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Optimization of Iron Ore and Concentrate Required by the Forecasted Factories According to the Per Capita Consumption of Steel in Afghanistan Based on the Linear Programming Model Until 2030

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Abstract:- Global growth of the steel industry, existence of rich iron ore resources and excessive domestic demand for this product; the idea of designing and optimizing the amount of iron ore and concentrate required by the factories was created according to the domestic demand for steel in Afghanistan. In this research, first all provinces were evaluated according to factors (iron ore reserves, distance to consumers, water resources, energy resources, infrastructure and security, etc.) and then by arranging and distributing questionnaires and interviewing with experts, Six provinces are envisaged as candidate options for the construction of processing plants and another six provinces as candidate options for the construction of steel industries. In the linear planning model, three separate areas of mines, processing plants and steel industries are formed and each area is divided into its respective zones based on location and production capacity. After forming the matrix of road transport distances between the zones using GIS software, a linear programming model is formed to optimize the amount of iron ore required by processing plants and concentrate required by the steel industry. Optimization of iron ore, concentrate and steel production required by Afghanistan up to 2030 horizon has been done using linear programming model in Excel software. According to estimates, Afghanistan will need 2.89 million tons of iron ore, 1.7 million tons of concentrate and 1 million tons of steel annually by 2030.

Keywords:- *Afghanistan, Steel mills, Iron ore mines, Linear programming model.*

I. INTRODUCTION

Iron is the main building block of the Earth's outer and inner nuclei and the fourth most common element in the Earth's crust. The abundance of iron on the planet Earth and other rocky spheres, such as the moon, is due to the phenomenon of nuclear fusion in stars [1]. Iron, with the chemical symbol Fe, has an atomic number of 26 and a density of 7874 kg / m 3. Iron is the largest building block of the planet in terms of mass [2]. According to a 2010 U.S. Geological Survey of Afghanistan's mineral resources, the value of these resources is estimated at $ 1131.840 trillion with a variety of minerals, with iron ore mining accounting for the bulk of these resources. [3]. According to the Afghan Ministry of Trade and Industry, 4,500 tons of iron and steel are imported daily from various countries [4]. The steel industry in Afghanistan is not in a good position because no effective investments and fundamental work have been done so far. Only a few small factories with private investment have started operating in recent years that cannot meet domestic needs. Therefore, there is a need to plan and locate development programs in the field of iron and steel industry. If efficient investment can create appropriate added value in related industries and prosperity of the country's economic sectors. One of the most important issues in the mining and mineral industries is the proper use of mineral and natural resources, the priority of which is to get suitable places to create iron and steel industries [5]. The identification of suitable locations should be done on the basis of specific and comprehensive criteria, and these criteria are divided into their respective sub-criteria that have a direct effect on location [6]. One of the main issues in this research is to identify suitable places for the construction of processing plants and steel industries. Identifying iron ore mines and providing connections between zones (mines, processing plants and steel industries) is also part of the research. The zones of the mines have been stabilized according to geological documents and evidence, and the processing zones and steel have been identified based on internal requirements and the results of questionnaires. Marking the provinces for the construction of factories on the map of Afghanistan and forming a matrix of road distances between the zones has been done using GIS software.

Linear programming is one of the most powerful techniques that managers can use to solve their various problems according to the problem situation [7]. Linear programming is a mathematical model for searching and selecting the best program from a set of possible ways [8]. An effective method for calculating the minimum or maximum value of a linear function on a convex polygon [9]. In this research, linear programming model has been used to optimize the amount of iron ore, concentrate and steel required by Afghanistan according to the amount of annual consumption.

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II. RESEARCH STRUCTURE

In this study, first all provinces were evaluated according to factors (iron ore reserves, distance to consumers, water resources, energy resources, infrastructure and security, etc.) and then by arranging and distributing questionnaires and interviewing Experts have identified six provinces with high scores as candidate options for the construction of processing plants and six provinces as candidate options for the construction of steel industries. Using GIS software, the mentioned provinces are marked on the map of Afghanistan and a matrix of road distances between the zones is formed. In the linear planning model, three areas (mines, processing plants and steel industries) are separated and based on the needs of factories and market demand, product, functions and constraints are defined. Finally, the amount of iron ore, concentrate and steel required by Afghanistan until the horizon of 2030 is optimized using the linear programming model in Excel software. The general structure of the research performance process is shown in Figure 1.

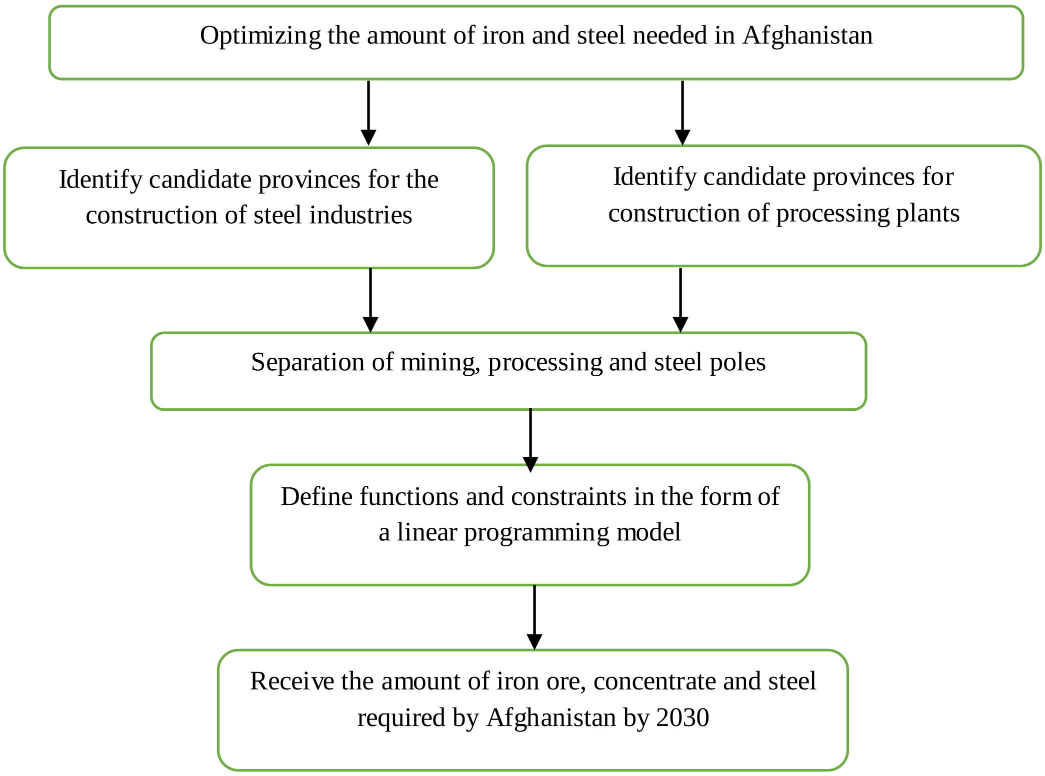

Fig. 1: The general structure of the research process

III. MATERIALS AND WORKING METHODS

A. Optimizing the amount of iron and steel needed in Afghanistan

According to the World Bank report on per capita income and per capita consumption of steel in Table 1, Afghanistan is one of the countries with a per capita income of less than $ 735 per year, and in proportion to that, per capita consumption of steel should be less than 15 Be kilograms [10]. On the other hand, considering the amount of iron and steel imports, the per capita consumption of 15 kg of steel is very small. Therefore, according to the amount of steel imports and economic growth of the country, the per capita consumption of steel is calculated at 25 kg.

Afghanistan's population is calculated according to population growth rate in three scenarios until 2030. According to population growth and average per capita steel consumption, the amount of iron and steel required by Afghanistan in three scenarios until 2030 has been calculated, which is included in Table 2.

Group	Countries	Per capita income in dollars	Average per capita consumption of steel per kilogram
A	Industrial and developed countries	more than 9075	514
B	Argentina, Hungary, Mexico, Venezuela, Saudi Arabia, Lebanon and Malaysia	9075 - 2936	254
C	Algeria, Bulgaria, China, Turkey and Russia	2935 - 735	115
D	India, Indonesia, Bangladesh, Azerbaijan, Pakistan, Sudan and Kenya	more than 735	15

Table 1: Per capita consumption of steel by per capita income in kilograms per year [10]

Year	Scenarios			Optimal amount of iron and steel required per million tons per year
	Realistic	Optimistic	Pessimistic	
2021	0.797	0.802	0.781	0.795
2022	0.815	0.822	0.793	0.813
2023	0.834	0.842	0.806	0.831
2024	0.853	0.863	0.819	0.849
2025	0.873	0.885	0.832	0.868
2026	0.893	0.907	0.845	0.887
2027	0.914	0.930	0.859	0.907
2028	0.935	0.953	0.873	0.927
2029	0.956	0.977	0.887	0.948
2030	0.978	1.001	0.901	0.969
The average steel required is millions of tons per year	0.885	0.898	0.840	0.880

Table 2: The amount of iron and steel required by Afghanistan in different scenarios by 2030 to million tons per year

B. *Identify suitable provinces for construction of processing plants*

In order to get suitable places for construction of processing plants, first all the provinces of Afghanistan have been evaluated according to the factors (iron ore reserves, distance to consumers, water resources, energy resources, infrastructure and security, etc.). Provinces were selected based on the order and distribution of questionnaires and interviews with experts through Google Forms. According to the results of the questionnaires, six provinces (Bamyan, Herat, Badakhshan, Wardak, Kabul and Balkh) have been selected as candidate options for the construction of processing plants. Candidate provinces are marked on a map of Afghanistan using GIS software in Figure 2.

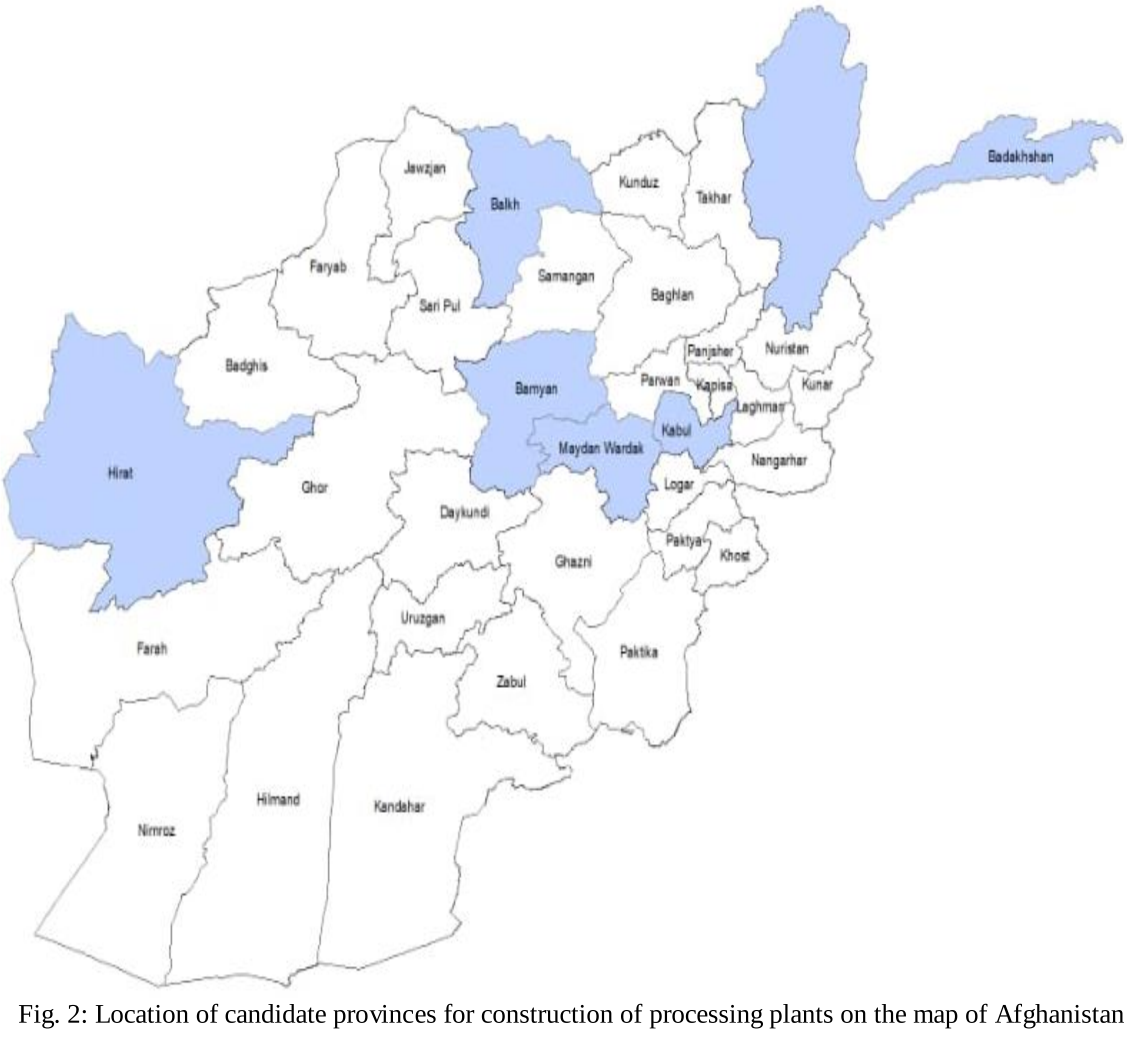

Fig. 2: Location of candidate provinces for construction of processing plants on the map of Afghanistan

C. Identify suitable provinces for the construction of steel industries

As Afghanistan has 34 provinces and most of these provinces are rich in mineral resources and are also eligible for investment in the iron and steel industry. Therefore, first, all provinces are evaluated in terms of main and sub-criteria. Questionnaires were prepared in Google Form and interviews were conducted with experts. According to the results of the questionnaires, provinces (Bamyan, Badakhshan, Herat, Nangarhar, Panjshir and Kandahar) were selected as candidate options for the construction of steel industries and in Figure 3 They are separated on a map of Afghanistan using GIS software.

Fig. 3: Location of candidate provinces for the construction of steel industries on the map of Afghanistan

IV. CONSOLIDATION AND DEFINITION OF ZONES AND LINEAR PROGRAMMING MODEL

In the linear planning model, three separate areas (mines, processing plants and steel industries) are formed and each area is divided into its respective zones based on location and production capacity, which include tables (3, 4 and 5). The problem analysis is based on the linear planning model and after forming the matrix of road transport distances between the zones using GIS software, the linear planning model to optimize the amount of iron ore required by processing plants and concentrate required by industries. Steel is formed.

Zone symbol	The name of mines zone	The center of zone	Provinces covered	Production capacity to millions of tons per year
M_1	Hajigak	Bamyan	Bamyan, Parwan and Kapisa	2.773
M_2	Khaesh	Bamyan	Panjshir and Kabul	2.925
M_3	Sya jar	Badakhshan	Badakhshan and Takhar	1.000
M_4	Formakh	Badakhshan	Kunduz	0.875
M_5	Bacha kerkh	Herat	Herat and Badghis	0.300
M_6	Surkh Kutal	Herat	Kandahar and Zabul	0.225
M_7	Farakhlum	Wardak	Wardak and Paktia	0.300
M_8	Qamchenbaf	Wardak	Nangarhar and Logar	0.250
Total				8.648

Table 3: Mineszones according to the provinces covered by it

Zone symbol	The name of processing zone	The center of zone	Provinces covered	Production capacity to millions of tons per year
F_1	Bamyan	Bamyan	Bamyan and Panjshir	1.005
F_2	Badakhshan	Badakhshan	Badakhshan	0.412
F_3	Herat	Herat	Herat and Kandahar	0.185
F_4	Wardak	Wardak	Nengharhar	0.097
F_5	Kabul	Kabul	Panjshir and Nangarhar	0.000
F_6	Balkh	Balkh	Bamyan and Badakhshan	0.000
Total				1.700

Table 4: Iron ore processing zones according to the provinces covered and its production capacity

Zone symbol	The name of steel zone	The center of zone	Provinces covered	Population zone	Zone consumption in millions of tons per year (2019)
S_1	Bamyan	Bamyan	Bamyan, Parwan, Kapisa, Balkh, Jawzjan, Faryab, Samangan, Sarpol, Uruzgan and Daikundi	6.588	0.165
S_2	Badakhshan	Badakhshan	Badakhshan, Takhar, Kunduz and Baghlan	4.635	0.116
S_3	Herat	Herat	Herat, Badghis, Ghor, Farah and Nimroz	4.190	0.105
S_4	Panjshir	Panjshir	Panjshir, Kabul, Nuristan and Kunar	6.666	0.167
S_5	Nangarhar	Nangarhar	Nangarhar, Laghman, Khost, Logar, Wardak and Paktia	4.319	0.108
S_6	Kandahar	Kandahar	Kandahar, Helmand, Paktika, Zabul and Ghazni	4.044	0.101
Total					0.761

Table 5: Zones of steel mills according to the amount of iron and steel consumption in 2019 to million tons per year

The function of the linear objective is to minimize the combined tonnage of iron ore transport from mineral zones to processing zones and also to minimize the transfer of concentrate from factories to the iron and steel industries. The constraints of the problem are defined based on meeting the needs of processing and steel zones according to the technical and capacity constraints of factories and mines.

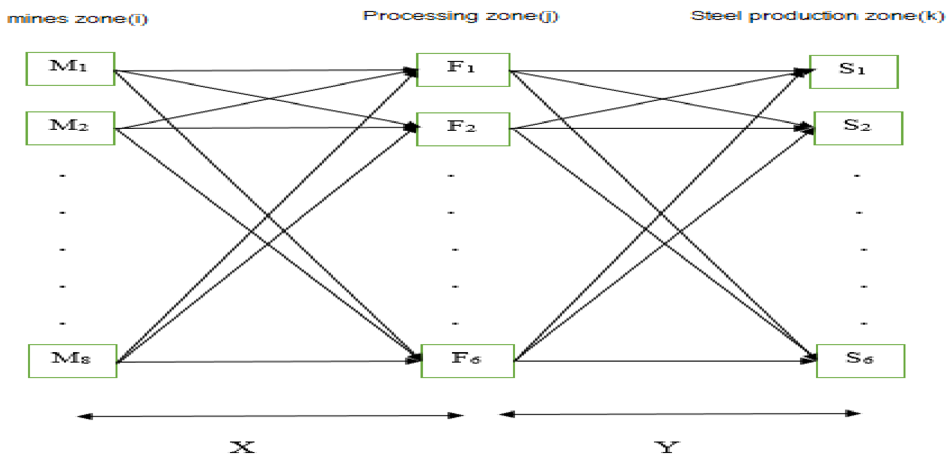

Fig. 4: Material transport model between mineral-processing and processing-steel zones

According to Figure 4, the zones of the mines as suppliers of raw materials with the symbol M_1 to M_8, the zones of processing plants as the applicant of raw materials and the producer of concentrate with the symbol F_1 to F_6 and the zones of iron and steel as the symbol of demand for concentrate products with the symbol S_1 Named up to S_6.

Index i is specified for the mining zone, index j is specified for the processing zone, and index k is specified for the steel zone. Matrices X and Y are a set of decision variables that the optimal transport tonnage from the mining zone to the processing plant zone is expressed by the X matrix and the optimal transport tonnage from the processing plant zone to the steel industry zone is expressed by the Y matrix.

The objective function of the problem is defined based on the combined minimization of two linear functions, including the tonnage of transporting raw materials from mineral zones to processing zones and the tonnage function of concentrate transfer from factories to steel zones according to Equation 1.

$$Min\ Z = \sum_{i=1}^{N}\sum_{i=1}^{M} X_{ij} \times C_{ij} + \sum_{j=1}^{M}\sum_{k=1}^{T} Y_{jk} \times E_{jk} (1)$$
$$X_{ij}.Y_{jk} \geq 0$$

where in:

X_{ij} is the displacement between the mining zone i to the processing zone j and Y_{jk} is the displacement between the processing zone j to the steel zone k.

The tables of transport distances between the zones include C_{ij} and E_{jk}, which represent the distances between the mining zone i to the processing zone j and the displacement between the processing zone j to the steel zone k, respectively. Also, for the mentioned objective function, the constraints based on the considerations of the iron and steel industries are defined as follows:

Limitation 1: The total tonnage transported from each mineral zone to different processing zones according to Equation No. 2 is the maximum equivalent to the production of that mineral zone, in this respect C_i is equivalent to the production of iron ore of the i zone.

$$\sum_{j=1}^{M} X_{ij} \leq C_i\ i = 1.2 \ldots\ldots N \qquad j = 1.2 \ldots\ldots M \qquad (2)$$

Limitation 2: The amount of tonnage transferred from the mineral zones to each processing zone according to

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Equation 3 must be less than or equal to the capacity of the processing zone. In this respect, V_j is equal to the capacitance of the j zone.

$$\sum_{i=1}^{N} X_{ij} \leq V_j \qquad j = 1.2 \ldots \ldots M \tag{3}$$

Limitation 3: The amount of tonnage transferred from the total of processing plants to each steel zone must be equal to or greater than the amount of consumer demand according to Equation 4 to be able to cover the entire demand of the consumption zone.

$$\sum_{j=1}^{M} Y_{jk} \geq D_k \quad k = 1.2 \ldots\ldots T \tag{4}$$

Limitation 4: The total production of the steel industry according to Equation 5 must be equal to the amount of steel demand (one million tons). S_k in this regard is the production capacity of iron and steel industries km.

$$\sum_{i=1}^{M} S_k = 1 \; k = 1 \tag{5}$$

Limitation 5: The total tonnage transported from each processing plant to the steel industry according to Equation 6 must be less than or equal to the total tonnage transported from the mines to the processing plants.

$$\sum_{j=1}^{M} Y_{jk} \leq X_{ij} \; i = 1.2 \ldots\ldots N \qquad j = 1.2 \ldots \ldots M \tag{6}$$

Limitation 6: The total production capacity of processing plants according to Equation 7 must be greater than or equal to the amount of concentrate required (1.7 million tons per year).

$$\sum_{i=1}^{M} V_j \geq 1.7 \; j = 1.2 \ldots \ldots M \tag{7}$$

Limitation 7: The total tonnage transferred from the mining zones to the processing zones according to Equation 8 must be greater than or equal to the amount of iron ore required (2.89 million tons per year).

$$\sum_{j=1}^{M} X_{ij} \geq 2.89 \, i = 1.2 \ldots\ldots N \tag{8}$$

V. DISCUSSION AND RESULTS

A. linear programming model to optimize iron ore production capacity in mines

According to the objective function, defined constraints and the matrix of distances between mines and processing plants, the amount of iron ore required by processing plants is optimized in Excel software. In the first step, the matrix of distances between processing plants and iron ore mines has been arranged using GIS software, which is included in Table 6. Then, according to the defined constraints and the distance matrix, the amount of portable iron ore from the mines to the processing plants is optimized and is included in Table 7. It should be noted that after optimizing the candidate provinces for the construction of processing plants, four provinces were valid for investment due to the defined restrictions, and the other two provinces (Kabul and Balkh) were omitted due to non-valid conditions.

Mines / Processing	Bamyan(F_1)	Badakhshan(F_2)	Herat(F_3)	Wardak(F_4)	Kabul(F_5)	Balkh(F_6)
Hajigak(M_1)	6	510	1295	145	180	427
Khesh (M_2)	5	505	1300	150	185	422
Sya jar(M_3)	510	5	1652	555	1350	950
Furmakh(M_4)	500	4	1642	545	470	397
Bachkerkh(M_5)	1295	1625	6	1010	1045	1439
Surkh kutal(M_6)	1285	1642	7	1000	1035	1429
Farkhlum(M_7)	145	555	1010	5	47	481
Qamchen Baf(M_8)	135	545	1000	5	45	479

Table 6: Matrix of distances between mines zones and processing zones in kilometers

Mines / Processing	Bamyan(F_1)	Badakhshan(F_2)	Herat(F_3)	Wardak(F_4)	Kabul(F_5)	Balkh(F_6)	Total portable iron ore from mines to processing plants
Hajigak(M_1)	0.832						0.832
Khesh (M_2)	0.878						0.878
Sya jar(M_3)		0.438					0.438
Furmakh(M_4)		0.263					0.263
Bachkerkh(M_5)			0.090				0.090
Surkh kutal(M_6)			0.225				0.225
Farkhlum(M_7)				0.090			0.090
Qamchen Baf(M_8)				0.075	×	×	0.075
Total iron ore transported	1.709	0.701	0.315	0.165	×	×	2.890

Table 7: Portability of portable iron ore from mines to processing plants based on model implementation in millions of tons per year

B. linear programming model to optimize the concentrate required by the steel industry

According to the defined constraints and the matrix of distances between processing plants and steel industries, the production capacity of processing plants is calculated. First, the matrix of distances between processing plants and steel industries is arranged using GIS software, which is included in Table 8. Then, according to the defined distance matrix and constraints, the production capacity of processing plants or the amount of concentrate portable to the steel industry is optimized using Excel software and is included in Table 9. It is noteworthy that among the candidate provinces for the construction of steel industries, four provinces after the optimization are honest for investment and including the other two provinces (Panjshir and Kandahar) have been omitted due to lack of conditions.

Steel plant / processing plant	Bamyan(F_1)	Badakhshan (F_2)	Herat(F_3)	Wardak(F_4)	Kabul(F_5)	Balkh(F_6)
Bamyan(S_1)	10	510	1295	145	180	427
Badakhshan(S_2)	510	15	1625	555	470	397
Herat(S_3)	1295	1625	10	1010	1045	1439
Panjshir(S_4)	170	385	1165	175	120	375
Nengarhar(S_5)	358	620	1192	200	150	587
Kandahar(S_6)	597	940	564	445	480	928

Table 8: Matrix of distances between processing and steel zones in kilometers

Steel plant / processing plant	Bamyan(F_1)	Badakhshan (F_2)	Herat(F_3)	Wardak (F_4)	Kabul(F_5)	Balkh (F_6)	Concentrate required by the steel industry	producible steel
Bamyan (S_1)	1.005						1.005	0.6
Badakhshan (S_2)		0.412					0.412	0.2
Herat (S_3)			0.185				0.185	0.1
Panjshir(S_4)								
Nengarhar(S_5)				0.097			0.097	0.1
Kandahar (S_6)					×	×		
Total	1.005	0.412	0.185	0.097	×	×	1.700	1.000

Table 9: Portable concentrate tonnage from processing plants to steel industries based on model implementation in millions of tons per year

VI. CONCLUSION

According to the results of the questionnaire, Kabul, Bamyan, Balkh, Herat, Badakhshan and Wardak provinces were nominated as suitable options for the construction of processing plants. After optimization, Bamyan, Badakhshan, Herat and Wardak provinces were selected and selected from the provinces. Kabul and Balkh have been waived due to restrictions.

Factors (security, iron ore reserves and infrastructure) have a greater impact on the location of processing plants than other factors and are of great importance.

In this study, according to effective criteria and sub-criteria, Bamyan, Herat, Badakhshan, Panjshir, Nangarhar and Kandahar provinces were selected as candidate options for the construction of steel industries, and after optimization, Bamyan, Badakhshan, Herat and Nangarhar provinces for Construction of steel industry has been selected and provinces (Panjshir and Kandahar) have been abandoned due to conditions and restrictions.

According to the linear planning model, Afghanistan will need 2.89 million tons of iron ore, 1.7 million tons of concentrate and 1 million tons of steel annually by 2030.

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