can be increased up to 336,100 Iranian Rials. Ahern and Anandarajah (2007) used GP for prioritizing the railway projects' investment decision-making. Abedi et al. (2007) proposed a GP model for resource allocation in the educational and academic departments of the Ministry of Health and Medical Education of Iran and showed that their model leads to optimizing resource allocation and comparing the amount of deviation from the goals in research with actual values of the state variable indicate the high ability of the proposed method in optimizing the allocation of resources in the educational sector.
Leung and Chan (2008) focused on fuzzy GP in production and transportation planning decisions. The proposed model aims to minimize the total distribution and production costs, the total number of rejected goods, and the total delivery time according to the available capacity, work level, and constraints in each source, as well as forecasting demand and warehouse space in each destination.
Tsai et al. (2008) examined the priority fuzzy GP technique in allocating networks in the steel industry, which included decisions about network interconnection and capacity allocation for each distribution network. This problem has emerged as a multifunctional fuzzy mixed integer programming problem that includes competitive advantages such as maximizing net profit, minimizing end-user claims, and minimizing latency rates. They used actual data adopted from Taiwan Steel Company to evaluate the model's effectiveness.
Bravo and Gonzalez (2009) used stochastic GP on water resources planning in Mediterranean countries. Marcenaro et al. (2009), in their research, used the application of multi-objective programming to study the level of workers' satisfaction in Spanish workplaces. This study considered different aspects of job satisfaction such as income, type of work, job security, number of working hours. Aalam-Tabriz et al. (2009) proposed a GP model using Analytic Hierarchical Process (AHP) to optimize the production plan in an industrial plant. This study used nine factors to prioritize the products, nine considered soft, and 24 as systemic(hard) constraints.
Moheb-Rahmani and Heidari (2010) presented a comprehensive GP model with a fuzzy approach in the oil refining industry. The main objectives of this study were to maximize sales, maximize demand, and minimize inventory. In this paper, the hierarchical analysis process determines the importance weight of the goals and effective indicators in the oil industry. The results show that revenue has improved by 12.7%.
Nabavi and Yousefi (2011) used fuzzy GP to determine the optimal portfolio. Saeidi et al. (2014) proposed a multi-objective fuzzy GP model to solve the cell formation problem in cellular manufacturing systems and developed a GA-based algorithm for solving the model.
Saeidi (2015) proposed a fuzzy GP model for the university timetabling scheduling problem and developed a Genetic Algorithm for solving the model. Farhoudi and Abdollahi (2015) proposed a GP model for short-term mine production planning to minimize operating costs, reduce the plant's dependence on iron and bauxite additives, and reduce the number of supply mines. Based on the results, to supply the needed raw materials, the share of clay in the supply of raw materials was multiplied by the current capacity, and also the consumption of bauxite was removed from the list of raw materials.
Anggraeni et al. (2015) Used the GP method to optimize the production planning in the convection field. The objectives in this research are considered as revenue, production cost, and machine usage. Mehrgan et al. (2016) proposed a model at the Shahid Ghandi Telecommunication Cable Factory in Yazd and showed that the pro-

posed GP reduced the company's costs by 12%. Dehghani et al. (2016) used the linear programming method to solve a production planning problem in the mining industry. Rezayi et al. (2017) used fuzzy GP to optimize the allocation of agricultural acreage and annual program offers for various products. The model goals are the net profit, workforce, machine hour, etc.

Jong et al. (2018) used GP to o maximize production volume for providing customer's demands, maximize sales revenue, minimize production cost and maximize machine's working hour cost in production planning. The authors in this research did not consider the priority among different goals. Rohmah et al. (2018) developed a linear programming model to minimize the production cost in the peanut production industry. They compared the results on the customer's demand the company's policy. Ayough (2018) proposed a fuzzy GP model to optimize production planning considering consumer demand. Nobari et al. (2018) proposed a multi-objective for optimizing supply chain management.

Setiawati and Arisya (2018) proposed a GP model for production planning in a chocolate factory to minimize the total production cost, considering the production volume, profit, processing time, and raw material as the model goals. Babazadeh et al. (2019) developed a linear programming model for production planning in West Azarbaijans' Urmia cement company to minimize the total production cost. Solaja et al. (2019) showed that the linear programming technique is powerful in production planning and decision-making, allocating limited resources. Zamanian et al. (2019), in their case study research, developed a fuzzy GP model to optimize the natural gas-industry supply chain costs.

In their dissertation, Mahdavi and Safaei (2020) used GP for optimizing the production plan in meat products companies and showed that the proposed model does not reduce the company's costs but increases the profit. Dehnavi and Sadegheih (2020) proposed a fuzzy GP model for the Cell Formation Problem (CFP) and production planning. The authors considered the total profit and the machine utilization as objective functions. Jaggi et al. (2020) developed a mathematical programming model for a lock industry. They considered the production cost and the profit as the objective functions and solved the proposed model using Lingo.

Phuc (2021) developed a two-stage linear stochastic programming model for production planning to optimize the expected total cost. Vinsensia et al. (2021), in their study, proposed a fuzzy GP model to maximize the profit and minimize the total production cost.

A comparison summary of previous research is given in Table 1. According to this summary, it can be concluded that a comprehensive production optimization model with four objectives, each consisting of three sub-criteria, has not been proposed before in the literature and specifically in the Bohemite production industry worldwide. Besides, the ranking and weighting method among the multiple objectives or goals is not clearly defined and specified in previous research. The AHP method is used in this research for this purpose.

Table 1. The comparative summary of recent studies

Reference	Objective(s)	Approach	Solving Method
Anggraeeni et al. (2015)	Revenue, Production cost, Machine usage	Goal Programming	Not specified
Rezaei et al. (2017)	Production and net profit achievement, workforce, machine-hour, seed, fertilizers, and pesticides requirement	Fuzzy GP	Excel Solver
Ayough (2018)	Production, Workforce level	Fuzzy GP	Lingo
Nobari et al. (2018)	Inventory cost, Workforce cost, Hiring & Firing cost, Sypply chain relaibality	Linear Programming	MOICA, NSGA II
Setiawati & Arisya (2018)	Production volume, profit, processing time, Raw material	Goal Programming	Lindo
Rohmah et al. (2018)	Total production cost	Linear Programming	Not specified
Babazadeh et al. (2019)	Total production cost	Linear Programming	Not specified
Solaja et al. (2019)	Total profit	Linear Programming	Management Scientist
Zamanian et al. (2019)	Environmental and economic costs and revenue	Fuzzy GP	GAMS
Dehnavi & Sadegheih (2020)	Total profit for firms, The utilization rate of machine capacity	Fuzzy GP	GA toolbox
Jaggi et al. (2020)	Total production cost, Total profit	Linear Programming	Lingo
Phuc (2021)	Expected total cost	Linear Programming	Random Search & SSA
Vinsensia (2021)	Total profit and revenue, Labor cost, Raw material cost, Time machine production, Inventory cost	Fuzzy GP	Not specified

Proposed Method	Production According to market needs, reduce overhead cost, reduce raw material cost, Increase efficiency of equipment and machinery	Goal Program-ming	AHP, Lingo

3. The proposed model

In this section, the Boehmite production process is described, and the modeling and structure of the proposed model are discussed.

3.1. The Boehmite production process

Currently, the most important production of IWMARC is Boehmite, which is used as a valuable catalyst in other industries such as petrochemicals. Limestone and nepheline syenite are transported to the factory from different mines as the primary raw materials in the Boehmite production process. After grinding in two stages, they are first converted to dimensions 1 to 2 centimeters and then to 90-micron particles containing 30% moisture. It is then baked in an oven 26 meters long and 3 meters in diameter at about 1500 degrees Celsius. The furnace's output is the sinter, which contains 10% alumina. At this stage, about 5% of the waste is separated as dust and returned to the furnace in successive repetitions.

The sinter out of the furnace in a ratio of 1 to 4 with liquor is washed by leaching method and is converted into particles with dimensions less than 10 microns by rod-mil, which contains 25% solid and 75% of slurry, and 24% alumina. After smoothing and removing the mud (fumigation) and de-silicification, this mixture is placed in an autoclave under a pressure of 10 bar and a temperature of 180 degrees Celsius.

Afterward, Boehmite is obtained and sent to the stockroom for sale after washing and packing using two different methods, including 1) gasification, without the need to use auxiliary materials (known as internal or domestic method); 2) using external auxiliary materials (known as external method), inside the reactor with temperature, stirrer, duration, and other physical parameters. The nominal capacity of the line is one ton per day, which due to the depreciation of equipment, its practical capacity has been reduced to 700 kg per day. The flowchart of operations is shown in Figure 1, and the other production components are given in Table 2.

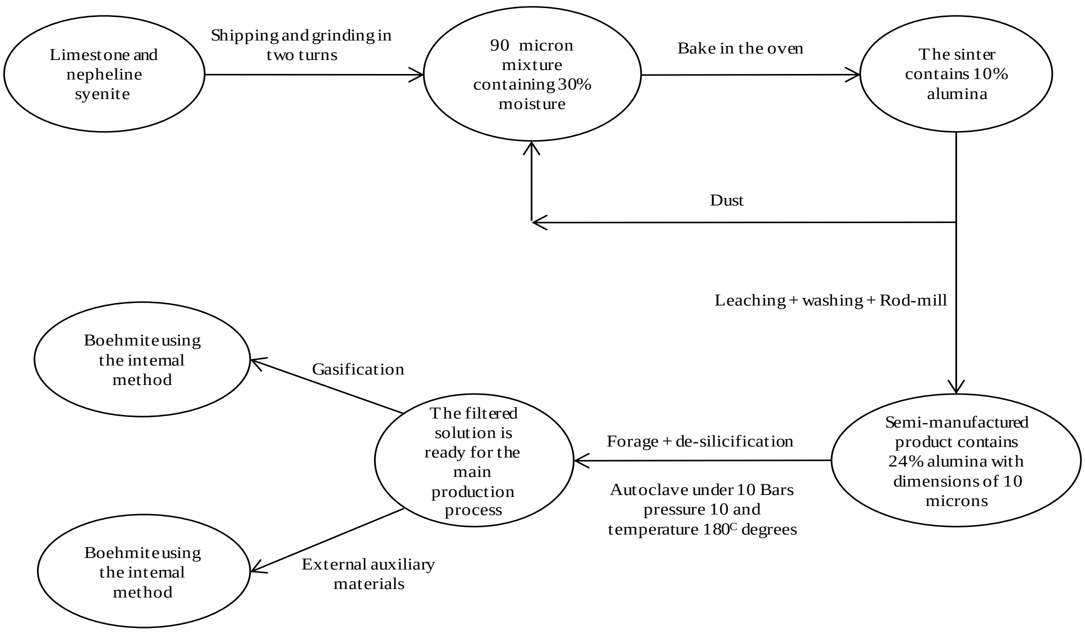

Figure.1. Schematic diagram of the production process in IWMARC

Table 2. Specifications of the Boehmite production line in IWMARC

Parameter	Value
The nominal capacity of the production line	One ton per day
The Practical capacity of the production line	700 kg per day
Electricity consumption value	500 kW per hour
Water consumption value	30 m3 per hour
The natural gas consumption value	60 m3 per hour
Number of personnel	58
Production line waste	5%

3.2. The Problem Modeling

The purpose of the GP model in this research is to optimize the production of Boehmite using both internal and external methods in the production center. The GP structure consists of decision variables, system constraints, goal constraints, and the objective function.

System Constraints: These limitations include machine capacity, workforce, and the ratio of overtime and under-employment to regular working hours. It should be noted that in solving the model, before examining the goal constraints, the systemic constraints must be fully satisfied.

Goal constraints can be violated, and the deviation (positive or negative) from these restrictions is allowed. The objective function of the model minimizes the weighted sum of undesirable deviations. Therefore, the general form of the proposed GP model is defined as follows:

$$Min\ Z = \{W_1P_1(d_1^+, d_1^+), W_2P_2(d_2^+, d_2^+), \ldots, W_kP_k(d_k^+, d_k^+)\} \quad (1)$$

s.t.

$$g_i(x_i)\begin{cases}\leq \\ = b_i \\ \geq\end{cases} \qquad i=1,2, \ldots, m \quad (2)$$

$$f_i(x) - d_j^+ + d_j^- = h_j \qquad j=1,2, \ldots, k \quad (3)$$

$$x, d_j^+, d_j^- \geq 0 \quad (4)$$

$$d_j^+ \times d_j^- = 0 \quad (5)$$

Where:

Z: objective function,
Wj: jth deviation variable weight,
xi: ith decision variable,
Pj: the priority function of jth goal,
bi: RHS of the system constraints,
gi(x): the equation of ith system constraint,
hj: RHS of goal constraints,
fj(x): the equation of jth ideal constraint,
d_j^-: negative deviational variable from the jth goal,
d_j^+: positive deviational variable from the jth goal,
m: number of system constraints,
k: number of goal constraints.

Equation (5) implies that both overachievement and underachievement of a goal cannot coincide. Hence, either one or both of these variables must be zero.

3.2.1 The system constraints

In order to form the system constraints inequalities, the machine capacity and output capacity of each stage of the production process were calculated by timing for each section. The different stages of production in both methods were divided into seven stages, and the time required to process one ton in each stage was considered. As mentioned before, the production process can be performed in the following two ways:

1) Internal(domestic) Method: Includes milling, baking, leaching, rod-mill, flossing and silicification, autoclave, gasification.
2) External(foreign) Method: Includes milling, baking, leaching, rod-mill, flossing and de-silicification, autoclave, use of foreign auxiliary materials.

The timing of the Boehmite production process is given in Table 3. According to the table, the time required to complete the production process is the same in both the methods, and the only difference is the seventh stage of production which is performed using gasification in the former and external auxiliary raw materials in the latter method.

Table 3. The timing of the seven stages of internal and external methods

The seven steps of the internal method	Time required to process one ton (minutes)	Seven steps of using external materials	Time required to process one ton (minutes)
Milling	90	Milling	90
Baking	1440	Baking	1440
Leaching	1440	Leaching	1440
Rod-Mill	1440	Rod-Mill	1440
Forage + de-silicification	300	Forage + de-silicification	300
Autoclave	1080	Autoclave	1080
Gasification	120	Using auxiliary external materials	120

The subsequent systemic constraint is the amount of Boehmite demand generated domestically and externally in other months of the year. This information is given in Table 4. The values show that sales in May and June are higher than those of the other months.

The current sale amount is 40 tons per year, targeted to 150 tons per year. The production capacity and the production volume of IWMARC can currently meet this number of sales, but mainly due to the lack of production of Boehmite meeting the technical specifications requested by customers, most of the product is currently stored in the depot. Therefore, considering the production capacity of one ton per month, if the technical specifications requested by customers are provided, this goal will be achieved.

Table 4: Sales and demand of Boehmite produced domestically and externally in different months of the year

Month	Sales for Boehmite domestically produced) Tons per month(	Sales for Boehmite externally produced) Tons per month(	Customer demand (Tons per month)
May	5	5	15
June	5	5	15
July	3	3	12
August	3	3	12
September	3	3	12
October	3	3	12
November	3	3	12
December	3	3	12
January	3	3	12
February	3	3	12
March	3	3	12
April	3	3	12
Sum	40	40	150

The next system constraint relates to the number of labor (person-hours per month) added to the model. The number of human resources employed in the center is 58, of which 45 are working as production personnel in three 12-hour shifts on a rotating basis all days of the year (even on holidays), and 13 are administrative personnel (only on working days) are working for 8 hours per day. Therefore, the total working hours of the workforce in a month is equal to 13,400 hours.

3.2.2. The goal constraints

In the proposed method, the goal (soft) constraints are defined as:
production cost Constraints: including workforce cost and production cost. The former is divided into workforce increasing cost, workforce reduction cost, overtime cost, and underemployment cost.
Gross profit constraints: The goal equation of the workforce is equal to the number of person-hours required to produce each product multiplied by the production volume.

3.2.3. The objectives

The main objective of the IWMARC is divided into four micro-objectives(sub-objectives), each of which includes several criteria, and all seven stages defined in the production process try to achieve these micro-objectives and ultimately the macro-objectives. Obviously, each sector pays more attention to its related criteria, but cooperation and coordination between departments are essential to achieve these goals fully. In this research, the AHP method is used for ranking the goals. The details are given in Table 5.

Table 5: Sub objectives and critical criteria defined in the Boehmite production process

Sub-objective	Criteria	Sub-objective	Criteria
a) Production according to market needs	• Improving production processes • Improving sales potency • Upgrade sales revenue	c) Reduce consumption of raw materials	• Reduce water, electricity, and gas consumption • Reduce purchasing and raw materials handling cost • Eliminate the purchase of foreign auxiliary material
b) Reduce overhead costs	• Reduce non-compliant products • Reduce waste • Reduce excess working hours	d) Increase the efficiency of equipment and machinery	• Reduce person-hours of emergency repairs • Reduce person-hours of preventive repairs • Use of quality parts

The AHP method is implemented in ExpertChoice software, and the weights of the criteria, sub-criteria and the final score were calculated. The logical consistency and the compatibility rate for all pairwise comparison matrices were calculated as less than 0.1, which indicates the compatibility of all these matrices. The micro-objectives ranking is given in Table 6.

Table 6: Ranking of micro-objectives of the production process

• Micro Objective	• Priority weight (Wj)	• Rank
• a) Production based on market needs	• 0.435	• 1
• b) Reduce overhead costs	• 0.187	• 3
• c) Reduce consumption of raw materials	• 0.286	• 2
• d) Increase the efficiency of equipment and machinery	• 0.092	• 4

According to Table 6, it can be concluded that all criteria related to the goal (a) have the first-order priority; criteria related to the goal (c), have the second-order priority; related criteria of goal (b) have the third-order priority; and finally, the goal (d) criteria are the fourth-order priority.
Besides, from the aspect of micro-purpose of production and delivery of the product based on market needs and related sub-criteria (production according to the technical specifications and the specifications desired by customers listed in Table 8), the desired goal is divided into two parts, including 1) increasing the porosity volume

from 0.5 cm3/g (cubic centimeters per gram) to 0.7 cm3/g, 2) increasing the cross-sectional area from [220-250] cm2/g to [280-300] cm2/g. The rest of the technical parameters align with the customer requirements.

Table 7: Comparison of technical specifications of Boehmite produced and required by customers

Technical Specification	Unit	Produced Boehmite in IWMARC	Boehmite requested by customers
cross-sectional area	cm2/gr	220-250	280-300
porosity volume	cm3/gr	0.5	0.7
Average porosity diameter	nm	8-12	8-12
Free density	gr/cm3	0.35- 0.4	0.35- 0.4
Density under pressure	gr/cm3	0.55	0.55
Percentage of aluminum trioxide	%	70-78	70-78
Percentage of silicon dioxide	%	< 0.2	< 0.2
Percentage of sodium oxide	%	< 0.05	< 0.05
Percentage of potassium oxide	%	0.05	0.05
Percentage of iron trioxide	%	0.03	0.03
Percentage of magnesium oxide	%	< 0.01	< 0.01
Percentage of sulfur trioxide	%	< 0.70	< 0.70

3.2.4 Objective function

Considering that each of the existing criteria is defined as a goal in the proposed model, the prioritization of these goals is performed as follows:

1. First-order Priority Golas:
   - Including two sub-goals:
     a. Increasing the porosity level from 0.5 to 0.7 cm3/g.
     b. Increasing the cross-section area from [220-250] to [280-300] cm2/g.
   - Improving the sales potency of Boehmite.
   - Maximizing sales revenue.

2. Second-order Priority Golas:
   - Reduce water, electricity, and gas consumption.
   - Reduce the cost of purchasing and transporting raw materials.
   - Eliminate the purchase of foreign auxiliary raw materials.

3. Third-order Priority Goals:
   - Reduce non-compliant products.
   - Reduce production waste.
   - Reduce excess working hours.

4. Fourth-order Priority Goals:
   - Reduce person-hours of emergency repairs.
   - Reduce person-hours of preventive repairs.
   - Maximum use of high-quality and long-lasting parts.

3.2.5 Parameters, Indices, and Decision Variables

Parameters:

A: The goal amount of total production of Boehmite product (tons per month).
B: The goal amount of Boehmite production according to customer needs (tons per month).
α: Boehmite production capacity according to customer needs (tons per month).
β: Consumption coefficient of limestone to produce one ton of Boehmite.
C: The goal amount of limestone consumption (kg per ton)
ϒ: Consumption coefficient of nepheline syenite to produce one ton of Boehmite.
D: The goal amount of nepheline syenite consumption per ton (kg per ton)
δ: Permissible amount of non-compliant Boehmite in production of one ton of product (kg).
E: Goal amount of non-compliant Boehmite (tons per month).
ε: Permissible waste in producing one ton of Boehmite (kg).
F: The goal amount of waste produced (tons per month).
ζ: Water consumption coefficient for the production of one-ton Boehmite.
G: The goal amount of water consumption (m3) to produce one ton of Boehmite.
η: Consumption coefficient of liqueur solution for each ton of Boehmite.
H: The Goal amount of liqueur solution used for each ton of Boehmite.
θ: Power consumption coefficient to produce each ton of Boehmite.
I: The goal amount of electricity consumption in kw/h to produce each ton of Boehmite.
κ: Gas consumption coefficient for the production of each ton of Boehmite.
J: The goal amount of gas consumption (m3/h) to produce each ton of Boehmite.
K: The goal of person-hour preventive repairs in one ton of Boehmite production process.
L: The goal amount of workforce for emergency repairs in the production process of one ton of Boehmite.
M: The goal amount of overtime in one ton of Boehmite production.
N: The goal amount of Bohemian sales (tons per month).
O: The goal amount of revenue from the sale of Boehmite (Rials per ton).
P: The goal amount of costs of purchasing and transporting one ton of limestone to produce one ton of Boehmite.
Pr_{SA}: Cost per ton of limestone (Rials).
Q: The goal amount of costs to purchase and transport one ton of nepheline syenite in the production of Boehmite (Rials).
Pr_{NS}: Cost per tone of Nepheline syenite (Rials).
R: The goal amount of costs for purchasing and transporting one ton of liqueur solution to produce one tone Boehmite (Rials).
Pr_{LS}: The cost price of each ton of liqueur consumed (Rials).
S: The goal amount of quality materials used to produce one ton of Boehmite.
T: The goal amount of using foreign auxiliary raw material in the production of Boehmite.
σ: Consumption coefficient of foreign auxiliary raw material produced per ton of Boehmite.
Pr_{FA}: Cost of each kilogram of foreign auxiliary raw material (Rials).
Indices:
j: Index of goal deviation.

Decision variable(s)

X: Decision variable, the production amount of Boehmite (tons per month).

Finally, the equations of the proposed goal programming model are as follows:

$$Min\ Z = W_1(d_1^- + d_2^- + d_{14}^- + d_{15}^- + d_{20}^+) + W_2(d_3^+ + d_4^+ + d_7^+ + d_8^+ + d_9^+ + d_{10}^+ + d_{16}^+ + d_{17}^+ + d_{18}^+) + W_3(d_5^+ + d_6^+) + W_4(d_{11}^+ + d_{12}^+ + d_{13}^+ + d_{19}^-) \quad (6)$$

s.t.

$$X + d_1^- - d_1^+ = A \quad (7)$$

$$\alpha X + d_2^- - d_2^+ = B \quad (8)$$

$$\beta X + d_3^- - d_3^+ = C \quad (9)$$

$$\Upsilon X + d_4^- - d_4^+ = D \quad (10)$$

$$\delta X+d_5^- - d_5^+ = E \quad (11)$$

$$\varepsilon X+d_6^- - d_6^+ = F \quad (12)$$

$$\zeta X+d_7^- - d_7^+ = G \quad (13)$$

$$\eta X+d_8^- - d_8^+ = H \quad (14)$$

$$\theta X+d_9^- - d_9^+ = I \quad (15)$$

$$\kappa X+d_{10}^- - d_{10}^+ = J \quad (16)$$

$$X+d_{11}^- - d_{12}^+ = K \quad (17)$$

$$X+d_{12}^- - d_{12}^+ = L \quad (18)$$

$$X+d_{13}^- - d_{13}^+ = M \quad (19)$$

$$X+d_{14}^- - d_{14}^+ = N \quad (20)$$

$$X+d_{15}^- - d_{15}^+ = O \quad (21)$$

$$\beta.Pr_{SA}X+d_{16}^- - d_{16}^+ = P \quad (22)$$

$$\Upsilon.Pr_{NS}X+d_{17}^- - d_{17}^+ = Q \quad (23)$$

$$\eta.Pr_{LS}X+d_{18}^- - d_{18}^+ = R \quad (24)$$

$$X+d_{19}^- - d_{19}^+ = S \quad (25)$$

$$\sigma.Pr_{FA}X1+d_{20}^- - d_{20}^+ = T \quad (26)$$

$$\forall j \quad X, d_j^-, d_j^+ \geq 0 \quad (27)$$

4. Computations results

The proposed mathematical model is coded and executed in Lingo 11 software using the coefficients and parameters defined in Table 8. The computational results of solving the model are given in Table 9. It should be noted that negative deviation variables (d_j^-) and positive deviation variables (d_j^+) are shown with the symbol Nj and Pj, respectively.

Table 8. Goal values and coefficients of the proposed GP model

Parameter	Value	Unit	Parameter	Value	Unit
A	30	Ton/month	B	20	Ton/month
α	12	Ton/month	β	14	%
C	13000	Kg	ϒ	28	%
D	6500	Kg	δ	1	%
E	300	Kg/month	ε	1	%
F	300	Kg/month	ζ	100	%
G	30	m3/ton	η	200	gram/liter
H	50	m3/ton	θ	500	KWatt/hour
I	12000	KWatt/hour	κ	60	m3/day
J	60	m3/ton	K	16	man-hour/day
L	16	man-hour/day	M	0	man-hour/day
N	150	Ton/year	O	45	Billion Rials
P	130000	Rials/ton	PrSA	150000	Rials/ton
Q	150000	Rials/ton	PrNS	170000	Rials/ton
R	0	Rials/ton	PrLS	0	Rials/ton
S	5000000	Rials/ton	T	0	Kg
σ	13500	Kg/ton	PrFA	38000	Rials/Kg

Table 9. The final results of solving the proposed model in Lingo

Negative deviation variable values	Negative deviation variable values	Positive deviation variable values	Positive deviation variable values
N1 = 0	N11 = 9800	P1 = 0	P11 = 0
N2 = 0	N12 = 0	P2 = 0	P12 = 550
N3 = 2727	N13 = 1890	P3 = 0	P13 = 0
N4 = 1172	N14 = 11200	P4 = 0	P14 = 0
N5 = 8	N15 = 0	P5 = 0	P15 = 835
N6 = 32	N16 = 6700	P6 = 0	P16 = 0
N7 = 60000	N17 = 1230	P7 = 0	P17 = 0
N8 = 0	N18 = 1570	P8 = 11000	P18 = 0
N9 = 450	N19 = 0	P9 = 0	P19 = 468
N10 = 702000	N20 = 600	P10 = 0	P20 = 0

According to table 9, for constraints (1) and (2), both Pi (d_j^+) and Ni (d_j^-) are calculated equal to zero, which means the exact satisfaction of these constraints. Besides, the negative deviation variables for constraints (7), (9), and (10) have a positive value representing a significant reduction in water, electricity, and gas consumption, respectively. In the same way, other negative deviation variables having positive values indicate a frugality in related constraints. So, it can be claimed that all the first-priority criteria are achieved. Obtaining zero values for negative deviation variables indicates the realization of that goal which means the minimum desired values for related constraints are obtained. In the case of a positive deviation variable greater than zero (constraints 8, 12, 15, and 19), the goal is obtained more remarkably than the intended value. These are the goals that have not been reached by solving the model. This issue may be considered as one of the limitations of the proposed model, which cannot satisfy all the desired goals or is raised from the nature of the problem and the conflict of the objectives.

Considering the impact of the price of raw materials and the limitations of its use, and the excellent efficiency of the gasification method, it can be concluded that using the domestic method can well target macro and micro objectives of the production system IWMARC. As a result, the goal limit defined for this quantity (N20) is 600 units of negative deviation (and no positive deviation), which means the possibility of achieving fewer values of the primary target.

Besides, using the domestic production method can lead to the following results:

1. Required raw materials (1700 kg) to produce one ton of Boehmite are purchased in 40,000 Rials, and considering 150 tons of Boehmite produced annually, 255 tons of raw materials must be purchased, the annual cost of which will be about 100 billion Rials. Using the domestic method will lead to a reduction of 60 billion Rials of raw materials costs.
2. An initial investment of 10 billion Rials is needed for domestic production to construct essential equipment, which can be returned in the first production year by reducing purchased raw materials costs.

Also, the comparison of the numerical results of the model implementation with the actual costs of the center is as follows:

3. Increase the product sales from 40 tons per year to 150 tons per year (%375).
4. Increase in revenue from product sales from 8000 million Rials to 30 billion Rials per year.
5. Reduction of product depot and consequently reduction of inventory costs by about %32.

5. Conclusions

In this study, the production process of Boehmite in the Iranian West Minerals Applied Research Center was studied, and a goal programming optimization model was proposed. The proposed GP model consists of four objectives: considering the customer needs in production, reducing overhead cost, reducing raw material consumption cost, and more efficient use of machinery. The ranking and importance weight among the objectives is calculated using the AHP approach. Each of the objectives consists of some goal criteria defined as 20 equations. The model is implemented in Lingo 11, and the computational results show that all the defined goals, except equations (14), (18), (21), and (25), have a zero or positive deviation from their goals. The results also indicate that implementing the proposed method can increase sales and revenue up to 3.75 times its current value. Besides, using the domestic method leads to a reduction of raw material cost up to %60, increasing the production volume and sales revenue by about %375, and decreasing the inventory cost by %32. Therefore, the management can determine the optimal values for the production of Boehmite and the consumption of primary and secondary materials for the next year to produce it according to the customer's needs, considering the existing goal constraints. However, changes in model priorities and the pre-set values of the goals or coefficients of variables in constraints will change the problem's solution; the proposed model can also be helpful for organizations having similar production processes.

The limitations of the proposed model can be considered as follows: a) Due to the conflict of the goals and objectives defined in the proposed model, achieving all desired goal values would not be possible; b) The modeling of the problem is complex and time-consuming and many parameters should be considered, included, measured and initialized; c) More decision-maker involvement is required, that is in the establishment of aspiration levels and weightings; d) Difficulty of precise measuring procedures and lack of some accurate measurement tools. Future studies are suggested to change the priority of goal constraints, using other goal programming models such as weighted goal programming, fuzzy goal programming, fractional goal programming, or integer goal programming.

References

Aalam-Tabriz, A., Bagherzadeh, M. (2009). A combined AGH-GP model for measuring the structure of the quality of the control system in the service organizations, Transformation Management Journal (in Persian), 1(1), 69-86.

Abedi, Gh., Delgoshaei, B., Tabibi, S.J., Ariyanezhad, M.B.Gh. (2007). Fuzzy goal programming model in resource allocation at the education section of the ministry of health, Journal of Mazandaran University of Medical Science (In Persian), 17(57), 82-87.

Ahern, A., Anandarajah, G. (2007). Railway projects prioritization for investment: Application of goal programming, Transport Policy, 14(1), 70-80.

Akoz, O., Petrovic, D. (2007). A fuzzy goal programming method with imprecise goal hierarchy, European Journal of Operational Research, 181(3), 1427-1433.

Anggraeni, W., Vinarti, R.A., Tyasnurita, R., Permatsari, J. (2015). Production Planning Optimization Using Goal Programming Method in Habibah Busana , Journal of Advanced Management Science, 3(4), 270-275.

Asadpoor, H., Hasanimogaddam, M., Ahmadi, GH. (2007). Designing a multi-objective decision-making model for determining optimum cropping pattern in Dashtenaz Sari, Iranian Journal of Agriculture Economics (in Persian), 1(3), 53-65.

Ayough, A. (2018). Adaptive aggregate production planning with fuzzy goal programming approach, Journal of Industrial Engineering and Management Studies, 5(2), 38-60.

Babazadeh, R., Ezati, F., Sabbaghnia, A. (2019). A linear programming model for production planning: an Iranian case study in cement, International Journal of Optimization in Civil Engineering, 9(4), 561-574.

Bravo, M., Gonzalez, I. (2009). Applying stochastic goal programming: A case study on water use planning, European Journal of Operational Research, 196(3), 1123-1129.

Charnes, A., Cooper, W., lnjiri, Y. (1993). Breach Budgeting and Programming to Goals, Journal of Accounting Research, 9(2), 111-120.

Dehghani, M., Ahmadian, P. (2015). Modeling production planning in mines using linear programming method and optimizing using Lingo software, International Conference on New Horizons in Basic Sciences, Engineering, and Technology (in Persian), Eslamshahr, Iran.

Dehnavi-Arani, S., Sadegheih, A., (2020). A Fuzzy Goal Programming for Dynamic Cell Formation and Production Planning Problem Together with Pricing and Advertising Decisions, International Journal of Industrial Engineering & Production Research, 31(1) 13- 34.

Farhoudi, P., Abdollahi, J. (2015). Optimization of the short-term production planning process of Tehran Cement Factory with ideal planning model, 3rd Iranian Open Mines Conference, Kerman, Iran.

Jaggi, C.K., Haq, A., Maheshvari, S. (2020). Multi-Objective Production Planning Problem for A Lock Industry: A Case Study and Mathematical Analysis, Revista Investigation Operational, 41(4), 893-901.

Jong, C.H., Medina, N., Fakhroyah, N., Hidayat, C., Hamali, S. (2018). Using Goal Programming Method for Optimizing of production Planning, 2018 International Conference on Information Management and Technology (ICIMTech), 155-159.

Kanai, N., Yokoi, S., Fukunaga, K., Tozawa, Y. (1988). An expert system to assist production planning, Proceedings of the International Workshop on Artificial Intelligence for Industrial Applications, 219-224.

Leung, S.C.H. (2007). A non-linear goal programming model and solution method for the multi-objective trip distribution problem in transportation engineering, Optimization and Engineering, 8(3), 277-298.

Leung S.C.H, NG, W. (2007). A goal programming model for production planning of perishable products with postponement, Computers & Industrial Engineering, 53(3):531-541.

Leung, S.C.H., Chan, S.S.W. (2009). A goal programming model for aggregate production planning with resource utilization constraint. Computers & Industrial Engineering, 56(3), 1053–1064.

Mahdavi, G., Safaei, A., (2020). Using goal programming for optimizing the production planning in meat products industries, Journal of Humanities and Social Sciences (in Persian), 4, 93-112.

Marcenaro, O.D., Luque M., Ruiz F. (2010). An application of multi-objective programming to the study of workers' satisfaction in the Spanish labour market, European Journal of Operational Research, 203(2), 430-443.

Mehrgan, M., Kazemi, A., Kamyab, A. (2016). Designing a goal programming production planning model for Yazd Shahid Ghandi Telecommunication Cables Company, Management Science (in Persian), 74, 133-147.

Moheb-Rahmani, S., Heidari, H. (2010). Proposing a comprehensive fuzzy goal programming model for oil refining industry, Journal of Management (in Persian), 18, 48-60.

Momeni, M. (2014). New topics in operations research, Moalef Press (in Persian), Tehran.

Nabavi, A., Yousefi, R. (2011). Determining optimal portfolio using fuzzy goal programming, Financial Engineering and Securities Management (in Persian), 2(9), 107-134.

Nixon, J.D., Dey, P.K., Davies, P.A., Sagi, S., Berry, R.F. (2014). Supply chain optimization of pyrolysis plant deployment using goal programming. Energy, 68, 262–271.

Nobari, A., Khierkhah, A., and Hajipour, V., (2018). A Pareto-based approach to optimize aggregate production planning problem considering reliable supplier selection, International Journal of Services and Operations Management, 29(1) 59–84.

Phuc, PNK, (2021). Stochastic Programming for Order Allocation and Production Planning, Computer Systems Science & Engineering, 4(1), 75-85.

Rezayi, A., Esfanjani, R., Mardani, M., (2017). Using Fuzzy Goal Programming Technique in Optimal Cropping Pattern, International Journal of Applied Operational Research, 7(1), 63-75.

Rohmah, W.G., Puwaningsih, I., Santoso, EF.S.M. (2018). Applying linear programming model to aggregate production planning of coated peanut products, International Conference on Green Agro-industry and Bioeconomy, doi:10.1088/1755-1315/131/1/012035.

Saeidi, S., Solimanpoor, M., Mahdavi, I., Javadian, N. (2014). A multi-objective genetic algorithm for solving cell formation problem using a fuzzy goal programming approach, Int. J. Advanced Manufacturing Technology, 70, 1635-1652.

Saeidi, S. (2015). A new model for University course timetabling problem using fuzzy goal programming approach and genetic algorithm, Journal of Soft Computing and Information Technology, 4(1), 67-78.

Setiawati, L., Arisya, A. (2018). Optimization of production planning using goal programming approach at chocolate factory, 4th Engineering Science and Technology International Conference (ESTIC 2018), MATEC Web of Conference, Vol. 248, 03016.

Solaja, O., Abiodum, J., Abioro, M., Ekpudu, J., Olasubulumi, O. (2019). Application of linear programming technique in production planning, International Journal of Applied Operational Research, 9(3), 11-19.

Tsai, K., You, S., Lin, Y., Tsai, C. (2008). "A fuzzy goal programming approach with priority for channel allocation problem in steel industry", Expert Systems with Applications, 34(3), 1870-1876.

Vinsenisa, D., Utami, Y., Simanjuntak, M.S., Tarigan, A.R. (2021). Study of Fuzzy Goal Programming Model to Production planning Problems Approach, Jurnal Teknin Informatikca C.I.T Medicom, 13(2), 75-81.

Zamanian, M.R, Sadeh, E., Aminisabegh, Z., Ehteshamrasi, R., (2019). A Fuzzy Goal-Programming Model for Optimization of Sustainable Supply Chain by Focusing on the Environmental and Economic Costs and Revenue: A Case Study, Advanced in Mathematical Finance & Applications, 4(1), 103-123.

This article can be cited: Alai, M., Saeidi, SH., (2022). Optimizing Boehmite Production Process Using Goal Programming Approach (Case study: Iranian West Mineral Applied Research Center). Journal of Industrial Engineering and Management Studies, Vol. 9, No. 2, pp. 182-195.