

ANKARA YILDIRIM BEYAZIT UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES



**EVALUATION OF MULTI-OBJECTIVE CLOSED LOOP SUPPLY
CHAIN NETWORK INTEGRATED WITH BLOCKCHAIN FOR USED
LUBRICATION OILS OBTAINED FROM VEHICLES IN MILITARY
FORCES BY THE LINEAR PROGRAMMING**

M.Sc. Thesis by
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January, 2019

ANKARA

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By

Mustafa Burak ÖZDEMİR

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M.Sc. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled “**EVALUATION OF MULTI-OBJECTIVE CLOSED LOOP SUPPLY CHAIN NETWORK INTEGRATED WITH BLOCKCHAIN FOR USED LUBRICATION OILS OBTAINED FROM VEHICLES IN MILITARY FORCES BY THE LINEAR PROGRAMMING**” completed by M. Burak ÖZDEMİR under the supervision of ASSIST. PROF. DR. ABDULLAH YILDIZBAŞI and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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Mustafa Burak ÖZDEMİR

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ABSTRACT

This thesis focuses on possible a solution about the Multi-objective Closed Loop Supply Chain Network which is integrated with Blockchain was designed for reduced costs and be provided visibility in the supply chain. Our first objective function is to reduce the cost by minimizing the amount of lubrication oil that purchase from the outside. Other objective function is to minimizing the environmental damage caused by used lubricating oil. We used the traceability and transparency features of Blockchain technology to reduce costs. We tried to reduce production and transfer costs by making these properties a parameter. The network is converted into the mathematical model and the mathematical model is solved with GAMS-CPLEX package program, the results of the long-term solution of the system solved by linear programming methods were evaluated.

Keywords: Closed loop supply chain network and blockchain integration, military forces, crypto currency, used lubrication oils, blockchain technology, environmental damage.

SİLAHLI KUVVETLERDE İHTİYAÇ DUYULAN YAĞLAMA YAĞLARININ BLOKZİNCİRLE BÜTÜNLEŞTİRİLMİŞ KAPALI ÇEVİRİM TEDARİK ZİNCİRİNDE ÇOK AMAÇLI LİNEER PROGRAMLAMA İLE DEĞERLENDİRİLMESİ

ÖZ

Bu tez çalışması, ülkelerin silahlı kuvvetleri için ihtiyaç duyulan yağlama yağı maliyetlerin düşürülebilmesi amacıyla, Blockchain ile bütünleştirilmiş olan Çok Amaçlı Kapalı Döngü Tedarik Zinciri Ağı üzerinde tasarlanmıştır. İlk amaç fonksiyonumuz, dışarıdan satın alınan yağlama yağı miktarını en aza indirerek maliyetleri düşürmektir. Diğer amaç fonksiyonumuz ise, kullanılmış yağlama yağının neden olduğu çevresel zararın en aza indirilmesidir. Maliyetleri azaltmak için Blockchain teknolojisinin izlenebilirlik ve şeffaflık özellikleri kullanılmıştır. Bu özellikler bir parametre olarak modele eklenmiş, busayedeüretim ve transfer maliyetleri düşürülmeye çalışılmıştır. Ağ matematiksel modele dönüştürülmüş ve matematiksel model GAMS-CPLEX paket programı ile çözülmüştür, Doğrusal programlama yöntemleriyle çözülen sistemin uzun vadeli çözümünün sonuçları değerlendirilmiştir.

Anahtar Kelimeler: Kapalı çevrim tedarik zinciri ağı ve blok zinciri entegrasyonu, silahlı kuvvetler, kripto para birimi, kullanılmış yağlama yağı, blok zinciri teknolojisi, çevresel zarar.

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NOMENCLATURE

Roman Letter Symbols

q	Set of lube oil suppliers
f	Set of distribution centers
i	Set of users
d	1st class oil collection center
b	2nd class oil collection center
c	3rd class oil collection center
k	Set of recycling plants
g	Set of disposal centers
p	Set of period
H	Lube oil raw material (Tons)
A	Lube oil (Tons) sent to distribution center,
Z	Lube oil (Tons) sent to user,
U	Used lube oil (Tons) sent to 1st class oil collection center
V	Used lube oil (Tons) sent to 2nd class oil collection
T	Used lube oil (Tons) sent to 3rd class oil collection center
W	Used lube oil (Tons) sent to the recycling center,
X	Used lube oil (Tons) sent to 2nd class oil collection center,
Y	Used lube oil (Tons) sent to 3rd class oil collection center,
S	Not recycled used lube oil (Tons)
L	Recycled used lube oil (Tons),
t	The lube oil (Tons) capacity of factory,
h	Raw material capacity (Tons),
b	The distribution center storage capacity (Tons)
d	The user demand (Tons)
T	Unit cost of transportation (\$),

Greek Letter Symbols

α	1st class oil acquisition rate,
β	2nd class oil acquisition rate,
γ	3rd class oil acquisition rate,
ρ	Recycle rate from 1st class oil,
θ	Not Recycled rate from 1st class oil,

σ	Recycle rate from 2nd class oil,
τ	Not recycled rate from 2nd class oilc,
μ	recycle ratio from 3rd class oil
φ	not recycled rate from 3rd class oil

Acronyms

ds	1st class oil collection center d storage capacity (Tons),
bs	2nd class oil collection center b storage capacity (Tons),
cs	3th class oil collection center c storage capacity (Tons)
rcs	The recycling center capacity (Tons)
DIS	The distance (km)
qq	The maximum number of factory
dd	The maximum number of 1st grade oil collection center
bb	The maximum number of 2nd grade oil collection,
cc	The maximum number of 3rd grade oil collection center,
kk	The maximum number of a recycling center
BCT	Discount rate on the transportation cost of the blockchain use,
BC	Discount rate on money transfer cost of blockchain use, (Bitcoin use)
BCO	Discount rate on production costs of blockchain use,
ZCVR	Transportation damage to the environment,
COST	Lube oil price (\$),
rcost	The recycling center set up cost (\$),
rrcost	reCycling cost of 1 TON used lube oil (\$),

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CHAPTER 1

INTRODUCTION

Today's technology has made it necessary to use defensive devices with high mobility and high impact powers. Tanks, armored personnel carriers, and heavy tactical wheeled vehicles are at the forefront of vehicles that are indispensable for high protection and maneuverability in a battle environment. In addition to these, light tactical wheeled vehicles are used intensively in order to provide the necessary logistic support for the continuity of the operation. There are a number of needs for the smooth transition of vehicles. These needs need to be supplied and used from the time of peace. At the beginning of these are fuel and lubricants. Fuel is a material that is constantly spent and constantly integrated to move the vehicle. After use, it provides the movement energy of the vehicle, and as a residue, a gaseous material is given to the atmosphere. The lubricants used for vehicles are an auxiliary material that can be used for a long time to work efficiently and give the best performance. All of these vehicles require oil to lubricate machine parts found in their structures. The demand for petroleum is also increasing due to the increase in the amount of machinery and vehicles produced in the defense industry.

In addition, products of petroleum origin create great damage in the soil ecosystem. This is due to the fact that these substances are often described as potentially carcinogenic and mutagenic. Biological degradation of petroleum-derived hydrocarbons in the soil accumulation, enzyme activity and microorganism causes changes in biological parameters such as the presence.

The treatment of oil contaminated soils is very expensive and difficult and requires a long time. Oil affects the soil structure by dispersing the soil crumbs, thus disrupting the air and water economy of the soil. It covers the surface of humus and clay which is the soil colloids and decreases the capacity (adsorption capacity) of these nutrients and thus causes the deterioration of nutrient ion balance in soil. Mineral oil residual oil (30-40 years), which is the petroleum product, is so dangerous that the oil residence time (more than 70 years) is too long. Therefore, petroleum-derived

hydrocarbon concentrations should be determined and monitored in the removal of pollution. The content of crude oil contains high levels of metal and heavy polycyclic aromatic hydrocarbons (PAH) [1]. It was found that a large part of the PAHs were polluted by the environment and had a negative effect on the biological balance. PAHs and petroleum and petroleum derivatives, which significantly affect the biological balance due to their pollutant properties, are very important in terms of environmental cleanliness, environment and applied microbiology.

Supply time and costs will be reduced by the use of the Blockchain approach to determine which lubrication oils are needed in the area in which the lubricating oil is needed in which region in the same time, it is considered that the use of the blockchain system to determine the oil needed to be purchased and the oil that the recycling plant needs to produce and the shortest distance and cost of the transportation roads to be used in the recovery of used lubricating oils will decrease the costs. In addition to these benefits, Bitcoin, a product of the Blockchain system, can cover all the costs that need to be paid during the treatment, by reducing the amount of subsidies to the third party, especially the banks used in money transfers, and reducing the costs to a significant level.

The global market potential for petroleum products and derivatives is expected to increase over the coming years. According to statistics, the global oil market is estimated to reach 12.4 billion gallons by 2020 [2]. For this reason, there is an increasing use of the reverse logistics supply chain for the recycling of petroleum products to meet the demands. This work focuses on the sustainable supply chain management integrated with blockchain of lubrication oil within the military forces. Since lubrication oil is one of the most important petroleum products and it will be difficult to reach the raw materials during the war and the countries can encounter many obstacles and problems such as natural disasters, damage of transportation line and damage of pipelines to supply the raw materials.

A supply chain integrated with blockchain consists of a network which has the supplier, the distributor, and the producer. The supply chain is aimed at bringing products and services to the markets. Reverse logistics starts with the collection of used product. Used products are collected and checked; recycling through exceeding

such as the regeneration and disposal are to introduce a reuse on reverse logistics. The system which is forms with Reverse supply chain and the forward supply chain is defined as a closed loop supply chain. The closed loop supply chain integrated with blockchain also sets out the design that companies need to build a sustainable system. Closed cycle a supply chain requires the creation of a system to maximize profitability over a lifetime from a product [3]. A Blockchain system executes, verifies, and collects and stores data in blocks. Every block has a reference to at least one predecessor, hence the term blockchain. Blockchains are deployed and are allowed for new type distributed applications. A key interest in the financial sector to utilize blockchain is to automate and digitalize processes, especially with the participation of multiple stakeholders. Automated processes can save money and many new ventures believe that these cost savings can also be applied in other areas [4].

At this point, companies try to recycle their used products and put them back into the system as input. In order to build such a chain, reverse logistics networks, as well as reverse supply chains, must be implemented. Companies simultaneously implement these applications and the Blockchain system to be able to follow up to the extreme points under transparency. In addition, increased awareness of environmental pollution has led to the emergence of concepts such as green and sustainable supply chains. Nowadays, customers take into consideration the damage that the products give to the environment as well as the quality. As a result, not only logistics systems are concerned with the economic impacts on the organization that carries them, but also with the wider impacts on society, such as the effects of pollution on the environment [5].

In this study, it is aimed to create a sustainable supply chain integrated with Blockchain by reusing lubricating oils that are produced in the military forces' vehicles by processing them in recycling facilities and to reduce the lubricating oils costs which should be paid for military forces' vehicles by the countries for a long period of time like 20 years. In addition, efforts have been made to minimize the harm that is caused by the waste lubricating oils on the environment. For this purpose, firstly the literature review of waste oil's CLSC and literature review of the

supply chain integrated with Blockchain were done. After that information about Blockchain, CLSC and waste oil recycling systems was given. Later, a closed loop supply chain integrated with Blockchain was established for a sustainable system involving the supply of lubricant needed for the military forces. The mathematical model of lube oil's Close loop Supply Chain integrated with Blockchain for Military Force, which is established as multi-period, single object and multipurpose, is modeled and the results of the long-term solution of the system solved by linear programming methods and the obtained result were evaluated.



CHAPTER 2

LITERATURE REVIEW

2.1 The Waste Oil's SSCM

Mohammad Mahdi Paydar and his colleagues (2017) studied the motor oil collection and distribution process from one of the most valuable natural sources. A mixed integer linear programming model for the closed loop supply chain of the used motor oil was presented and implemented on a petroleum refinery company to check the model's accuracy. Two objective functions have been taken into account in maximizing profits and minimizing the risk of the collection in this study. An extended-constraint approach was used in solving the two objective models. The mathematical model was solved using LINGO 15.0 [6].

The problem of modeling the reverse logistics processes within a closed loop supply chain of the palm oil industry is addressed by Edgar H. Alfonso-Lizarazo and his colleagues (2013). A mathematical model with a closed-loop supply chain was established and evaluated using realistic data from the industrial sector. Costs are assessed in terms of energy and utility, along with the application of all forward flows and all possible reverse flows. It has been found that the application of green-chain-bound flows, although not very important, is more beneficial than the application of forwarding flows. Finally, the implementation of rescue flows (regardless of green logistics operations) has been flagged as not providing significant benefits for the entire supply chain [7].

Ali Azadeh and his colleagues (2013) reviewed a strategic and tactical decision in the oil industry. In the study, a mixed integer nonlinear programming model with two different objective functions is discussed. The first objective function was to maximize the net present value of the project and the second one to minimize the environmental threats. The study also presents modeled long-term and interim decisions once and for all. The uncertain but important parameters such as the production cost for each product, the capacity of the refineries and the petroleum

crude oil consumption rate are discussed. Three well-known Metaheuristics, MOEA-D, NSGA II and MOPSO, were used to optimize the model. It has been determined that the final results show that the MOEA-D approach for large-scale problems is based on criteria such as a number of Pareto front, time, interval, diversity and mean relative spacing [8].

Yong Zhang and Yunjian Jiang have worked on the design of a WCO-biodiesel supply chain at both strategic and tactical levels. the supply chain has been assessed and it has been determined that the problem was the collection of waste (from the kitchen of restaurants) and the conversion. It is assumed that the WCO supplier, the integrated bio-refinery, and the demand zone, are the three-part supply chain. Three key issues have been addressed for the optimal design of the supply chain: (1) the number, size, and location of bio-refiner; (2) collected WCO sites and amount; (3) WCO and biodiesel's transportation plans. A robust multi-objective (economic, environmental and social targets mixed integer linear model was established for the problems identified. A large-scale application based on Suzhou, an eastern city of China, was conducted to verify the model [9].

Amin et al. was designed on tire recovery and worked on an optimized tire reproduction CLSC network. The purpose of the optimization model is to maximize total profits. The optimization model includes multiple products, suppliers, factories, retailers, demand markets and release warehouses. The application of the model was based on a realistic network in Toronto, Canada. The study created a new decision tree to calculate the present value of the problem under unknown sources such as demands and returns. It is also seen as a new and innovative approach in the discounted cash flow methodology. This methodology suggests that CLSCs should be used to compare the profitability of different design options [10].

As a result of the review, the table of work on the closed loop supply chain is presented in table 2.1.

Table 2.1 Work on the closed loop supply chain model integrated with blockchain

Author(s)	Research	Number of Obj. Functon(s)		Number of Period(s)		Type Of Product(s)		Type of Supply Chin	
		Single	Multi	Single	Multi	Single	Multi	Open Loop	Closed Loop
Tosarkani et al. (2018)	Battery		✓		✓	✓			✓
Mohammad et al. (2017)	Motor Oil		✓		✓	✓			✓
Amine et.al (2017)	Tire		✓		✓		✓		✓
Chen et al. (2017)	Solar Energy		✓			✓			✓
Jeihoonian et al. (2017)			✓				✓		✓
Shakourloo et al., (2016)			✓				✓		✓
Subulan et. Al (2015)	Tire		✓		✓		✓		✓
Mirakhorli (2014)	Bread		✓		✓		✓		✓
Edgar et al. (2013)	Palm Oil	✓		✓		✓			✓
Mahmoudzadeh et al. (2013)	Vehicle		✓	✓			✓		✓
Kannana et al. (2010)	Battery		✓		✓		✓		✓
Beanas et al. (2010)	Battery		✓		✓	✓		✓	
Sasikumar et al. (2010)	Tire	✓			✓	✓			✓
Rivera et al. (2009)	Vehicles		✓		✓		✓		✓
Proposed Model	Lube Oil		✓		✓				✓

Thomas Bocek and his colleagues (2017) conducted a study on the use of IoT (Internet of Things) sensor devices utilizing blockchain technology to provide data invariance and ring accessibility of temperature records while lowering operational costs in the drug supply chain. The temperature of each parcel was monitored in order to fully ensure the regulation of GDP during transfers with sensor devices. All data evaluated were transferred to the block chain. As a result, besides the single

non-financial benefits that work with blockchains, there is a list of fields and other beginnings aimed at reducing bureaucracy, deploying infrastructure, and saving costs by using blockchains [4].

Kari Korpela, Jukka Hallikas and Tomi Dahlberg (2017) studied how to integrate the supply chain integration with blockchain technology into a destructive transformation in digital supply chains and networks. Business partners and value-added service providers focused on business (B2B) integration in the supply chain based on electronic data exchanged over the Internet. The goal was to enable all partners to become partners in the standardized integration of business processes and cooperation processes. The most important idea was to find common solutions, technology and standards to connect business processes to a large supply chain. The study explores how to integrate blockchain technology and digital supply chain [11].

Feng Tian (2016) examined the use of Radio Frequency Identification (RFID) and blockchain technology. The advantages and disadvantages of using RFID and blockchain technology in the establishment of the agricultural-food supply chain traceability system were then evaluated. The company has advocated traceability with the information in the agri-food supply chain, which effectively provides food security by collecting, transferring and sharing the data of agricultural food in the production, processing, storage, distribution and sales network [12].

Kristoffer Francisco and David Swanson (2018) conducted a study on the transparency of blockchain. The study uses the concept of adopting technology innovation as a basic framework for the Unified Theory of Acceptance and Use of Technology (UTAUT) and supply chain traceability. A conceptual model was created and the supply chain effects of the block chain inspired by research, theory and literature review were evaluated [13].

Janusz J. Sikorski, Joy Haughton and Markus Kraft (2017) used the block chain method to study the applications of block chain technology related to the 4th Industrial Revolution (Industry 4.0) and facilitate the interaction of machine to machine (M2M). They applied on an M2M electricity market in the chemical industry. There are two electricity producers and one electric consumer in a block

chain in their application. Their work identifies and discusses the research and application landscape of blockchain technology in conjunction with industry industry 4.0 [14].

In literature review of the waste oil's SSCM, it has been reported that waste tire and battery recycling from valuable wastes are given more importance. it has been determined that much work has not been done with the recycling of the lubricating oil as determined by the author. Also It was evaluated that the blockchain approach was not used frequently in the closed loop supply chains that provide recycling. It has been determined that there is no particular study of recycling of valuable wastes that military systems would need to reduce outward dependency during the times of crisis. For this purpose, an attempt was made to establish a sustainable system integrated with blockchain in this work by recycling lubricating oil required by military vehicles.

CHAPTER 3

METHODOLOGY

3.1. Closed Loop Supply Chain

The forward supply chain is a network of facilities and distribution centers that start with the supply of materials, transforms the procured material into intermediate and final products, and distributes final products to customers. The size and difficulty of the supply chain differ according to the size of the firms and the type of industry in which the chain is built. However, almost all of the supply chains have both service and manufacturing organizations.

A reverse supply chain tries to minimize the total reverse logistics cost by maximizing the amount of material returned to the supplier (or an alternative element) by focusing on the backflow of the material. Reverse delivery can be achieved either through the use of existing advanced distribution centers or through the use of separate reverse collection centers, or combinations of both forward distribution and collection centers [15].

Due to wastes damages to the nature and the strict rules of international organizations for the use of products through its life period and after it. Closed loop supply chain (CLSC) has gained great importance nowadays. A CLSC consists of both the advanced supply chain and the reverse supply chain [3].

3.2. Used Lube Oil Re-refining Systems

Conversion and refinement of used lubricating oils to original lubricating oils can be an important option to minimize the damage to the environment of used oils. Another benefit of recycling waste lubrication oil is the economic benefit of high lube oil prices. Waste lubrication oils can be assessed using a variety of alternative methods such as disposal at the storage site, recycling of metals, use as raw material to produce renewal/reuse and other useful products. The choice between these options depends on technical feasibility and economic appraisal [16].

Re-refinement requires that the waste oil is converted into a product with properties similar to those of the original oil. The re-refining process involves preheating by heat or filtration followed by either finishing with hydrogen or vacuum distillation with clay or chemical extraction with solvent extraction with clay and hydro-heating. Following the choice of vacuum distillation, it produces a less polluting and more economical solution to the refinement process, especially for small-scale installations ranging from 10000 to 30000 tones, following clay contact. The residual by-product obtained is well compacted and baled in thick plastic layers before being disposed of in storage areas. Performing the activities of a recycling company that meets the required standards will increase the quality of the product produced [17].

However, the purpose of reprocessing is to produce fuel oil which is low in basic sediment and water content from the used lubricating oil and does not cause clogging of the burners, boiler pipes or accumulation of deposits in customer tanks. For this reason, the process requires filtration and removal of coarse solids, which can lead to environmental hazards or operational problems. a conversion method, it is a physical process such as precipitation, centrifugation, filtration, or a combination of these processes. However, the processes applied alone are not sufficient to remove all chemical contaminants in the oil. Additional methods such as contact with clay and distillation have to be used Table 3-1 presents a comparative example between re-refining and reprocessing operations [17].

Table 3.1 Waste oil management option

Options	Advantage	Disadvantage
Re-refining into the lube oil	Environmentally sound long-term solution.	Requires a well-developed waste-oil collection system to be established.
	Creates jobs locally.	Recycled lube oil requires a well-developed market.
	Reduces the amount of imported lubricating oil.	Requires extensive capital investment.
		The re-refining option requires a reputable recycling company to ensure the marketability of the product.
		Proper disposal of end-waste residues is costly and problematic.
Re-processing into the lube oil	Benefits from a well-established demand for a fuel substitute	Requires a well-developed waste-oil collection system to be established
	Creates jobs locally and reduces the amount of imported fuel	Requires extensive capital investment
	Limits the negative effects of the current practice of uncontrolled burning of waste	Proper disposal of end-waste residues are costly and problematic
	The quality control of the re-processed fuel oil is monitored by the purchaser	
	Destruction	

3.3 Blockchain Technology

Blockchain is a relatively new research topic in the existing systems. While the subject is taking place in visual and written research these days, researchers may not have met some technical terms. Blockchain is a distributed electronic database (ledger) that can record any data (eg, records, events, processes) and can set rules for how this data is updated. Blockchain grows continuously in blocks (files such as data, for example, processes) are added and linked to the previous block using a hash (chained) [14].

With the help of public key encryption, Blockchain technology benefits the solution of the double spending problem, so that each agent is assigned a private key (kept secret as a password) and a shared key shared with all other agents. A process is initiated when the future owner of coins (or digital tokens) sends their original key to the original owner. The coins are transferred with a digital signature of a hash. Public keys are cryptographically generated addresses stored in the blockchain. Each coin is

linked to an address, and a transaction in the crypto economy is the trade of money from one address to another. The distinctive feature of Blockchain is that public keys are never linked to real-world identity. Transactions are trackable, but are activated without revealing their identity; this is an important difference in transactions in the currency of a particular economic agent, which is provided with legal entities (natural or legal), except for (non-traceable) cash transactions [18].

The technical and near-ontological debates in the inner circles of core developers were shaken in August 2015 about the possibility of blocking the block developer to improve the timing, execution and scalability of the Bitcoin XT 0.11C with the official version of Bitcoin XT 0.11C [19].

An organization's appetite for risk associated with its block chain can be measured in three main areas: Standard Risk, Value Transfer Risk, and Smart Contract Risk. In addition, issues such as market acceptance and levels of regulatory participation raise concerns in most new technologies. Increased transparency, a natural flair and the most important advantage of the blockchain can cause some businesses to think twice before moving forward. There are concerns about implementation due to competitive advantages and security concerns. However, concerns can be mitigated by effective planning [20].

The foundation of the blockchain is based on the article Bitcoin: A Peer-to-Peer Electronic Cash System [1], written in 2008 [21]. The inventor / inventor of the article, Satoshi Nakamoto, who is the author of the article and who develops Bitcoin, is to create an unregulated currency that is not controlled by any bank or government. Blockchain, which is a part of this electronic money that does not need centralized financial intermediaries and is not controlled by the government and allows the transfer of interpersonal money, is also designed as a notebook. In other words, the blockchain was born as a digital scaffold, which allows the operation of the currency transactions in Figure 3.2.

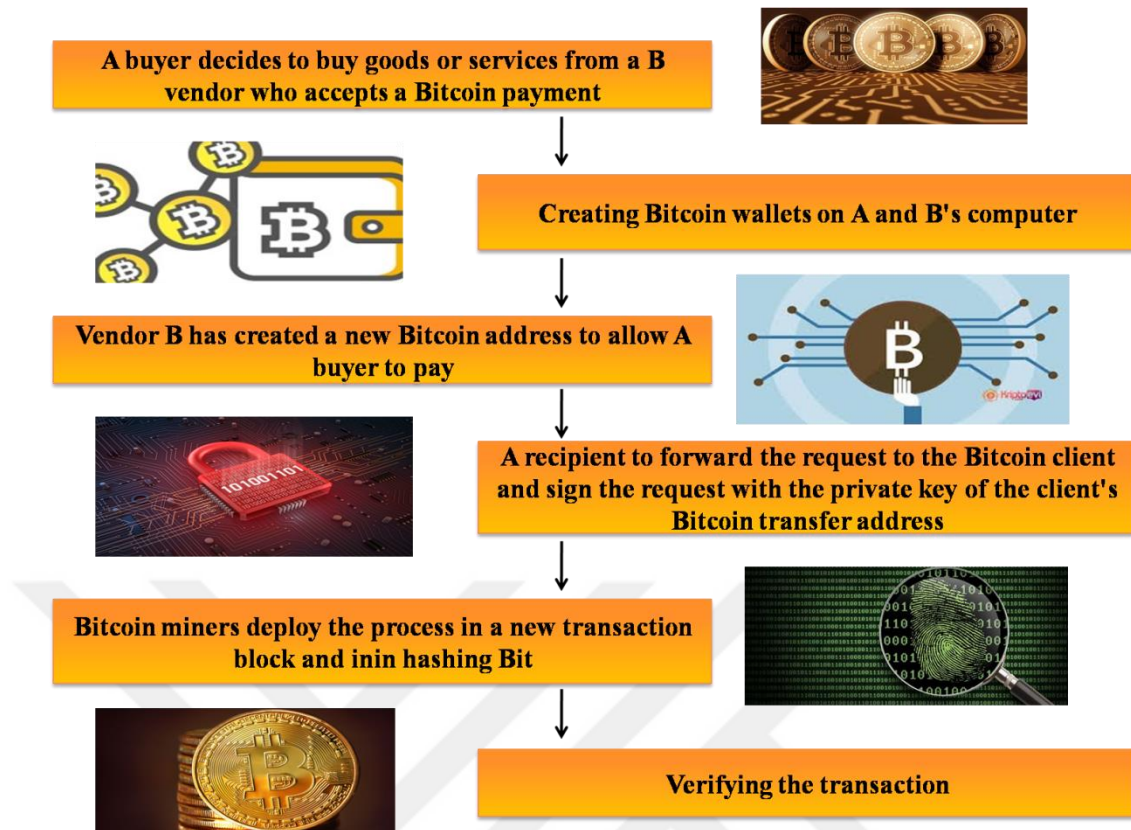


Figure 3.1 Bitcoin operating principle (source: visually)

However, in this digital notebook structure where no third party is a guarantor, measures have to be taken on important issues such as the risk of cheating of users and the control of the cycle of money. For this reason, the entire network is delegated with authorization and all transactions are processed in the public books of computers holding an identical copy of each book. When users spend their money, these books are updated [21].

There are four main characteristics that distinguish blockchain technology from other information systems. These ;

- decentralized structure,
- security,
- auditability and
- It is a smart application.

The decentralized structure of the blockchain increases its validity by providing control of the exchange of information. In addition, thanks to this distributed structure, an error is not collected at a single point and attacks on the network are prevented [22].

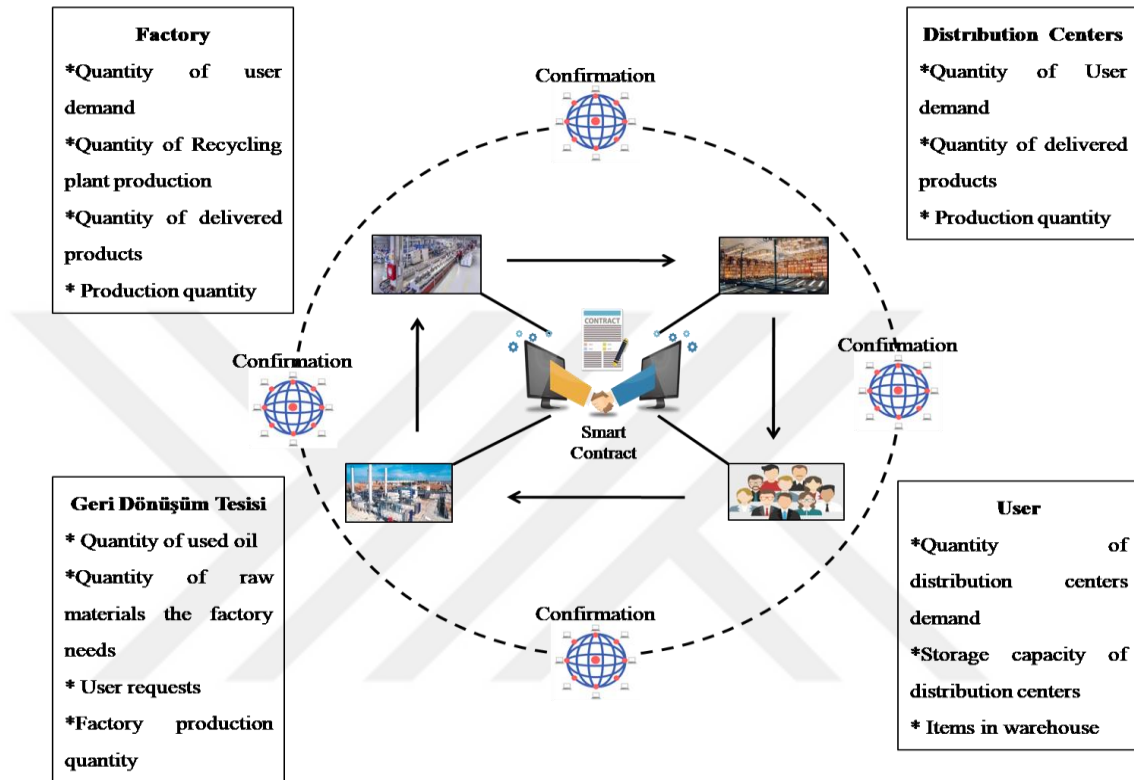


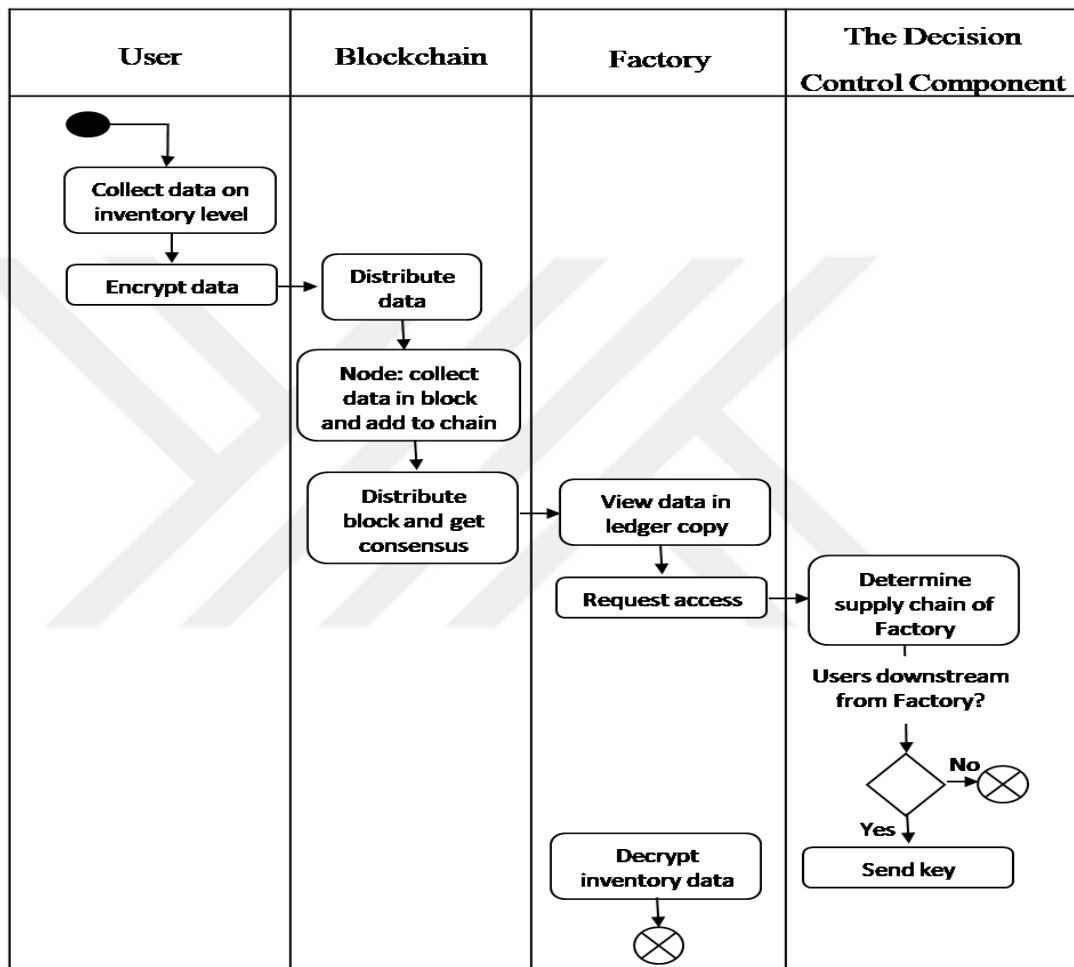
Figure 3.2 Block chain technology based closed loop used oil supply chain

The contribution of the blockchain within the scope of the study is the sharing of the information needed by the elements within the supply chain. Thanks to this information, the elements in the supply chain will determine their needs correctly. Lubricating oil factory will produce raw materials and make production according to the information they need. In this way, both the excess stock, storage and excess production cost will be saved. Distribution centers will determine the needs in advance. It shall make a distribution plan according to the needs determined. Will request the factory according to the needs identified. n this way, both the excess storage cost will be saved as well as users will send a sufficient amount of lubricating oil at the right time. Recycling plants will see the amount of used oil collected in the

collection centers and will see the amount of raw material required by the factory. This knowledge will make its own production planning at the optimum level.

The blockchain architecture between User and Factory within the generated supply chain is shown in Figure 3.4.

Table 3.2 Blockchain architecture between user and factory



The blockchain architecture shown above is used in the same way for all other elements. In this way, the supply chain costs are optimized.

3.4 The Closed Loop Supply Chain integrated Blockchain for Lubricating Oil used on Military Forces

This work focuses on the recycling of oils used in the defense sector, which must be included in many vehicles in order to have a high mobility. Firstly, We focused reduce costs minimum level and establish a sustainable supply chain management

with the required lubricating oils can be supplied by recycling the used lubricating oil and the other products that will obtain in the conversion of the used lubricating oil are used in different systems (Cement factories, Gypsum factories, Lime factories, Clay drying factories, iron-steel blast furnaces, Power plants). Along with this, it has been tried to minimize the harm that the used lubrication oil can give to human and environmental health. For these purposes, a 20-year long process is designed to help assess the use of lubricating oils obtained as a result of the processing of petroleum in the period of crisis and war, in case the required amount of petroleum cannot be obtained, or to ensure that the resulting oil is used as fuel, which is more needed and strategically more important. We also embarked on the closed-loop supply chain to block the blockchain system, which is a new approach to lowering costs. In doing so, our aim is to be able to see the information of the chain of all products in the supply chain and to supply the product which is needed in the shortest time from the closest element. Thus, it is evaluated that transportation and storage costs will be reduced thanks to the transparency and traceability of the blockchain system [20].

The recycling strategy of waste lubrication oil is driven by the fact that most of the waste oil is refined and a smaller portion is sold to the cement plants and the unused waste is destroyed at controlled high temperatures [17].

At the beginning of the problem, it is assumed that the lubricants used in the military force were taken directly from outside by the procurement authorities. The new lubrication oils supplied are stored primarily in reservoirs at the distribution centers, then distributed from the the distribution centers and lubrication oils are transferred to the storage of user units from the distribution centers where storage is made in the distribution centers according to user requirement. The lubricating oils used were stored as waste oil in the places where the subunits of the land defense system were located and were sold annually as a tender procedure by the commercial firm. Transfer of used lubrication oils to distribution centers by the public entity to which the defense sector depends, and then the used lubricating oils collected from the users are transferred to the used oil collection centers according to their class. for the purpose of enabling the process to be carried out and establishing a sustainable lubrication oil supply chain. Waste oil conversion facilities to be used in the waste oil

conversion facilities to be installed by considering the conversion of waste oil was considered. The second stage is to determine the oil that can be transformed after the tests performed in waste oil conversion plants. and The collection requirements for Waste Lube Oil (actual production-regression requirements) are determined by the requirements of the user elements for the final product lubrication products.[23] Included in the lubrication oil supply process of those convertible from recyclable waste oils as reusable lubrication oil is the lowest possible level of payable for the new lubrication oil required. Profits have been earned by selling oils that cannot be converted from recyclable waste oil into reusable lubrication oil, but which can be used in other sectors. Besides, it is assumed that those who cannot recycle the collected waste oil are burned in the recycling plant to be established and destroyed in such a way as to cause minimum harm to the environment and human health. The closed loop supply chain for lubrication oil is shown in Figure 3-1.

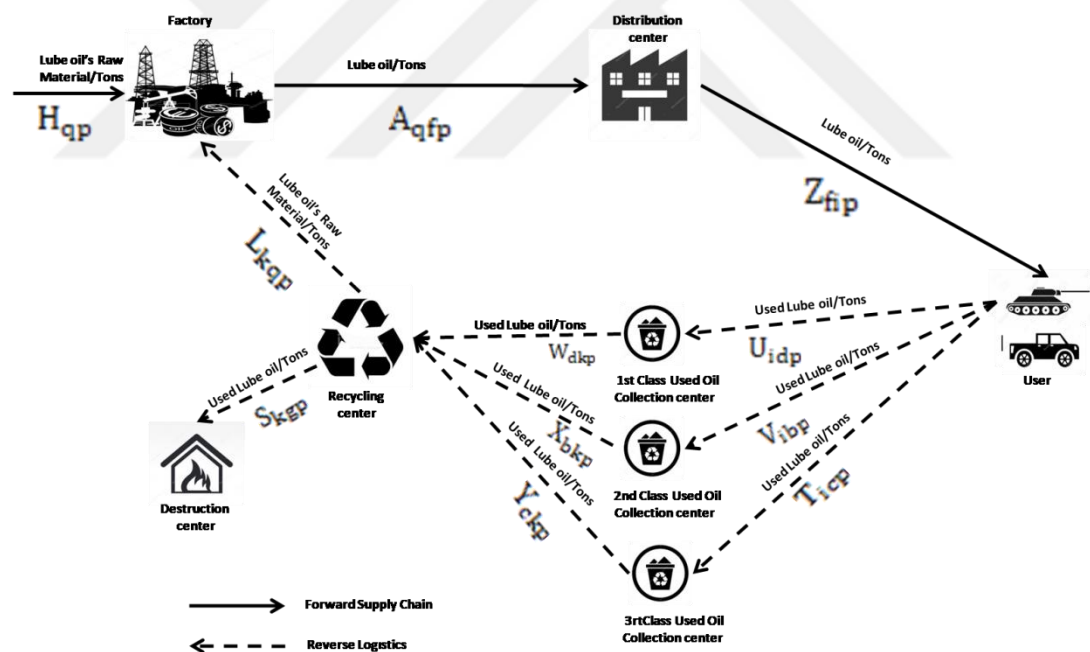


Figure 3.1 The closed loop supply chain for lubrication oil

When we combine the problem with blockchain, it is aimed to complete the fastest and fastest way to follow the requirements of the customer, main distributor, regional distributor, lubricant oil in the unit. Likewise, collecting centers, recycling center,

facilities where third products are used, can monitor the used oil at the same time and can meet the required oils with minimum transportation and storage costs. In this system, the recycling plant sees how much oil the user needs, he sees the oil in the hands of the buyer and accordingly calculates how much oil he produces. In line with these calculations, the users can supply the used oil in the shortest way and reduce the storage and transportation costs. This system is valid for suppliers and third-party users. Thus, it is evaluated that transportation and storage costs can be considered as a significant reduction. The closed loop supply chain integrated with blockchain for lubrication oil is shown in Figure 3-2.

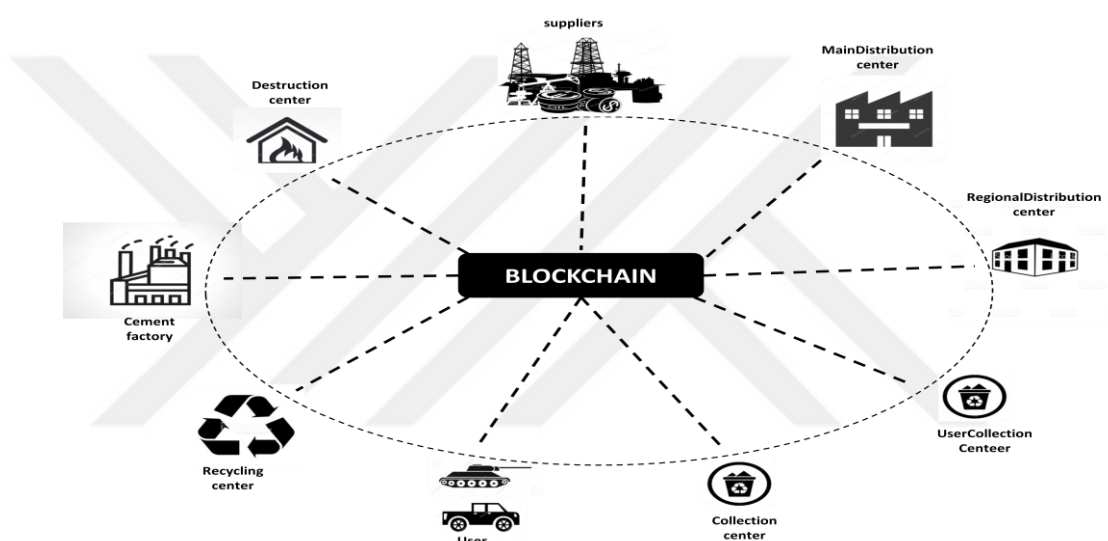


Figure 3.2 The closed loop supply chain integrated with blockchain for lubrication oil

In addition to its impact on transportation and storage costs, the use of Bitcoin, a product of Blockchain system, in all payment tools would disable the third party (especially the banks) that would have to pay the cash flow on the system [18]. In this respect, it has been evaluated that the costs will be significantly reduced.

3.5 Damage To The Environment Of Used Lubricating Oils

In order to reduce greenhouse gas emissions, which are the main source of climate change, global warming works and evaluations are carried out at international level. The decisions taken in line with the Intergovernmental Panel on Climate Change (IPCC) are to make efforts to determine the greenhouse gases, greenhouse effects

and real contributions to global warming and to make efforts to protect the natural balance. In general, the level of emissions in a country is a result of economic activities and changes in the standard of living. Air pollution is the result of modern life [24].

The most important factor polluting the air is the combustion reaction. Therefore, the selection of socio-economic indicators should not be dependent on a single indicator but should be evaluated together with a few parameters. The energy required for transportation, heating and enlightenment in the settlements fills the air with intensive gas and dust residues. Artificial sources causing air pollution can be grouped under three headings:

- Air pollution based on heating,
- Industrial air pollution,
- Air pollution from motor vehicles.

In all three sources, the gases formed by the use of fossil fuels (petroleum and petroleum products, coal and natural gas) are mixed into the atmosphere. The atmosphere is involved in 80-85% of carbon dioxide from fossil fuels, 15-20% is due to the decomposition of inhalation of microscopic creatures alive and organic matter. On the one hand, the rapid increase in the use of fossil fuels, on the other hand, the destruction of forests and vegetative plankton, which consume tons of carbon dioxide for photosynthesis, has increased the amount of carbon dioxide in the atmosphere to the highest level of the last 160 thousand years [24].

Measurements show that this increase continues. As stated in the scientific explanations, carbon dioxide in greenhouse gases has a share of 50% in global warming. The reason for this is that both the amount and the carbon dioxide molecules have a very long life in the atmosphere, such as 50 to 100 years. For this reason, international efforts are being made at the international level regarding the reduction of carbon dioxide emissions among the measures to be taken against global warming. As can be seen, this result gives an idea of how high the effect of carbon dioxide in global warming. Considering the human life and the future of the

atmosphere in which all living things are breathing, everyone, both as an individual and as a society, should do their part and show the necessary sensitivity.

Carbon dioxide is the most important anthropogenic greenhouse gas. The density of carbon dioxide in the world atmosphere increased from 378 ppm in 2005 to 280 ppm in the pre-industrial period. United Nations Convention on the Protection of the Ozone Layer (1987); It contains all greenhouse gases that cannot be controlled by the Montreal Protocol. Moreover, there are six greenhouse gases in the Kyoto Protocol. Carbon dioxide (CO₂), Methane (CH₄), Diazotmonoxide (N₂O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulfur hexafluoride (SF₆) [24].

In terms of CO₂ Emissions, Land Vehicles are the main and largest producer of harmful vehicle exhaust emissions in residential areas. Exhaust emissions are produced by gasoline or diesel, a mixture of air-fuel combustion in strong internal combustion engines. Vehicle emissions vary according to the type of fuel in the car (gasoline, LPG, CNG or diesel) and trucks (diesel) and working characteristics. Components of vehicle emissions are water vapor, carbon dioxide, nitrogen and oxygen [25].

Other pollutants are also available; these are carbon monoxide, nitrogen oxides, unburned fuel and small dust particles. Some of these contents play a major role in climate change as well as in vehicle-based air pollution. Toxic gases from automobile exhausts form a layer in the air. Each thousand cars emit 3000 kg of carbon dioxide, 200-400 kg of hydrocarbon vapor, 50-150 kg of nitrogen oxides per day. Gases from motor vehicles constitute 31% of carbon dioxide released into the atmosphere and 82% of carbon monoxide [24].

60% of these gases are released within a few minutes when the engine is first started. Emissions from motor vehicles continue to attract the attention of environmentalists and toxicologists, not only because they trigger global warming, but also deforming the ozone layer and damaging many living organisms. As the number of vehicles in use worldwide increases, so as to reduce the effects of motor vehicle emissions on

the environment and ecosystem, many arrangements are planned including the re-design of engines.

There are two known methods for maintaining the O₂ balance in the air. One is photosynthesis, the other is the absorption of carbon dioxide by the oceans. In addition to the absorption of CO₂ by the oceans, the studies on the injection of CO₂ into the oceans continue. The other issue is the activities to increase the photosynthesis phenomenon, which depends on increasing the green areas. There is 21% oxygen in the atmosphere. The source of oxygen creates the free oxygen that results from photosynthesis. Photosynthesis is the production of organic compounds using light energy in living organisms carrying chlorophyll (chromosomes) [26].

All of the food-producing organisms are called photosynthetic organisms and the majority of these plants form plants. Thanks to the photosynthesis of plants and the ocean storage capabilities of the oceans, it has been able to remain stable for centuries. 15-30 m² of leaf area is required for the production of oxygen for 24 hours. An adult normal tree takes 2-3 kg of carbon dioxide in an hour, producing 1.7 kg of oxygen by photosynthesis.

Within the scope of the calculations made to be input to the model under the conditions specified, carbon dioxide and carbon monoxide gases emitted into the atmosphere were tried to be given a coefficient. For this purpose, the gas delivered to the atmosphere per tonne per tonne was calculated. The 40-ton trailer / tractor combination is assumed to emit 37 g / tkm CO₂. This value is added to the mathematical model by assigning a constant coefficient.

According to the Regulation on Control of Industrial Air Pollution, within the scope of annihilation plant, the emission mass flows arising from the chimney are taken as the basis. In this context, 1,100 mg / Nm³ of liquid hazardous waste incineration facility of Kocaeli Metropolitan Municipality and IZAYDAS hazardous waste disposal facility was used. It was determined that Nm³ emission was made and $0,0480 / 1,6 = 0,03$ mg / Nm³ emission per hour per tonne.

With the help of the formula $m \text{ (kg / h)} = (P * V * M) / (R * T)$, $m \text{ (kg / h)} = 0.044 M * V \text{ (Nm}^3 \text{ / h)} = 0.044 * 28 * 0.03 = 0.037 \text{ kg / h}$. 1 tonne of used lubrication fuel as 37 g / hour was determined as damage to the environment and this was added to the mathematical model by assigning a value.

3.6. Mathematical Model

There is no publication addressing the complexity arising from the application of mathematical models in the design and management of reverse logistics systems on the use of lubrication oil in military forces. We can suggest a mathematical model that evaluates the optimal configuration of the closed loop supply chain integrated with blockchain in operation based on the prominent characterization of forward and reverse logistics flows. The aim is to optimize transportation costs, operating costs and economic benefits from the application of reverse logistics processes. The formulation for the mixed integer mathematical model developed in the light of the information is given below;

Indices

q	set of lube oil suppliers
f	set of distribution centers
i	set of users
d	1st class oil collection center
b	2nd class oil collection center
c	3rd class oil collection center
k	set of recycling plants
g	set of disposal centers
p	set of period

Variables

H_{qp} lube oil raw material (Tons) purchased by factory q in period p ,

A_{qfp} lube oil (Tons) sent to distribution center f from the factory q in period p ,

Z_{fip} lube oil (Tons) sent to user i from distribution centers f in period p ,

U_{idp} used lube oil (Tons) sent to 1st class oil collection center d from user i in period p ,

V_{ibp} used lube oil (Tons) sent to 2nd class oil collection center b from user i in period p ,

T_{icp} used lube oil (Tons) sent to 3rd class oil collection center c from user i in period p ,

W_{dkp} used lube oil (Tons) sent to the recycling center k from 1st class oil collection center d in period p ,

X_{bkp} used lube oil (Tons) sent to 2nd class oil collection center b to the recycling center k in period p ,

Y_{ckp} used lube oil (Tons) sent to 3rd class oil collection center c to the recycling center k in period p ,

S_{kp} not recycled used lube oil (Tons) sent to the recycling center to destruction facility g in period p ,

L_{kqp} recycled used lube oil (Tons) sent to the recycling center k to factory q in period p ,

QQ_{qp} if the factory q is opened in period p 1 otherwise 0,

FF_{fp} if the distribution center is opened in period p 1 otherwise 0,

DD_{dp} if 1st class oil collection center d is opened in period p 1 otherwise 0,

BB_{bp} if 2nd class oil collection center b is opened in period p 1 otherwise 0,

CC_{cp} if 3rd grade oil collection center c is opened in period p 1 otherwise 0,

KK_{kp} if recycling centers k is opened in period p 1 otherwise 0,

Parameters

t_{qp} the lube oil (Tons) capacity of factory q in the period p ,

h_p raw material capacity (Tons) purchased by factory in the period p ,

b_{fp} the distribution center f storage capacity (Tons) in the period p ,

d_{ip} the user i demand (Tons) in the period p ,

ds_{dp} 1st class oil collection center d storage capacity (Tons) in the period p ,

bs_{kp} 2nd class oil collection center b storage capacity (Tons) in the period p ,

cs_{mp} 3th class oil collection center c storage capacity (Tons) in the period p ,

$r_{cs_{kp}}$ the recycling center k capacity (Tons) in the period p ,

$r_{cs_{kp}}$ the recycling center k capacity (Tons) in the period p ,

DIS_{qf} the distance (km) between factory q and distribution center f ,

DIS_{fi} the distance (km) between distribution center f and the user i ,

DIS_{id} the distance (km) between the user i and if 1st grade oil collection center d ,

DIS_{ib} the distance (km) between the user i and if 2nd grade oil collection center b ,

DIS_{ic} the distance between (km) the user i and if 3rd grade oil collection center c ,

DIS_{dk} the distance (km) between 1st grade oil collection center d and the recycling center k ,

DIS_{bk} the distance (km) between 2nd grade oil collection center b and the recycling center k,

DIS_{ck} the distance (km) between 3rd grade oil collection center c and the recycling center k,

DIS_{kg} the distance (km) between the recycling center k and destruction facility g,

COST lube oil price (\$),

DCOST disposal costs (\$),

rcost the recycling center set up cost (\$),

rrcost recycling cost of 1 TON used lube oil (\$),

ff_p the maximum number of distribution centers that can be opened in the period p,

qq_p the maximum number of factory that can be used in the period p,

dd_p the maximum number of 1st grade oil collection center that can be opened in the period p,

bb_p the maximum number of 2nd grade oil collection center that can be opened in the period p,

cc_p the maximum number of 3rd grade oil collection center that can be opened in the period p,

kk_p the maximum number of a recycling center that can be opened in the period p,

T unit cost of transportation (\$),

α 1st class oil acquisition rate,

β 2nd class oil acquisition rate,

γ	3rd class oil acquisition rate,
ρ	recycle rate from 1st class oil,
θ	not recycled rate from 1st class oil,
σ	recycle rate from 2nd class oil,
τ	not recycled rate from 2nd class oilc,
μ	recycle ratio from 3rd class oil
φ	not recycled rate from 3rd class oil
BCT	discount rate on the transportation cost of the blockchain use,
BC	discount rate on money transfer cost of blockchain use, (Bitcoin use)
BCO	discount rate on production costs of blockchain use,
ZCVR	transportation damage to the environment,
YOKETCVR	destruction of environmental damage,

Objective Function

The Minimization

$$E = E_1 + E_2 + E_3 + E_4 + E_5$$

Supplied lubrication oil cost

$$E_1 = BC * \sum_q \sum_p (H_{qp}) * COST * BC \quad (3.1)$$

Cost of elimination

$$E_2 = BC * BCO * \sum_k \sum_p S_{kp} * DCOST \quad (3.2)$$

Recycling plant operation costs

$$E_3 = BC * (\sum_k \sum_p KK_{kp} * rcost + \sum_k \sum_q \sum_p L_{kqp} * rrcost) \quad (3.3)$$

Transportation cost

$$E_4 = [(\sum_q \sum_f \sum_p A_{qfp} * DIS_{qf}) + (\sum_f \sum_i \sum_p Z_{fip} * DIS_{fi}) + (\sum_i \sum_d \sum_p U_{idp} * DIS_{id}) + (\sum_i \sum_b \sum_p V_{ibp} * DIS_{ip}) + (\sum_i \sum_c \sum_p T_{icp} * DIS_{ic}) + (\sum_d \sum_k \sum_p W_{dkp} * DIS_{dk}) + (\sum_b \sum_k \sum_p X_{bkp} * DIS_{bk}) + (\sum_c \sum_k \sum_p Y_{ckp} * DIS_{ck}) + (\sum_k \sum_q \sum_p L_{kqp} * DIS_{dk}) + (\sum_k \sum_{cg} \sum_p S_{kgp} * DIS_{kg})) + (\sum_i \sum_c \sum_p T_{icp} * DIS_{ic}) + (\sum_q \sum_f \sum_r W_{dkp} * DIS_{dk})] * T * BC * BCO \quad (3.4)$$

Environmental Damage Cost

$$E_5 = [(\sum_q \sum_f \sum_p A_{qfp} * DIS_{qf}) + (\sum_f \sum_i \sum_p Z_{fip} * DIS_{fi}) + (\sum_i \sum_d \sum_p U_{idp} * DIS_{id}) + (\sum_i \sum_b \sum_p V_{ibp} * DIS_{ip}) + (\sum_i \sum_c \sum_p T_{icp} * DIS_{ic}) + (\sum_d \sum_k \sum_p W_{dkp} * DIS_{dk}) + (\sum_b \sum_k \sum_p X_{bkp} * DIS_{bk}) + (\sum_c \sum_k \sum_p Y_{ckp} * DIS_{ck}) + (\sum_k \sum_q \sum_p L_{kqp} * DIS_{dk}) + (\sum_k \sum_{cg} \sum_p S_{kgp} * DIS_{kg})) + (\sum_i \sum_c \sum_p T_{icp} * DIS_{ic}) + (\sum_q \sum_f \sum_r W_{dkp} * DIS_{dk})] * (ZCVR * BC)] + [(\sum_k \sum_{cg} \sum_p S_{kgp} * DIS_{kg}) * (YOKETCVR * BC)] \quad (3.5)$$

Constraints

Capacity constraints

$$\sum_q H_{qp} + \sum_k L_{kqp} \leq t_{qp} * QQ_{qp} \quad \forall_{q,p} \quad (3.6)$$

$$\sum_q A_{qfp} \leq b_{fp} * FF_{fp} \quad \forall_{f,p} \quad (3.7)$$

$$\sum_f Z_{fip} \geq d_{ip} \quad \forall_{i,p} \quad (3.8)$$

$$\sum_i \sum_d \sum_p U_{idp} \geq \sum_d \sum_p ds_{dp} * \sum_d \sum_p DD_{dp} \quad \forall_{f,p} \quad (3.9)$$

$$\sum_i V_{ibp} \geq \sum_{bp} bs_{bp} * \sum_{bp} BB_{bp} \quad \forall_{b,p} \quad (3.10)$$

$$\sum_i T_{icp} \geq \sum_{cp} cs_{cp} * \sum_{bp} CC_{cp} \quad \forall_{c,p} \quad (3.11)$$

$$\sum_d W_{dkp} + \sum_b X_{bkp} + \sum_c Y_{ckp} \leq rcs_{kp} * KK_{kp} \quad \forall_{k,p} \quad (3.12)$$

Const6. The amount of lubricating oil's raw materials entering the factory can not be more than the production capacity of the factory .Const7. The amount of lubricating oil used from the distribution center will not exceed the distribution center capacity.Const8. The amount of lubricating oil delivered to the user cannot exceed the demand of the customers.Const9. 1st Class used lubricating oil amount can not be more than 1st Class used lubricating oil storage center capacity.Const10. 2 nd Class used lubricating oil amount can not be more than 2 nd Class used lubricating oil storage center capacity.Const11. 3 th Class used lubricating oil amount can not be more than 3 th Class used lubricating oil storage center capacity.Const12. The total amount of used lubricating oil entering the recycling center cannot exceed the production capacities of the recycling center.

Input Output Constraints

$$\sum_q H_{qp} + \sum_k \sum_q L_{kqp} = \sum_q \sum_f A_{qfp} \quad \forall_p \quad (3.13)$$

$$\sum_q \sum_f A_{qfp} = \sum_f \sum_i Z_{fip} \quad \forall_p \quad (3.14)$$

$$\sum_i \sum_d U_{idp} = \sum_d \sum_k W_{dkp} \quad \forall_p \quad (3.15)$$

$$\sum_i \sum_b V_{ibp} = \sum_b \sum_k X_{bkp} \quad \forall_p \quad (3.16)$$

$$\sum_i \sum_c T_{icp} = \sum_c \sum_k Y_{ckp} \quad \forall_p \quad (3.17)$$

$$\sum_f \sum_i Z_{fip} = \sum_i \sum_d U_{idp} + \sum_i \sum_b V_{ibp} + \sum_i \sum_c T_{icp} \quad \forall_p \quad (3.18)$$

$$\sum_k \sum_q \sum_p L_{kqp} + \sum_k \sum_p S_{kp} = \sum_d \sum_k \sum_p W_{dkp} + \sum_b \sum_k \sum_p X_{bkp} + \sum_c \sum_k \sum_p Y_{ckp} \quad (3.19)$$

Const13.The amount of raw materials entering the factory will be equal to the amount of lubricating oil exiting the factory. Const14. The amount of lubricating oil entering the distribution center will be equal to the amount of lubricating oil exiting from the distribution center.Const15. The amount of 1 st class used lubricating oil entering the will be equal toThe amount of 1 st class used lubricating oil exiting from 1 st class used lubricating oil collection center.Const16. The amount of 2 nd class

used lubricating oil entering the will be equal to toThe amount of 2 nd class used lubricating oil exiting from 2 nd class used lubricating oil collection center.Const17. The amount of 3 th class used lubricating oil entering the will be equal to toThe amount of 3 th class used lubricating oil exiting from 3 th class used lubricating oil collection center.Const18. The amount of lubricating oil that comes to users will be equal to the total amount of oil used by user.Const19. The amount of used oil entering the recycling center will be equal to the total amount of oil exiting from the recycling center.

Installation Constraints:

$$Q_{qp} \leq q_{qp} \quad \forall_{q,p} \quad (3.20)$$

$$F_{fp} \leq f_{fp} \quad \forall_{f,p} \quad (3.21)$$

$$D_{dp} \leq d_{dp} \quad \forall_{d,p} \quad (3.22)$$

$$B_{bp} \leq b_{bp} \quad \forall_{b,p} \quad (3.23)$$

$$C_{cp} \leq c_{cp} \quad \forall_{c,p} \quad (3.24)$$

$$K_{kp} \leq k_{kp} \quad \forall_{k,p} \quad (3.25)$$

Const20. Maximum number of factories.Const21. Maximum number of distribution centers.Const22. Maximum 2 nd Class used lubricating oil collection center.Const23. Maximum 3 th Class used lubricating oil collection center.Const24. Maximum 1st Class used lubricating oil collection center.Const25. Maximum number of recycling centers.

Recycling Capacity Constraints

$$\sum_i d_{ip} * \alpha \leq \sum_i \sum_d U_{idp} \quad \forall_p \quad (3.26)$$

$$\sum_i d_{ip} * \beta \leq \sum_i \sum_b Y_{ibp} \quad \forall_p \quad (3.27)$$

$$\sum_i d_{ip} * \gamma \leq \sum_i \sum_c T_{icp} \quad \forall_p \quad (3.28)$$

$$\sum_d W_{dkp} * \rho + \sum_b X_{bkp} * \sigma + \sum_c Y_{ckp} * \mu \geq \sum_q L_{kqp} \quad \forall_{k,p} \quad (3.29)$$

$$\sum_d W_{dkp} * \theta + \sum_b X_{bkp} * \tau + \sum_c Y_{ckp} * \varphi \geq S_{kp} \quad \forall_{k,p} \quad (3.30)$$

Const26. The 1st Class of used lubricating oil that can obtain from user can not exceed the 1st Class of used lubricating oil generation rate. Const27. The 2nd Class of used lubricating oil that can obtain from user can not exceed the 2nd Class of used lubricating oil generation rate. Const28. The 3th Class of used lubricating oil that can obtain from user can not exceed the 3th Class of used lubricating oil generation rate. Const29. The lubricating oil's raw material produced at the recycling center should not be less than the lubricating oil raw material obtained from the used lubricating oil that sent to the factory. Const30. The amount of used lubricating oil that cannot be recycled at the recycling center should not be less than the amount of used lubricating oil that sent to the disposal plant.

$$A_{qfp} \geq 0 \quad \forall_{q,f,p} \quad (3.31)$$

$$Z_{fip} \geq 0 \quad \forall_{f,i,p} \quad (3.32)$$

$$U_{idp} \geq 0 \quad \forall_{i,d,p} \quad (3.33)$$

$$V_{ibp} \geq 0 \quad \forall_{i,b,p} \quad (3.34)$$

$$T_{icp} \geq 0 \quad \forall_{i,c,p} \quad (3.35)$$

$$W_{dkp} \geq 0 \quad \forall_{d,k,p} \quad (3.36)$$

$$X_{bkp} \geq 0 \quad \forall_{b,k,p} \quad (3.37)$$

$$Y_{ckp} \geq 0 \quad \forall_{c,k,p} \quad (3.38)$$

$$L_{kqp} \geq 0 \quad \forall_{k,q,p} \quad (3.39)$$

$$S_{kgp} \geq 0 \quad \forall_{k,g,p} \quad (3.40)$$

$$KK_{kp}, FF_{fp}, QQ_{qp}, DD_{dp}, BB_{bp}, CC_{cp} = \{0,1\} \quad (3.41)$$

The constraints between Const31 and Const41 are the sign constraints of decision variables.



CHAPTER 4

RESULTS AND ANALYSIS

In this section, the results obtained from the elements found in the defense sector, which was formed as a mathematical model is given in the previous section with the formulations, were tested in the GAMS package program and the applicability and validity of the proposed model were examined. As shown in Figure 4-1, the advanced stage of the CLSC network integrated with blockchain.

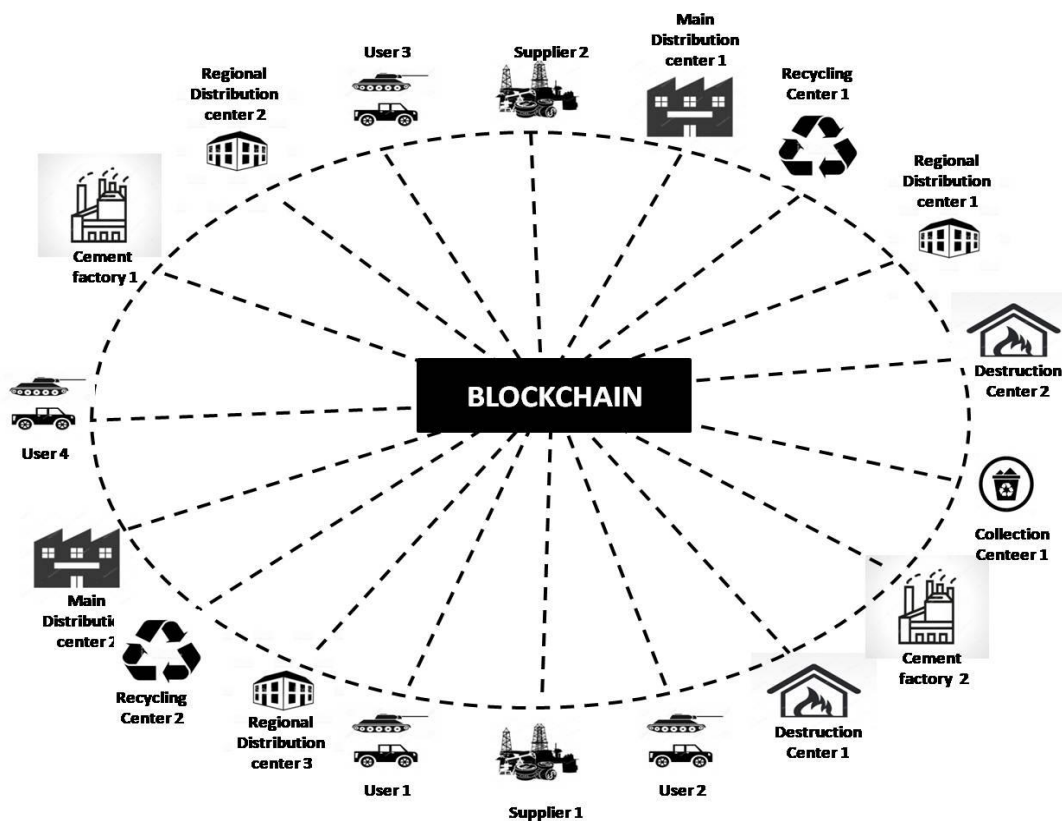


Figure 4. 1 The network structure integrated with blockchain of the numerical examples

In order to simulate the representative model, the armed forces of one country were divided into 4 regions. The distribution of users to the country is shown in Figure 4-2.



Figure 4. 2 Users layout

The amount of lubricating oil needed for armored vehicles, non-armored vehicles, airplanes, helicopters and ships in the regions is specified in table 4-1.

Table 4. 1 Needed lube oil for each brigade per period.

	1 st Period	2 nd Period	3 th Period	4 th Period
Brigade 1	10 Ton	25 Ton	25 Ton	15 Ton
Brigade 2	20 Ton	30 Ton	20 Ton	25 Ton
Brigade 3	10 Ton	22Ton	10Ton	24Ton
Brigade 4	20 Ton	37 Ton	10 Ton	26 Ton
TOTAL	60 Ton	114 Ton	65 Ton	90 Ton

Lubricating oils required by the vehicles are supplied from 4 factories that can be installed most. The lubricating oils supplied are stored in a maximum of 4 distribution centers. Lubricating oils in the warehouses in distribution centers are distributed to users in 4 regions. The lubrication oil from the vehicles are divided into three categories by testing the fluidity and color by the user elements during the

period of lubricating oil change. Categorization rates are presented in table 5-2. Lubricating oils divided into three categories are called Class 1 used oil, 2nd class used oil and Class 3 used oil. Each grade of oil is collected in up to 4 collection centers. Each class of oil collected in the collection centers is sent to 4 recycling centers which will be opened for recycling at the most. Used lubricating oils from recycling centers are recycled at different rates according to their class. The recycling rates of lubricating oils used by recycling centers according to their class are presented in table 5-3. The resulting lubricating oil raw material is sent back to the factories for reuse. Used lubricating oils that cannot be recycled are destroyed in 1 disposal plant.

Table 4.2 Categorization rates

Used lubrication Oil % 100	
PRODUCTS	
1 st class used lubrication oil	%50
2 nd class used lubrication oil	%30
3 th class used lubrication oil	%20

Table 4.3 Recycling rates of used lubricating oils according to their class

1st class used lubrication oil % 100	
PRODUCTS	
Recycled used lubrication oil	%70
Not recycled used lubrication oil	%30
2nd class used lubrication oil % 100	
PRODUCTS	
Recycled used lubrication oil	%50
Not recycled used lubrication oil	%50
3th class used lubrication oil % 100	
PRODUCTS	
Recycled used lubrication oil	%30
Not recycled used lubrication oil	%70

The layout of the units according to the generated model is presented in Figure 5-1. Unit transport cost (t) is assumed to be 0.5 \$ per ton-km. Unit lubrication oil

purchase costs and unit recycling costs are fixed. Fixed operating costs of distribution centers, collection centers, and recycling centers also vary periodically. The other parameters are limited to KK_{kp} (4), FF_{fp} (4), QQ_{qp} (4), DD_{dp} (4), BB_{bp} (4) and CC_{cp} (4). The parameters related to the use of Blockchain were accepted as 0.1 for BC, 0.12 for BCT, and 0.15 for 0.2 BCS.

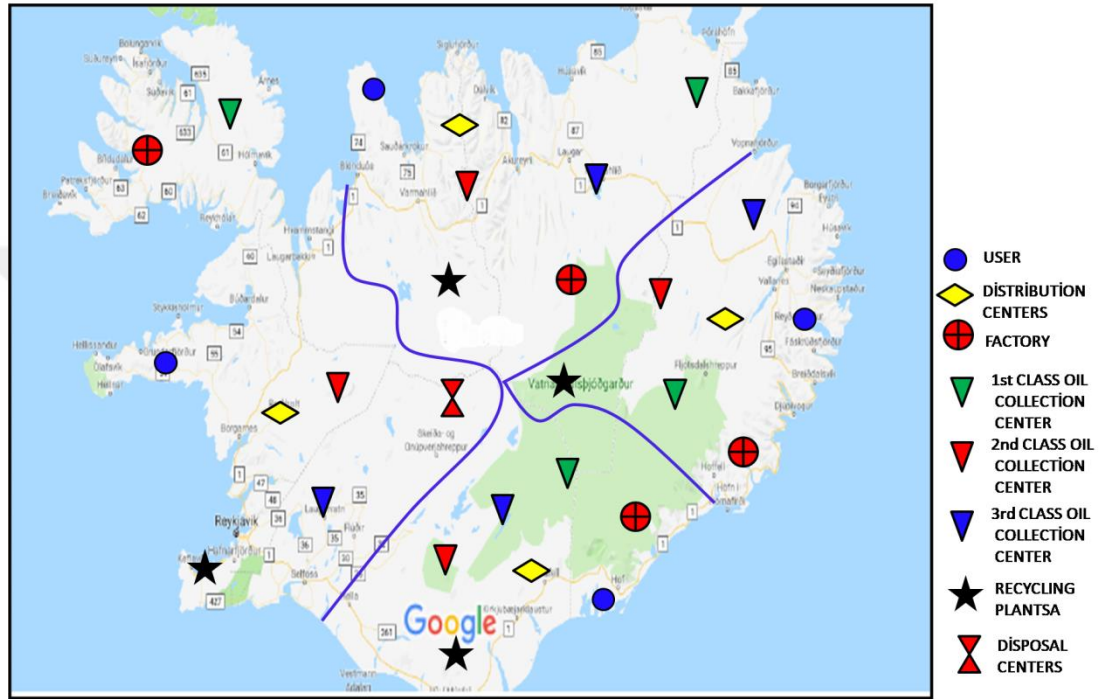


Figure 4. 3 Location of Units by Representative Model

In the data obtained from the representative system without integrated with Blockchain the developed Mixed Integer Linear Programming model is solved with GAMS-CPLEX package program on a computer with 2.40 GHz processor and 4GB RAM.

As a solution, costs are calculated within the scope of the forward clap supply chain, which was formed primarily without the establishment of a recycling center. Subsequently, costs were calculated with the tchatch cycle supply chain integrated with Blockchain. The data obtained within the scope of advanced cycle treatment chain are presented in Table 4-4.

Table 4.1 Costs resulting from forward flow chain.

The Objective Functions of Forward Supply Chain	
Total Objective Function	327373,75 \$
Cost of Oil Purchase	319000 \$
Transportation Costs	3987,5 \$
Destruction Cost	3190 \$
Cost of Environmental Damage	1196,25 \$

Within the scope of the model created with Blockchaine integrated closed cycle supply chain, the factory numbered 1 and 4 were used to minimize capacity and transportation costs and damage to the environment. Distribution centers 1, 2 and 3 are used as distribution centers. 1 and 2 collection centers were used in 1st class, 2nd class and 3rd class used oil collection centers. Recycling centers number 1, number 2 and 4 are used.

As a result, the lubrication oil raw material required by the factories 1 and 4 was obtained from the recycling plants of the number 2 and 4 and the total cost was minimized. The data obtained from the solution of the mathematical model are presented in the following tables;

Table 4.2 Amount of lubricating oil sent from factories to distribution centers in periods (ton)

Assignments_A(Q,F,P)			
Q	F	P	
1	1	1	40.00
1	1	2	80.00
1	1	3	55.00
1	1	4	80.00
1	2	1	10.00
1	2	2	22.00
1	2	3	10.00
1	2	4	10.00
4	3	2	12.00

Table 4.3 Amount of lubricating oil sent from distribution centers to users (ton)

Assignments_Z(F,I,P)			
F	I	P	
1	1	1	10.00
1	1	2	25.00
1	1	3	25.00
1	1	4	15.00
1	2	1	20.00
1	2	2	18.00
1	2	3	20.00

1	2	4	25.00
1	3	4	14.00
1	4	1	10.00
1	4	2	37.00
1	4	3	10.00
1	4	4	26.00
2	3	1	10.00
2	3	2	22.00
2	3	3	10.00
2	3	4	10.00
3	2	2	12.00

Table 4.4 Amount of used lubricating oil(tons) sent to 1 st class used lubricating oil collection centers from users

Assignments_U(I,D,P)			
I	D	P	
1	1	1	5.00
1	1	2	2.00
1	1	3	2.50
1	2	2	10.50
1	2	3	10.00
1	2	4	7.50
2	1	1	10.00
2	1	2	15.00
2	1	3	10.00
2	1	4	5.00
2	2	4	7.50
3	1	1	5.00
3	2	2	11.00
3	2	3	5.00
3	2	4	12.00
4	2	1	5.00
4	2	2	18.50
4	2	3	5.00
4	2	4	13.00

Table 4.5 Amount of used lubricating oil(ton) sent to used 2nd class used lubricating oil collection centers from users.

Assignments_V(I,B,P)			
I	B	P	
1	1	1	3.00
1	1	2	1.00
1	1	3	4.00
1	1	4	2.50
1	2	2	6.50
1	2	3	3.50
1	2	4	2.00
2	1	1	6.00
2	1	2	9.00

2	1	3	6.00
2	1	4	7.50
3	2	1	3.00
3	2	2	6.60
3	2	3	3.00
3	2	4	7.20
4	2	1	3.00
4	2	2	11.10
4	2	3	3.00
4	2	4	7.80

Table 4.6 Amount of used lubricating oil (tons) send to 3rt class used lubrication oil collection center from user

Assignments_T(I,C,P)			
I	C	P	
1	2	1	2.00
1	2	2	5.00
1	2	3	5.00
1	2	4	3.00
2	1	1	1.00
2	1	3	1.00
2	2	1	3.00
2	2	2	6.00
2	2	3	3.00
2	2	4	5.00
3	1	1	2.00
3	1	3	2.00
3	2	2	4.40
3	2	4	4.80
4	1	1	2.00
4	1	2	5.00
4	1	3	2.00
4	1	4	5.00
4	2	2	2.40
4	2	4	0.20

Table 4.7 Amount of used lubricating oil (tons) sent to recycle center from 1st class used lubrication oil collection

Assignments_W(D,K,P)			
D	K	P	
1	1	1	20.00
1	1	2	3.00
1	1	3	12.50
1	2	2	14.00
1	2	4	5.00
2	4	1	5.00
2	4	2	40.00

2	4	3	20.00
2	4	4	40.00

Table 4.8 Amount of used lubricating oil (tons) sent to recycle center from 2nd class used lubrication oil collection

Assignments_Y(C,K,P)			
C	K	P	
1	1	1	5.00
1	1	3	5.00
1	1	4	5.00
1	2	2	5.00
2	1	1	5.00
2	1	2	17.80
2	1	3	8.00
2	1	4	13.00

Table 4.9 Amount of used lubricating oil (tons) sent to recycle center from 3th class used lubrication oil collection

Assignments_X(B,K,P)			
B	K	P	
1	1	1	9.00
1	1	3	10.00
1	1	4	10.00
1	2	2	10.00
2	1	1	6.00
2	1	2	24.20
2	1	3	9.50
2	1	4	17.00

Table 4.10 The Amount of lubrication oil's Raw Material(Ton) that obtained by The Recycled Center, sent to Factories

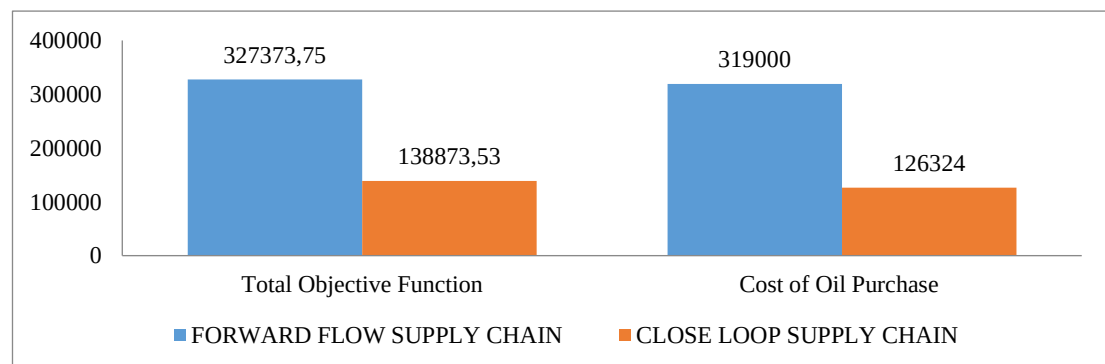
Assignments_L(K,Q,P)			
L	Q	P	
1	1	1	39.66
1	1	3	24.66
2	1	2	4.66
2	1	4	4.66
4	1	1	5.00
4	1	2	28.00
4	1	3	20.00
4	1	4	40.00
4	4	2	12.00

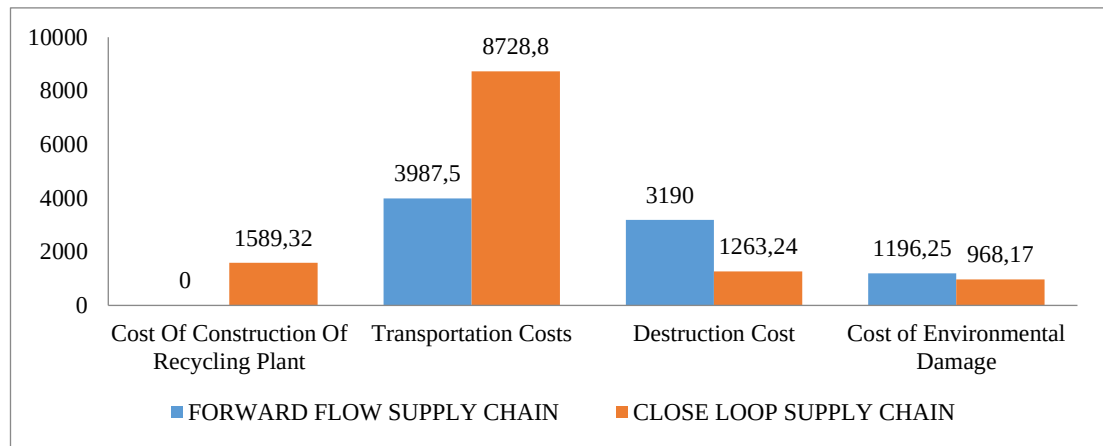
The solution of objective functions obtained with the solution of the mathematical model is presented in Table 4-14.

Table 4.11 The solution of blockchain integrated CLSC's results obtained by the mathematical model

The Objective Functions of Blockchain Integrated CLSC	
Total Objective Function	138873,53 \$
Cost of Oil Purchase	126324,00
Cost Of Construction Of Recycling Plant	1589,32\$
Transportation Costs	8728,80 \$
Destruction Cost	1263,24 \$
Cost of Environmental Damage	968,17 \$

When the values obtained from the forward flow supply chain and the Blockchain integrated CLSC were analyzed, As a result of the acquisition of raw materials from the recycling facilities, the total cost is decreased \$ 192676.00 by the cost of the purchased raw materials. Furthermore, the installation cost of the recycling plant increased to \$ 1589.32 and the transport costs increased to \$ 4741.30. 1926,76 \$ has been gained from Destruction Cost and 1926,76 \$ has been gained from Cost of Environmental Damage. As a result of the mathematical model created with the aim of reducing the cost and reducing the damage to the environment, our main purpose functions totaled \$ 188500.22 profit. Comparison of the obtained data is presented in table 4-15 and table 4-16.

Table 4.12 Comparison of The Obtained Data.**Table 4.16** Comparison of The Obtained Data.



CHAPTER 5

CONCLUSION

Increasing the population of the world industrialization intensifies the energy consumption of urbanization and the comfort need of people increases. The oil resources used as the most important energy source in the world are decreasing day by day and their prices are increasing. It is very important for the future of humanity to produce new universal renewable energy sources that are not connected to a region or a resource because of this limited increase in energy use and the general fossil fuel reserves and environmental damage. Recycling of waste oils with high efficiency and quality is very important in terms of resource savings and environmental pollution besides economic gains. Recycling is a productive economic investment in the long term. As a result of the decrease in raw material and the rapid depletion of natural resources, economic problems can arise and recycling at this point has a positive effect on the economy. It provides new job opportunities and offers natural resources to future generations. In this study, it will be ensured that the country's economy will gain big gains through the use of waste oils in recovery. Waste oils are collected by licensed companies due to their pollutant properties and are subject to recovery and disposal operations. It is extremely wrong to look at waste oils like substances that are useless and have no economic value. Today, biodiesel, soap, feeder, diesel fuel alternative, is produced with the recovery of waste oil and energy recovery is achieved by incineration in facilities licensed from the Ministry of Environment and Urbanization.

There is a need for lubrication in order to ensure that both the peace and warfare-time vehicles which are used military forces, can operate properly. A lubrication closed loop supply chain has been set up to know how to reduce oil sources and limited time to apply petroleum buffers or raw petroleum which cannot be reached in an unreachable state and to meet the oil requirement in a continuous manner. It is tried to minimize the damage caused by waste lubricated oils to the environment. In addition to this, tried to reduced the cost by blockchain technology.. In this process, the

transparency and traceability features of the blockchain technology were utilized. At the same time, Bitcon, which is the firm of Blockchain technology, used all payments to reduce the costs required for money transfers. For this purpose, we first researched whether or not the literature review has been working on the use of the lubricating oil in the closed loop supply chain and supply chain integrated with blockchain. Other different systems under literature review have been examined. A literature review has provided information on closed loop supply chain and blockchain. A lubrication oil closed loop supply chain integrated Blockchain network is created, and a multi-purpose, multi-purpose, single-product mathematical model of the network is introduced.

As a result, normally, the cost of lubricating oil from external suppliers is reduced by establishing a closed-loop supply chain. With the blockchain technology added to this system, it is thought that costs will be reduced to the minimum level by reducing costs such as transportation and storage. In this respect, it has been tried to minimize the dependency of the armed forces on the need for lubrication oil.

Within the scope of the calculation of the damage caused to the environment, it has been revealed which activities harm the environment. These were identified as transport, destruction and production activities. When the environmental damage of these activities is examined, the carbon dioxide gas released the atmosphere is based on. The carbon dioxide gas in which the tankers used for the transportation of the lubricating oils are released per kilometer is divided by the weight of the lubricating oil it carries. Thus, the amount of carbon dioxide produced per kilometer is found. By assigning a coefficient to this amount, the damage caused to the environment as a result of the transport activity has been minimized. In addition, the amount of carbon dioxide released during the destruction activity was divided by the amount of converted oil and the amount of carbon dioxide released per tonne was calculated. The value has been assigned a coefficient compared to the value in the transport asset.

According to the resulting model, factories numbered 1 and 4 and distribution centers numbered 1,2 and 3 were used. 1st and 2nd class 1st and 2nd class used lubricating oil collection centers are used. 3rd class used lubrication oil collection centers 1, 2

and 4 were used. Recycling plants with recycling number 1 and 2 were used and the costs were reduced to a minimum.

Future Research

In future studies, the harm to the environment can be added to the mathematical model to calculate the harm to the environment. At the same time, the lubrication oil supply that the system needs not only be limited to the used lubrication oil obtained from the armed forces, but which is especially needed for mass transportation vehicles, which have a large number of vehicles and are in constant motion and need oil change in the short term, can be considered.



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APPENDICES

Appendix A- GAMS KODLARI

SET

Q FABRİKA SAYISI /1*4/

P PERİYOT /1*4/

F DEPO SAYISI /1*4/

K DONUSUM MERKEZİ SAYISI /1*4/

I KULLANICI SAYISI /1*4/

D 1 INCI SINIF YAG TOLAMA MERKEZİ /1*3/

B 2 INCI SINIF YAG TOLAMA MERKEZİ /1*3/

C 3 INCI SINIF YAG TOLAMA MERKEZİ /1*3/

G YOKETME MERKEZİ SAYISI/1/

PARAMETER

MESAFE1(Q,F)

/1.1 10

1.2 20

1.3 63

1.4 41

2.1 15

2.2 30

2.3 75

2.4 23

3.1 48

3.2 98

3.3 75

3.4 69

4.1 63

4.2 25

4.3 35

4.4 45 /

MESAFE2(F,I)

/ 1.1 10

1.2 20

1.3 25

1.4 5

2.1 15

2.2 30

2.3 15

2.4 8

3.1 12

3.2 5

3.3 15

3.4 6

4.1 25

4.2 45

4.3 62

4.4 36 /

MESAFE3(I,D)

/ 1.1 10

1.2 20

1.3 25

2.1 15

2.2 30

2.3 52

3.1 13

3.2 21

3.3 26

4.1 25

4.2 15

4.3 16 /

MESAFE4(I,B)

/ 1.1 10

1.2 20

1.3 47

2.1 15

2.2 30

2.3 41

3.1 36

3.2 21

3.3 25

4.1 52

4.2 45

4.3 75 /

MESAFE5(I,C)

/1.1 10

1.2 20

1.3 25

2.1 15

2.2 30

2.3 28

3.1 15

3.2 35

3.3 45

4.1 24

4.2 45

4.3 62 /

MESAFE6(D,K)

/ 1.1 10

1.2 20

1.3 58

1.4 74

2.1 15

2.2 30

2.3 74

2.4 15

3.1 65

3.2 85

3.3 62

3.4 14 /

MESAFE7(B,K)

/ 1.1 10

1.2 20

1.3 200

1.4 235

2.1 15

2.2 30

2.3 15

2.4 250

3.1 369

3.2 2547

3.4 256 /

MESAFE8(C,K)

/ 1.1 10

1.2 20

1.3 25

1.4 40

2.1 15

2.2 30

2.3 20

2.4 52

3.1 26

3.2 69

3.3 25

3.4 85 /

MESAFE9(K,Q)

/ 1.1 10

1.2 20

1.3 30

1.4 25

2.1 15

2.2 30

2.3 25

2.4 25

3.1 26

3.2 56

3.3 78

3.4 65 /

MESAFE10(K,G)

/ 1.1 10

2.1 25

3.1 268

4.1 486 /

FABKAP(Q,P)

/ 1.1 500

1.2 500

1.3 500

1.4 500

2.1 100

2.2 100

2.3 200

2.4 200

3.1 500

3.2 500

3.3 500

3.4 500

4.1 100

4.2 100

4.3 200

4.4 200 /

HMKAP(P)

/ 1 125

2 125

3 100

4 100 /

DEPKAP(F,P)

/ 1.1 80

1.2 80

1.3 80

1.4 80

2.1 40

2.2 40

2.3 40

2.4 40

3.1 20

3.2 15

3.3 25

3.4 14

4.1 14

4.2 14

4.3 10

4.4 10 /

TALEP(I,P)

/ 1.1 10

1.2 25

1.3 25

1.4 15

2.1 20

2.2 30

2.3 20

2.4 25

3.1 10

3.2 22

3.3 10

3.4 24

4.1 10

4.2 37

4.3 10

4.4 26 /

DKAP(D,P)

/ 1.1 20

1.2 20

1.3 20

1.4 40

2.1 40

2.2 40

2.3 40

2.4 40

3.1 5

3.2 5

3.3 5

3.4 5 /

BKAP(B,P)

/ 1.1 10

1.2 10

1.3 10

1.4 10

2.1 25

2.2 25

2.3 25

2.4 25

3.1 251

3.2 247

3.3 26

3.4 14 /

CKAP(C,P)

/ 1.1 5

1.2 5

1.3 5

1.4 5

2.1 25

2.2 25

2.3 25

2.4 25

3.1 986

3.2 756

3.3 14

3.4 741 /

DMRKAP(K,P)

/ 1.1 45

1.2 45

1.3 45

1.4 45

2.1 65

2.2 85

2.3 65

2.4 65

3.1 54

3.2 47

3.3 45

3.4 79

4.1 69

4.2 78

4.3 74

4.4 75 /

FAB(P)

/ 1 4

2 4

3 4

4 4 /

DEP(P)

/ 1 4

2 4

3 4

4 4 /

ASAY(P)

/ 1 4

2 4

3 4

4 4/

BSAY(P)

/ 1 4

2 4

3 4

4 4/

CSAY(P)

/ 1 4

2 4

3 4

4 4/

KSAY(P)

/ 1 4

2 4

3 4

4 4/

SAT

/1000/

DMFXCOST

/500/

DMCOST

/2/

TRN

/0.5/

YOKETMALY

/10/

ZCVR

/0.03/

YOKETCVR

/3/

ALFA /0.5/

BETA /0.3/

TETA /0.2/

KAPPA /0.70/

LAMBDA /0.30/

DELTA/0.5/

ROMEO/0.3/

TANGO/0.7/

BC /0.1/

BCT /0.2/

VARIABLES

OBJFUNC

OBJFUNC1

OBJFUNC2

OBJFUNC3

OBJFUNC4

OBJFUNC5

 $H(Q,P)$ $A(Q,F,P)$ $Z(F,I,P)$ $U(I,D,P)$ $V(I,B,P)$ $T(I,C,P)$ $W(D,K,P)$ $X(B,K,P)$ $Y(C,K,P)$ $S(K,G,P)$ $L(K,Q,P)$ $QQ(Q,P)$ $FF(F,P)$

DD(D,P)

BB(B,P)

CC(C,P)

KK(K,P)

BINARY VARIABLES

KK(K,P),FF(F,P),QQ(Q,P),DD(D,P),BB(B,P),CC(C,P) ;

POSITIVE VARIABLES

H(Q,P),A(Q,F,P),Z(F,I,P),U(I,D,P),V(I,B,P),T(I,C,P),W(D,K,P),X(B,K,P),Y(C,K,P),
S(K,G,P), L(K,Q,P);

EQUATIONS

OBJ

OBJ1

OBJ2

OBJ3

OBJ4

OBJ5

CONST1

CONST2

CONST3

CONST4

CONST5

CONST6

CONST7

CONST8

CONST9

CONST10

CONST11

CONST12

CONST13

CONST14

CONST15

CONST16

CONST17

CONST18

CONST19

CONST20

CONST21

CONST22

CONST23

CONST24

CONST25 ;

OBJ..

OBJFUNC=E=OBJFUNC1+OBJFUNC2+OBJFUNC3+OBJFUNC4+OBJFUNC5;

OBJ1.. OBJFUNC1=E=SUM((Q,P),H(Q,P))*(SAT-(SAT*BC));

OBJ2(P)..OBJFUNC2=E=(SUM((K),KK(K,P))*DMFXCOST)+(SUM((K,Q),L(K,Q,P))*DMCOST);

OBJ3..OBJFUNC3=E=(SUM((Q,F,P),MESAFE1(Q,F)*(TRN-(TRN*BCT))*A(Q,F,P))+SUM((F,I,P),MESAFE2(F,I)*(TRN-(TRN*BCT))*Z(F,I,P))+SUM((I,D,P),MESAFE3(I,D)*(TRN-(TRN*BCT))*U(I,D,P))+SUM((I,B,P),MESAFE4(I,B)*(TRN-(TRN*BCT))*V(I,B,P))+SUM((I,C,P),MESAFE5(I,C)*(TRN-(TRN*BCT))*T(I,C,P))+SUM((D,K,P),MESAFE6(D,K)*(TRN-(TRN*BCT))*W(D,K,P))+SUM((B,K,P),MESAFE7(B,K)*(TRN-(TRN*BCT))*X(B,K,P))+SUM((C,K,P),MESAFE8(C,K)*(TRN-(TRN*BCT))*Y(C,K,P))+SUM((K,Q,P),MESAFE9(K,Q)*(TRN-(TRN*BCT))*L(K,Q,P))+SUM((K,G,P),MESAFE10(K,G)*(TRN-(TRN*BCT))*S(K,G,P)));

OBJ4..OBJFUNC4=E=SUM((K,G,P),S(K,G,P))*(YOKETMALY-(YOKETMALY*BC));

OBJ5..OBJFUNC5=E=SUM((Q,F,P),MESAFE1(Q,F)*(ZCVR-(ZCVR*BC))*A(Q,F,P))+SUM((F,I,P),MESAFE2(F,I)*(ZCVR-(ZCVR*BC))*Z(F,I,P))+SUM((I,D,P),MESAFE3(I,D)*(ZCVR-(ZCVR*BC))*U(I,D,P))+SUM((I,B,P),MESAFE4(I,B)*(ZCVR-(ZCVR*BC))*V(I,B,P))+SUM((I,C,P),MESAFE5(I,C)*(ZCVR-(ZCVR*BC))*T(I,C,P))+SUM((D,K,P),MESAFE6(D,K)*(ZCVR-(ZCVR*BC))*W(D,K,P))+SUM((B,K,P),MESAFE7(B,K)*(ZCVR-(ZCVR*BC))*X(B,K,P))+SUM((C,K,P),MESAFE8(C,K)*(ZCVR-(ZCVR*BC))*Y(C,K,P))+SUM((K,Q,P),MESAFE9(K,Q)*(ZCVR-(ZCVR*BC))*L(K,Q,P))+SUM((K,G,P),MESAFE10(K,G)*(ZCVR-

$(ZCVR*BC))*S(K,G,P))+SUM((K,G,P),S(K,G,P))*(YOKETCVR-(YOKETCVR*BC));$

$CONST1(Q,P)..H(Q,P)+SUM((K),L(K,Q,P))=E=SUM((F),A(Q,F,P));$

$CONST2(Q,P)..H(Q,P)+SUM((K),L(K,Q,P-1))=L=FABKAP(Q,P)*QQ(Q,P);$

$CONST3(P)..SUM((Q),QQ(Q,P))=L=FAB(P);$

$CONST4(F,P)..SUM(Q,A(Q,F,P))=E=SUM(I,Z(F,I,P));$

$CONST5(F,P)..SUM(Q,A(Q,F,P))=L=DEPKAP(F,P)*FF(F,P);$

$CONST6(P)..SUM((F),FF(F,P))=L=DEP(P);$

$CONST7(I,P)..SUM((F),Z(F,I,P))=E=TALEP(I,P);$

$CONST8(I,P)..TALEP(I,P)*ALFA=E=SUM((D),U(I,D,P));$

$CONST9(I,P)..TALEP(I,P)*BETA=E=SUM((B),V(I,B,P));$

$CONST10(I,P)..TALEP(I,P)*TETA=E=SUM((C),T(I,C,P));$

$CONST11(I,P)..SUM((F),Z(F,I,P))=E=SUM((D),U(I,D,P))+SUM((B),V(I,B,P))+SUM((C),T(I,C,P));$

$CONST12(D,P)..SUM((I),U(I,D,P))=E=SUM((K),W(D,K,P));$

$CONST13(D,P)..SUM((I),U(I,D,P))=L=DKAP(D,P)*DD(D,P);$

$CONST14(P)..SUM((D),DD(D,P))=L=ASAY(P);$

$CONST15(B,P)..SUM((I),V(I,B,P))=E=SUM((K),X(B,K,P));$

$CONST16(B,P)..SUM((I),V(I,B,P))=L=BKAP(B,P)*BB(B,P);$

$CONST17(P)..SUM((B),BB(B,P))=L=BSAY(P);$

CONST18(C,P)..SUM((I),T(I,C,P))=E=SUM((K),Y(C,K,P));

CONST19(C,P)..SUM((I),T(I,C,P))=L=CKAP(C,P)*CC(C,P);

CONST20(P)..SUM((C),CC(C,P))=L=CSAY(P);

CONST21(K,P)..SUM((D),W(D,K,P))+SUM((B),X(B,K,P))+SUM((C),Y(C,K,P))=
E=SUM((Q),L(K,Q,P))+SUM((G),S(K,G,P));

CONST22(K,P)..SUM((D),W(D,K,P))+SUM((B),X(B,K,P))+SUM((C),Y(C,K,P))=
L=DMRKAP(K,P)*KK(K,P);

CONST23(P)..SUM((K),KK(K,P))=L=KSAY(P);

CONST24..(SUM((K,P,D),W(D,K,P))*KAPPA)+(SUM((B,K,P),X(B,K,P))*DELT
A)+(SUM((C,K,P),Y(C,K,P))*ROMEO)=E=SUM((K,Q,P),L(K,Q,P));

CONST25..SUM((K,P,D),W(D,K,P))*LAMBDA+SUM((B,K,P),X(B,K,P))*DELT
A+SUM((C,K,P),Y(C,K,P))*TANGO=E=SUM((K,G,P),S(K,G,P));

MODEL CLOSEDLOOPSCM /all/;

CLOSEDLOOPSCM.optcr=0;

CLOSEDLOOPSCM.reslim=3600;

CLOSEDLOOPSCM.iterlim=1e9;

CLOSEDLOOPSCM.limrow=1000;

CLOSEDLOOPSCM.limcol=1000;

SOLVE CLOSEDLOOPSCM USING MIP MINIMIZING OBJFUNC;

file outfile /_CLOSEDLOOPSCM.txt/;

put outfile;

put 'IsOptimum'; put CLOSEDLOOPSCM.modelstat; put /;

```

put 'Objective_Value'; put OBJFUNC.l; put /;

put 'Objective_Value1'; put OBJFUNC1.l; put /;

put 'Objective_Value2'; put OBJFUNC2.l; put /;

put 'Objective_Value3'; put OBJFUNC3.l; put /;

put 'Objective_Value4'; put OBJFUNC4.l; put /;

put 'Lower_Bound'; put CLOSEDLOOPSCM.ObjEst; put /;

put 'Number_of_Iteration'; put CLOSEDLOOPSCM.iterusd; put /;

put 'CPU_Second'; put CLOSEDLOOPSCM.resusd; put /;

put 'Number_of_variables'; put CLOSEDLOOPSCM.numvar; put /;

put 'Number_of_equations'; put CLOSEDLOOPSCM.numequ; put /;

put /; put 'Assignments_A(Q,F,P)'; put /;    Loop((Q,F,P)$A.l(Q,F,P), put Q.tl; PUT
F.tl; PUT P.tl; put A.l(Q,F,P); put /;);

put /; put 'Assignments_Z(F,I,P)'; put /;    Loop((F,I,P)$Z.l(F,I,P), put F.tl; PUT I.tl;
PUT P.tl; put Z.l(F,I,P); put /;);

put /; put 'Assignments_U(I,D,P)'; put /;    Loop((I,D,P)$U.l(I,D,P), put I.tl; PUT
D.tl; PUT P.tl; put U.l(I,D,P); put /;);

put /; put 'Assignments_V(I,B,P)'; put /;    Loop((I,B,P)$V.l(I,B,P), put I.tl; PUT
B.tl; PUT P.tl; put V.l(I,B,P); put /;);

put /; put 'Assignments_T(I,C,P)'; put /;    Loop((I,C,P)$T.l(I,C,P), put I.tl; PUT
C.tl; PUT P.tl; put T.l(I,C,P); put /;);

put /; put 'Assignments_W(D,K,P)'; put /;    Loop((D,K,P)$W.l(D,K,P), put D.tl;
PUT K.tl; PUT P.tl; put W.l(D,K,P); put /;);

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put /; put 'Assignments_X(B,K,P)'; put /; Loop((B,K,P)\$X.l(B,K,P), put B.tl; PUT
K.tl; PUT P.tl; put X.l(B,K,P); put /;);

put /; put 'Assignments_H(Q,P)'; put /; Loop((Q,P)\$H.l(Q,P),PUT Q.tl; PUT P.tl;
put H.l(Q,P); put /;);

put /; put 'Assignments_Y(C,K,P)'; put /; Loop((C,K,P)\$Y.l(C,K,P), put C.tl; PUT
K.tl; PUT P.tl; put Y.l(C,K,P); put /;);

put /; put 'Assignments_S(K,G,P)'; put /; Loop((K,G,P)\$S.l(K,G,P),PUT K.tl;PUT
G.tl; PUT P.tl; put S.l(K,G,P); put /;);

put /; put 'Assignments_L(K,Q,P)'; put /; Loop((K,Q,P)\$L.l(K,Q,P), put K.tl; PUT
Q.tl; PUT P.tl; put L.l(K,Q,P); put /;);

put /; put 'Assignments_QQ(Q,P)'; put /; Loop((Q,P)\$QQ.l(Q,P), put Q.tl; PUT
P.tl; put QQ.l(Q,P); put /;);

put /; put 'Assignments_FF(F,P)'; put /; Loop((F,P)\$FF.l(F,P), put F.tl; PUT P.tl;
put FF.l(F,P); put /;);

put /; put 'Assignments_DD(D,P)'; put /; Loop((D,P)\$DD.l(D,P), put D.tl; PUT
P.tl; put DD.l(D,P); put /;);

put /; put 'Assignments_BB(B,P)'; put /; Loop((B,P)\$BB.l(B,P), put B.tl; PUT
P.tl; put BB.l(B,P); put /;);

put /; put 'Assignments_CC(C,P)'; put /; Loop((C,P)\$CC.l(C,P), put C.tl; PUT
P.tl; put CC.l(C,P); put /;);

put /; put 'Assignments_KK(K,P)'; put /; Loop((K,P)\$KK.l(K,P), put K.tl; PUT
P.tl; put KK.l(K,P); put /;);

CURRICULUM VITAE

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EDUCATION

High School : 60. Year Anatolian High School

Bachelor : Naval Academy, Industrial Engineering (2003-2007)

Master Degree : Ankara Yıldırım Beyazıt University, Industrial Engineering (2017-2019)

WORK EXPERIENCE

Turkish Navy Force (2007-)

TOPICS OF INTEREST

- Supply Chain

- Multi Criteria Decision Methods