TRANSPORTATION APPRAISAL OF GLOBAL OIL TRADE FLOWS

Manouchehr Vaziri
Professor
Department of Civil and Transportation Engineering
Sharif University of Technology
Iran, Tehran, Azadi Street
P.O.Box: 11365-9313
manouchehrvaziri@yahoo.com

Shahram Tabatabaei
Research Assistant
Department of Civil and Transportation Engineering
Sharif University of Technology
Iran, Tehran, Azadi Street
P.O.Box: 15338-36744
Telephone: +98-912-3703768, +98-21-88741697
shahramtbt@yahoo.com

ABSTRACT

Among energy supply resources, crude oil has special importance as it supplies more than half of the world energy demands, today. In oil trade, transportation costs have significant effect on ultimate price like other commodities; therefore trade partners often try to select the nearest demand and supply resources.

In the research reported herein, global oil trade flows were investigated during 2003 and role of distance as a transportation factor, in trade distribution was appraised. Accessible and relevant oil trade data for 115 countries were gathered. The study database consisted of 20 variables in four categories of trade, geographical, economical and political. Firstly, preliminary statistical analyses of the database were performed. Compared to other variables, country distances and gross domestic product showed higher correlation with national oil trade variables. Furthermore, simple modeling demonstrated that models in form of power had the best fit between oil trade variables, as dependent variables, and the others as independent variables. Moreover, multivariable oil trade models were developed and evaluated. Country distance, which is a geographic variable, was found as a significant decreasing factor in global oil trade. Gravity models for global oil trade were found as good descriptive models. The key variables of the models were gross domestic product of exporters and importers, and country distances which had positive and negative effect on growth of international trade. Finally, linear programming optimized oil trade and the results were compared with observed distribution. Comparison of observed and optimized distribution for the sea network showed possibility of improvements up to one third in total transportation cost.

Key words: Global oil trade, distribution modeling, freight transportation, linear programming

INTRODUCTION

All the mankind's activities need energy and among energy supply resources, crude oil has special importance. For example half of total oil productions in the world are assigned to transportation industries which are responsible to economic, military, strategic, social and political demands of humanity; and no more would exist without crude oil and its refineries. In the other hand, crude oil resources and amount of demands in countries aren't same. Therefore, as a result of this difference between demand and supply, oil trade flows create among countries such as other commodities. Economic development of countries and also recent trends like e-commerce, economic globalization, and interregional and international trade development are heightening the already important role played by the freight industries. As a consequence of these pressures, the freight transportation system is expected to cover a larger geographic area, be more responsive to world's demand and expectations, and reduce negative externalities. World increasing oil demands have put great pressure on transportation planners to model and improve freight transportation planning and come up with the new ideas to make system wide efficiency (*1*).

Oil trade has been one of the most important trades in the world for the recent 25 years and high amount of money transmits among exporters and importers. Also crude oil has changed to the one of the most complicated commodities in global trade as a result of so many factors. Existence of different type of crude oil with different properties, variety of refinery production, and lack of standards, criteria and fix scale has made the valuing process of crude oil, very difficult and so ambiguous. Swing prices besides daily and seasonal changing in amount of demand or supply has entangled planning process and estimation of trade patterns. Unexpected events and political factors which play important role in this trade are beyond of estimation and need comprehensive planning to face. Finally transportation costs which have significant effect on ultimate prices such as other commodities; encourage the trade partners, try to select nearest demand and supply centers and reduce these costs by effective transportation planning (*2*).

So many factors affect oil trade as said before. In this research four categories of variables were considered as trade, geographical, economical and political. Each category consists of some variables that would be discussed in database section. Research database containing variables, was created in Excel software and statistical analysis was performed by SPSS. For solving linear programming, a computer program which was written in MATLAB software, was used.

The main objective of this paper is to appraise global oil trade and its distribution as a cross-sectional analysis. According to data which were collected in research database, preliminary analysis was performed. Models were developed for global oil trade based on considered variables. Then evaluation of developed models was attended and the results were investigated. Application of gravity model as a transportation descriptive model of global oil trade was appraised in continuation of this study. Final scope was to optimize observed distribution via linear programming and total transportation costs of optimized distribution were compared with observed distribution.

Broadly speaking, the paper is divided into four sections in addition to the introduction and conclusion. Variables introduction, collecting data process and creating the research database are presented in first section. Description of the survey for used database and general results are presented in the second section as preliminary statistical analyses. Correlation analysis of variables is considered in third section. Fourth section of this paper, deals with oil trade modeling which consists of four parts as simple modeling, multivariable modeling, gravity model and linear programming model. Finally, conclusions of this study are discussed in the last section of paper. Figure 1 shows framework of this research.

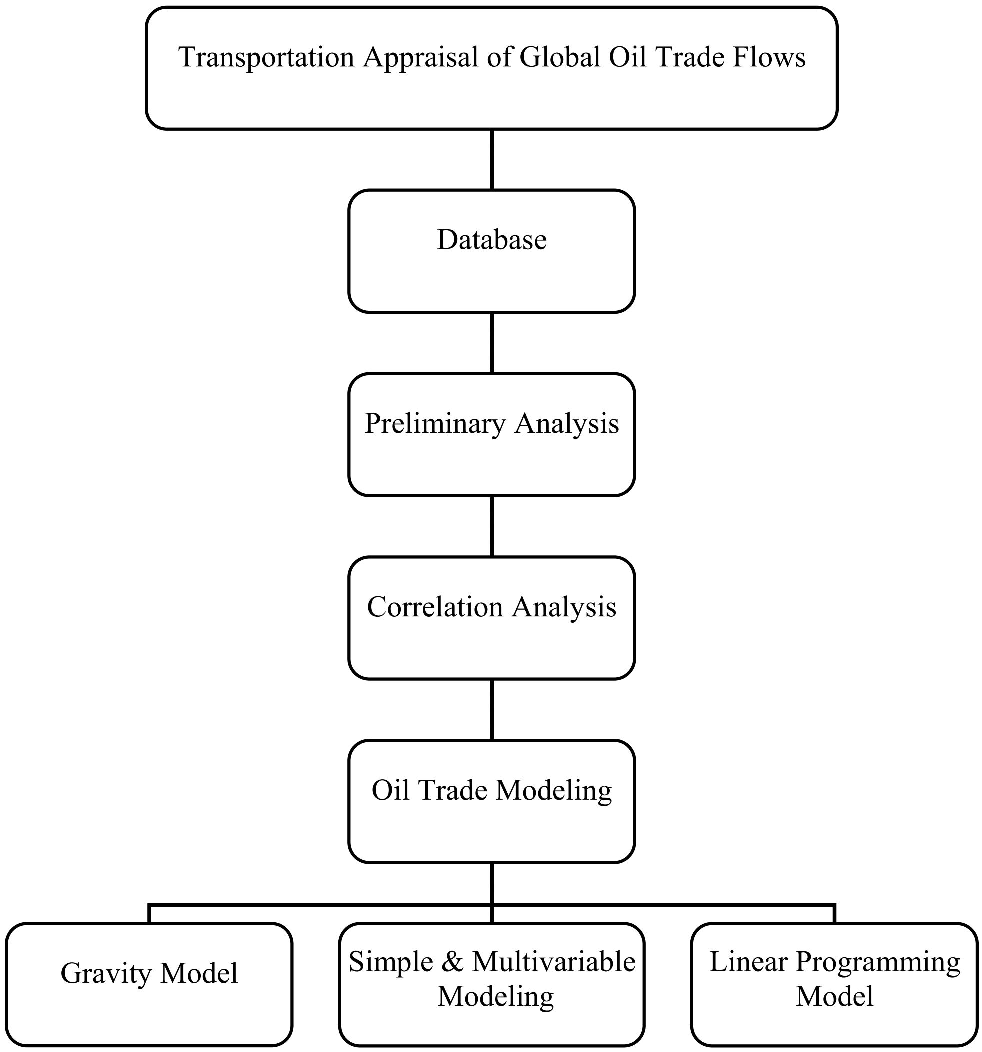

FIGURE 1 Framework of the research

DATABASE

The appraisal of global oil trade required establishing a conceptual framework for analysis and a corresponding set of definition and data. This section briefly introduces sources which were used to gather reliable information needed for purposes of this research. Considered variables of this research classified as four categories of trade, geographical, economical and political. Current section shortly discusses about each category, respective variables and their information resources. Finally, table 1 summarized the 20 considered variables in this research and their introductions. Also this table contains summary sign of variables, used for analyses and presentation.

Trade Category

The commodity structure of external trade flows of goods is analyzed using various internationally adopted commodity classification which have different levels of detail and are based on different classification criteria. The basic reason for applying a goods nomenclature is to be able to identify details of the commodities in order to satisfy a variety of purposes, including customs, statistical and analytical purposes, particularly for the presentation of external trade statistics with the most detailed commodity specifications (*3*).

For the purpose of this study, commodity code 2709, from HS2002 was selected. The Harmonized System (HS) is an internationally six-digit commodity classification and selected code is related to crude oil trade. So, the independent variable considered in this study, was the value or weight of oil trade transmitted between O/D pair. Relevant oil trade data were directly extracted from United Nations Commodity Trade Statistical Division's webpage, COMTRADE. Year 2003 was chosen as the base year for study and available oil trade data for 115 countries were collected (*4*). By this, four O/D matrixes, as trade value and weight of trade for oil exporting and importing, were created.

Geographical Category

Geographic variables indicate innate properties of countries which can affect the oil trade. These geographic variables consist of area, population, sea land lockness and country distances.

Area information was available for every country in the link presented in references section (*5*). Population data was extracted from centralized database of WDI 2002 on CD-ROM (*6*).

Distances of countries were considered in three networks. First network which known as air network, was straight distance of trade centers of countries like capitals and respective data were gathered from a distance measuring webpage (*7*). The second one, which known as Sea network, was marine distances between ports of countries and related data were collected from a maritime webpage (*8*). Third network was introduced as a multimodal network. In this network, expanse of countries was considered in freight distance as a possible effective factor. In this way, countries areas were assumed as an equivalent circle shape. So its radius would be calculated by simple equation of circular area and known as radius equivalent of country. Calculation process of radius equivalent and multimodal distance is presented in equation 1 and 2, respectively.

$$GRAEQ_i = \sqrt{\frac{GAREA_i}{\pi}} \tag{1}$$

$$GDCPC_{ij} = \sqrt{\frac{GAREA_i}{\pi}} + \sqrt{\frac{GAREA_j}{\pi}} + GDSEA_{ij} = GRAEQ_i + GRAEQ_j + GDSEA_{ij} \tag{2}$$

Where:

$GRAEQ_i$: Radius equivalent of country i, geographic variable

$GAREA_i$: Area of country i, geographic variable

$GDSEA_{ij}$: Sea distance of country i to j, geographic variable

$GDCPC_{ij}$: Multimodal distance of country i to j, geographic variable

Economical Category

Economical variables demonstrate economic properties of countries which can affect oil trade. Economical variables consist of gross domestic product, gross domestic product per capita based on energy use and two development indicators based on energy consumption.

Gross Domestic Product, GDP, is an aggregate measure of production equals to sum of the gross values added of all resident institutional units engaged in production (plus any taxes, and minus any subsides, on products not included in the value of their outputs). The sum of the final uses of goods and services (all uses except intermediate consumption) measured in purchaser's price, less the value of imports of goods and services, or the sum of primary incomes distributed by resident producer units (*9*). In this study GDP's data were extracted from centralized database of WDI 2002 on CD-ROM (*6*). Also, data of gross domestic product per capita, GDPP, per unit of energy use were collected from the same resource of GDP's data. There were five missed data for this variable that considered in database.

Development indicators based on energy consumption consists of 2 separate variables. These variables inform energy consumption of countries as a development indicator. First one informs amount of energy consumption in kilo ton of oil equivalent for country in one year. The second one gives energy consumption, kilogram of oil equivalent, per one dollar of GDP in one year. Data of these variables were extracted from a centralized database of UNCTAD Handbook of Statistics 2002 on CD-ROM (*10*). There were a few inaccessible data for these variables which considered in database.

Political Category

Political variables which are dummy variables consist of two oil organizations, one group of oil cooperation, a military organization and finally an organization for economic cooperation. If a country was a member of those groups or organizations, related variable had been assigned 1 and other hand assignment was zero.

Organization of Petroleum Exporting Countries, OPEC, is an oil organization and has an important role in global oil trade. OPEC members include Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

Organization of Arab Petroleum Exporting Countries, OAPEC, is an Arabic oil organization. OAPEC members include Algeria, Bahrain, Egypt, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, Syria and United Arab Emirates.

NON-OPEC members are the United States, Russia, Mexico, China, Canada, and North Sea countries Norway and the United Kingdom. These countries produce a large amount of oil and are rival OPEC countries.

Organization for Economic Cooperation and Development, OECD, is an economic organization and its members include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

The North Atlantic Treaty Organization, NATO, is a military organization and its members consist of Belgium, Bulgaria, Canada, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Iceland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Turkey, United Kingdom, and United States.

Finally data of 20 variables for 115 countries were gathered in research database. Research database was created in Excel 2003. All the analysis in next sections were based on this database.

TABLE 1 Introduction of variables and their signs

No.	Class	Symbol	Description
1	Trade	$TODIM_{ij}$	Trade, oil, dollar, import, i to j
2		$TOWIM_{ij}$	Trade, oil, weight, import, i to j
3		$TODEX_{ij}$	Trade, oil, dollar, export, i to j
4		$TOWEX_{ij}$	Trade, oil, weight, export, i to j
5	Geographical	$GAREA_i$	Geographic, area, i
6		$GPOPU_i$	Geographic, population, i
7		$GDAIR_{ij}$	Geographic, distance, air, i to j
8		$GDSEA_{ij}$	Geographic, distance, sea, i to j
9		$GDCPC_{ij}$	Geographic, distance, center to port to port to center, i to j
10		$GRAEQ_i$	Geographic, equivalent radius, i
11		$GSLLN_i$	Geographic, sea land lockness, i
12	Economical	$ECGDP_i$	Economic, GDP, i
13		$EGUEU_i$	Economic, GDPP per unit of energy use, i
14		$EDIEC_i$	Economic, development indicators, energy consumption, i
15		$EDIECG_i$	Economic, development indicators, energy consumption, GDP, i
16	Political	$POPEC_i$	Political, OPEC, i
17		$PNOPEC_i$	Political, NON-OPEC, i
18		$POAPEC_i$	Political, OAPEC, i
19		$POECD_i$	Political, OECD, i
20		$PNATO_i$	Political, NATO, i

i: Country i, origin
j: Country j, destination
ij: Country i to country j, port to port or capital to capital

PRELIMINARY STATISTICAL ANALYSIS

In order to investigate the variables statistically and recognize properties of collected data, this section focused on preliminary statistical analysis. First of all, 20 Variable of this research were divided into 13 vector and 7 matrix variables. Dimensions of 13 vector variables were 115 which were equaled with number of considered countries in this study. Matrix variables which were belonged to trade and country distances had 115×115 dimension. Table 2 shows obtained results from preliminary statistical analysis. It is contained of dimension of each variable, minimum, maximum, mean, number of accessible data, standard deviation and coefficient of variation. It was observed that trade data had more variation when compared with the others variables. Geographic variables and specially sea land lockness showed minimum coefficient of variation.

TABLE 2 Preliminary statistical analysis results

No.	Description	Dimension	Min	Max	Mean	Standard deviation	Number of accessible data	Coefficient of variation, CV
1	$TODIM_{ij}$	\$/Year	0	18220.95×10^6	35305164	400444208.33	13108	11.342
2	$TOWIM_{ij}$	Kg/Year	0	86519.65×10^6	162702614	1926847032.98	13110	11.842
3	$TODEX_{ij}$	\$/Year	0	25657.97×10^6	33986060	425362831.61	13106	12.515
4	$TOWEX_{ij}$	Kg/Year	0	77509.02×10^6	154897494	1869804945.73	13110	12.071
5	$GAREA_i$	Km^2	193	17075200	994263.3	2421250.5	115	2.435
6	$GPOPU_i$	Person	109937	1296696481	49464223.5	159413373	115	3.222
7	$GDAIR_{ij}$	Km	60	19845	7204.5	4519.85	13110	0.627
8	$GDSEA_{ij}$	Km	26	25000	9758.8	5300.37	13110	0.543
9	$GDCPC_{ij}$	Km	177.2	25879.7	10536.4	5383.91	13110	0.510
10	$GRAEQ_i$	Km	7.8	2331.39	388.77	408.41	115	1.050
11	$GSLLN_i$	-	0	1	0.878	0.328	115	0.373
12	$ECGDP_i$	\$/Year	267×10^6	11129706×10^6	303406×10^6	1175098.6×10^6	115	3.873
13	$EGUEU_i$	PPP \$ per Kg of Oil Equivalent	0.5	12.881	4.772	2.461	110	0.515
14	$EDIEC_i$	KTOE	829.48	2419484.83	90843.290	269723.103	110	2.969
15	$EDIECG_i$	Kg OE per 1\$ of GDP	0.0775	2.9684	0.6266	0.5379	105	0.858
16	$POPEC_i$	-	0	1	0.0956	0.295	115	3.085
17	$PNOPEC_i$	-	0	1	0.0608	0.240	115	3.947
18	$POAPEC_i$	-	0	1	0.086	0.2401	115	2.791
19	$POECD_i$	-	0	1	0.217	0.414	115	1.907
20	$PNATO_i$	-	0	1	0.252	0.431	115	1.710

CORRELATION ANALYSIS

In order to have a good judgment about results of modeling and have initial information about relationship of two variables, correlation analysis would be seemed needful. Correlation analysis and its coefficient are used to measure the strength of the relationship between two variables ,but do not quantify it. The correlation coefficient can provide the basis for further analysis designed to determine a causal relationship. The correlation coefficient varies from -1 to +1 which -1 means an inverse and +1 means linear relationship between variables. Zero value for correlation coefficient of two variables, shows no relationship between them (*11*).

Correlation analysis in this research was performed by SPSS which is statistical software in three steps. In first step correlation of vector variables was surveyed. Correlation of matrix variables was perused in second step. In third step correlation of trade variables as dependent variables, to other variables as independent variables, was appraised. So three set of results were obtained and summarized for here usage.

Firstly, table 3 shows what amount of basic categories of variables had significant correlation to each other. It could be seen that trade and geographic variables had the most amount of relation to each other when compared with the other category pairs. Inversely, geographical and political categories had shown less relation among other pairs.

TABLE 3 Summary correlation analysis results for categories

	Trade	**Geographical**	**Economical**	**Political**
Trade	100%	80%	59.1%	63.73%
Geographical	80%	69.09%	56.70%	54.26%
Economical	59.1%	56.70%	33.33%	70.51%
Political	63.73%	54.26%	70.51%	50.00%

Table 4 shows the results of last step correlation analysis. In this table, N.S is sign of "Not Significant" phrase. Correlation analysis showed that area, sea land lockness, population and GDP of importers & exporters, development indicator based on energy consumption, development indicator based on energy consumption for 1 $ of GDP of exporters, membership of exporters in OPEC, OAPEC, and NON-OPEC, membership of importers in NATO and OECD had positive effect on increscent of oil trade. In the other hand, some of the variables such as country distances, development indicator based on energy consumption for 1 $ of GDP of importers, GDPP based on energy use of exporters and some political memberships had negative effect on increscent of oil trade.

For summary of this section, it could be seen that among variables GDP and energy consumption of countries had a significant correlation with trade variables and affected trade positively. Also, it should be noticed that distance variables had negative correlation with trade variables and their significance were appropriate. As a result of these analyses, global oil trade could be described with GDP and distance variables.

TABLE 4 Correlation analysis results

Variable	TODEXij	TOWEXij	TODIMij	TOWIMij
GAREAi	0.069(**)	0.078(**)	0.092(**)	0.089(**)
GAREAj	0.085(**)	0.088(**)	0.084(**)	0.087(**)
GPOPUi	N.S	N.S	0.079(**)	0.076(**)
GPOPUj	0.072(**)	0.077(**)	N.S	N.S
GDAIRij	-0.051(**)	-0.051(**)	-0.055(**)	-0.052(**)
GDSEAij	-0.054(**)	-0.054(**)	-0.059(**)	-0.056(**)
GDCPCij	-0.042(**)	-0.041(**)	-0.045(**)	-0.042(**)
GRAEQi	0.073(**)	0.080(**)	0.089(**)	0.086(**)
GRAEQj	0.081(**)	0.084(**)	0.085(**)	0.086(**)
GSLLNi	0.023(**)	0.024(**)	0.024(**)	0.022(*)
GSLLNj	0.021(*)	0.021(*)	0.026(**)	0.025(**)
ECGDPi	0.233(**)	0.229(**)	0.247(**)	0.243(**)
ECGDPj	0.243(**)	0.245(**)	0.237(**)	0.236(**)
EGUEUi	-0.040(**)	-0.044(**)	N.S	N.S
EGUEUj	N.S	N.S	-0.045(**)	-0.046(**)
EDIECi	N.S	0.019(*)	0.227(**)	0.224(**)
EDIECj	0.222(**)	0.226(**)	0.034(**)	0.030(**)
EDIECGi	0.029(**)	0.037(**)	-0.054(**)	-0.050(**)
EDIECGj	-0.049(**)	-0.048(**)	0.036(**)	0.038(**)
POPECi	0.101(**)	0.108(**)	-0.025(**)	-0.024(**)
POPECj	-0.023(**)	-0.024(**)	0.113(**)	0.109(**)
PNOPECi	0.076(**)	0.082(**)	0.104(**)	0.102(**)
PNOPECj	0.099(**)	0.102(**)	0.089(**)	0.087(**)
POAPECi	0.065(**)	0.069(**)	-0.025(**)	-0.024(**)
POAPECj	-0.023(**)	-0.024(**)	0.074(**)	0.072(**)
POECDi	N.S	N.S	0.105(**)	0.100(**)
POECDj	0.099(**)	0.100(**)	N.S	N.S
PNATOi	N.S	N.S	0.074(**)	0.071(**)
PNATOj	0.073(**)	0.072(**)	N.S	N.S

*** Correlation is significant at the 0.01 level (2-tailed)*

** Correlation is significant at the 0.05 level (2-tailed)*

OIL TRADE MODELING

After data gathering, a database was created containing all dependent and independent variables. There were 4 dependent variables as trade category and 16 independent variables as other three categories. Preliminary analysis was performed to give some initial information about variables properties and their relationship. Here, it's necessary to explain the steps of oil trade modeling. This section consists of four modeling parts: simple modeling, multivariable modeling, gravity model and linear programming model. Except linear programming, all models were developed using SPSS software. By inserting database in the software, SPSS was used to create linear models using different variables. All models created by this software treated the missing values listwise. Simple models were created using Curve Estimate method. Multivariable models were created by Stepwise method. Finally gravity models were built using Enter method by SPSS software.

For LP model, MATLAB software was used. By writing a program which was exerted in software, LP problem solved using Simplex method.

Simple Modeling

The aim of simple modeling was to develop oil trade models with a single independent variable, using Curve Estimate method by SPSS. After evaluating the results, form of modeling which could describe oil trade better, was recognized. Then selected form in simple modeling was used for multivariable modeling. Evaluation criteria were goodness of model known as R^2, significance of independent variable in model, sign of coefficient for independent variable in model according to correlation analysis results, and constant of model investigation. In this way, for each one of four dependent variables, considering twenty nine independent variables, eleven form of model were built and appraised. By evaluation of 1276 models which were built here, power form was selected among eleven form of modeling. Table 5 shows 11 form of modeling, for oil export values, $TODEX_{ij}$, based on air straight distance of countries, $GDAIR_{ij}$, as a sample. In Logistic model, u is positive number and should be more than maximum values of dependent variable.

TABLE 5 Example of simple modeling process

No	Model form	Model R^2	Parameter estimates				Equation $TODEX_{ij}$: y $GDAIR_{ij}$: x
			Constant		Independent coefficient		
			α	t	β	t	
1	Linear	0.004	2.85E+08	7.946	-14615.62	-2.9	$y = \alpha + \beta \times x$
2	Logarithmic	0.003	6.82E+08	3.801	-58.2E+06	-2.69	$y = \alpha + \beta \times Ln(x)$
3	Inverse	0.001	1.83E+08	7.519	389.3E+08	1.74	$y = \alpha + \beta / x$
4	Quadratic	0.004	2.61E+08	5.278	-3933.99	-0.24	$y = \alpha + \beta_1 \times x + \beta_2 \times x^2$
					-0.72	-0.71	
5	Cubic	0.004	2.72E+08	4.086	-13010.10	-0.33	$y = \alpha + \beta_1 \times x + \beta_2 \times x^2 + \beta_3 \times x^3$
					0.683	0.124	
					-5. E0-5	-0.26	
6	Compound	0.130	14.03E+06	6.951	1.000	49559	$Ln(y)=Ln(\alpha)+ Ln(\beta) \times x$
7	Power	0.124	5480.8E+08	1.384	-1.532	-17.6	$Ln(y)=Ln(\alpha)+ \beta \times Ln(x)$
8	S	0.036	13.961	136.0	858.257	9.10	$Ln(y)=\alpha+\beta/x$
9	Growth	0.130	16.457	114.3	.000	-18.1	$Ln(y)=\alpha+\beta \times x$
10	Exponential	0.130	14.03E+06	6.951	.000	-18.1	$Ln(y)=Ln(\alpha)+\beta \times x$
11	Logistic	0.130	7.13E-008	6.951	1.000	49559	$Ln(1/y-1/u) =Ln(\alpha)+Ln(\beta) \times x$

Multivariable Modeling

In previous section, power form was recognized as the most appropriate form for oil trade modeling. After that, multivariable models were built in form of power, using Stepwise method by SPSS. In this method all independent variables were include for modeling development. The SPSS selected independent variable based of probability values of F, step by step. At each step, the independent variable which is not in the equation and has the smallest probability of F is entered, if that probability is sufficiently small. Variables already in the regression equation are removed if their probability of F becomes sufficiently large. The method terminates when no more variables are eligible for inclusion or removal. Models were built two times according to existence of dummy variables. Except Power form, Linear form was considered, too. So, 16 models were developed in this section. Table 6 shows example results of this section. It was found that some independent variables such as GDP, distance and energy consumption were included in initially steps of modeling. This demonstrates the significance of these variables in developing models for global oil trade. Also political variables were included in models and showed their role in global oil trade, as could be seen in table 6.

TABLE 6 Example of multivariable modeling in form of Power

No	Description	R^2	Model
1	Power	$R^2=0.629$	$TODEXij = \frac{10^{4.927} \times ECGDPj^{0.572} \times ECGDP_i^{0.435} \times 10^{1.136POPECi} \times GRAEQi^{0.512}}{EGUEUi^{2.111} \times GDAIRij^{1.14} \times 10^{0.782POAPECj} \times GAREAj^{0.143}} \times \frac{GPOPUi^{0.256} \times 10^{0.42GSLLNj} \times EDIECj^{0.457} \times 10^{0.286PNOPECi} \times 10^{0.333GSLLNi}}{10^{0.33PNATOj} \times 10^{0.38POPECj} \times GDCPCij^{1.293} \times EDIECGi^{0.697} \times 10^{0.328POECDi}}$
2		$R^2=0.631$	$TODIMij = \frac{10^{3.907} \times 10^{0.679POPECj} \times 10^{0.513PNOPECj} \times GRAEQj^{0674} \times 10^{0.727GSLLNi} \times ECGDPi^{0.803}}{EGUEUj^{2.918} \times 10^{0.685POPECi} \times GDAIRij^{0.722} \times GRAEQi^{0.312}} \times \frac{EDIECi^{1.922} \times 10^{0.489POAPECj} \times ECGDPj^{1.333} \times GPOPUj^{0.513}}{GDCPCij^{1.746} \times EDIECGi^{1.064} \times 10^{0.342POECDj} \times EDIECj^{1.521} \times 10^{0.671POAPECi} \times 10^{0.198PNATOi}}$
3	Power, without dummy	$R^2=0.768$	$TODEXij = \frac{10^{8.070} \times GRAEQi^{0.698} \times GPOPUi^{0.246} \times EDIECj^{0.983}}{EGUEUi^{1.978} \times GDAIRij^{0.929} \times GDCPCij^{1..315} \times EDIECGj^{0.596} \times GAREAj^{0.116}}$
4		$R^2=0.791$	$TODIMij = \frac{GAREAj^{0.472} \times ECGDPj^{2.93} \times GPOPUi^{0.272}}{ECGDPi^{1.748} \times EGUEUj^{2.314} \times GDCPCij^{1.819} \times GRAEQi^{0.416}} \times \frac{EDIECi^{2.687} \times EDIECGj^{2.333}}{EDIECj^{2.737} \times EDIECGi^{2.138} \times GDAIRij^{0.487}}$

Gravity Model

The gravity model of international trade was developed independently by Tinbergen (1962) and Pöyhönen (1963). In its basic form, the amount of trade between two countries is assumed to be increasing in their size, as measured by their national incomes, and decreasing in the cost of transport between them, as measured by the distance between their economic centers (*12*). In this study, this model was used as the empirical model. Here, it was decided that some independent variables to describe trade between any O/D pair in the study network and insert them to the gravity model. The original Gravity model is presented in equation 3. The log form of this function has a linear form as presented in equation 4.

$$T_{ij} = G \times \frac{M_i^{\eta} \times M_j^{\theta}}{D_{ij}^{\rho}} \quad (3)$$

$$Ln(T_{ij}) = \alpha + \beta Ln(M_i) + \gamma Ln(M_j) - \lambda Ln(D_{ij}) + \varepsilon \quad (4)$$

Where:
T_{ij}: Trade between two counties
M_i & M_j: Size of countries, measured such as national incomes, GDP, population
D_{ij}: Distance between countries
Other coefficient are constant numerical

In this research GDP was chosen as economic size of countries and oil trade was appraised in three transportation networks. Transportation costs were assumed constant and equal with distance of countries. For creation of gravity models all variables except trade, GDP and distance variables, were excluded and models were built using Enter method by SPSS. By models developing, GDP of exporter and importer countries were found as a significant variable in description of global oil trade. Table 7 shows example results of this section. Therefore it was obtained that GDP and distances between trade partners were significant variables and gravity model could be applied for describing oil trade flows. GDP as a measurement of economic size and power of countries increased oil consumption. Inversely, distance and transportation costs decreased tendency of trade.

TABLE 7 Example of gravity models

No.	R^2	Model
1	0.664	$TODEXij = 10^{3.535} \frac{ECGDPi^{0.448} \times ECGDPj^{0.788}}{GDAIRij^{1.660}}$
2	0.741	$TODIMij = 10^{2.480} \frac{ECGDPi^{0.883} \times ECGDPj^{0.683}}{GDAIRij^{1.660}}$
3	0.672	$TODEXij = 10^{3.456} \frac{ECGDPi^{0.648} \times ECGDPj^{0.777}}{GDAIRij^{1.549}}$
4	0.755	$TODIMij = 10^{2.573} \frac{ECGDPi^{0.873} \times ECGDPj^{0.713}}{GDSEAij^{1.599}}$
5	0.661	$TODEXij = 10^{4.551} \frac{ECGDPi^{0.689} \times ECGDPj^{0.796}}{GDCPCij^{1.850}}$
6	0.744	$TODIMij = 10^{3.589} \frac{ECGDPi^{0.6900} \times ECGDPj^{0.810}}{GDCPCij^{1.900}}$

Linear Programming Model

Linear Programming, LP, is an important field of optimization for several reasons. Many practical problems in operation research can be expressed as LP problems. Certain special cases of LP, such as network flow problem and multi commodity flow problems are considered important enough to have generated much research on specialized algorithms for their solution. Historically, ideas from linear programming have inspired many of the central concepts of optimization theory, such as duality, decomposition, and the importance of convexity and its generalizations. Likewise, linear programming is heavily used in microeconomics and business management, either to maximize the income or minimize the costs of a production scheme (*1*3). Transportation problem as a LP model is presented in equations 5 to 8.

$$\text{Min } Z = \sum_{i=1}^{I}\sum_{j=1}^{J} t_{ij} d_{ij} \qquad (5)$$

$$\sum_{j=1}^{J} t_{ij} \le s_i \qquad \text{for } i = 1,\ldots I \qquad (6)$$

$$\sum_{i=1}^{I} t_{ij} \ge r_j \qquad \text{for } j = 1,\ldots J \qquad (7)$$

$$t_{ij} \ge 0 \qquad \text{for } i = 1,\ldots I \text{ and } j = 1,\ldots J \qquad (8)$$

Where:
Z: Total transportation costs
t_{ij}: Trade between two counties
s_i: Oil Production capacity of exporter country
r_j: Oil demand of importer country
d_{ij}: Distance between countries

For this part of study MATLAB software was used to solve LP problem. By writing a program for this purpose, the sum of each row and column in the O/D matrix of trade were calculated as supply and demands limitation (s_i and r_j in equations 6 and 7). Coefficients of variables in constraint were created by program (coefficient of t_{ij} in equations 6 and 7) in 0-1 matrix. So this program had 230 constraints (115+115). As mentioned before, transportation costs were assumed equal to distance between each O/D pair. Number of coefficient of objective function (d_{ij} in equation 5) was equal to 13225 (115×115). It is obvious that distance of country to itself was assumed zero and also there was not any trade for them.

Optimized distribution was obtained from solving LP program and then optimized distribution was compared with observed distribution. Comparison criteria were value of objective function which known as total transportation costs. Therefore, 12 LP were solved in this section for 4 observed oil trade distribution in 3 transportation networks. Table 8 shows result of LP model for global oil trade. In this table kind of oil trade in network and percentage of improvement in total transportation cost are mentioned. Best improvement in distribution was found in sea network around one third of total transportation cost in objective function. Improvements of multimodal and air networks were found same around. So, possibility of improvement in transportation costs for global oil trade was found in this section.

TABLE 8 Linear programming model results

No.	Model	Unit	Z-Obs.	Z-Est.	Improvement percentage
1	TODEXij & GDAIRij	US$-Km	1.92863×10^{15}	1.47931×10^{15}	23.30%
2	TODEXij & GDSEAij	US$-Km	2.75362×10^{15}	1.97741×10^{15}	28.19%
3	TODEXij & GDCPCij	US$-Km	3.44784×10^{15}	2.66204×10^{15}	22.79%
4	TOWEXij & GDAIRij	Kg-Km	9.08735×10^{15}	6.91134×10^{15}	23.95%
5	TOWEXij & GDSEAij	Kg-Km	12.9089×10^{15}	9.19788×10^{15}	28.75%
6	TOWEXij & GDCPCij	Kg-Km	16.1300×10^{15}	12.3475×10^{15}	23.45%
7	TODIMij & GDAIRij	US$-Km	2.03944×10^{15}	1.57830×10^{15}	22.61%
8	TODIMij & GDSEAij	US$-Km	2.88585×10^{15}	2.04665×10^{15}	29.08%
9	TODIMij & GDCPCij	US$-Km	3.61713×10^{15}	2.77793×10^{15}	23.20%
10	TOWIMij & GDAIRij	Kg-Km	9.44068×10^{15}	7.3655×10^{15}	21.98%
11	TOWIMij & GDSEAij	Kg-Km	13.3786×10^{15}	10.1343×10^{15}	24.25%
12	TOWIMij & GDCPCij	Kg-Km	16.8085×10^{15}	13.5426×10^{15}	19.43%

CONCLUSION

In this paper, global oil trade flows were studied and the effects of sixteen independent variables on this trade were appraised. For this purpose, three categories of geographical, economical and political variables in addition to trade category were considered in database. Accessible and relevant oil trade data for 115 countries were collected in O/D pair matrix as four trade dependent variables. Properties of countries, three mentioned categories, were extracted from various resources and gathered in independent variables. By creating database and analyzing it some results were obtained that would be discussed in this section.

Firstly, oil trade variables had higher variation when compared with the other categories and reversely, geographic variables showed lower variation in analysis. Then, by investigation of correlation analysis results, it was found that gross domestic product, GDP, development indicator based on energy consumption, and distance of countries were significant variables in describing oil trade. Moreover, trade and geographical variables demonstrated more correlation when compared with the other pairs. Reversely, political and geographical variables showed minimum correlation in comparison of the other pair categories.

For oil trade modeling, simple models which were created in form of power, gave more reliable results. In addition, it was found that some independent variables such as GDP, distance and energy consumption were the significant variables in developing models for oil trade. Also in this study, important role of political variables in oil trade modeling was observed according to initial expectation. Political variables such as OPEC and OECD were significant variables in describing oil trade.

It was obtained that GDP of exporter and importer countries and distances between trade partners were significant variables and gravity model could be applied for describing oil trade flows. GDP as a measurement of countries economic size increased oil trade. Inversely, distance and transportation costs decreased tendency of trade.

The maximum improvement in total transportation costs for observed distributions was found in sea network up to one third of total transportation costs. Oil trade distribution in multimodal and air network showed possibility of around the same improvement in total transportation costs optimization. It means possibility of improvement in total transportation costs for global oil trade.

Although oil trade is a very complicate trade and so many unknown factors like political relationships affect on it, but this research showed that by some accessible data like GDP and freight distance which were found as significant variables in oil trade models, it's possible to create descriptive models for oil trade and appraise its global distribution.

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