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STUDY OF TRANSPORTATION PROBLEM OF IRON AND STEEL INDUSTRY IN TURKEY BASED ON LINEAR PROGRAMMING, VAM AND MODI METHODS

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ABSTRACT. The subject of this study is the investigation of the minimization of the total transportation costs for finished product produced by Alter Iron and Steel Industry Company in its own production facilities in Karabuk. Firstly, the current situation in the Iron and Steel Industry in the world and Turkey are briefly discussed. In the second stage, the distribution to the demand point from the factory operating in the Iron and Steel Sector is considered as the basic problem. The demand points were determined as geographical regions. We have two targets: the total cost to be minimized and the total amount of goods to be sent from supply center to the demand centers to be equal to the total demand or supply amount. The optimum solution of the transportation model were solved both the traditional transportation model methods such as Vogels Approximation Method (VAM), Modified Distribution (MODI) method and the linear programming method. The optimal solution for last model was found using the R /SIMPLEX package program. Obtained results by different approaches are discussed. Critical aspect of this problem is to use the single source transportation model, where all demand amounts are met from a single production center..

1. INTRODUCTION

1a. Iron and Steel Industry in the World

The iron and steel sector is one of the main sectors of the heavy industry sector, which gives majority contributes to the development of the national economy. Conventionally, the economic impact of an industry is measured by its contribution to GDP (Gross Domestic Product), i.e. gross value added from the industry - the

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difference between the value of output and intermediate inputs. Another important indicator is the number of people working in the industry. These indicators help to describe the direct impact. The steel industry has a gross value added of US$500 billion, which is 0.7% of global GDP and employs just over 6 million people.

Steel is a key input in the work of many other industrial sectors, which produce items essential to the functioning of the wider economy-including hand tools and complex factory machinery; lorries, trains, and aircraft; and countless items used by individuals in their everyday lives, from cutlery to cars and other. It also creates opportunities for innovative solutions in other sectors and is indispensable in research and development projects around the world. Given such a wide range of steel applications and its functions, it is not an easy and simple task to give a fair assessment of the economic impact of the steel industry through numbers. This is why in 2019 the World Steel Association commissioned Oxford Economics to evaluate our industry's impact on a global scale [1].

According to this report [1] the steel industry is active in all parts of the world, transforming iron ore into a range of products that are sold for a total annual value of US $2.5 trillion. The industry employed more than six million people around the world in 2017, and the "added value" of its production processes totaled almost US $500 billion. This figure comprises the industry's employment costs, capital costs, and net profits, and is the standard way of allocating global or national output GDP between sectors.

As shown in the report [1], we also find that for every two jobs in the steel sector, 13 more jobs are supported throughout its supply chain-meaning that, in total, some 40 million people work within the steel industry's global supply chain, generating over US $1.2 trillion of added value. This economic activity extends across multiple sectors and countries, far beyond the major steel-producing locations. The world steel study differentiates itself from the existing national studies by taking a global approach. Trade and the scope of impact is not limited to national borders and takes into consideration global supply chains and steel using sectors. It underlines the complexity of the role which the steel industry plays in the global economy. The overall impact of the steel industry is US$2.9 trillion value added, and 96 million jobs globally [1].

In Fig. 1, we can see how the growth in the world iron and steel sector is realized with the production amount; crude steel production in the world has achieved rapid growth due to steady growth and increasing demand in the world economy from 2005 until to 2008-2009 global crisis. World crude steel production, which was 1.15

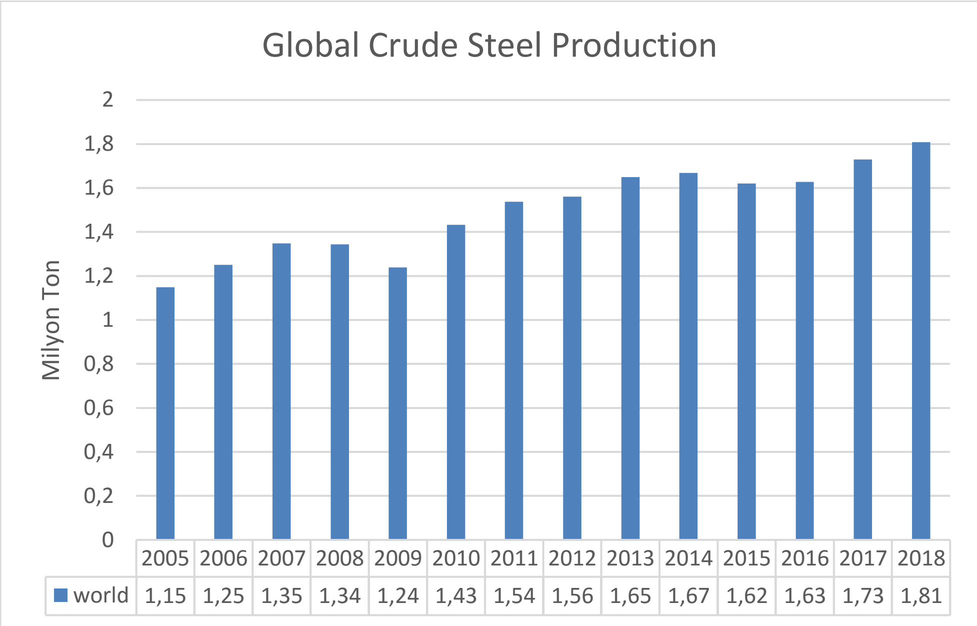

FIGURE 1. Crude (Liquid) Steel Production in the World (Billion Ton) World Steel

million tons in 2005, reached 1.24 million tons in 2009, but in 2007, production decreased significantly compared to approximately 1.35 million tons. Due to the decreasing demand as a result of the global economic crisis, the world steel production, which decreased in 2008 and 2009, started to increase again in 2010 and the production reached 1.43 million tons. Due to the lack of demand in 2015, production decreased by 0.05 million tons again compared to the previous year and reached 1.80 million tons in 2018.

According to World Steel Association (world steel) data on February 2020, world crude steel production increased by 2.8% compared to the same month of the previous year, reaching 143 million tons and 1% increase in the first two months of the year, at 294 million tons. As of the first two months of the year, China's crude steel production increased by 3.1% compared to the same period of 2019 achieved to 155 million tons, while India's second-place crude steel production decreased by 0.8% to 18.9 million tons. Among the top 15 countries producing the most crude steel, Iran was the country with the highest production increase with a rate of 40.5% in January-February period, Turkey increase of the production by 12.7% took second place. In the first 2 months, Germany's production continued to decline and decreased by 10.9% to 6 million tons.

1b. Iron and Steel Industry in Turkey

Turkish steel industry was founded in the 1930s in order to meet the steel needs of the defense industry. Steel production started with the installation of two sixteen-ton Siemens-Martin mills in Kırıkkale. With the establishment of this sector, the country's economy started to develop and industrialization gave its first shoots. The first investments related to the steel sector were made in the 1930s within the scope of the 1st and 2nd industrial plans and the industry developed for a long time in the monopoly of the public sector, with integrated facilities predominantly [2].

Crude steel production in the world and in our country is carried out in Integrated Iron Steel (IIS) facilities using iron ore and in Induction and Electric Arc Furnace (EAF) facilities that produce scrap. When we view the production infrastructure of the sector, we see that a production infrastructure mainly based on scrap. As of 2018, there are 3 Integrated Iron and Steel plants producing iron ore and 31 Induction and Electric Arc Furnace plants producing scrap. As of 2018, 39.4 million tons of 51.8 million tons of crude steel capacity belong to facilities producing scrap and 12.4 million tons of iron ore. In addition, the sector has 22 Researcher centers and 3 Design Centers along with other metal sectors [3].

Karabuk Iron and Steel Manufacturer (Kardemir) is the first integrated steel mill which producing long products in Turkey. In the early years of the republic, KARDEMİR, the first integrated iron and steel plant, was established in Sümerbank as a public economic enterprise due to the lack of resources of the private sector. Then, the second integrated facility of the country Eregli Iron and Steel Factories (ERDEMİR) started production in 1965. The main purpose of this Manufacturer is to provide the demand of flat products. In order to provide the demand for the long and semi-finished products the third integrated facility in Turkey, Iskenderun Iron and Steel Factories (ISDEMIR) was opened for business. According to statistic dates for 2020 year, 32 facilities are operating in the sector which divided into four regions. There are 10 companies which operate in the Iskenderun region, 9 companies take place in the Marmara region, 8 companies are in the Izmir region and 5 companies are in the Black Sea (2020 year).

Steel production capacities are following for regions: 16.7 million tons for Iskenderun region, 15.2 million tons for Marmara region, 11.3 million tons for Izmir region and 8.3 million tons for Black Sea region. The crude steel production capacity for the Iron and Steel Factories in Turkey following: for 11 Factories 2 million tons and above, the capacity of 7 Factories are 1 - 2 million tons and 6 companies of them have a capacity from 500 thousands to 1 million tons, the capacity 8 companies between 50 and 500 thousand tons.

On Table 1 and 2, we can see the Turkey's Industry and Productivity directorate Sector Reports by years (2013-2020).

TABLE 1. *Turkey's Steel Production (Million Tons)*

	2013	**2014**	**2015**	**2016**	**2017**	**2018**
Billet	26,294	24,612	23,231	23,015	25,839	24,669
Slab	8,360	9,423	8,286	10,148	11,685	12,643
TOTAL	**34,654**	**34,035**	**31,517**	**33,163**	**37,524**	**37,312**
EAF	24,723	23,752	20,482	21,846	25,963	25,799
IIS	9,931	10,283	11,035	11,317	11,561	11,513
TOTAL	**34,654**	**34,035**	**31,517**	**33,163**	**37,524**	**37,312**

TABLE 2. Turkey's Steel Production (Million Tons)

	2019 2months	**2020 2months**	%difference2020-2019
Billet	3.176	3.725	17.3
Slab	2.027	2.139	5.5
TOTAL	**5.203**	**5.865**	**12.7**
EAF	3.333	3.932	18
IIS	1.870	1.933	3.4

January-February period of 2020, Turkey's total crude steel production increased by 12.7%, rise from 5.2 million tons to 5.9 million tons in the same period of 2019. In the first two months of this year, facilities with electric arc furnaces increased by 18% achieved to 3.9 million tons; integrated plants produced 1.9 million tons of crude steel, increasing by 3.4%. January-February period Turkey's billet production 17.3% increase over last year from 3.2 million tons to 3.7 million tons in the same period. The slab production was increasing by 5.5% achieved value from 2 million tons to 2.1 million tons [4]. However, now due to the contracting effect of the coronavirus on the international market, has caused our exports to decline by 8.2% in February. On the other hand, our production was only able to increase by 8.2% due to the increase in imports by 31.2% despite the 68.2% increase in consumption. Thus, in the first 2 months of the year, imports increased by 40.4%, while the increase in domestic steel production was 12.7%.

2. Problem description

The subject of this paper is the investigation of the minimization of the total transportation costs for finished product produced by Alter Iron and Steel Industry Company in its own production facilities in Karabuk. Thus, production planning involves decisions such as distribution of the production mix between several plants according to their individual capacity, the need for totally external storage, and management of inventory levels for each plant.

Critical aspect of this problem is using the single source transportation model, in which all demand amounts are met from a single production center [5]. The problem of minimizing the total transportation cost is generally considered as a single source linear transportation model in the literature. The single-source transportation problem was developed in [6-8]. In this study, one-year numerical data of the production amount and unit transportation costs of each product of 2018 year for the six types of products produced by the company were used. The traditional transportation model methods such as VAM (Vogels Approximation Method) [9], MODI (Modified Distribution methods) [10] and Simplex methods [11-14] were used to solve the problem.

The model includes a total of 6 products and 6 demand centers (provinces). As one can see from table1, we have 6 products and 6 demand centers (provinces). In other words, all demand amount are met from a single supply center. In our model, the products are produced in the Organized Industrial Zone of Karabuk and distribute products to six cities in total, namely Kocaeli, Istanbul, Ankara, Izmir, Samsun and Karabuk. The solution of the transportation model can be solved both the traditional transportation model methods as VAM, MODI and with the help of the linear programming model. Data input, transportation table and mathematical form of the problem are as follows:

TABLE 3. Transportation Model

products	Kocaeli	İstanbul	Ankara	Izmir	Samsun	Karabuk	supply amount
Steel Billet Products-1	51 X_{11}	65 X_{12}	43 X_{13}	85 X_{14}	70 X_{15}	17 X_{16}	17440
Steel Billet Products-2	51 X_{21}	65 X_{22}	43 X_{23}	85 X_{24}	70 X_{25}	17 X_{26}	29057
Steel Billet Products-3	51 X_{31}	65 X_{32}	43 X_{33}	85 X_{34}	70 X_{35}	17 X_{36}	21904
Rebar Products-1	41 X_{41}	55 X_{42}	43 X_{43}	75 X_{44}	60 X_{45}	7 X_{46}	6608
Rebar Products-2	41 X_{51}	55 X_{52}	43 X_{53}	75 X_{54}	60 X_{55}	7 8000	8000
Rebar Products-3	41 X_{61}	55 X_{62}	43 X_{63}	75 X_{64}	60 X_{65}	7 X_{66}	5500
demand amount	24443	10958	9000	6000	4000	34108	88509

Our aim is fined the optimal solution of the objective Function which determined as:

$$Z_{min} = \sum_{i=1}^{6} \sum_{j=1}^{6} C_{ij} X_{ij} \qquad (i - product)\ ,\ \ (j - demand\ zone) \qquad (1)$$

Here the variable X_{ij} is the i-product amount from producton region to the j-transshipment point. C_{ij}- the unit transportation cost of the i- product from producton region to the j- transshipment point. So,

$$Z_{min} = 51 * X_{11} + 65 * X_{12} + 43 * X_{13} + 85 * X_{14} + 70 * X_{15} + 17 * X_{16} + 51 * X_{21} + 65 * X_{22} + 43 * X_{23} + 85 * X_{24} + 70 * X_{25} + 17 * X_{26} + 51 * X_{31} + 65 * X_{32} + 43 * X_{33} + 85 * X_{34} + 70 * X_{35} + 17 * X_{36} + 41 * X_{41} + 55 * X_{42} + 33 * X_{43} + 75 * X_{44} + 60 * X_{45} + 7 * X_{46} + 41 * X_{51} + 55 * X_{52} + 33 * X_{53} + 75 * X_{54} + 60 * X_{55} + 7 * X_{56} + 41 * X_{61} + 55 * X_{62} + 33 * X_{63} + 75 * X_{64} + 60 * X_{65} + 7 * X_{66} \qquad (2)$$

Constraints set consist of three parts: supply, demand and the condition of being nonnegative.
Constraints set of supply:

$$\sum_{j=1}^{6} X_{ij} \leq a_i \qquad (i - product) \qquad (3)$$

Here a_i is the supply amount of i-product .
$X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} \leq 17443$
$X_{21} + X_{22} + X_{23} + X_{24} + X_{25} + X_{26} \leq 29057$
$X_{31} + X_{32} + X_{33} + X_{34} + X_{35} + X_{36} \leq 21904$
$X_{41} + X_{42} + X_{43} + X_{44} + X_{45} + X_{46} \leq 6608$
$X_{51} + X_{52} + X_{53} + X_{54} + X_{55} + X_{56} \leq 8000$
$X_{61} + X_{62} + X_{63} + X_{64} + X_{65} + X_{66} \leq 5500$

Constraints set of demand:

$$\sum_{i=1}^{6} X_{ij} \geq b_j \qquad (j - demand\ zone), \qquad (4)$$

where b_i is the demand amount of j-demand zone:

$X_{11} + X_{21} + X_{31} + X_{41} + X_{51} + X_{61} \geq 24443$

$X_{12} + X_{22} + X_{32} + X_{42} + X_{52} + X_{62} \geq 10958$
$X_{13} + X_{23} + X_{33} + X_{43} + X_{53} + X_{63} \geq 9000$
$X_{14} + X_{24} + X_{34} + X_{44} + X_{54} + X_{64} \geq 6000$
$X_{15} + X_{25} + X_{35} + X_{45} + X_{55} + X_{65} \geq 4000$
$X_{16} + X_{26} + X_{36} + X_{46} + X_{56} + X_{66} \geq 34108$

The set of constraints (3) defines the transportation limitations for i- product from production region to the transshipment point j.

$$X_{ij} \geq 0 \qquad (i = the\ product), (j = demand\ point) \tag{5}$$

Constraints (5) ensure that decision variable are non-negative.

It is essentially that according to the data Table 3 the total supply amount of the company is equal to the total demand amount from the individual centers. Thus, we consider the balance problem and this fact can be expressed mathematically as:

$$\sum_{j=1}^{n} b_j = \sum_{i=1}^{m} a_i = 88509\ ton \tag{6}$$

TABLE 4. The market prices of the produced products are as follows:

Products	**Unit price of product (Turkish lira)**
Steel Billet Products-1	1445
Steel Billet Products-2	1560
Steel Billet Products-3	2060
Rebar Products-1	1712
Rebar Products-2	2030
Rebar Products-3	2200

2a. Solving the Problem by VAM Method

According to the VAM method, firstly, the differences between the smallest C_{ij} for each row and column and the second smallest C_{ij} are determined for the respective row and column [6,9]. Here C_{ij} represents unit transportation costs in each frame.

According to Table 3, the differences (penalty values) for the each row (SA) following:

SA1=43-17=26; SA2=43-17=26;SA3=43-17=26;SA4=33-7=26;SA5=33-7=26;SA6=33-7=26

The differences (penalty values) for the each column (ST) defined as:

ST1=51-41=10;ST2=65-55=10;ST3=43-33=10;ST4=85-75=10;ST5=70-60=10;ST6=17-10=10

In generally, we must select the square with maximum penalty value. But one can see, there is equality between the calculated penalty values. So, the smallest cost square in the row is optimally assigned. It ıs $C_{ij} = 7$. If the assignment is made to the row with the smallest cost, i.e. $C_{56} = 7$, $X_{56} = 8000$ and according to the assigned frame, the order is filled and this row is drawn out and processed. This process is shown in Table 5:

TABLE 5. VAM Transportation Model

	Kocaeli	İstanbul	Ankara	Izmir	Samsun	Karabuk	supply amount
Steel Billet Products-1	51 / X_{11}	65 / X_{12}	43 / X_{13}	85 / X_{14}	70 / X_{15}	17 / X_{16}	17440
Steel Billet Products-2	51 / X_{21}	65 / X_{22}	43 / X_{23}	85 / X_{24}	70 / X_{25}	17 / X_{26}	29057
Steel Billet Products-3	51 / X_{31}	65 / X_{32}	43 / X_{33}	85 / X_{34}	70 / X_{35}	17 / X_{36}	21904
Rebar Products-1	41 / X_{41}	55 / X_{42}	43 / X_{43}	75 / X_{44}	60 / X_{45}	7 / X_{46}	6608
Rebar Products-2	41 / X_{51}	55 / X_{52}	43 / X_{53}	75 / X_{54}	60 / X_{55}	7 / 8000	8000
Rebar Products-3	41 / X_{61}	55 / X_{62}	43 / X_{63}	75 / X_{64}	60 / X_{65}	7 / X_{66}	5500
demand amount	24443	10958	9000	6000	4000	34108	88509

Penalty values are recalculated for each remaining row and column. Penalty values for lines (SA):

SA1=43-17=26 ; SA2=43-17=26; SA3=43-17=26;SA4=33-7=26; SA6=33-7=26.

Penalty values for the each column (ST) defined as:

ST1=51-41=10; ST2=65-55=10; ST3=43-33=10; ST4=85-75=10; ST5=70-60=10; ST6=17-10=10.

In this stage we must take account a change was occurred in the demand of the sixth column due to the first operation. So, the demand amount decreases from 34108 tons to26108 tons.

Based on the same logic new assignments are the following cells:

$$X_{46} = 6608$$
$$X_{66} = 5500.$$

As the fourth and fifth lines are filled with their supply, the relevant rows are drawn out and removed from the operation.

After second stage, Rebar-1, Rebar -2 and Rebar-3 products have been completely distributed and the new appearance of the table is shown below.

TABLE 6. VAM Transportation Method

products	Kocaeli	İstanbul	Ankara	Izmir	Samsun	Karabuk	supply amount
Steel Billet Products-1	X_{11}	65 X_{12}	43 X_{13}	85 X_{14}	70 X_{15}	17 X_{16}	17440
Steel Billet Products-2	51 X_{21}	65 X_{22}	43 X_{23}	85 X_{24}	70 X_{25}	17 X_{26}	29057
Steel Billet Products-3	51 X_{31}	65 X_{32}	43 X_{33}	85 X_{34}	70 X_{35}	17 X_{36}	21904
demand amount	24443	10958	9000	6000	4000	14000	88509

On following stage, we calculate Penalty values for the remaining row and column, and the maximum value is placed on the smallest cost square, according to supply and demand constraints and the result will be the following distribution table:

TABLE 7. VAM the Transportation Method

Products	Kocaeli	İstanbul	Ankara	Izmir	Samsun	Karabuk	supply amount
Steel Billet Products-1	51 2539	65 0	43 0	85 901	70 0	17 14000	17440
Steel Billet Products-2	51 0	65 10958	43 9000	85 5099	70 4000	17 0	29057
Steel Billet Products-3	51 21904	65 0	43 0	85 0	70 0	17 0	21904

Rebar Products-1	41 0	55 0	33 0	75 0	60 0	7 6608	6608
Rebar Products-2	41 0	55 0	33 0	75 0	60 0	7 8000	8000
Rebar Products-3	41 0	55 0	33 0	75 0	60 0	7 5500	5500
demand amount	24443	10958	9000	6000	4000	34108	88509

TABLE 8. VAM transportation Model

variable	value	variable	value	variable	value
X11	2539	X31	21904	X51	0
X12	0	X32	0	X52	0
X13	0	X33	0	X53	0
X14	901	X34	0	X54	0
X15	0	X35	0	X55	0
X16	14000	X36	0	X56	8000
X21	0	X41	0	X61	0
X22	10958	X42	0	X62	0
X23	9000	X43	0	X63	0
X24	5099	X44	0	X64	0
X25	4000	X45	0	X65	0
X26	0	X46	6608	X66	5500

$$\text{TOTAL COST } Z=51*2539+85*901+17*14000+65*10958+43*9000+85*5099+70*4000+51*21904+7*6608+7*8000+7*5500=3514619(\text{TL}) \quad (7)$$

Thus, the basic solution is completed with the VAM method. KH=n+m-1=6+6-1=11 is a number of used Cells. Here n and m are the total number of the rows and the column correspondingly.

2b. Solving the Problem by MODI Method.

In this section we will investigate the optimalness of the founding solution using the MODI method [6,10]. If the rows of the tables are denoted by R_i and the columns are K_j, based on the C_{ij} values for the filled squares, using the the formula

$$R_i + K_j = C_{ij},$$

we can calculate the coefficients R_i and K_j for each row and column, correspondingly:

$R_1=R_2=R_3=0, R_4=R_5=R_6=-10, K_1=51, K_2=65, K_3=43, K_4=85, K_5=70, K_6=17.$

TABLE 9. MODI Transportation Method Table

		K1=51	K2=65	K3=43	K4=85	K5=70	K6=17	
	products	Kocaeli	İstanbul	Ankara	Izmir	Samsun	Karabuk	supply amount
R1=0	Steel Billet Products-1	51 2539	65 0	43 0	85 901	70 0	17 14000	17440
R2=0	Steel Billet Products-2	51 0	65 10958	43 9000	85 5099	70 4000	17 0	29057

R3=0	Steel Billet Products-3	51 21904	65 0	43 0	85 0	70 0	17 0	21904
R4=-10	Rebar Products-1	41 0	55 0	33 0	75 0	60 0	7 6608	6608
R5=-10	Rebar Products-2	41 0	55 0	33 0	75 0	60 0	7 8000	8000
R6=-10	Rebar Products-3	41 0	55 0	33 0	75 0	60 0	7 5500	5500
	demand amount	24443	10958	9000	6000	4000	34108	88509

After the R_i and K_j development coefficients stated for each rows and columns of the table, the 'Development index' (GI_{ij}) for all empty (unused squares) are calculated by the formula

$GI_{ij}= C_{ij}-R_i-K_j$.

Now, let's calculate the Development Index (GI) for empty squares.

GI12=C12-R1-K2=65-0-65=0, GI13=C13-R1-K3=43-0-43=0,
GI15=C15-R1-K5=70-0-70=0, GI21=C21-R2-K1=51-0-51=0,
GI26=C26-R2-K6=17-0-17=0, GI32=C32-R3-K2=65-0-65=0,
GI33=C33-R3-K3=43-0-43=0, G34=C34-R3-K4=85-0-85=0,
GI35=C35-R3-K5=70-0-70=0, GI36=C36-R3-K6=17-0-17=0,
GI41=C41-R4-K1=41+10-51=0, GI42=C42-R4-K2=55+10-65=0,
GI43=C43-R4-K3=33+10-43=0, GI44=C44-R4-K4=75+10-85=0,
GI45=C45-R4-K5=60+10-70=0, GI51=C51-R5-K1=41+10-51=0,

GI52=C52-R5-K2=55+10-65=0, GI53=C53-R5-K3=33+10-43=0,
GI54=C54-R5-K4=75+10-85=0, GI55=C55-R5-K5=60+10-70=0,
GI61=C61-R6-K1=41+10-51=0, GI62=C62-R6-K2=55+10-65=0,
GI63=C63-R6-K3=33+10-43=0, GI64=C64-R6-K4=75+10-85=0,
GI65=C65-R6-K5=60+10-70=0.

If the Development Indices are not negative, it means that the optimal solution is found.

2c. Solving the Problem with the Simplex Method

The solution of the transportation problem can be made not only with the traditional transportation model methods, but also using of the linear programing method [11-14]. Linear programming is a method to achieve the best outcome (such as maximum profit or lowest cost) in a mathematical model whose requirements are represented by linear relationships.

Linear programming is a technique in which we maximize or minimize a function. Every linear programming problem can be written in the following standard form

$$Maximize\ \zeta = c^T x \tag{8}$$

subject to

$$\begin{aligned} Ax &= b, \\ x &\geq 0 \end{aligned} \tag{9}$$

The Simplex Method developed in [14] is the earliest solution algorithm for solving LP problems. It is an efficient implementation of solving a series of systems of linear equations. By using a greedy strategy while jumping from a feasible vertex of the next adjacent vertex, the algorithm terminates at an optimal solution. Simplex method uses row operations to obtain the maximum or minimum values of *function*. The simplex method moves from one extreme point to one of its neighboring extreme point. Typical uses of the simplex algorithm are to find the right mix of ingredients at the lowest cost (the goal). If the ingredients are food, the constraints would be having at least so many calories, so much protein, fats, carbohydrates, vitamins, minerals, etc.

R is a free software programming language and software environment for statistical computing and graphics. The R language is widely used among statisticians and data miners for developing statistical software and data analysis [15]. The optimal solution for this application has been solved with the R / SIMPLEX package program [15] and the results are shown in Table 9.

TABLE 10. Transportation Table Simplex Solution Results

variable	value	variable	value	variable	value
X11	0	X31	4335	X51	8000
X12	0	X32	10958	X52	0
X13	0	X33	6611	X53	0
X14	0	X34	0	X54	0
X15	0	X35	0	X55	0
X16	17440	X36	0	X56	0
X21	0	X41	6608	X61	5500
X22	0	X42	0	X62	0
X23	2389	X43	0	X63	0
X24	6000	X44	0	X64	0
X25	4000	X45	0	X65	0
X26	16668	X46	0	X66	0

Resulting solutions which obtained by the linear programming are as follows

TABLE 11. The optimal solution of the transportation problem by R / SIMPLEX paket program

products	Kocaeli	İstanbul	Ankara	Izmir	Samsun	Karabuk	supply amount
Steel Billet Products-1	0	65 0	43 0	85 0	70 0	17 17440	17440
Steel Billet Products-2	51 0	65 0	43 2389	85 6000	70 4000	17 16668	29057

Steel Billet Products-3	51 4335	65 10958	43 6611	85 0	70 0	17 0	21904
Rebar Products-1	41 6608	55 X_{42}	33 X_{43}	75 X_{44}	60 X_{45}	7 0	6608
Rebar Products-2	41 8000	55 X_{52}	33 X_{53}	75 X_{54}	60 X_{55}	7 0	8000
Rebar Products-3	41 5500	55 X_{62}	33 X_{63}	75 X_{64}	60 X_{65}	7 0	5500
demand amount	24443	10958	9000	6000	4000	34108	88509

Thus, according to the table 10, the minimum value of the Total Transportation Cost is equal to:

Z=17*17440+43*2389+85*6000+70*4000+ 7*16668+51*4335+65*10958+43*6611+41*6608+41*8000+41*5500=3514619 (TL) . (10)

In comparison, the results obtained by VAM transportation Model (7) with the optimal solution of the transportation problem by R / SIMPLEX packaged software (8), we can reach this conclusion: although we have two different distribution plans, the optimal total transportation cost is the same in both cases and equal to Z_{min}=3514619 (TL) .

3. Calculation of the Dollar Exchange Rate Fluctuations

The fluctuation of the dollar currency is reflected in fuel price and, consequently, affects on the total transportation costs. For this reason, let's examine how the total transportation costs change with the 5% increase and decrease in unit transportation costs.

TABLE 12. The coefficients of C_{ij} in the Objective Function by 5% Unit transport price increasing

Coefficients Cij	Value	Coefficients Cij	Value	Coefficients Cij	Value
C11	53.55	C31	53.55	C51	43.05
C12	68.25	C32	68.25	C52	57.75
C13	45.15	C33	45.15	C53	34.65
C14	89.25	C34	89.25	C54	78.75
C15	73.50	C35	73.50	C55	63.00
C16	17.85	C36	17.85	C56	7.35
C21	53.55	C41	43.05	C61	43.05
C22	68.25	C42	57.75	C62	57.75
C23	45.15	C43	34.65	C63	34.65
C24	89.25	C44	78.75	C64	78.75
C25	73.50	C45	63.00	C65	63.00
C26	17.85	C46	7.35	C66	7.35

We observe that there is no change in the resulting distribution plan. But we can say that the total transportation cost has increased significantly. We see that the value of the Total transportation cost will be Z_{min} =3690349.95TL, i.e. an increase by 175730.95 TL.

Similarly, the decreasing of the unit transport prices lead to a decreasing of the total transportation cost, a namely:

TABLE 13. The coefficients of C_{ij} in the Aim Function by 5% Unit transport price decreasing

Coefficients Cij	Value	Coefficients Cij	Value	Coefficients Cij	Value
C11	48.45	C31	48.45	C51	38.95
C12	61.75	C32	61.75	C52	52.25
C13	40.85	C33	40.85	C53	31.35
C14	80.75	C34	80.75	C54	71.25
C15	66.5	C35	66.5	C55	57

C16	16.15	C36	16.15	C56	6.65
C21	48.45	C41	38.95	C61	38.95
C22	61.75	C42	52.25	C62	52.25
C23	40.85	C43	31.35	C63	31.35
C24	80.75	C44	71.25	C64	71.25
C25	66.5	C45	57	C65	57
C26	16.15	C46	6.65	C66	6.65

In this case the Total transportation cost will be Z_{min}=3338888.05TL, i.e. the value of the cost will decrease by 175730.95 TL.

6. Conclusion

In this paper the optimum solution of the transportation model were obtained by using the traditional transportation model methods such as VAM, MODI and the linear programming model (using R /SIMPLEX package software). Here we consider the single source transportation model, namely, all demand amounts are met from a single production center. Results of calculations practically coincide for different approaches.

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