VOL. 11, NO. 22, NOVEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

TRANSPORTATION PROGRAMMING MODEL FOR GAS NETWORK

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ABSTRACT

The normal practices in transporting gas from sources to consumers are using gas pipeline. One option to optimize the transportation cost is to model the distribution pipeline using mathematical programming. The aim of this paper is to present the transportation programming model for minimizing the cost of gas transportation. The model has included three units, gas production sites, refinery stations and consumers or cities. The model solved by two parts. The first part is gas transportation from production sites to refinery stations and the second part is gas transportation from refinery stations to consumers. The Vogel method is used to solve the model. The Iranian natural gas network is used as case study. The data of the network was collected from Iranian Natural Gas Company directly. The results of the comparison between two parts of the model and case study reveal that the Iranian natural gas network could save approximately 7 percent of the current cost by using the results of the model.

Keywords: transportation, gas network, optimization.

INTRODUCTION

The transportation programming model is one of the simplest optimization models in transporting. Up to know many research methods are studied in the optimizing the transportation networks. The studies are focused on maximizing the benefit or minimize the cost of projects. There aresix kinds of the optimization model. Linear Programming [1, 2], Integer Programming [3, 4], Dynamic Programming [5, 6], Network Programming [7, 8], Nonlinear Programming [9, 10] and Heuristics [11, 12]. Transportation programming is a linear programming model. The model is based on two units; suppliers and customers. The aim of the model is to calculate the amount of units transfer from supplier to consumers, to minimize the total transportation cost.

There are seven methods to solve the transportation programming model.

1) The North West Corner (NWC)
2) The Least Cost Method (LCM)
3) The Vogel Approximation Method (VAM)
4) The Russell Method (RM)
5) The Stepping stone Method
6) The Multipliers or Modify Distribution (MODI)
7) The Hungarian Method

In this study, the Vogel method[13-15] is used for solving the model.

The main objective of this study is minimizing the gas transportation cost. The fuel transportation is expensive. The transportation company needs to pay the extra cost for fault in the transportation. Due to this objective, gas transportation optimization has been a research focus.

The Iranian natural gas data is used for this study as a case study. Iran is in the second place in terms of gas reserves worldwide and also has many cities that are natural gas consumers. The importance of optimizing the gas transport from sources to cities is high because Iran has many gas networks and the gas sources are very far from the cities resulting to high transporting cost. There are 16 active gas production sites, seven gas refinery stations, four compressor stations and 24 cities in Iran.

MATHEMATICAL MODEL

There are three stations in this model. Production sites, refinery stations and cities. There are two models in this study. Transportation programming model for gas transfer from production sites to refinery stations and from refinery stations to cities.

The capacity of producing for the supplier, the capacity of receiving and refining for refinery stations and amount of consumers demand are considered in this paper.

The first rule of the method is the total amount of supplier must be equal to the total of the amount of consumers demand. If the amount of supplier and consumers demand is not equal, one supplier or consumer with zero unit cost and $\left|\sum_i^n s_i - \sum_j^m d_j\right|$capacity should add to solve this problem.

The total cost is the cost of transportation from production sites to refinery stations (part one) and from refinery stations to consumers (part two). It shows in equation 1.

Equation 2 and 6 are the total cost of part one and two. The total cost is the amount of gas transfer multiple unitscosts.

Equation 3 and 4 means the total amount of gas transfer in part one is equal to the amount of gas production and the amount of gas receiving in refinery stations.

Equation 7 and 8 means the total amount of gas transfer in part two is equal to the amount of gas refining and a number of consumers demand.

Equation 5 and 9 means the amount of gas transfer is nonnegative and the total amount of supplier and consumers are equal due to the first rule of transportation programming method.

$$Total\ cost = Z_1 + Z_2 \quad (1)$$

The model for part one is:

$$\text{Min } Z_1 = \sum_i^n \sum_j^m cp_{ij} * x_{ij} \quad (2)$$

Subject to (St):

$$\sum_i^n \sum_j^m x_{ij} = s_i \quad (3)$$

$$\sum_j^m \sum_i^n x_{ij} = d_j \quad (4)$$

$$x_{ij} \geq 0 \& \sum_i^n s_i = \sum_j^m d_j \quad (5)$$

And part two:

$$\text{Min } Z_2 = \sum_j^m \sum_p^k cc_{jp} * y_{jp} \quad (6)$$

St:

$$\sum_j^m \sum_p^k y_{jp} = t_j \quad (7)$$

$$\sum_p^k \sum_j^m y_{jp} = e_p \quad (8)$$

$$y_{jp} \geq 0 \& \sum_j^m d_j = \sum_p^k e_p \quad (9)$$

$i = 1,2,\dots,n$
$j = 1,2,\dots,m$
$p = 1,2,\dots,k$
$x_{ij} = quantity\ transported\ from\ i\ to\ j$
y_{jp} = quantity transported from j to p
cp = unit cost of gas transportation from gas production sites to refinery stations.
S_i= amount of gas production in production sites
d_j= amount of receiving gas in refinery stations
t_j= amount of refining gas in refinery stations
e_p= amount of consumer's demand

The transportation programming table is shown in Table-1:

Table-1. Transportation programming method

S_1	c_{11}	c_{12}	c_{13}
	x_{11}	x_{12}	x_{13}
S_2	c_{21}	c_{22}	c_{23}
	x_{21}	x_{22}	x_{23}
S_3	c_{22}	c_{33}	c_{33}
	x_{31}	x_{32}	x_{33}
	d_1	d_2	d_3

S_i is amount of supplier, d_j is amount of consumers demand, x_{ij} is amount the of unit transfer and c_{ij} is the cost of transportation between the supplier and consumers.

RESULTS AND DISCUSSIONS

The data of Iranian natural gas are shown in table two and three. The data is based on million cubic meters per day.

Table-2. The data of production sites and consumers.

Gas production sites			Cities		
Name	**Sign**	**Capacity of production**	**Name**	**Sign**	**Amount of demand**
South pars	s_1	300	Tabriz	e_1	64.7
North pars	s_2	102	Esfahan	e_2	47
Homa&Shanul	s_3	35.6	Ilam	e_3	1.4
Veravy	s_4	5.8	Bushehr	e_4	26.3
Sarkhun	s_5	2.2	Tehran	e_5	65
Gorzin	s_6	1.2	Shahrkord	e_6	2.5
South geshoy	s_7	14.1	Mashhad	e_7	31.1
Arash	s_8	14.6	Ahvaz	e_8	29.6
Salman	s_9	2.2	Zanjan	e_9	4.4
Tangebijar	s_{10}	10	Semnan	e_{10}	24.6
Khangiran	s_{11}	60	Zahedan	e_{11}	30
Dalan	s_{12}	20	Shiraz	e_{12}	25.2
Aghar	s_{13}	95.2	Ghazvin	e_{13}	10
Madar	s_{14}	56.6	Ghom	e_{14}	6
Khayam	s_{15}	23.7	Sanandaj	e_{15}	4
Halkan	s_{16}	50	Kerman	e_{16}	7.9

			Kermanshah	e_{17}	9
			Yasuj	e_{18}	9.2
			Khoramabad	e_{19}	6
			Sari	e_{20}	51.5
			Arak	e_{21}	23
			Bandarabbas	e_{22}	16
			Hamedan	e_{23}	13
			Yazd	e_{24}	14.8

Table-3. The data of input and output of refinery stations

Gas refinery stations					
Name	**Sign**	**Capacity of receiving**	**Productivity factor (α)**	**Sign**	**Capacity of refining**
Fajr jam	d_1	175	%72	t_1	126
Parsian	d_2	93	%87	t_2	80.9
Ilam	d_3	15	%86	t_3	12.9
Khangiran	d_4	98	%88	t_4	86.2
Bidboland	d_5	40	%86	t_5	34.4
Sarkhun-gheshm	d_6	22	%87	t_6	19.1
South pars	d_7	321.5	%72	t_7	231.5

The productivity factor of refinery stations is shown in Table-3. The productivity factor is base on the refinery stations facilities and the purity of the gas.

The results of solving the transportation programming model are shown in tables four and five.

The Vogel method is used to solve the model. The results are compared with the case study results. For a fair comparison, the data of the Iranian natural gas network replaced in the model and calculated the total cost for the case study.

Table-4. Results of part one of the model

300	**0.79** **139.2**	**6.48**	**66.12**	**14.2**	**12.92**	**23.38**	**0.49** **160.8**	**0**
102	1.09	7.37	45.99 5	13.1	5.91 40	27	0.77 57	0
35.6	0.57	5.15	64.73	12.95	12.73	17.31 14	0.16 21.6	0
5.8	0.75	4.83	66.44	12.79	13.28	16.37 5.8	0.21	0
2.2	2.49	2.17	79.95	11.4	18.7	5.57 2.2	1.07	0
1.2	2.12	2.89	80	12.14	18.58	8.94	0.95 1.2	0
14.1	1.89	2.93	74.91	11.78	17.46	9.16	0.83 14.1	0
14.6	1.02	6.78	62.46	14.34	13.05	23.76	0.53 14.6	0
2.2	1.67	6.81	77.38	14.82	16.98	23.94	0.65 2.2	0

VOL. 11, NO. 22, NOVEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

10	4.54	13.91	6.34	14.59	11.87	53.95	2.94	0
			10					
60	7.34	10.41	92.18	0.2	30.58	45.18	3.9	0
				60				
20	0.56	6.21	52.83	12.36	8.26	20.97	0.41	0
	20							
95.2	0.49	5.92	56.14	11.76	9.54	18.16	0.28	0
	15.8	41.4		38				
56.6	0.34	5.53	62.25	12.97	11.76	18.88	0.13	0
		51.6						5
23.7	0.28	5.69	61.58	13.15	11.58	19.56	0.16	0
								23.7
50	0.68	6.33	63.59	12.6	10.72	18.44	0.14	0
							50	
	175	93	15	98	40	22	321.5	28.7

The results of first part of the model shown in Table-4. The last column is the extra destination to balance the total of the amount of supplier with a total of the amount of destinations (refinery stations). The amount of gas transfer is highlighted in the table. The total cost of gas transportation for the first part is based on equation 2. The total cost is calculated 2152.81 million dollars. The fifteenth gas production site is not used for the gas network.

The total gas transportation cost for a case study for the first part is calculated 2422.7 Million Dollars.

Due to the results, the Vogel method is trying to find the minimum transportation costc_{ij} and allocate the min $[s_i, d_j]$ to the current x_{ij}. The first step in the method is find the difference cost of two minimum cost in the each rows and columns. In the formal it called the Penalty of row and column. Then choose the maximum of the penalty. If the maximum penalty is for row, find the minimum cost in the current row. If the maximum penalty is for column find the minimum cost of the current column. The next step is to allocate the min $[s_i, d_j]$ to the current cell and update the tables and difference numbers. Continue this role to finish the total amount of supplier and consumers.

Table-5. Results of part two of the model

64.7	39.28	49.17	14.43	40.9	26.51	47.06	40.15
	20.5						44.2
47	12.9	20.26	12.23	23.56	6.33	18.06	13.2
	47						
1.4	697.01	1075.9	14.29	1131.6	354.05	969.26	742.57
			1.4				
26.3	7.87	34.47	30.12	55.92	10.27	25.18	10.69
	26.3						
65	15.31	18.76	8.74	15.39	9.59	18.36	15.48
		43		3.6		3.1	15.3
2.5	234.43	400.1	206.54	483.1	82.48	349.26	244.1
					2.5		
31.1	59.39	44.04	6.25	7.02	55.4	52.96	57.81
				31.1			
29.6	20.03	40.15	13.63	49.92	4.69	33.52	22.26
							29.6
4.4	268.32	346.62	94.16	296.15	168.32	332.77	278.24
			4.4				
24.6	39.99	43.89	30.53	32.9	28.61	44.44	39.87
							24.6
30	32.45	8.64	55.16	29.48	40.86	18.78	30.26
		30					

25.2	8.46	28.21	33.89	50.17	13.27	20.62	8.67
							25.2
10	109.7	137.23	47.25	113.64	68.43	133.14	111.62
					10		
6	144.93	195.96	78.33	181.83	80.11	183.89	150.54
					6		
4	277.2	390.13	46.65	367.97	161.48	361.8	290.85
			4				
7.9	76.39	38.23	156.1	115.33	101.14	46.28	69.35
		7.9					
9	110.63	164.84	8.59	165.47	58.92	150.3	117.1
			3.1		5.9		
9.2	38.78	92.36	74.66	136.29	20.28	74.35	43.18
	9.2						
6	139.22	219.8	33.48	231.01	59.36	197.52	145.64
					6		
51.5	41	44.62	28.75	30.62	29.68	45.34	41
				51.5			
23	36.53	53.37	14.63	53.5	17.76	48.87	37.71
	23						
16	27.94	20.45	85.61	81.65	53.15	1.51	22.64
						16	
13	74.81	105.97	18.14	102.3	40.11	97.91	77.27
					4		9
14.8	37.81	44.84	59.17	62.86	33.54	41.32	36.43
							14.8
68.8	0	0	0	0	0	0	0
							68.8
	126	80.9	12.9	86.2	34.4	19.1	231.5

The results of part two areshown in Table-5. The columns are refinery stations and the rows are the consumers. The last row is the extra consumers to balance the total amount of refined gas and consumers demand.

The total cost of gas transportation from refinery stations to consumers is calculated by equation 6. The total cost is 14102 million dollars. The total gas transportation cost for a case study for the second part is calculated 16270.1 Million Dollars.

The comparison result between the model and case study is shown in the Figure-1.

The comparison of the results between the model and the case study reveal that the Iranian natural gas network could save approximately 6 percent for part one and 7 per cent for part two.

CONCLUSIONS

Transportation programming model is proposed for gas distribution network optimization. The results of this paper are the model is tried to solve by using the spreadsheet. The transportation programming method indicated gives lower cost than the actual. The transportation programming model optimized the gas network of a case study by saving 2437.99 million dollars which are approximately 7%of the total cost of transportation.

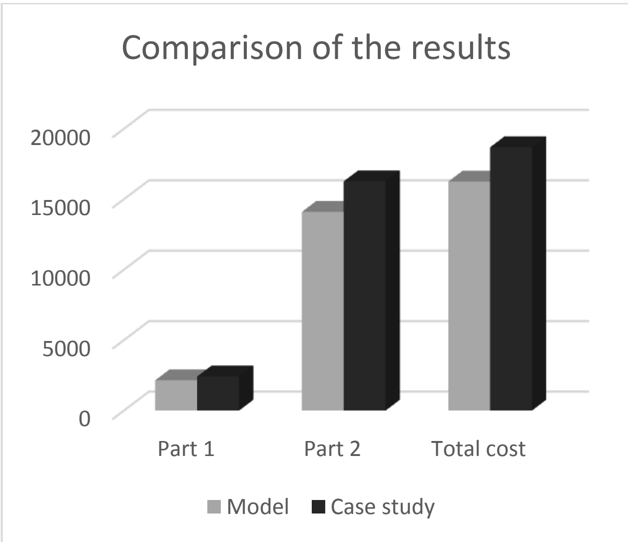

Figure-1. Comparison of model and case study.

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