Journal of Quality Engineering and Production Optimization

Vol. 7, No. 1, Winter & Spring 2022

http://jqepo.shahed.ac.ir

Research Paper

DOI: 10.22070/JQEPO.2022.15940.1227

An Application of Mixed-Integer Linear Programming Method in Production Planning of Pipe Industry

Elahe Javadi[1], Reza Babazadeh[1*], Ali Doniavi[1], Hatef Javadi[2]

[1] *Faculty of Engineering, Urmia University, Urmia, West Azerbaijan Province, Iran*
[2] *Department of Industrial Engineering, Hacettepe University, Ankara, Turkey*

**** Corresponding Author:** Reza Babazadeh (Emails: r.babazadeh@urmia.ac.ir; r.babazadeh@ut.ac.ir)*

***Abstract** – Different types of pipes are used in various industries, and linear programming of pipe production is an effective subject in this industry. Especially, efficient planning in operational level leads to reduce total cost and improves competitiveness. In this paper, the mixed integer linear programming (MILP) approach is applied for operational planning of pipe production in different periods. To provide, moreover, a mathematical model for the manufacturing line, the model which is described in this study can choose the best supplier among a variety of suppliers. This model also optimizes the amount of raw materials acquired from suppliers as well as the amount of final product manufacturing, reducing final product and raw material inventory level in the factory. The final product inventory level, raw material inventory level, manufacturing capacity, supplier and warehouse capacity for keeping the final product and raw materials are also taken into account. The model is applied in a case study in GRP pipe production plants in Turkey.*

***Keywords**– Production planning, Supply chain, Integrated production planning, Glass Reinforced Polyester (GRP)*

I. INTRODUCTION

Production planning is a well-organized strategy to convert raw materials into final products as efficiently as possible while maintaining the quality and cost of the product. The main goal of any production planning is to understand market demands and requirements, design and develop products in response to customer needs, and ultimately profit. The universal goal of the machines is the manufacturing the required quantity of products in requested period of time, satisfying the number of product types, producing the demands of employee qualifications, the production cycle (process) and the work character division should be evaluated for a particular product. Production planning has an impact on the profit and degree of service provided to consumers, which requires flexibility in the production planning process as well as greater thoughtfulness to ensure high profit and service levels. Many manufacturing companies are forced to optimize their production processes in order to compete in the international market. Today, most researchers and industry experts use optimization approaches in production planning models to produce the most elements while ensuring the best profit (Khan et al., 2021).

Manuscript Received:30- Nov -2021 & Revised: 16- Feb -2022 & Accepted: 30- April -2022
ISSN: 2423-3781

On the other hand, one of the best ways to direct the water to the required points is the GRP pipe. GRP pipe is more suitable for irrigation and distribution of water due to many advantages and benefits such as high corrosion resistance, leak-proof system for maximum lossless flow, low weight, smooth inner surfaces reducing friction, high rigidity class available, high. Wear resistance, UV resistance, low operation and service life of more than 50 years (Kabak et al., 2022). Therefore, the demand for GRP pipes has increased in recent years. GRP pipe manufacturers aim to produce the optimum amount of pipes at the lowest cost in order to achieve the highest demand response due to the high demand. The main purpose of this study is to minimize all related costs in GRP Pipe production by considering different constraints. This article proposes a new multi-product multi-period problem.

Information about resources and existing facilities, demand projection for the planning period, and cost of various alternatives and resources are the most important inputs for production planning. Inventory holding, ordering, and production costs through various production options such as subcontracting, backorders, and overtime are all included in the costs. Organizational policies that take into account the utility of the aforesaid options are also required. Organizational policies are necessary considering the application of these options (Mehdizadeh et al., 2018). The key difference between high-volume and low-volume production planning is that, for the first time, rounding these variables is not uncertain. This is important because it makes the problem of mid-term production planning difficult for the low-tech industry, and is difficult even with NP-hard, given the similarities between product selection using existing capacity and the loop problem. In practice, however, medium-term planning is done weekly or monthly, and before making a decision, the problem is solved for many different demand forecasts. Therefore, the time required to solve a sample is very important (Kruijff et al., 2018).

This paper aims to reduce production costs, improve production line, ease of supplier selection and how to distribute and improve the quality and efficiency of the factory. The motivation for developing the proposed model is to improve the manufacturing line, decrease total production costs, and boost profits. The ideal suppliers, ordering time, order quantity, and optimal production amount for each time period are optimally determined using the proposed model.

The proposed problem is modeled using single-objective linear mathematical programming. One objective function which minimizes total cost that includes purchasing, raw material and final product holding, selection, production costs. Several constraints such as raw materials inventory level, safety stock, warehouse capacity level, and final product inventory level are also considered. The proposed approach is used in a real case study in a GRP pipe production company. The main contributions of this study are to 1) propose a multi-product multi-period problem through mathematical modeling, 2) suggest a dictionary for data collection 3) implement the mentioned model in a real case study and 4) compare the consequences of the mentioned approach with the existing experimental method in the case study.

The rest of the paper is organized as follows. In section 2, the literature of past and related works are given. The multi-product multi-period model production scheduling model is developed in section 3. The results of the developing model are presented in section 4. In the last which is section 5, the conclusions and the recommendations are presented.

II. RELATED WORKS

In this paper a selective summary of studies related to the proposed approach is reviewed. The main body of literature in this paper is production planning. Increasing the efficiency and decreasing the costs are two significant aims of organizations because of intensive competition and commercial globalization. There are three basic functions in each production plant; 1) production planning, 2) maintenance scheduling 3) quality control. (Beheshti-Fakher et al., 2016). One of the most important and crucial issues in industrial plants is production planning. Production planning seeks to find optimal amounts of production, inventory and other required production variables considering the limitation of planning zones (Ramezanian et al., 2012). Multi-objective production planning is one of the largest forms of production planning where the final product is accomplished by different steps (Feylizadeh et al., 2018). There are several papers dealing with production planning. Generally, there are two different production planning models which are stochastic and deterministic. Among the stochastic approaches, Lee (2001) proposed an artificial intelligence search approach including simulated annealing, tabu and neighborhood search, and genetic algorithm for modeling of two-stage multi-product problem which comprises due date penalty. A multi-stage process with parallel elements where the problem was into mixed integer linear programming (MILP) and non-linear dynamic optimization, was scheduled as a case study in polymeric plants (Nyström et al., 2006). A bi-level decomposition algorithm was presented by Dogan and Grossmann (2006) to solve synchronous scheduling and planning of single stage multi-product plants. Ghosh and Mondal (2017) proposed a production-distribution planning model for a multiple supply chain, with the genetic algorithm as the decision-making tool. Dong and Medeiros (2012) presented a minimizing schedule cost through simulation optimization which was a case study for pipe production. Sohn et al. (2017) presented a mixed-integer programming methodology for L.G. display production planning system. Iglesias-Escudero et al. (2019) presented a planning and scheduling problem with uncertainty in the steel industry which includes steel pipes. Li et al. (2016) have presented a mathematical model of production planning to maximize profits with limited capacity. Four types of cost factors (material cost, process cost, delay cost and facility cost) are considered in the proposed model. Different factors not only lead to different profits but also to different degrees of customer satisfaction. In particular, the cost of delays and occupation facilities can't be minimized at the same time because the two goals are reciprocal. In this paper, a mathematical model based on the actual production process of a foundry is presented. Also, gene encoding and decoding, definition of fitness function and genetic actuators are shown. In addition, they use the proposed algorithm to solve the production planning problem of a foundry. And comparisons with other recently published algorithms show the efficiency and effectiveness of the proposed algorithm. Sharifzadegan et al. (2021) proposed an integrated hybrid optimization problem for production and maintenance scheduling within a comprehensive system using overall cost and reliability. They used NSGA-II metaheuristic method to evaluate the model in larger dimension. Mosadegh et al. (2017) looked at inventory and shortages, unscheduled downtime and overtime, workforce level, and currency savings as four criteria in a mid-term planning horizon. Lei et al. (2020) presented a multi-factory production planning and scheduling in different areas and analyzed its application in PVC Pipe production. Gupta et al. (2021) addressed a two-stage transportation problem in a known and unknown environment, using fuzzy multi - objective programming for optimal shipment. Gitinavard et al. (2019) presented a case study of perishable dairy products to demonstrate the applicability of the proposed bi-objective multi-echelon supply chain model by establishing distribution centers. Vakili et al. (2021) proposed a robust stochastic programming approach to handle the uncertainty in a multi-echelon open location-routing model. In their model environmental objective function is optimized besides optimizing economic objective function. Also, Solgi et al. (2021) considered the technological, economic, environmental, social, and energy-oriented criteria to select the optimal brick production technologies. Moreover, Ghaderi et al. (2020) developed a group decision making methodology based on data envelopment analysis method for ranking DMUs in an intuitionistic fuzzy setting. Khadem et al. (2021) proposed a decentralized multi-commodity and multi-period mathematical model for disaster relief commodities' location and distribution which was a case study in Tehran, Iran. Keshmiry Zadeh et al. (2021) developed a multi-objective mixed-integer programming mathematical model to design a green multi-echelon closed-loop supply chain with the possibility of disruptions. Gao et al. (2020) presented a multi-period MILP model for optimizing the offshore oil production planning. Zhang et al. (2017) presented a MILP model to optimize the topology of collection in pipeline systems which produce wells, taking terrain, barriers and three mutual joint designs of pipeline consideration. Rosa et al. (2018) proposed a model of optimization implicated store dynamics and polyphaser stream to design undersea manufacturing networks. In order to formulate the layout design problem as a MILP, the piecewise linearization was implemented. For solving the mentioned model CPLEX solver was applied. Billal and Hossain (2020) proposed a multi-objective supply chain network including production plants, distribution center, and retailers which have uncertain services and customer nodes. The mentioned paper is not only multi-objective but also multi-product, multi-period and four-echelon.

III. METHODOLOGY

This paper proposes a linear mathematical model for optimization decisions in production planning of AKBOR GRP Pipe Production Company which produces GRP pipes. AKBOR produces pipes from diameter 300-4200 mm with pressure range of 1-40 bar and stiffness range of 2500 N/m2 to 10000 N/m2. GRP pipes generally are being used in irrigation projects, sewage, and potable water projects. The better production planning will help company to produce more pipes with optimal costs. For this reason, paper makes the best multi period multi products model.

The flow of material and product are assumed as shown in figure 1. As figure 1, five raw materials as silica sand, glass fiber, resin, cobalt and styrene are purchased and entered to the raw materials warehouse. The raw materials are then fed into the production line, and the finished product is delivered to the final product warehouses. The final customer will receive the order from the final warehouse after purchasing the merchandise. It is considered to produce only a single product with different diameters from 300-4200 mm.

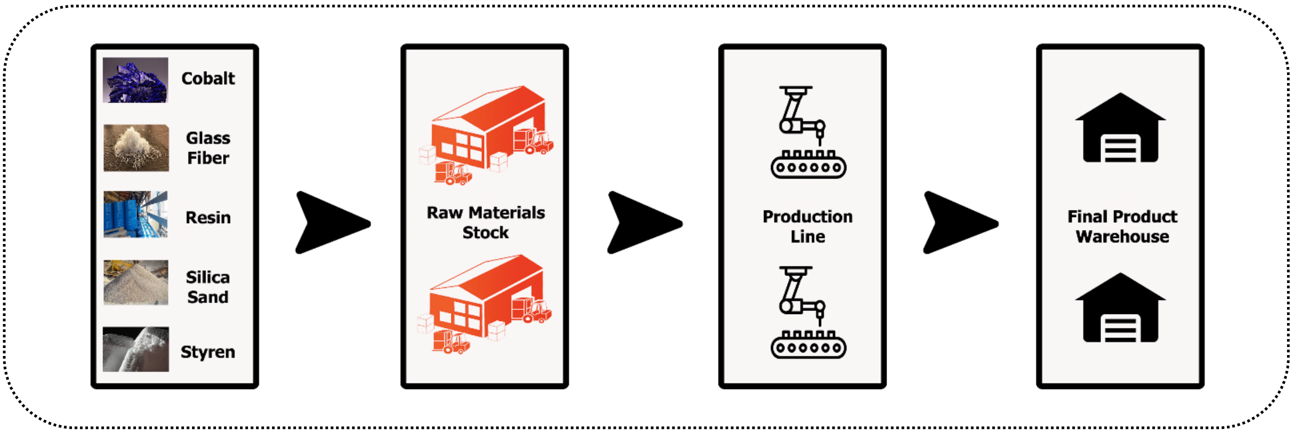

Fig 1. Supply Chain Flow

Pipes are produced with 3 machines and then final products are sent to Hydrostatics test. Further, after Hydrostatics test procedure, final products directly are shipped to clients because company does not have any branches or official representatives at demand points.

A. Model Formulation

Sets:

i: Raw materials index i = (1, …, I)

S: Suppliers index s = (1, …, S)

t: Time period index t = (1, …, T)

Parameters:

Ca_{ist}: Capacity of supplier s for raw material i in period of t

Cap_t: Capacity of manufacturing in period t

IC_{it}: Holding cost of raw material i in warehouse in period t

IP_t: holding cost of final product in period t

PU_{ist}: purchasing cost of raw material *i* from supplier *s* in period of *t*

PC_t: Production cost of final product in period *t*

SCT_{st}: Selection cost of supplier *s* in period *t*

csl: Defined service level for customers

α_i: Usage coefficient of raw material *i*

WI: Capacity of raw materials warehouse

WO: Capacity of final product warehouse

D_t: Demand of final product in period *t*

IB_{it}: Safety Stock for raw material *i* in period of *t*

Decision Variables:

Il_{it}: Inventory level of raw material i in period of t

x_{ist}: Purchase quantity of raw material i from supplier s in period t

Px_t: Number of manufacturing of final product in period t

Ir_t Number of inventory of final product in period t

y_{st}: Binary variable equal to 1 if supplier s is ordered in period t

B. Objective Function

The objective of the model is to minimize the total production costs. The model considers selection cost of suppliers, purchasing cost, holding cost of raw materials, production cost of pipe, holding cost of final product.

$$MinZ = \sum_s \sum_t SCT_{st} \,.\, y_{st} + \sum_i \sum_s \sum_t PU_{ist} . x_{ist} + \sum_i \sum_t IC_{it} . Il_{it} + \sum_t PC_t \,.\, Px_t + \sum_t IP_t \,.\, Ir_t \tag{1}$$

$$Ir_t = Ir_{t-1} + Px_t - D_t \qquad \forall\, t \tag{2}$$

Safety stock constraint

$$Ir_t = csl. D_t \qquad \forall\, t \tag{3}$$

$$Il_{it} = Il_{i,t-1} + \sum_s x_{ist} - \alpha_i . Px_t \qquad \forall\, i, t \tag{4}$$

Capacity constraints

$$\sum_i x_{ist} \leq Ca_{st} . y_{st} \qquad \forall\, s, t \tag{5}$$

$$Px_t \leq Cap_t \qquad \forall\, t \tag{6}$$

$$\sum_i Il_{it} \leq WI \qquad \forall\, t \tag{7}$$

Raw materials inventory constraints

$$Il_{it} \geq lB_{it} \qquad \forall\, i, t \tag{8}$$

$$Ir_t \leq WO \qquad \forall\, t \tag{9}$$

Variables constraints

$$y_{st} \in \{0,1\} \qquad \forall\ s,t \tag{10}$$

$$x_{ist}, Il_{it}, Px_t, Ir_t \geq 0 \qquad \forall\ i, s, t \tag{11}$$

Constraint (2) ensures that number of inventory of final product in period *t* equal the of number of inventory of final product in period *t*-1 and number of manufacturing of final product in period *t* minus Demand of final product in period *t*. Constraint (3) ensures that number of inventory of final product in period *t* greater or equal than defined service level to avoid shortages. Constraint (4) ensures that final inventory level of raw material *i* in the factory in period *t* is equal to the total inventory of raw material from the previous period plus the amount of raw material purchased from supplier *s* in period *t* minus the amount of raw material in period t to product. Constraint (5) ensures that factory cannot order more than the capacity of suppliers in period *t*. If a supplier is selected, the binary variable can set 1. Constraint (6) ensures that number of manufacturing of final product in period *t* does not exceed the production capacity of factory in period *t*. Constraint (7) ensures that inventory level of raw material *i* in period of t does not exceed capacity of raw materials warehouse in period *t*.

Constraint (8) ensures that inventory level of raw material *i* in period of *t* must be greater or equal the safety stock for raw material *i* in period of *t*. Constraint (9) ensures that number of inventory of final product in period *t* does not exceed capacity of final product warehouse

C. Model Verification

This study is a case for one of the GRP pipe production plants in Turkey. This company is one of the leading manufacturers in Turkey in the pipeline industry. The data related to the model of this research were collected from the location of factory and its different departments, including warehouse, sales and marketing, procurement, design and quality control units. Procurement department of factory presented all purchasing quantities of two glass fiber suppliers that are located in Istanbul and Kayseri. Factory buys silica sand from two various companies from Hatay and Konya. Resins are the production are being supplied by two different producers from Istanbul and Kocaeli. Cobalt and Styrene are raw materials that factory purchases from the Anatolian region. Also, production department shares raw materials' usage quantities. Two different suppliers are considered for each raw material. Glass fiber, silica sand, resin, cobalt, and styrene are raw materials that the company use to produce GRP pipe. Raw materials suppliers' production capacity is given in table 1.

Table I. Production capacity of supplier s in period t (ton)

Period(Month)	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
Supplier 1 for Glass Fiber (S1G)	146	146	146	146	146	146	146	146	146	146	146	146
Supplier 2 for Glass Fiber (S2G)	125	125	125	125	125	125	125	125	125	125	125	125
Supplier 1 for Silica Sand (S1S)	175	175	175	175	175	175	175	175	175	175	175	175
Supplier 2 for Silica Sand (S2S)	133	133	133	133	133	133	133	133	133	133	133	133
Supplier 1 for Resin (S1R)	30	30	30	30	30	30	30	30	30	30	30	30
Supplier 2 for Resin (S2R)	22	22	22	22	22	22	22	22	22	22	22	22
Supplier 1 for Cobalt (S1C)	100	100	100	100	100	100	100	100	100	100	100	100
Supplier 2 for Cobalt (S2C)	75	75	75	75	75	75	75	75	75	75	75	75
Supplier 1 for Styrene (S1Y)	50	50	50	50	50	50	50	50	50	50	50	50
Supplier 2 for Styrene (S2Y)	50	50	50	50	50	50	50	50	50	50	50	50

D. Model Description

The model is coded in GAMS 23.5 software with CPLEX solver as MILP method. Limitations for proposed model are as below:

- Inventory of final product in period t limitations
- Safety stock limitations
- Warehouse capacity limitations
- Order Capacity limitation
- Inventory level of Raw material limitations

Results for inventory of final products are shown in table 2. For example, the inventory for final product should be 11 kilometers of GRP pipe in period t.

Table II. Inventory for Final Product (km)

Period(t)	*Inventory of final product*
1	6
2	8
3	9
4	9
5	16
6	14
7	10
8	5
9	6
10	1
11	1
12	1

Results for Supplier selection are shown in table 3 and it is considered only 6 suppliers are selected among ten of them.

Table III. Binary variable for supplier selection

Period(t)	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
S1G	1	1	1	1	1	1	1	1	1	1	1	1
S2G	0	0	0	0	0	0	0	0	0	0	0	0
S1S	1	1	1	1	1	1	1	1	1	1	1	1
S2S	0	0	0	0	0	0	0	0	0	0	0	0
S1R	1	1	1	1	1	1	1	1	1	1	1	1
S2R	1	1	1	1	1	1	1	1	1	1	1	1
S1C	1	1	1	1	1	1	1	1	1	1	1	1
S2C	0	0	0	0	0	0	0	0	0	0	0	0
S1Y	1	1	1	1	1	1	1	1	1	1	1	1
S2Y	0	0	0	0	0	0	0	0	0	0	0	0

Raw materials purchasing quantity results are shown in table 4. According to the mentioned table, factory needs to buy 2.25 ton of cobalt from S1C.

Table IV. Purchasing quantity of raw materials from

Period(t)	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
S1G	17.6	14.7	15.1	15.75	30.45	24.8	14.1	0	11.85	0	0.75	1.75
S2G	0	0	0	0	0	0	0	0	0	0	0	0
S1S	13	10.5	10.5	11.25	21.75	18	14.1	0	11.85	0	0.75	1.75
S2S	0	0	0	0	0	0	0	0	0	0	0	0
S1R	17.6	14.7	15.1	15.75	30	24.8	14.1	0	11.85	0	0.75	1.75
S2R	0	0	0	0	0.45	0	0	0	0	0	0	0
S1C	4.8	2.1	1.3	2.25	4.35	0	4.4	0	1.3	0	0.25	0.25
S2C	0	0	0	0	0	0	0	0	0	0	0	0
S1Y	5.6	4.2	3.6	4.5	8.7	7.8	3.60	0	3.1	0	0.5	0.5
S2Y	0	0	0	0	0	0	0	0	0	0	0	0

In table 5, inventory level of raw materials is shown. According to mentioned table, all type of raw materials should be existed at the warehouse. For example, four tons of resin should be stocked in the warehouse in period five.

Table V. Inventory Level of Raw Material

Period(t)	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Glass Fiber	5	5	4	4	4	5	3	3	4	4	3	3
Silica Sand	4	4	3	3	3	4	2	2	1	1	2	2
Resin	5	4	4	4	4	5	3	3	4	4	3	3
Cobalt	3	2	2	2	2	3	2	2	2	2	2	2
Styrene	2	1	1	1	1	2	1	1	1	1	1	1

In table 6, the results for the optimal output of the final product in period t are shown. According to mentioned table, for example, in the seventh period, the optimal production of the final product is 46.

Table VI. The optimal amount of production of the final product

Period(t)	*The optimal amount of production of the final product*
1	36
2	42
3	46
4	45
5	87
6	68
7	46
8	0
9	31
10	0
11	5
12	5

The optimal solution for objective function is 1.057.476.48 USD.

E. Sensitivity Analysis

The sensitivity analysis of model output is an important technique in modeling expertise. It could help in ensuring that a model's response to its input is consistent with theory. It could help with model calibration by determining the best experimental circumstances for determining a certain unknown factor, for example. When comparing different mechanistic theories to the evidence, SA can assist in determining to what extent the current uncertainties allow a given mechanism to be identified clearly. In this section, sensitivity analysis is performed on the parameter of production costs, production demand and supply costs.

According to the results, the value of the objective function rises by 6.4 percent when production expenses rise by 10%. When supply expenses are increased by 10%, the value of the objective function increases by 2.7 percent. Additionally, a 10% increase in production demand results in a 3.1 percent rise in objective function value.

Figure 2 illustrates the objective function's sensitivity to changes in production costs. The value of the objective function rises in parallel with the cost of production. This graph represents the direct impact of the amount of production costs on the objective function's performance.

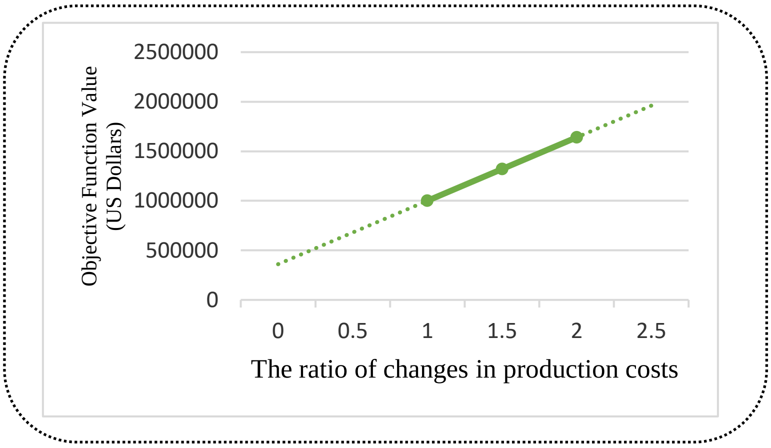

Fig 2. Objective function changes respect to changes of production costs.

Figure 3 shows the objective function's sensitivity to changes in supply costs. Like can be noticed, as with production costs, the objective function's value rises as supply costs rise.

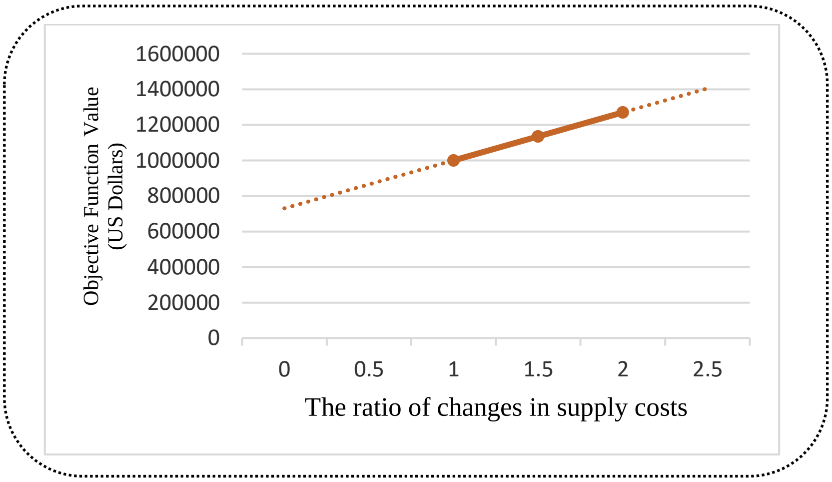

Fig 3. Objective function changes respect to changes of supply costs.

Figure 4 shows the sensitivity of the objective function to changes of production demand. Although the increase in demand reduces the inventory level in the raw material warehouse, but due to the increase in inventory level of products and the higher cost of maintaining the product warehouse, It is seen an increase in the total amount of the objective function.

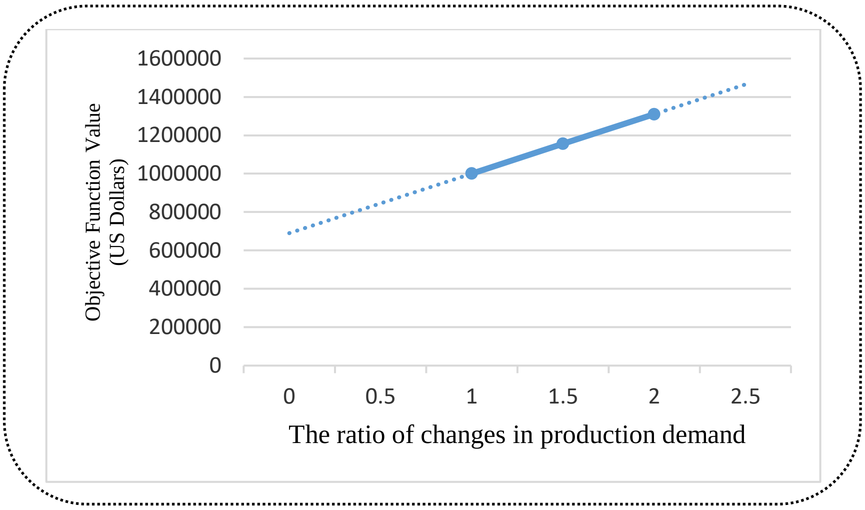

Fig 4. Objective function changes respect to changes of production demand.

IV. CONCLUSION AND FUTURE DIRECTIONS

Today, the importance of scheduling in the fields of raw materials supply, production, and distribution of products is undeniable in every organization and production unit. Therefore, scheduling and production planning based on specific parameters according to every organization's requirements plays a significant role in all production units. Production planning is closely related to the processes of material supply, ordering, production, sales, and maintenance. These connections are especially necessary for compiling comprehensive planning that works well. Production managers can Schedule production operations, raw materials purchasing, and resource management by doing MILP. Different parameters and various variables are considered in MILP such as cost factors, product demands, materials necessity factors, capacity constraints and etc. Mentioned factors generally meet certainty and are determined exactly. In this paper, all factors are assumed as definite. According to the obtained results, it can be shown that the developed model is able to reduce the total cost of production by approximately 20% and reach the inventory of the final product to the optimal amount. Customer demand is also met in a timely manner. It should be noted that the proposed model has the potential for optimal planning to select the appropriate suppliers from different ones. The total cost before the implementation of the mixed-integer linear programming was 211.495,29 USD. According to the results, a 20% reduction in total costs occurred. As the objective function tries to minimize the total cost, so it is concluded that this model is efficient and optimizes the production line. This model selected 6 ideal suppliers from among the 10 available suppliers, which has a great impact on optimizing the production line. Selected suppliers not only supply the demand of the company but also minimize the supply cost. For future directions, the supply chain can be considered more broadly and also the uncertainty of the model can be examined to achieve more realistic results.

A. Managerial insights

Improving managerial performance and speeding up the work process are among the other goals of this paper. The proposed model helps decision makers to optimally select the suppliers and determine the optimal amount of raw material orders, production and inventory level in different periods.

Also, the managers could investigate the sensitivity of the proposed model with respect to the changes of different parameters. By this way, decisions would be optimally made under changes of parameters.

REFERENCES

Beheshti-Fakher, H., Nourelfath, M., & Gendreau, M. (2016). Joint planning of production and maintenance in a single machine deteriorating system. IFAC-PapersOnLine, 49(12), 745-750.

Billal, M. M., & Hossain, M. (2020). Multi-Objective Optimization for Multi-Product Multi-Period Four Echelon Supply Chain Problems Under Uncertainty. Journal of Optimization in Industrial Engineering, 13(1), 1-17.

Dogan, M. E., & Grossmann, I. E. (2006). A decomposition method for the simultaneous planning and scheduling of single-stage continuous multiproduct plants. Industrial & engineering chemistry research, 45(1), 299-315.

Dong, S., & Medeiros, D. J. (2012). Minimising schedule cost via simulation optimisation: an application in pipe manufacturing. International journal of production research, 50(3), 831-841.

Feylizadeh, M. R., Karimi, N., & Li, D. F. (2018). Multi-stage production planning using fuzzy multi-objective programming with consideration of maintenance. Journal of Intelligent & Fuzzy Systems, 34(4), 2753-2769.

Gao, X., Xie, Y., Wang, S., Wu, M., Wang, Y., Tan, C., ... & Chen, T. (2020). Offshore oil production planning optimization: An MINLP model considering well operation and flow assurance. Computers & Chemical Engineering, 133, 106674.

Ghaderi, H., Gitinavard, H., & Mehralizadeh, M. (2020). An Intuitionistic Fuzzy DEA Cross-Efficiency Methodology with an Application to Production Group Decision-Making Problems. Journal of Quality Engineering and Production Optimization, 5(2), 69-86.

Ghosh, D., & Mondal, S. (2017). An integrated production-distribution planning with transshipment between warehouses. International Journal of Advanced Operations Management, 9(1), 23-36.

Gitinavard, H., Ghodsypour, S., & Akbarpour Shirazi, M. (2019). A bi-objective multi-echelon supply chain model with Pareto optimal points evaluation for perishable products under uncertainty. Scientia Iranica, 26(5), 2952-2970.

Gupta, S., Haq, A., Ali, I., & Sarkar, B. (2021). Significance of multi-objective optimization in logistics problem for multi-product supply chain network under the intuitionistic fuzzy environment. Complex & Intelligent Systems, 7(4), 2119-2139.

Iglesias-Escudero, M., Villanueva-Balsera, J., Ortega-Fernandez, F., & Rodriguez-Montequín, V. (2019). Planning and Scheduling with Uncertainty in the Steel Sector: A Review. Applied Sciences, 9(13), 2692.

Kabak, M., Javadi, H., Aktas, A., & Ecer, B. (2022). GIS-Based Multi-Criteria Decision Making for Site Selection: An Application of GRP Pipe Production Plant. Journal of Multiple-Valued Logic & Soft Computing, 38.

Keshmiry Zadeh, K., Harsej, F., Sadeghpour, M., & Molani Aghdam, M. (2021). A multi-objective multi-echelon closed-loop supply chain with disruption in the centers. Journal of Quality Engineering and Production Optimization, 6(2), 31-58.

Khadem, M., Toloie Eshlaghy, A., & Fathi Hafshejani, K. (2021). Decentralized Multi-Commodity and Multi-Period Mathematical Model for Disaster Relief Goods Location and Distribution using HACO-VNS Hybrid Algorithm. Journal of Quality Engineering and Production Optimization, 6(2), 157-180.

Khan, M. F., Haq, A., Ahmed, A., & Ali, I. (2021). Multiobjective multi-product production planning problem using intuitionistic and neutrosophic fuzzy programming. IEEE Access, 9, 37466-37486.

Kruijff, J. T., Hurkens, C. A., & de Kok, T. G. (2018). Integer programming models for mid-term production planning for high-tech low-volume supply chains. European Journal of Operational Research, 269(3), 984-997.

Lee, I. (2001). Artificial intelligence search methods for multi-machine two-stage scheduling with due date penalty, inventory, and machining costs. Computers & Operations Research, 28(9), 835-852.

Lei, D., Yuan, Y., Cai, J., & Bai, D. (2020). An imperialist competitive algorithm with memory for distributed unrelated parallel machines scheduling. International Journal of Production Research, 58(2), 597-614.

Li, M., Yang, F., Uzsoy, R., & Xu, J. (2016). A meta model-based Monte Carlo simulation approach for responsive production planning of manufacturing systems. Journal of a Manufacturing Systems, 38, 114-133.

Mehdizadeh, E., Niaki, S. T. A., & Hemati, M. (2018). A bi-objective aggregate production planning problem with learning effect and machine deterioration: Modeling and solution.Computers & Operations research, 91, 21-36.

Mosadegh, H., Khakbazan, E., Salmasnia, A., & Mokhtari, H. (2017). A fuzzy multi-objective goal programming model for solving an aggregate production planning problem with uncertainty. International Journal of Information and Decision Sciences, 9(2), 97-115.

Nyström, R. H., Harjunkoski, I., & Kroll, A. (2006). Production optimization for continuously operated processes with optimal operation and scheduling of multiple units. Computers & chemical engineering, 30(3), 392-406.

Ramezanian, R., Rahmani, D., & Barzinpour, F. (2012). An aggregate production planning model for two phase production systems: Solving with genetic algorithm and tabu search. Expert Systems with Applications, 39(1), 1256-1263.

Rosa, V. R., Camponogara, E., & Ferreira Filho, V. J. M. (2018). Design optimization of oilfield subsea infrastructures with manifold placement and pipeline layout. Computers & Chemical Engineering, 108, 163-178.

Sharifzadegan, M., Sohrabi, T., & Jafarnejad Chaghoshi, A. (2021). Hybrid optimization of production scheduling and maintenance using mathematical programming and NSGA-II meta-heuristic method. Journal of Quality Engineering and Production Optimization, 6(2), 79-96.

Sohn, M. S., Choi, J., Kang, H., & Choi, I. C. (2017). Multiobjective production planning at LG display. Interfaces, 47(4), 279-291.

Solgi, E., Gitinavard, H., & Tavakkoli-Moghaddam, R. (2021). Sustainable High-Tech Brick Production with Energy-Oriented Consumption: An Integrated Possibilistic Approach Based on Criteria Interdependencies. Sustainability, 14(1), 202.

Vakili, R., Akbarpour Shirazi, M., & Gitinavard, H. (2021). Multi-echelon green open-location-routing problem: A robust-based stochastic optimization approach. Scientia Iranica, 28(2), 985-1000.

Zhang, H., Liang, Y., Ma, J., Qian, C., & Yan, X. (2017). An MILP method for optimal offshore oilfield gathering system. Ocean Engineering, 141, 25-34. Korea, 2009, pp.23-29.