International Journal of Industrial Engineering & Production Research June 2021 Vol. 32, No. 2: 1-18
DOI: 10.22068/ijiepr.32.2.1

RESEARCH PAPER

Simulation Based Optimization Model for Logistic Network in a Multi-Stage Supply Chain Network with Considering Operational Production Planning "Truck Loading System and Transportation Network"

Mohsen Khezeli[1], Esmaeil Najafi [*2], Mohammad Haji Molana[3] & Masoud Seidi[4]

Received 25 August 2020; Revised 18 February 2021; Accepted 10 May 2021;

ABSTRACT
One of the most important fields of logistic network is transportation network design that has an important effect on strategic decisions in supply chain management. It has recently attracted the attention of many researchers. In this paper, a multi-stage and multi-product logistic network design is considered. This paper presents a hybrid approach based on simulation and optimization (Simulation based optimization), the model is formulated and presented in three stages. At first, the practical production capacity of each product is calculated using the Overall Equipment Effectiveness (OEE) index, in the second stage, the optimization of loading schedules is simulated. The layout of the loading equipment, the number of equipment per line, the time of each step of the loading process, the resources used by each equipment were simulated, and the output of the model determines the maximum number of loaded vehicles in each period. Finally, a multi-objective model is presented to optimize the transportation time and cost of products. A mixed integer nonlinear programming (MINLP) model is formulated in such a way as to minimize transportation costs and maximize the use of time on the planning horizon. We have used Arena simulation software to solve the second stage of the problem, the results of which will be explained. It is also used GAMS software to solve the final stage of the model and optimize the transporting cost and find the optimal solutions. Several test problems were generated and it showed that the proposed algorithm could find good solutions in reasonable time spans.

KEYWORDS: *Transportation network design; Supply chain management; Overall equipment effectiveness (OEE); Mixed integer nonlinear programming; Simulation based optimization.*

1. Introduction

In supply chain management, one of the most important problems is logistics network design. Hitchcock proposed transportation network design [1]. Finding the way for transporting the products from several sources to several destinations was the objective of this research so that the total cost can be minimized. Agile logistics, lean logistics, logistics and supply chain Association, logistics services companies, National Conference on logistics and supply chain are literals that are known as supply chain management. According to Tilanus [2], efficiency of the supply chain can be considered by bringing the right amount of right products to the right place at the right time. Supply chain includes all steps that directly or indirectly affect the customer's demand supply. Hence, the supply chain, in addition to transportation, warehouses, retailers, and customers, includes manufacturers and suppliers [3]. It includes the physical part of the supply chain when analyzing the manufacturing systems, such as Automotive. This part has allocated a large part of supply chain activities to itself, including all physical activities from raw material to final production and activities such as production scheduling, warehousing and transport. One of the most important strategic decisions in supply chain management is the logistics network designing.

* Corresponding author: ***Esmaeil Najafi***
e.najafi@srbiau.ac.ir

1. *Department of Industrial Engineering, Islamic Azad University,Tehran, Iran & Ilam Gas Treating Company, National Iranian Gas Company, Ilam, Iran.*
2. *Department of Industrial Engineering, Science and Research Branch, Islamic Azad University,Tehran, Iran.*
3. *Department of Industrial Engineering, Science and Research Branch, Islamic Azad University,Tehran, Iran.*
4. *Faculty of Engineering, Ilam University, Ilam, Iran.*

The costs are influenced by decisions about the number, type and capacity of equipment or about amount or number of portable materials. Therefore, stable competitive advantage can be obtained by an efficient supply chain design for firms. In today's organizations, an agile supply chain is essential, and managing it involves activities that require the exclusive strategies, which prevent customers from finding the products anywhere [4]. A key component of an agile supply chain is the ability to continuously monitor and evaluate the supply and demand for market volatility and effective communication with suppliers and customers [5].

According to Rahimi et.al [6], using effective practices in the agility of the supply chain of military products in the format of hierarchical relations will lead to the proper responsiveness of the supply chain of products to its customers. These practices are the supplier's relationship, workshop level management, product design, process integration and improvement, improving the organizational structure, improving the human resources, IT utilization, and customer's relation. Logistics network design was done by many researchers. The solutions for integrated production and distribution planning was proposed by Park [7] and he investigated the effectiveness of their integration, in a multi-plant, multi-retailer logistic environment where maximizing the total net profit was the main objective. Lejeune [8] used a mixed integer programming (MIP) model to minimize the costs in a three-stage supply chain, including supplier, manufacturer and distribution centers.

A linear programming model was developed by Liang [9] for integrated production-transportation planning problems in a supply chain which minimized the total production and transportation costs and total number of return products. Aggregate Production and Distribution Plans was considered by Fahimnia et al. [10] and he developed a MINLP formulation for a two-echelon supply chain network. The focus of Ryu et al. [11] was on integrating the production and distribution problems in a supply chain in order to minimize the production, transportation and warehousing costs. Jo et al. [12] used a genetic algorithm (GA) to solve the nonlinear fixed charge transportation problem in two-stage supply chain networks.

Karabuk [13] described a transportation problem, i.e. the scheduling of pickup and delivery of daily inventory movement between plants, in textile manufacturing. A bi-objective MILP model for just in time (JIT) distribution in a multi-period, multi-product and multi-channel network was developed by Farahani and Elahipanah [14] to minimize the costs and the sum of backorders and surpluses of products in all periods. They used an algorithm called the hybrid non-dominated sorting genetic algorithm (NSGA) to solve the problem. The production and transportation scheduling is considered by Zegordi and Beheshti Nia [15] in a two-stage supply chain environment that is composed of m suppliers in the first stage and l vehicles at the second stage to minimize the total tardiness and total deviations of assigned workloads of suppliers from their quotas. A MIP problem is formulated and an algorithm proposed by them is called the multi-society genetic algorithm. Many exact, heuristics and metaheuristics methods have been developed for solving these problems because of categorizing the majority of these problems as NP-hard.

The non-standard genetic algorithm approach is used to solve a nonlinear transportation problem that is developed by Michalewicz et al. [16], and the matrix representation is used to construct a chromosome and the matrix-based crossover and mutation is developed. A multi-objective solid transportation problem considered by Li et al. [17] is solved using GA. They used the three-dimensional matrix to represent the chromosome. Gen et al. [18] used the new decoding and encoding procedures to consider the characteristic of tsTP, Pb-GA. They encoded the solutions as arrays, the sources and depots were used to show the position of each cell, and the priorities to represent the values in cells. They carried out a two-stage experimental study based on a new crossover operator called Weight Mapping Crossover (WMX). Pishvaee et al. [19] used the pb-GA and segment-based crossover in their study. Lin et al. [20] used an extended pb-GA named Ep-GA and represented the chromosome with two sections, one section for priorities, and other sections for guiding the information about how to assign retailers and how to assign customers. Based on Ep-GA, they combined a hybrid evolutionary algorithm and a local search (LS) technique and proposed a new fuzzy logic control (FLC) to enhance the search ability of EA.

2. Literature Review

2.1. Integrated planning of distributed manufacturing systems

Simulation-based optimization approach leads to the close optimal solutions in a feasible time, with capabilities to deal efficiently with an extended scenario taking into account the dynamics of the systems [21]. According to recent studies, the integration of production and transport in supply chains has the potential to decrease the costs, to improve the supply chain competitiveness through enhancing the on-time delivery of customer orders [22, 23]. Integrated scheduling, because of the multitude of involved production and transport processes, is a challenging task [24]. In the recent literature, an effort to integrate the supply chain planning leads to optimize the strategy and synchronization, but there are two barriers on the integration, (i) the availability of data to run and develop the planning models, (ii) the computation capacity for dealing with stochastic, dynamic and complex scenarios of integrated supply chains. Regarding the first challenge, they need to be monitored and automated, because of quickly reacting the integrated supply chains to changes and disruptive events. For the second challenge, hybrid-simulation optimization approaches constitute a promising research direction, by combining the analytical and simulation models [25].

The complexity of integrated production and transport scheduling has led to develop the simulation approaches connected to mathematical models, which on one hand, optimize activities in supply chains, and on the other hand, study the interactions, involved behavior and uncertainties [26]. Juan et al. [27] argue that the extension of simulation-based approaches is related to the solving of stochastic combinatorial optimization decision-making problems due to the increasing the current systems' complexity, although complex relationships and dynamic environments are able to challenge the management of supply chains [28]. Peidro et al. [29] consider that the uncertainty represents a challenge on supply chain modelling for planning and decision support tools and comes from three sources in a supply chain: demand, process/manufacturing and supply.

According to Banks et al. [30], the model is generally a set of hypotheses about the system operation. Simulation-based techniques can be used in the production context, for example, in the modelling of continuous manufacturing systems, stochastic production planning models, scheduling and system control effectiveness, work-in process storage requirements, queues and delays caused by material handling devices and systems [31, 32]. They [30] also believe that simulation can also be used to study the systems in the development phase, in its pre-construction. Therefore, modelling and simulation can be used both as an analysis tool and as a development tool, the former to forecast the consequences of changing an existing system, the latter to predict the performance of new systems under different sets of circumstances. Yet, O'Kane et al. [33] argue that the operational scope has the greater potential of the simulation to obtain better results. Simulation-based methods can be used to both develop and evaluate the complex systems, in order to consider the aspects such as physical configuration or operating rules of a system. It has the applications in several areas that in addition to assisting the managers in the decision making process, allow a better understanding of processes in complex systems [34]. For Pirard et al. [35], on one hand, simulation allows the decision maker to evaluate the various control policies, and numerous replications of the simulation can be performed for evaluating the robustness of the implemented design, on the other hand, the simulation does not guarantee an optimum design, but can be balanced with the integration of other tools, as mathematical modelling. According to Peidro et al. [29], hybrid approaches are an interesting option, since they have the advantages for both analytical and simulation approaches. Simulation-based optimization is proposed by Lin and Chen [20] to deal with complex systems, consisting of an adaptive simulation-based optimization. According to Liotta et al [21], simulation-based optimization is a strategy for dealing with uncertainty in the supply chain. In addition, according to Truong and Azadivar [36], managing a supply chain is much more complex than dealing with one facility, because of existing conflicting objectives among areas and how dynamic the systems are, and accordingly, they propose a simulation-based approach to deal with the supply chain configuration design. Indeed, in order to deal with the demand uncertainty in a supply chain, Jung et al. [32] proposed a simulation-based optimization. In the same direction, a simulation-based optimization approach is proposed by Schwartz et al. [37] to deal with the control policies for inventory management under high uncertainty. While Shang and Mao. [38] used the same approach to deal with the scheduling of wheat irrigation. Wan et al. [39] also decided to choose the approach interested in its capacity in dealing with stochastic environments and apply it in supply chain management. Similarly, Ding et al. [31] used simulation-based optimization to design the multi-objective production-distribution network. A simulation-based optimization is developed by Frazzon et al. [26] for production and transportation planning which combines the mixed integer linear programming, discrete event simulation and a genetic algorithm to achieve a significant reduction in the number of late orders in a manufacturing supply chain.

3. The Considered Logistics Problem in the Study.

The efficiency of logistics networks is affected by many factors. Determining the vehicles used to transport products is one of them. The kind of vehicles we use to move products can play a key role in reducing costs. Vehicles should be selected in such a way that, given the limited capacity and number of vehicles, the demand of retailers is met with the least transportation costs. Therefore, in the research, the cost of using vehicles is considered in addition to the unit shipping cost based on the shipping distance. In this case, the capacity of the vehicles and their limited numbers are considered. The multi-stage logistic network, considered in this paper, consists of three stages; Manufacturers, Storage tanks or Warehouses and customers. The problem intends to determine the optimal transportation network to satisfy the customers' demands of several products by using several kinds of vehicles with minimum cost. It is assumed that there are *m* vehicle types for transportations with limited budget for purchasing or hiring them. The capacity of vehicles and fixed travel cost of the vehicles are considered. The aim is to satisfy the demands of customers for *p* products with minimum costs.

This paper presents a hybrid approach based on simulation and optimization (Simulation based optimization), the model is formulated and presented in three stages. At first, the practical production capacity of each product is calculated using the Overall Equipment Effectiveness (OEE) index, in the second stage, the optimization of loading schedules is simulated. The layout of the loading equipment, the number of equipment per line, the time of each step of the loading process, the resources used by each equipment were simulated, and the output of the model determines the maximum number of loaded vehicles in each period . Finally, a multi-objective model is presented to optimize the transportation time and cost of products. A mixed integer nonlinear programming (MINLP) model is formulated in such a way as to minimize transportation costs and maximize the use of time on the planning horizon. We have used Arena simulation software to solve the second stage of the problem, the results of which will be explained. It is also used GAMS software to solve the final stage of the model and optimize the transporting cost and find the optimal solutions. Several test problems were generated and it showed that the proposed algorithm could find good solutions in reasonable time spans.

4. Problem Description and Formulation

In this paper, we are looking for a model to optimize cost and delivery time. This paper is a case study in Gas Refinery and pursues several goals. The main process of gas refinery is sour gas sweetening for domestic and industrial use. In addition, by-products such as ethane, liquefied petroleum gas, Condensate and granulated sulfur are produced in this refinery that each product is manufactured from a specific process as shown in Fig.1:

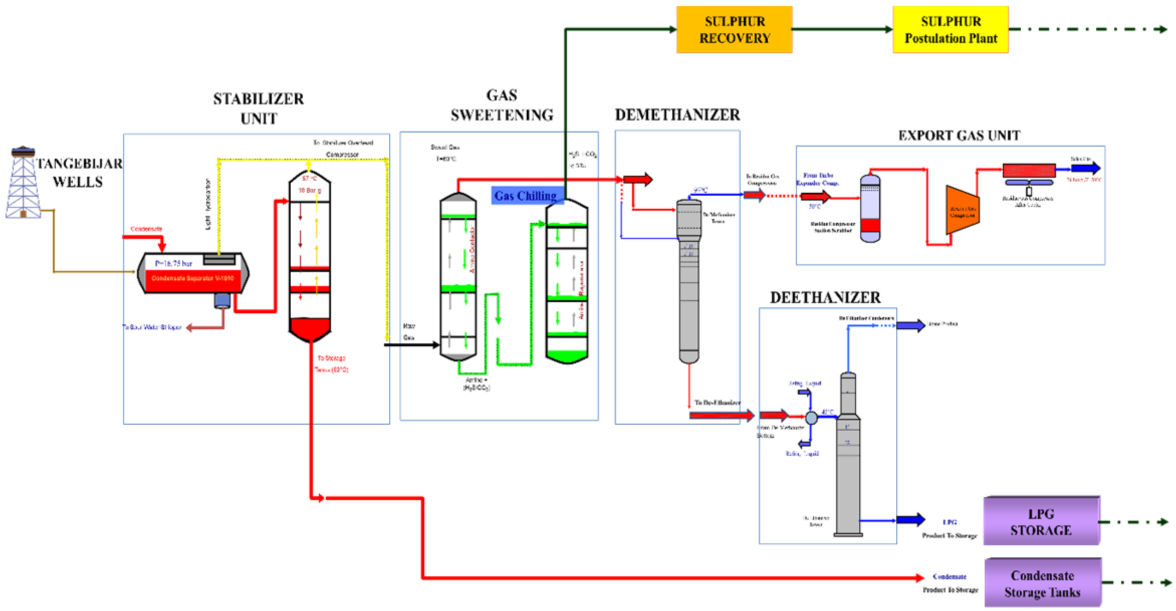


Fig.1. Structure of plant / refinery layout.

Some products are directly distributed by pipelines such as Sweet Gas, Ethane and LPG. And some other products should be shipped using transport fleets such as Sulfur and Condensate. In this article, we focus on two products "Sulfur and Condensate "that require a transportation system. In this model the following goals have been considered;

- Determine the maximum practical production capacity
- Determine the maximum product loading capacity per day
- Minimize the lost production
- Minimize the transportation cost
- Maximize the use of time available on the planning horizon.
- Providing an agile product distribution system

For designing the model three stages are considered, each of these steps is as follows:

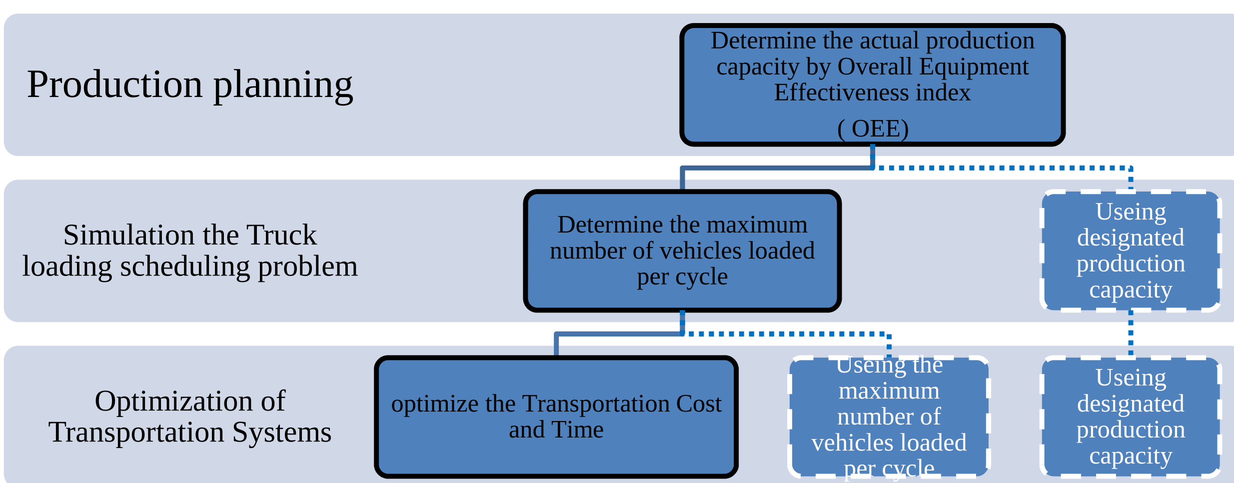


Fig. 2. Conceptual design of model implementation steps.

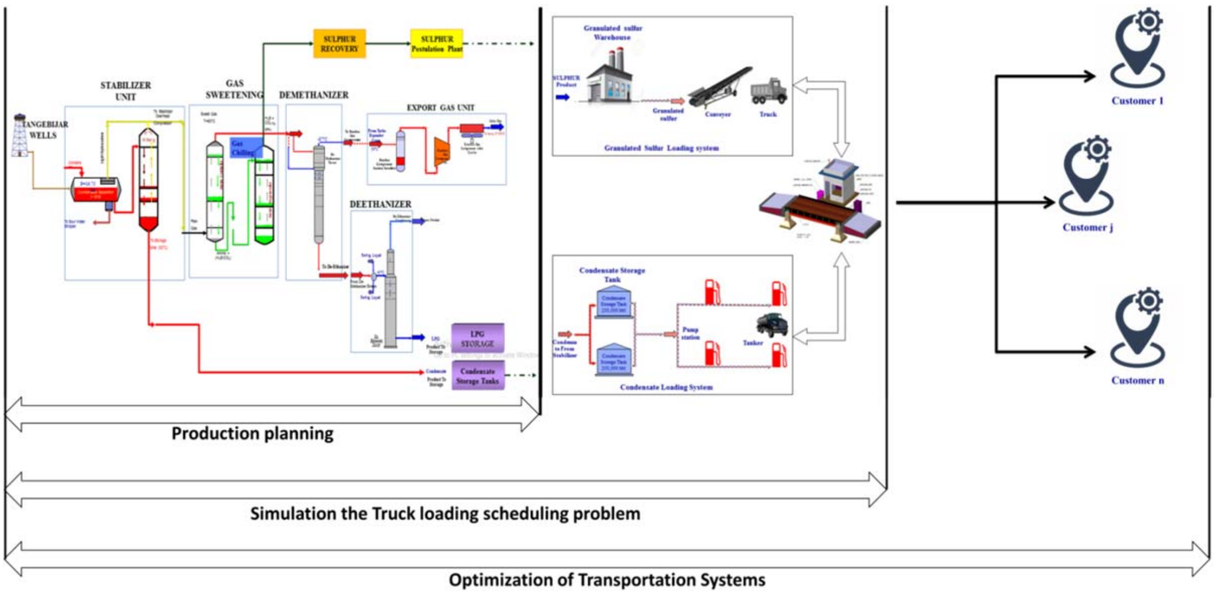


Fig. 3. Model review steps.

4.1. Determine the actual production capacity

At this point, it is sought to determine the actual production capacity of the refinery. For this purpose, the practical production capacity is determined based on the OEE index. The steps for calculating the OEE index are as follows:

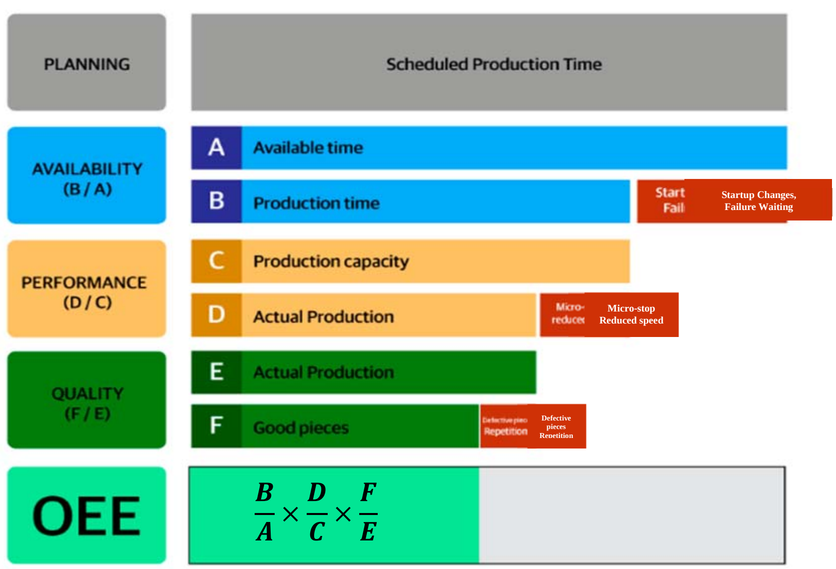


Fig. 4. Calculation method of OEE indicator.

4.1.1. Availability

Ratio between the Productive Time and Available Time, of a period of production. It is affected by the shutdowns that occur in the manufacturing process such as: machine starts, changes, breakdowns and waiting times.

4.1.2. Performance

Ratio between Actual Production and Production Capacity, of a given period of production. The performance is affected by micro-stops and reduced speeds.

4.1.3. Quality

Ratio between Good Production and Actual Production. The percentage of quality is hampered by repetition of work or defective parts.

After analyzing the graph, we can conclude that having the accurate information on the origin of production losses to increase the OEE index, and therefore, making the appropriate decisions to improve is necessary.

Tab. 1. Calculation of the index OEE for the condensate (C5+) product

Product :Condensate		Days	Percentage
Planning	Schedule Production Time	335	
Availability	A: Available Time	325	95.5%
	B: Production Time	320	
Performance	C: Production Capacity	1600000	98%
	D: Actual Production	1571087	
Quality	E: Actual Production	1571087	92%
	F: Good Pieces	1437550	
OEE			86%

Tab. 2. Calculation of the index OEE for the Sulfur product

Product : Sulfur		Days	Percentage
Planning	Schedule Production Time	325	
Availability	A: Available Time	325	98%
	B: Production Time	320	
Performance	C: Production Capacity	81000	83%
	D: Actual Production	67200	
Quality	E: Actual Production	57618	98%
	F: Good Pieces	56465	
OEE			80%

4.2. Loading scheduling problem

At this step, we want to present a model that determines the maximum loading possibility of vehicles by equipment. As shown in the figure (5), loading equipment for Sulfur and Condensate products includes a weighing machine, a conveyer for Sulfur loading and four condensate loading pumps. First, all empty vehicles go to bascule for weighing, which takes about 7 minutes, then depending on the product type, the vehicle goes to one of the Conveyor or Loading pumps which takes 60 minutes in the Conveyor and 55 minutes in the loading pump. At the end, the loaded vehicles go back to the Bascule for weighing. The flow diagram and processing time of each step are as follows:

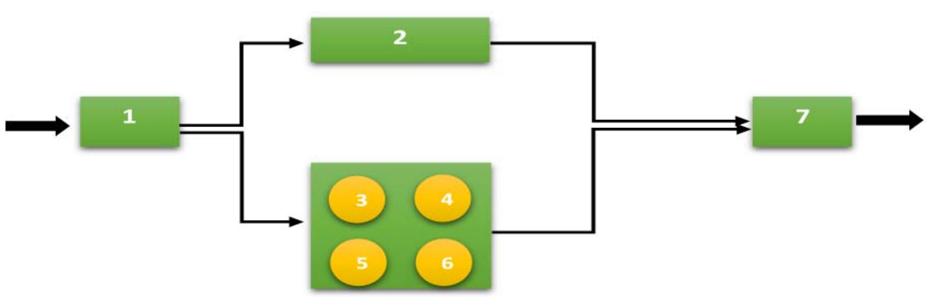


Fig. 5. Layout of equipment in loading system

Tab. 3. Loading sequence of each product and processing time on each equipment.

equipment	Processing Time (Minutes)			
	Bascule (empty)	Conveyor	Loading pump	Bascule (full)
product	1	2	3-6	7
1-Condensate	7		50	10
2-Sulfur	7	60		10

The loading scheduling design problem can be presented as follows:

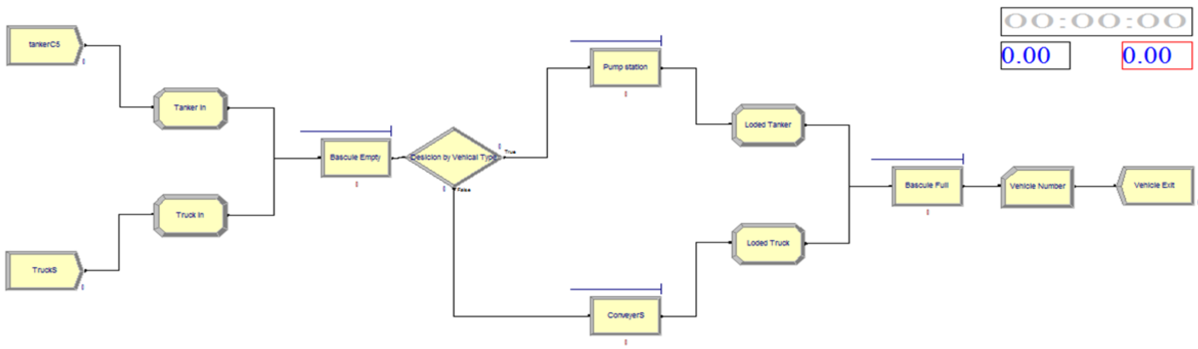


Fig. 6. Simulation of vehicles loading problem.

4. 3. Optimization of transportation problem.

The logistics network discussed in this paper is a three-stage logistics network, including Plant\Refinery, Warehouses and customers. The structure of the logistics network can be presented in Fig. (7). in the network, new products are sent from produce centers to warehouses, directly (sent directly from the refinery to the storage tank or warehouses) and indirectly (shipped from the storage tank or warehouses to the customers) to meet the demand of each customer.

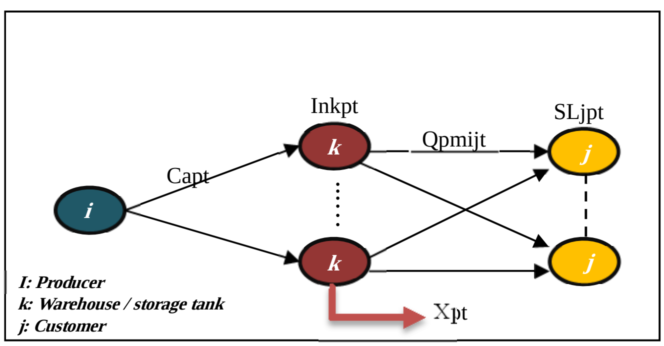


Fig. 7. Structure of logistics network.

In this section, a mathematical formula is presented for the problem. This model has two objective functions: the first objective function that minimizes the total cost includes transportation, surplus production (lost production) and lost sales (shortage) costs. The second objective function is used to maximize the use of time available on the planning horizon. The cost of transporting products is based on the distance and the fixed cost of using the vehicle. Also, the capacity of resources and warehouses, the capacity of vehicles and the limited number of vehicles are also considered in this network.

4.3.1. Indices and sets.

i	Plant \ Refinery index	i = 1,…, I
j	customer index	j = 1,…, J

p	product index	p = 1,…, P
m	vehicle index	m = 1,…, M
t	Period index	n = 1,…, N
k	storage tank / Warehouse index	

4.3.2. Parameters

Dpj: Amount of demand for product p by customer j during the whole set of planning horizons.
FCmij: Fixed cost of using vehicle m to carry products between Plant \ Refinery i to customer j.
DISij: Distance between Plant \ Refinery i to customer j.
Capt: Supply capacity of Plant \ Refinery i for product p during period t.
Pp: unit price of product p.
Skp: storage capacity of Tank / warehouse k for product p.
Cp: cost based prices p (cost per unit)
Ap: The volume of each unit of product p.
Timeij: Round trip time from Plant \ Refinery i to customer j
VEm: Average vehicle speed m
Bm: budget for purchasing or hiring vehicle m.
Nm: Maximum number of available vehicles m for each Period t in Plant \ Refinery i "output of the simulation model"
Vm: capacity of vehicle m for transporting product *p*.
Scalar
FVp: Unit transportation cost of product *p* along unit distance.
Hor: Working hours in a period
G: A Large Number

4.3.3. Decision variables

Inkpt: Amount Inventory of product p in Storage tank / Warehouse k at period t
Qpmijt: Amount of product p transported by vehicle m from Plant \ Refinery i to customer j at period t.
Xpt: Amount of lost production of product p due to storage tank / Warehouse K being full at time t
SLpjt Amount of shortage of product p for customer j at time t
Zpmjt: Binary variable denotes departure or non-departure of vehicle m from Plant \ Refinery i to customer j at period t
1, If vehicle m is used to carry product p between Plant \ Refinery i to customer j, 0 otherwise

4.3.4. Mathematical formulation.

In terms of the above-mentioned notations, the design problem can be formulated as follows

$$Min\ Z1 = \sum_p \sum_m \sum_i \sum_j \sum_t FCmij\ \left(\frac{\text{Qpmijt}}{Vm}\right) \times Zpmjt + \sum_p \sum_m \sum_i \sum_j \sum_t FVp \times DISij \times \text{Qpmijt} + \sum_j \sum_p \sum_t SLjpt \times \text{Pp} + \sum_p \sum_t Xpt \times \text{Cp} \quad (1)$$

$$\text{Max Z2} = \sum_p \sum_m \sum_i \sum_j \sum_t \text{Timeij} \times \left(\frac{\text{Qpmijt}}{Vm}\right) \times \text{Zpmjt} \quad (2)$$

S.T

$$\sum_{\text{m}} \sum_{\text{i}} \sum_{\text{t}} (\text{Qpmijt} + \text{SLjpt}) = \text{Dpj} \qquad \forall\ p, j \quad (3)$$

$$\sum_{\text{p}} \sum_i \sum_{\text{j}} \text{Qpmijt} \times \left(\frac{\text{Ap}}{\text{Vm}}\right) \leq \text{N(m)} \qquad \forall\ m, t \quad (4)$$

$$\sum_m \sum_j \text{Qpmijt} \leq \text{Capt} + \text{Inkp(t} - 1) \qquad \forall i, k, p, t \quad (5)$$

$$\text{Inkpt} = \text{Capt} - \sum_m \sum_j \text{Qpmijt} \qquad \forall\ i, k, p, t = 1 \quad (6)$$

$$\text{Inkpt} = \text{Capt} + \text{Ikp(t} - 1) - \sum_m \sum_j \text{Qpmijt} \qquad \forall\ i, k, p, t > 1 \quad (7)$$

$$\text{Xpt} = \text{Inkpt} - \text{Skp} \qquad \forall\ k, p, t \quad (8)$$

$$\sum_p \sum_m \sum_i \sum_j \sum_t FCmij \ (\frac{\text{Qpmijt}}{Vm}) \times Zpmjt + \sum_p \sum_m \sum_i \sum_j \sum_t FVp \times DISij \times \text{Qpmijt} \quad \leq \text{Bm} \tag{9}$$

$$\sum_j \text{Zpmjt} \leq \text{Nm} \qquad \forall\, m,p,t \tag{10}$$

$$\sum_m \text{Qpmijt} \leq \ G \ \times \sum_m \text{Zpmjt} \qquad \forall\, p,i,j,t \tag{11}$$

$$\sum_j \sum_t \text{Zpmjt} \leq 0 \qquad \forall\, p,m \ \text{Product j that cannot be carried by the vehicle m} \tag{12}$$

$$\sum_p \sum_i \sum_j \sum_t \text{Timeij} \times (\frac{\text{Qpmijt}}{Vm}) \times \text{Zpmjt} \leq \text{Hor} \qquad \forall\, m \tag{13}$$

$$\text{Inkpt}, \text{Qpmijt}, \text{Xpt}\,, \text{SLpjt} \geq 0\ , \text{Zpmjt} \ = binary \tag{14}$$

While the objective function (1), represents transportation cost of products, purchasing or hiring cost of vehicles and travel cost of vehicles to carry products between the related sources and depots, it represents the cost of stopping and lost production and the cost of not meeting demand and lost sales as well.. The objective function (2), represents transportation Time to sweep the vehicles from Plant \ Refinery to customers.

Constraint (3) assures that the amounts of all requirements are met or demand may not be met and may result in lost sales, i.e. the total amount of products shipped to customers must be equal to their total demand. Constraint (4) denotes the capacity of vehicles in each period. Constraint (5) ensures that the amount of products which are sent by refinery to the customer should not exceed the production of the product in that period and the inventory of the previous period. Constraint (6-7) indicates the amount of inventory at the end of the period. Constraint (8) represents the surpluses of production or lost production due to the filled Storage tank / Warehouse. Constraint (9) indicates budget constraints for the purchase or rental of vehicles. Constraint (10) displays the maximum number of vehicles per cycle to deliver products to customers. Constraints (11) enforce that there should be at least one vehicle to carry products. Constraints (12) ensure that each product is shipped by its own vehicle. Constraint (13) shows that in a cycle, a vehicle can be frequently dispatched from the factory to customers frequently, provided it is done during business hours. Constraint (14) represents the non-negativity restriction of the decision variables.

5. Solution Approach

In this section, according to the conceptual model and the stages defined, we present the outputs of each step.

5.1. Production planning

Tab. 4. Determine the actual production capacity by Overall Equipment Effectiveness index (OEE):

Product :	Unit	OEE Index	Design Capacity	Actual Production Capacity
Condensate	(barrel Per Day)	86%	4780	4110
Sulfur	(Ton Per Day)	80%	250	200

5. 2. Simulation of the vehicle loading scheduling problem

In this section, the problem of vehicles loading for transportation is simulated. Arena software is applied to solve the problem. The objective function maximizes the number of loaded vehicles and minimizes the loading time. The capacity of the sources and depots, the capacity of the vehicles and limited number of the vehicles are considered in this network. In terms of the above-mentioned notations, the loading scheduling design problem can be presented as follows:

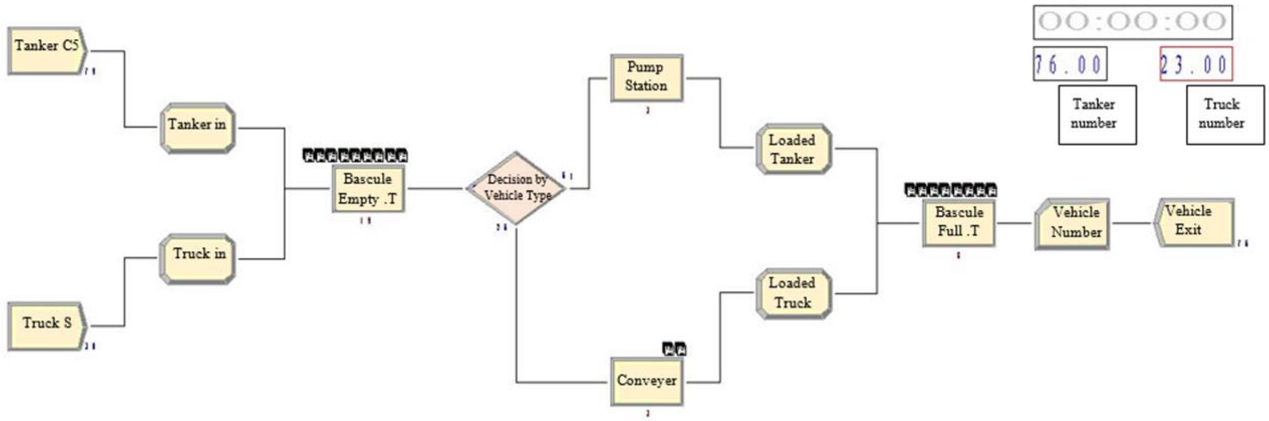


Fig. 8. Simulated loading of vehicles.

Tab. 5. Determine parameters of simulation problem:

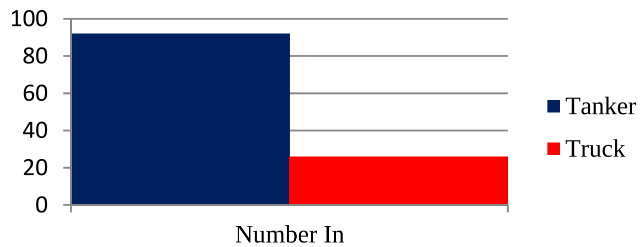
Name	Type	Action	Delay Type	Unite	Expression
Bascule For Empty Vehicle	Standard	Seize Delay Release	Normal	Minutes	N(7 , 1)
Pump station	Standard	Seize Delay Release	Exponential	Minutes	EXPO(50)
Conveyer	Standard	Seize Delay Release	Exponential	Minutes	EXPO(60)
Bascule For Full Vehicle	Standard	Seize Delay Release	Normal	Minutes	N(10 , 1)

Tab. 6. Determine parameters of available resources in simulation problem:

Name	Type	Capacity
Bascule Resource	Fixed Capacity	1
Conveyer Resource	Fixed Capacity	1
Pump station Resource	Fixed Capacity	4

Tab. 7. Determination of available vehicle values (Inputs):

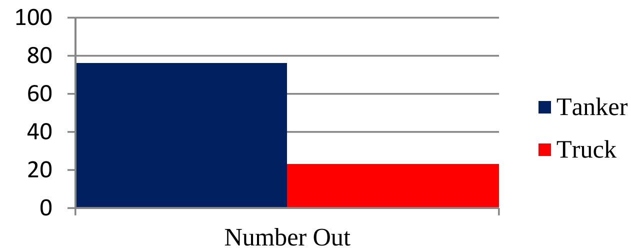
Number In	Average	Half Width	Minimum Average	Maximum Average
Tanker	91.910	1.91	66.000	116.000
Truck	26.210	1.10	12.000	40.000



Dig. 1. Number of vehicles entering the loading system.

Tab. 8. Determination of loaded vehicle quantities:

Number Out	Average	Half Width	Minimum Average	Maximum Average
Tanker	74.340	0.81	62.000	83.000
Truck	19.250	0.74	10.000	29.000



Dig. 2. Number of vehicles loaded by the loading system.

In order to validate the simulated model, The model was run several times with different "entities and resources" data to validate the simulated model, and the results are also compared with the actual conditions in the refinery. The results show that if an agile transport fleet is available, the maximum loading capacity can be reached in each period. As a second stage output, the product loading system is simulated and the maximum loading capacity of the vehicles is determined. The output of this section is used in the final stage of the paper and in the optimization of the transport problem as one of the model parameters.

5. 3. Transport optimization problem

5. 3. 1. The proposed algorithm

In this phase, the optimal amounts of products and shipping routes are determined using GAMS software. In this procedure, the transportation costs are determined by variable shipping costs and fixed vehicle costs. For each solution, a large number as a penalty function is added to the function to avoid infeasible solutions This penalty applies when the number of its all routes is higher than the number of available vehicles.The maximum available vehicles of kind "m" is determined at second step and the number of available vehicles of kind m is determined by [bm/summation of Vehicle cost]. After determining the optimal amounts of products and shipping routes in the first phase, in the next phase, the kind of vehicles for transporting the products between the selected sources and depots are determined. The number of optimal routes is less than or equal to the available vehicles.

5. 3. 2. Computational results.

We generate several instances to validate the performance of the algorithm. The mathematical model of the problem is coded in GAMS optimization software and the proposed algorithm is coded on a computer with 8.0 GB Ram and 2.66 GHz processor.

5. 3. 3. Data generation

We defined instances that can be characterized by the number of products (np) that are 2 , vehicles (nm) that are 2, Plant/Refinery (i) , Storage tank / Warehouse (nk) that are 2, Customer (nj) that are 12 and Period (nt) that are 30. The data required for the problem are generated as shown in Table 7.

Tab. 9. Parameter’s range in the test problems:

Parameters	For Sulphur	For Condensate
D(p,j)	[150 -300]	[1500 -3000]
Fv(p)	[50 - 100]	[50 - 100]
A(p)	[1]	[1]
N(m)	[76]	[29]
C(p)	[40000]	[80000]
Dis(i, j)	[100 - 300]	[100 - 2000]
Time(i, j)	[1 - 40]	[1 - 40]
S(k,p)	[30000]	[5000]
Ca(p,t)	[200 - 300] Ton	[600 - 1200] M^3
V(m)	[20 - 30]	[20 - 30]
FC(m,i,j)	[10,000 - 45,000]	
G	[1000000000]	
B	[700,000 -1,400,000]	
H	[1440]	

Eleven solver methods are implemented in GAMS to solve the problems, the best feasible solution is given as comparison. As shown in Table 10, the results show that three methods of SBB, DICOPT and BARON solver can find the optimal solutions within 1000 second and the proposed algorithm finds the solution near the objective bound of the problem in a reasonable time span.

Tab. 10. Results of the experiment of different solver test problems.

SOLVER	Iteration	Open nodes	Total time	Best solution found at node	Objective Function total transportation costs	Absolute gap
SBB	24601	16601	0:16:41.651	18326	1.063589E+9	1.80999994277954 optca = 1E-9
DICOPT	24601	16601	0:16:42.160	18326	1.063589E+9	1.80999994277954 optca = 1E-9
BARON	6298	4846	0:16:44.498	2842	1.063589E+9	5.5900000333786 optca = 1E-9
KNITRO		84	0:16:40.492		1.074573E+9	
LINDO	1707		0:00:04.959	450	1.085558E+9	4.76837158203125E-7
SCIP	15	1	0:00:03.034	14	1.085558E+9	----
ALPHAECP	24		0:18:54.036	10	1.140190E+9	
COUENNE		10	0:16:41.799		2.055672E+9	9.920839e+008
ANTIGONE	4		0:16:41.699		2.647880E+9	
BONMIN	276		0:18:10.669		No Answer	
OQNLP	505		0:36:38.572		No Answer	

Tab. 11. Amount of product p transported by vehicle m from refinery to customer j.

Product	Plant	Customer	Vehicle	period	SBB Solver Value	Baron Solver Value
Condensate	Refinery	Tehran	Tanker	30	4530	4533
		Qazvin		30	2791	2791
		Hamedan		30	2341	2341
		Kermanshah		30	3872	3872
		Urumieh		30	1921	1921
		Zanjan		30	1830	1832
		Tabriz		30	2009	2011
		Mashhad		30	1589	1591
		Esfahan		30	1940	1944
		Yazd		30	3002	3001
		Qom		30	2373	2371
Condensate	Refinery	all Customers	Tanker	sum	28198	28208
Product	**Plant**	**Customer**	**Vehicle**	**period**	**SBB Solver Value**	**Baron Solver Value**
Sulfur	Refinery	Tehran	Truck	30	300	299
		Qazvin		30	270	267
		Hamedan		30	150	150

		Kermanshah		30	1935	1924
		Urumieh		30	150	150
		Zanjan		30	180	179
		Tabriz		30	270	267
		Mashhad		30	210	210
		Esfahan		30	210	209
		Yazd		30	210	210
		Qom		30	150	150
		Tehran		30	150	150
Sulfur	Refinery	all Customers	Truck	sum	4185	4165

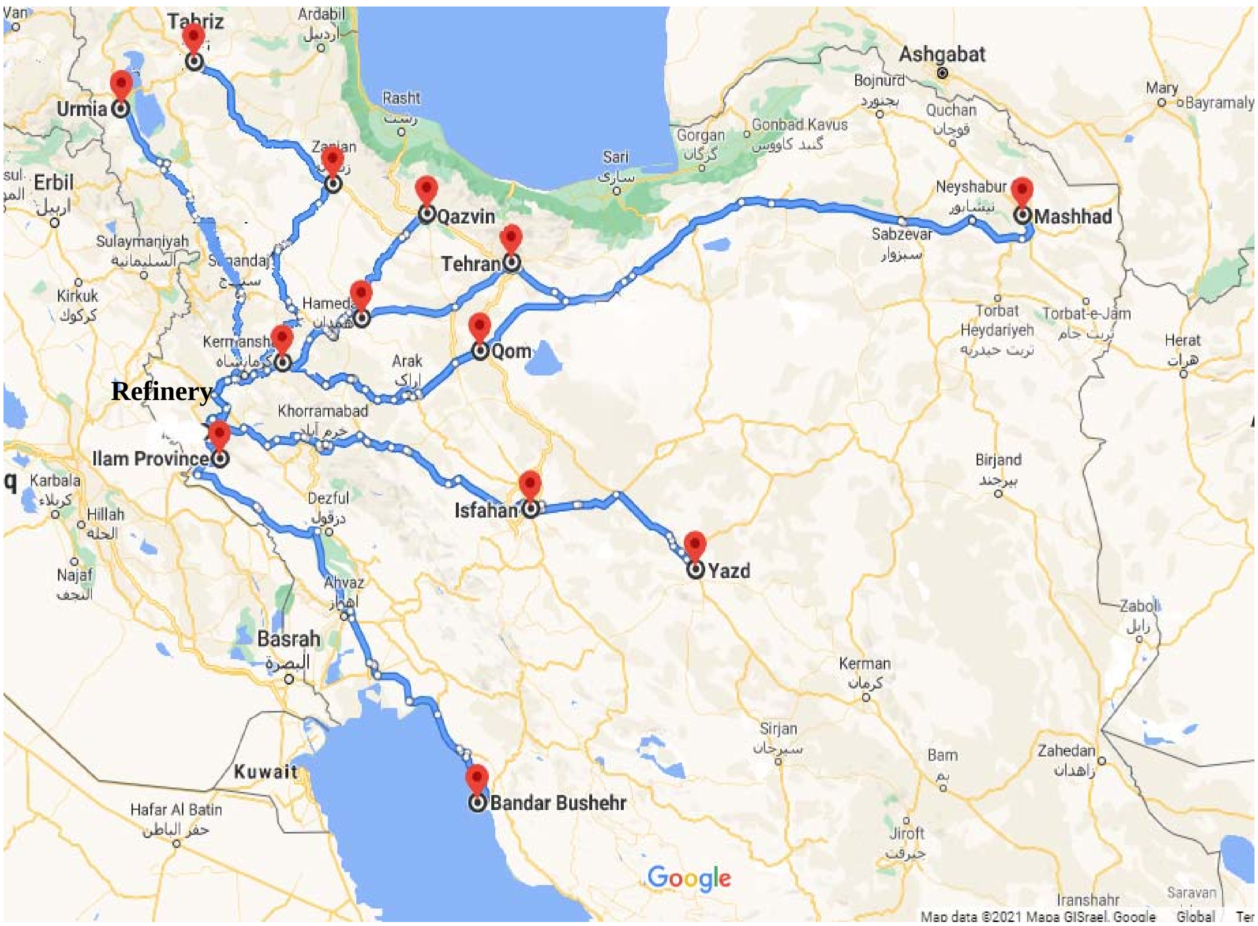


Fig. 9. Product distribution network map.

Tab. 12. Amount of lost production of product p due to storage tank or warehouse k being full at time t.

Product	period	SBB Solver	Baron Solver
		Value	Value
Sulfur	29	188	188
Sulfur	30	415	415

Tab. 13. Amount of shortage of product p at time t

Product	Customer	period	SBB Solver	Baron Solver
			Value	Value
Condensate	Mashhad	1	2790	418
	Mashhad	2	0	209
	Mashhad	3	0	209
	Mashhad	4	0	418
	Mashhad	5	0	418
	Mashhad		0	40
	Mashhad	29	0	380
	Mashhad	30	0	697
	Yazd	1	308	0
	Yazd	30	0	308

6. Conclusions

In the paper, the model is presented to improve the performance of the production and distribution system of the gas refinery and it is expected to achieve the following practical results.

- Determining the actual production schedule using the OEE index in order to develop a loading and distribution schedule
- Identifying the factors affecting the reduction of production using the three indicators "availability, performance and quality" and improving the current situation to the desired situation.
- Identifying the refinery loading capacity to create the agile and flexible loading and distribution system
- Preventing the production stoppage due to non-loading of products or slow loading system and filling of warehouses
- Policy regarding the sale of products due to budget constraints and with the aim of reducing shipping costs and finally selecting the best selling points.

In this paper, designing and transportation planning in a multi-stage multi-product supply chain network was examined. The decision makers need to determine the optimal routes and vehicles when there is a limited budget for hiring vehicles. We formulated the problem as a mixed integer nonlinear programming (MINLP) model to minimize the total costs of the network and also maximize the use of time available on the planning horizon. We examined the problem at three levels to achieve the desired result, and we applied the results at each level to the next level. We first calculated the production planning based on the Overall Equipment Effectiveness (OEE) index and we obtained an estimate of the actual production of the plant, using this method. Second, simulating the loading system, we determined the maximum amount of loading vehicles. Finally, we presented a mathematical model for the transport problem. The algorithm was composed of two phases. In the first phase, the amount of products to be sent and stored in the sources and depots were determined. Then, in the second phase, the vehicles for transporting the products and the amount of product to be carried to customers were determined. Several problems were generated and solved using the GAMS optimization software and the proposed algorithm. The results show that the proposed algorithm could find near optimal solutions in a reasonable time span. Eleven solver methods were implemented in GAMS to solve the problems, the best feasible solution was given as comparison. As shown in Table 10, the results show that three methods of SBB, DICOPT and BARON solver could find the optimal solutions within 1000 second, and these solvers found the solutions near optimal solutions in less computational times.

7. Recommendation

For future research, other objectives can be used in this logistic network. Minimizing maintenance costs can be added to the objective function. The network responsiveness can be used to satisfy the customers. Also satisfying customers' demands on time will increase the efficiency of the supply chain.

Metaheuristic algorithms can be used to solve the problem and then the neighborhood search algorithms like local search and Tabu search can be applied.

8. Acknowledgments

Acknowledgments The authors would like to Ilam Gas Treating Company for his steady support through the period of the study and for providing substantial input during the different phases of the project. The authors are extremely thankful to all the other professionals who contributed to the study and provided data and helpful comments in a timely manner, and finally to our colleagues at IGTC, for their constructive inputs.

References

[1] Hitchcock, F.L. The distribution of a product from several sources to numerous localities. Journal of Math. Phys., Vol. 20, (1941), pp. 224-230.

[2] Tilanus, B. Introduction to information systems in logistics and transportation. Elsevier, Amsterdam, (1997), pp. 7-16.

[3] Bashiri, M., and Rezaei, H. R., "Reconfiguration of Supply Chain: A Two Stage Stochastic Programming", International Journal of Industrial Engineering and Production Research (IJIEPR), Vo1. 24, No. 1, (2013), pp. 47-58.

[4] Jassbi, J., Pilevari, N., and Garmaki, M., "Role of Time in Agile Supply Chain", International Journal of Industrial Engineering and Production Research (IJIEPR), Vo1. 25, No. 2, (2014), pp. 115- 124.

[5] Staub, S., Khoury, S., and Jenab, K., "Mapping SAP-Six Sigma Resources to Agile Management Processes", International Journal of Industrial Engineering and Production Research (IJIEPR), Vo1. 26, No. 3, (2015), pp. 163- 173.

[6] Akbar Rahimi, Abbas Raad , Akbar Alamtabriz , Alireza Motameni., "Providing a Model for Supply Chain Agility of Ground-Based Military Products and Its Impact on Supply Chain Performance", International Journal of Industrial Engineering and Production Research (IJIEPR), Vol. 30, No. 3, (2019).

[7] Park, Y.B. An integrated approach for production and distribution planning in supply chain management. International Journal of Production Research, Vol. 43, (2005), pp. 1205-1224.

[8] Lejeune, M.A. A variable neighborhood decomposition search method for supply chain management planning problems. European Journal of Operational Research, Vol. 175, No. 2, (2006), pp. 959-976.

[9] Liang, T.F. Integrating production–transportation planning decision with fuzzy multiple goals in supply chains. International Journal of Production Research, Vol. 46, (2008), pp. 1477-1494.

[10] Fahimnia, B., Luong, L. and Marian, R. Genetic algorithm optimization of an integrated aggregate production–distribution plan in supply chains. International Journal of Production Research, (2011), pp. 1-16.

[11] Ryu, J., Dua, V. and Pistikopoulos, E.N. A bi-level programming framework for enterprise-wide process networks under uncertainty. Computers and Chemical Engineering, Vol. 28, Nos. 6-7, (2004), pp. 1121-1129.

[12] Jo, J.B., Li, Y.Z. and Gen, M. Nonlinear fixed charge transportation problem by spanning tree-based genetic algorithm. C.I.E., Vol. 53, (2007), pp. 290-298.

[13] Karabuk, S. Modeling and optimizing transportation decisions in a manufacturing supply chain. Transportation Research Part E, Vol. 43, No. 4, (2007), pp. 321-337.

[14] Farahani, R. Z. and Elahipanah, M. A genetic algorithm to optimize the total cost and service level for JIT distribution in a supply chain. International Journal of Production Economics, Vol. 111, (2008), pp. 229-243.

[15] Zegordi, S.H. and Beheshti Nia, M.A. A multi-population genetic algorithm for transportation scheduling. T. Research Part E, Vol. 45, (2009), pp. 946-959.

[16] Michalewicz, Z., Vignaux, G.A. and Hobbs, M. A non-standard genetic algorithm for the nonlinear transportation problem. ORSA Journal on Computing, Vol. 3, No. 4, (1991), pp. 307-316.

[17] Li, Y.Z., Gen, M. and Ida, K. Improved genetic algorithm for solving multi-objective solid transportation problems with fuzzy numbers. International journal of Fuzzy Theory Systems, Vol. 4, No. 3, (1998), pp. 220-229.

[18] Gen, M., Altiparmak, F. and Lin, L. A genetic algorithm for a two-stage transportation problem using priority-based encoding. ORS., Vol. 28, (2006), pp. 337-354.

[19] Pishvaee, M.S., Farahani, R.Z. and Dulaert, w. A memetic algorithm for bi-objective integrated forward/reverse logistics network design. Computer & Operation Research, Vol. 37, (2010), pp. 1100-1112.

[20] Lin J T, Chen C -M. Simulation optimization approach for hybrid flow shop scheduling problem in semiconductor back-end manufacturing. Simulation Modelling Practice and Theory, Vol. 51, (2015), pp. 100-114.

[21] Liotta G, Kaihara T, Stecca G. Optimization and Simulation of Collaborative Networks for Sustainable Production and Transportation. IEEE Transactions on Industrial Informatics, Vol. 12, No. 1, (2016), pp. 417-24.

[22] Ivanov D, Sokolov B, Pavlov A. Dual Problem Formulation and Its Application to Optimal Redesign of an Integrated Production – Distribution Network with Structure Dynamics and Ripple Effect Considerations. International Journal of Production Research, Vol. 51, No. 1, (2013), pp. 5386-5403.

[23] Frazzon E M, Albrecht A, Pires M, Israel E, Kück M, Freitag M. Hybrid Approach for the Integrated Scheduling of Production and Transport Processes along Supply Chains. International Journal of Production Research, 2017. [7] Lasi H, Fettke P, Kemper H G, Feld T, Hoffmann M. Industry 4.0. Business & Information Systems Engineering, Vol. 6, No. 4, (2014), pp. 239-242.

[24] Ehm J, Scholz-Reiter B, Makuschewitz T, Frazzon E M. Graph-Based Integrated Production and Intermodal Transport Scheduling with Capacity Restrictions. CIRP Journal of Manufacturing Science and Technology, Vol. 9, (2015), pp. 23-30.

[25] Sawik T. On the risk-averse optimization of service level in a supply chain under disruption risks. International Journal of Production Research, Vol. 54, No. 1, (2016), pp. 98-113.

[26] Nikolopoulou A, Ierapetritou M G. Hybrid Simulation Based Optimisation Approach for Supply Chain Management. Computers & Chemical Engineering, Vol. 47, (2012), pp. 183-193.

[27] Juan A A, Faulin J, Grasman S E, Rabe M, Figueira G. A review of simheuristics: Extending metaheuristics to deal with stochastic combinatorial optimisation problems. Operations Research Perspectives, Vol. 2, (2015), pp. 62-72.

[28] Scholz-Reiter B, Makuschewitz T, Novaes A G, Frazzon E M, Lima Jr O F. An approach for the sustainable integration of production and transportation scheduling. International Journal of Logistics Systems and Management, Vol. 10, No. 2, (2011), pp. 158-179.

[29] Peidro D, Mula J, Poler R, Lario F-C. Quantitative Models for Supply Chain Planning under Uncertainty: A Review. The International Journal of Advanced Manufacturing Technology, Vol. 43, Nos. (3-4), (2009), pp. 400-420.

[30] Banks J, Carson J S, Nelson B L, Nicol D M. Discrete-Event System Simulation.

3rd ed. Upper Saddle River, New Jersey: Prentice-Hall, Inc; (2000).

[31] Ding H, Benyoucef L, Xie X. Stochastic multi-objective production distribution network design using simulation-based optimization. International Journal of Production Research, Vol. 47, No. 2, (2009), pp. 479-505.

[32] Jung J Y, Blau G, Pekny J F, Reklaitis G V, Eversdyk D. A Simulation Based Optimization Approach to Supply Chain Management under Demand Uncertainty. Computers and Chemical Engineering, Vol. 28, No. 10, (2004), pp. 2087-2106.

[33] O'Kane J F, Spenceley J R, Taylor R. Simulation as an essential tool for advanced manufacturing technology problems. Journal of Materials Processing Technology, Vol. 107, Nos. 1-3, (2000), pp. 412-424.

[34] Sakurada N, Miyake D I. Aplicação de simuladores de eventos discretos no processo de modelagem de sistemas de operações de serviços. Gestão & Produção, Vol. 16, No. 1, (2009), pp. 25-43.

[35] Pirard F, Iassinovski S, Riane F. A simulation based approach for supply network control. International Journal of Production Research, Vol. 49, No. 2, (2011), pp. 7205-7226.

[36] Truong, T H, Azadivar F. Simulation based optimization for supply chain configuration design. Winter Simulation Conference Proceedings, Vol. 2, (2003), pp. 1268-1275.

[37] Schwartz J D, Wang W, Rivera D E. Simulation-Based Optimisation of Process Control Policies for Inventory Management in Supply Chains. Automatica, Vol. 42, No. 8, (2006), pp. 1311-1320.

[38] Shang S, Mao X. Application of a simulation based optimization model for winter wheat irrigation scheduling in North China. Agricultural Water Management, Vol. 85, No. 3, (2006), pp. 314-322.

[39] Wan X, Pekny J F, Reklaitis G V. Simulation-based optimization with surrogate models - Application to supply chain management. Computers and Chemical Engineering, Vol. 29, No. 6, (2005), pp. 1317-1328.

Follow This Article at The Following Site:

Khezeli M, Najafi E, Haji Molana M, Seidi M. Simulation based optimization model for logistic network in a multi-stage supply chain network with considering operational production planning "truck loading system and transportation network". IJIEPR. 2021; 32 (2) :1-18
URL: http://ijiepr.iust.ac.ir/article-1-1109-en.html