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Using the mathematical model of production planning and maintenance operations for the general company of oil products distribution

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Abstract
In this study, a mathematical model was made that combines the production and maintenance model with the two-stage supply chain. The model has four main goals, including minimizing production costs, keeping things in good shape, getting things to where they need to go, and making sure the system is as reliable as possible. The data from the General Company for the Distribution of Petroleum Products was put into the mathematical model. The model helped set production plans and maintenance schedules, as well as move products from the Dora refinery to 8 oil depots for storage, and then from the oil depots to the 120 gas stations in Baghdad, where 3 main products were approved (oil white, gasoline, and gas oil). After estimating the parameters of the Whipple distribution for signs of failure, the results showed how reliable the company's system was in the average planning periods. The results showed that the system didn't need to be fixed or replaced during any of the planning periods. In terms of production, there was a surplus of white oil and gasoline producers, but a shortage of gas oil producers during all of the planning periods.

Keywords: Production planning, maintenance scheduling, mathematical modeling

1. Introduction

Production Planning PP is a medium-term capacity planning technique that usually includes a time horizon anywhere, usually for a period of between (2 to 18) months. In general; its objective is to determine the quantity of production, inventory level, manpower, and others, in order to achieve the expected demand by using the enterprise's resources efficiently and effectively.

There are extensive studies dealing with the issue of production planning, as well as other studies to the same extent that discuss maintenance planning issues; Production planning models usually seek to balance the costs of setting up the system with the costs of production and maintaining various resources, while maintenance models usually attempt to balance the costs and benefits of maintenance plans; In order to improve the performance of the production system.

In both areas, the methods of building production and maintenance models have seen clear success from both practical and theoretical points of view. Paradoxically, the issue of combining or merging production and maintenance plans has received much less attention despite the great importance of this, imposed by industrial and investment realities. In all fields.

Most of the production planning models assume that the system is operating at its maximum performance during the planning horizon, and a large part of the maintenance planning models ignore the impact of maintenance on production capacity, and do not take into account the production requirements explicitly.

In practice, apart from preventive maintenance measures that can be scheduled during system downtime; any unplanned maintenance procedure will interrupt the production plan; therefore it is very important to consider both aspects of production system planning and maintenance at the same time, while developing optimal production and maintenance plans.

The concept of production capacity is defined as the maximum output (goods and services) that the production system and processes can produce during a specified period of time", or it is the production capacity of the enterprise during a specified period of time [1].

We can define the production capacity as: “the upper limit that can be handled or managed by the operating unit.” As for the production capacity for services; it has been defined as: “The number of customers that the organization can deal with and serve them during a specified period of time.”

As for energy planning; it can be defined as: “The set of decisions related to the selection of the size of the production capacity of the enterprise in the long run, and this type of planning depends to a large extent on the outcome of the forecasting processes for the demand for the company’s products” [2].

Energy planning can also be defined as: "Determining the appropriate level of production capacity, which is determined by choosing an appropriate mix of machinery, equipment, and workers to cover future demand for products" [3], and accordingly; Determining production capacity is linked to making a set of decisions to determine the optimal levels of material, financial and human resources that allow the institution to achieve the required level of production.

2. Methodology

2.1 Mathematical Modeling

Through what was presented above, and from the definition of the inventory model and the production network model, and to link the production model to the maintenance model by linking the process of the time available for production with the planned time for maintenance; we can define the proposed model in the following form:

2.2 Parameters

Z: fixed cost of maintenance

$\boldsymbol{M_{i,p}}$: The cost of maintaining part (i) of the machine that produces the product (p)

$\boldsymbol{R_{i,p}}$: The cost of replacing part (i) of the machine producing the product (p)

$\boldsymbol{MT_{i,p}}$: The time required to maintain the part (i) of the production machine of the product (p)

$\boldsymbol{RT_{i,p}}$: The time required to maintain the part (i) of the machine that produces the product (p)

$\boldsymbol{c_{jp}}$: The unit cost of transporting product p from the refinery to the main distribution center (j).

$\boldsymbol{e_{lp}}$:The unit cost of moving the product ((p) from the main distribution center (j) to the demand area (l).

$\boldsymbol{d_{lpt}}$: The order quantity demanded from the ordering area (l) of the product family (p) in period (t).

$\boldsymbol{f_j}$: The fixed cost of opening a major distribution center (j).

$\boldsymbol{SC_{jp}}$: The cost of one unit of storage for product p)) at the main distribution center (j).

$\boldsymbol{SB_{jp}}$:The cost of one unit of deferred demand for product p)) at the main distribution center (j).

$\boldsymbol{SS_{jp}}$: Safety stock of product (p) at the main distribution center (j).

$\boldsymbol{Bmax_p}$: upper bound on deferred demand for product p))

$\boldsymbol{\delta_{j,p}}$: The storage capacity of the main distribution center (j) for product (p).

$\boldsymbol{F_{i,p}}$: Cost of failure in part (i) of the machine to produce the product (p)

$\boldsymbol{\pi_p}$: The relative importance of the product (p).

$\boldsymbol{\rho_p}$: Cost per unit of manufacturing product (p).

$\boldsymbol{rc_p}$: The time it takes to produce the product (p) on the machine.

$\boldsymbol{\alpha_{i,p}}$: Amount of maintenance improvement in part (i) of the product making machine (p)

$\boldsymbol{M_{tmax}}$: The total time available for production.

2.3 Variables

$\boldsymbol{I_{jpt}}$: The stock level of the product family (p) at distribution center (j) in period (t)

$\boldsymbol{B_{jpt}}$: The backorder level of the product family (p) at the main distribution center (j) in period (t)

$\boldsymbol{O_{jlp,t}}$: Quantities of product (p) shipped from the main distribution center (j) to the demand area (l) in period (t).

$\boldsymbol{u_{jpt}}$: The quantity of production shipped from the product (p) that is shipped from the refinery to the main distribution center (j) in period (t)

$\boldsymbol{P_{p,t}}$: Production quantities of the product (p) in period (t)

$\boldsymbol{z_{j,p}}$: Binary variable when (1) opening a main distribution center (j) for product (p) and (0) otherwise.

$\boldsymbol{m_{i,p,tm,t}}$**:** Maintenance status of part (i) of the product production machine (p) in the maintenance period (tm) within the production planning period (t)

$\boldsymbol{r_{i,p,tm,t}}$**:** Replacement status of the part (i) of the product production machine (p) in the maintenance period (tm) within the production planning period (t)

2.4 Objectives

First objective: to reduce the total costs of production and distribution of products:

$$Min\ (w_1) = \sum_{jp} f_j z_{jp} + \sum_{t,p} \rho_p P_{p,t} + \sum_{j,t,p} c_{jp}\, u_{jpt} + \sum_{j,l,p,t} e_{jlp} O_{jlpt} + \sum_{j,p,t} SC_{jp}\, I_{jpt} + \sum_{j,p,t} SB_{jp}\, B_{jpt} \tag{1}$$

Second Objective: Reducing the percentage of deficit:

$$Min(w_2) = Max_{l,p,t}\{\pi_p(\, d_{lpt} - \textstyle\sum_j O_{jlpt})\} \tag{2}$$

2.5 Constraints

- Balancing inventory and backorder with distributed quantities:

$$I_{jp,t} - B_{jp,t} = I_{jp,t-1} - B_{jp,t-1} + u_{jpt} - \sum_l O_{jlpt} \ \forall (j = 1,2, \dots, J), (p = 1,2, \dots, NP), (t = 1,2, \dots, T) \quad (3)$$

- Equating the production quantities produced in the factory with the quantities distributed to the distribution centers:

$$\sum_j u_{jpt} = P_{p,t} \ \forall \ (p = 1,2, \dots, NP), (t = 1,2, \dots, T) \quad (4)$$

- Capacity limitation for each distribution center:

$$I_{jp,t-1} + u_{jpt} \ \leq \ \delta_{jp} \, z_{jp} \ \forall (j = 1,2, \dots, J), (p = 1,2, \dots, NP), (t = 1,2, \dots, T) \quad (5)$$

- Lower bound of Inventory for each distribution center:

$$I_{jpt} \ \geq \ SS_{jp} z_{jp} \ \forall (j = 1,2, \dots, J), (p = 1,2, \dots, NP), (t = 1,2, \dots, T) \quad (6)$$

- Limitation of the upper limit of the delayed order:

$$B_{jp,t} \leq Bmax_p \ \forall (j = 1,2, \dots, J), (p = 1,2, \dots . NP), (t = 1,2, \dots, T) \quad (7)$$

- Constraint of production capacity in the presence of maintenance:

$$rc_p \, P_{pt} + \sum_{tm=1}^{TM} \sum_{i=1}^{N} MT_{i,p} \, . \, m_{i,p,tm,t} + \sum_{tm=1}^{TM} \sum_{i=1}^{N} RT_{i,p} \, . \, r_{i,p,tm,t} \leq M_{tmax} \ \forall (p = 1,2, \dots, NP), (t = 1,2, \dots, T), (\, tm = 1,2, \dots, TM) \quad (8)$$

- Constraint of verification that maintenance and replacement are not performed simultaneously:

$$r_{i,p,tm,t} + m_{i,p,tm,t} \leq 1 \ \forall (\, i = 1,2, \dots, N), (\, p = 1,2, \dots, NP), (\, t = 1,2, \dots, T), (\, tm = 1,2, \dots, TM)$$

$$I_{jpt}, \ B_{jpt}, u_{jpt}, \ O_{jlp,t}, \ P_{p,t}, \geq 0, \ m_{i,p,tm,t}, r_{i,p,tm,t} \ \in [0,1]$$

2.6 Genetic algorithm

It is one of the more recent approaches to artificial intelligence and has emerged as an important method to use in the process of resolving difficult and extensive issues. As a result of the fact that it offers a large variety of potential solutions within a reasonable amount of time, the fact that the solution that is produced as a result of its application is frequently a solution that is very close to the ideal solution, and the fact that it offers an intelligent solution among a large number of possible solutions [8].

It is one of the general search algorithms, and its foundation is the natural gene system as well as the mechanism of natural selection. It was developed in 1970 by the scientist John Holland at the University of Michigan; He published many research papers in this field, the main objective of which was to build and improve many algorithms, software and systems, and in 1975 he applied them to the Combination Optimization Problems, then in 1987 Davis studied the effect of using different types of commutative interference and mutation and methods Cryptography on the Genetic Algorithm and its Results, and Golts studied the effect of using different types of commutative interference and mutation and methods [9].

Between the years 1992 and 1994, it was put to use by John Koza in the process of developing programs to address a variety of issues; the name of his approach was Genetic Programming (G.P). In the years that followed, its application became widespread in many different fields, including engineering, economics, money management, industry, and trade as well [10].

The concept of how the genetic algorithm is supposed to function is directly dependent on the ideas behind genetic engineering. Genetic engineering is distinguished by the deliberate production of inherited groups with the goal of developing solutions that have desirable qualities. On the basis of this information, the algorithm picks the best solutions out of a large number of solutions and then makes some overlaps and modifications between them in order to create even better solutions. The genetic algorithm has helped system and software designers save a significant amount of time and effort by locating a general algorithm that is reliable in solving different types of problems rather than building a special algorithm for each issue. This was accomplished by finding a general algorithm that is reliable in solving different types of problems and taking into account the necessary changes that are commensurate with the specificity of each issue in terms of the size and type of data used as well as the nature of the objective function and restrictions for each issue. In other words, the including but not limited to: (optimization, image processing, complex priority problems such as the traveling salesman problem, and applications of neural networks) [10].

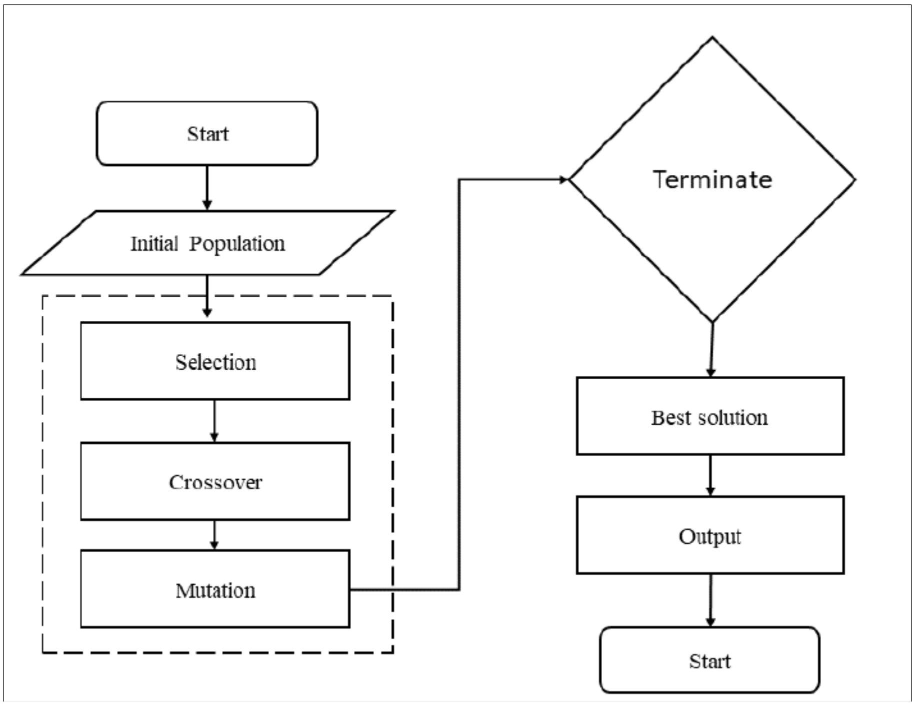

Fig 1: flow chart of genetic algorithm

3. Results and Discussion

Using the data obtained from the company, and based on the mathematical model proposed in this section, the mathematical model has been solved using the genetic algorithm that was explained in the previous chapter, which will be in several stages: The first stage will be the use of the genetic algorithm in scheduling maintenance and replacement operations Determining the total time of these operations, as the total time of maintenance operations will be subtracted from the total time available for the production process. As for the second stage; In which the quantities produced for each period of time will be determined according to the total time available, and then the transportation process is in reverse, where each demand area is determined on a specific warehouse to determine the number of warehouses required for transportation and to secure the total demand, and then the process of transferring products from the refinery to warehouses is carried out according to Quantities required from each warehouse.

Table 1: Inventory quantities for each time period and for each product in liters

Product	**Period**					
	1	**2**	**3**	**4**	**5**	**6**
Oil white	20003424	20007666	19982485	19990997	20001853	19986647
Gasoline	38905060	38872078	38937992	38851947	38861604	39073040
Gas oil	0	0	0	0	0	0

Table 2: Backorder quantities for each time period and for each product in liters

Product	**Period**					
	1	2	3	4	5	6
Oil white	0	0	0	0	0	0
Gasoline	0	0	0	0	0	0
Gas oil	2681094	2701782	2681987	2696937	2685818	2686729

In the above tables of storage and deferred demand, we can see that the producers of white oil and gasoline have more than they need in all time periods per month. There are two ways to deal with this oversupply. The first is for the company to store all of these products together, which costs the company money and can cause problems. Because they couldn't store more, they had to make things quickly. As for the second scenario, which makes more sense, it would be to sell these products locally or internationally. The company would make money and warehouse space would be less crowded. As for the gas oil product, there is a clear shortage in all planning periods. To meet the stations' needs for this product, the company has to do one of two things: either it tries to increase the refinery's production capacity or it subcontracts, which means it buys the shortage quantities of this product.

4. Conclusion

Given the complexity of the model and the number of many variables in it; Solving the model by exact methods is very difficult, especially in big problems, so we will adopt smart algorithms to solve the model.

In this paper, the genetic algorithm was adopted to solve the model; Due to the algorithm's ability to quickly adapt to the nature of any problem, as well as its high ability to solve mathematical models.

The process of solving the mathematical model took place based on several stages: in the first stage, the process of scheduling preventive maintenance was carried out based on the genetic algorithm in each period, while the second stage; It included the reverse distribution of products, where the carrying capacities of each warehouse and the demand for products were taken to determine the quantities supplied to each station by each warehouse.

After determining the quantities to be processed through each warehouse, the process of transferring the products from the refinery to the distribution centers and storing the surplus quantities is carried out. It should be noted that the bivariate genetic algorithm was adopted to solve the maintenance issue. As for the distribution stages; The cross-coding discrete genetic algorithm has been adopted.

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