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GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

EMERGENCY LOGISTIC PLANNING SITUATIONS AND FLOW GAMES

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APPROVAL OF THE THESIS

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COMMITMENT

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

M.Sc. Thesis

EMERGENCY LOGISTICS PLANNING SITUATIONS AND FLOW GAMES

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In this thesis, a theoretical model was developed for emergency logistics planning. As an application. A cooperative game model was created from the flow problem that followed a natural disaster in Iran. Many solutıon offers are given to maximize movable goods.

We aim to plan logistics in the event of a disaster using the flow of games. Logistics planning is necessary to cover initial needs immediately after a disaster. The planning and supply of emergency supplies, the type and quantity of current sources, the method of procurement and storage of supplies, the basic tracking and sports equipment of the affected area, the teams participating in the operation and the plan of cooperation between these teams are some vital coordination roles to save lives after natural disasters directly associated with logistics planning.

The thesis ends by presenting the results of the study and some suggestions for future studies.

Keywords: Logistic Network, Flow Problem, Cooperative Game Theory, Shapley value, Emergency planning.

2018, 52 pages

ÖZET

Yüksek Lisans Tezi

ACİL LOJİSTİK PLANLAMA DURUMLARI VE AKIŞ OYUNLARI

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Bu tezde, acil lojistik planlama durumları ile ilgili teorik bir model geliştirilmiştir. Uygulamada ise İran'daki doğal bir afet sonrası oluşan akış problemi ile ilgili bir işbirlikçi oyun modeli yaratılmıştır. Bu bağlamda, taşınabilir ürünleri maksimuma çıkarmak için çeşitli çözüm önerileri getirilmiştir.

Akış oyunları kullanılarak afet durumundaki lojistiği planlamak amaçlanmıştır. Acil ürünlerin planlanması ve tedariki, kaynakların çeşitliliği ve kalitesi, kullanılan tedarik etme ve depolama metotları, etkilenen alanın temel takibi, operasyona katılan takımlar ve takımlar arası işbirliğinin tamamı kurtarılacak hayatlar için hayati önem taşımaktadır ve lojistik planlama ile alakalıdır.

Tezimiz, çalışmamızın sonuçları sunularak ve gelecekte yapılabilecek çalışmalara dair önerilerde bulunularak sona ermektedir.

Anahtar Kelimeler: Lojistik Ağ, Akış Sorunu, Kooperatif Oyun Teorisi, Shapley değeri, Acil planlama.

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LIST OF SYMBOLS AND ABBREVIATION

R^N	N-dimensional real vector space
$\mathbb{Z}$	The set of complex numbers
$\mathbb{R}$	The set of all real numbers
$\mathbb{N}$	The set of all natural numbers
$\mathbb{Q}$	The set of rational numbers
I	The set of integer number
$A \subseteq B$	Subset: A has some (or all) elements of B
$A \subset B$	Proper Subset: A has some elements of B
$A \not\subset B$	Not a Subset: A is not a subset of B
$A \supseteq B$	Superset: A has same elements as B, or more
$A \supset B$	Proper Superset: A has B's elements and more
$A \not\supset B$	Not a Superset: A is not a superset of B
A^c	Complement: elements not in A
$A \cup B$	Union: in A or B (or both)
$A \cap B$	Intersection: in both A and B
$A \setminus B$	Difference: in A but not in B
$A = B$	Equality: both sets have the same members
$A \times B$	Cartesian product: set of ordered pairs from A and B
$\|A\|$	Cardinality: the number of elements of set A
$a \in A$	Element of: a is in A
$b \notin A$	Not element of: b is not in A

$\emptyset$	The empty set
$\leq$	Smaller or equal to
$\geq$	Greater or equal to
N	The set of players
i	A player
G	The game
G^N	The set of all cooperative games
$\langle N , v \rangle$	Cooperative game
v	Characteristic function
$v(S)$	The value of the coalition S
2^N	The set of subset of N
$\pi(N)$	The set of all permutations (possible orderings) of players N
$p^\sigma(i)$	A permutation
$m^\sigma(v)$	Marginal contribution vector
$\Phi(v)$	Shapley valaue
σ	Any permutation
Σ	Sum

1. INTRODUCTION

1.1. Disasters

The number of disasters has increased in recent years, and every year hundreds of millions of people are affected. The rapid response to emergency relief needs immediately after disasters through emergency logistics is vital to mitigate the impact of disasters in affected areas.

Disasters are divided into two types.

1- Natural disasters. For example earthquakes and volcanoes, etc .
2- Man – made disasters. For example war and bomb, etc.

Natural and man-made disasters differ in the amount of damage caused by natural disasters, such as earthquakes and volcanoes, causing human and material damage. Wars also cause deaths and explosions that pollute the environment.

Disasters are defined as unusual events that occur somewhat abruptly and therefore require extensive response efforts. These disasters affect the lives of individuals and society so that any organization or country that has the capacity to respond directly to disaster relief in order to save lives.

Natural disasters or man-made effects are related to the health, economic and social conditions of the affected area. In the event of disasters, it is difficult to control the direct leadership and the social relations disappear because of the disintegration of the daily performance and the inadequate health and relief systems where the survivors do not know where they are going to receive help. (John Wiley et al, 2005 ; Kovács, 2009). Therefore, the management of humanitarian assistance and use of resources must be improved. Although logistics are currently the largest and most complex component of relief operations, most relief workers usually see this only. It is necessary to maximize humanitarian relief by better preparedness to improve emergency logistics services after disasters occur.

In the planning and preparation phase, all information and activities that will be the basis for the development of the logistics planning should be collected. Also, responsibilities, procedures and timetables should be clarified in the implementation of the supply chain related to emergency supplies. Before and after disasters, both natural and man – made, the logistics of humanitarian supplies must be balanced between speed, storage, security and transport costs, All disasters have great human suffering. Hundreds of millions of people are affected every year by natural or man – made disasters. Therefore, the risks, supplies and relief needed from neighboring countries all over the world must be reduced to disaster.

Studies indicate that adequate emergency preparedness significantly reduces the negative consequences of disasters and can prevent most injuries, deaths and damage caused by disasters, and ensures people take care of themselves during the 72 hours after disaster. (Falkineret al, 2003). Strategies and logistical services help countries and organizations to organize access to the resources needed for rapid relief after a disaster, to achieve practical objectives systematically and to use available resources effectively. Emergency relief and response to care operations is carried out by a range of governmental and non-governmental organizations (NGOS) (Doerner, 2008).

The goal of responding to disasters is either natural or man-made and provide relief quickly (emergency food, water, medicine, shelter and supplies) . To areas affected by disasters, so as to minimize human loss and suffering and to minimize (Beamon, 2008). The design and implementation of the relief chain play important roles in effective response. But although logistics is key – factor to disaster response. Each country must reduce disaster risk by taking appropriate measures through regulations and legislation to prevent, mitigate, and alert disasters, conduct risk assessments, disseminate risk information and activate early warning systems for disasters. Humanitarian relief organizations have not begun to understand the importance of managing the relief chain and how important relief operations are in disaster situations. Their operations must be more transparent because they realize that they must be more results-oriented because they are accountable (Beamon, 2006; Van Wassenhove, 2006). Unfortunately, no standard model exists for using supply chain management (SCM) techniques to provide relief to populations affected by disasters. Also, the management of emergencies or disasters is often characterized as adjunct to ‘‘more routine’’ bureaucratic functions such as planning, financial management, human resources management, and economic development (Henderson, 2004).

1.2. Emergency Logistics Planning in Disasters

In this thesis, a planning model has been developed to be integrated into the logistic decision support system for both natural and man-made disasters. Emergency logistics planning involves the dispatch of goods for example, food, medical materials, personnel, specialized rescue teams, etc. To the distribution centers in the affected areas as soon as possible so as to speed up relief operations. The model addresses the problem of dynamic time – based transport that must be resolved frequently at specific time periods during ongoing assistance. The model restores plans containing new applications for aid materials and new supplies and transportation that are available during the current planning time horizon.

The plan refers to the ideal schedules for vehicle selection and delivery within the time horizon of planned planning, as well as the optimal quantities and types of loads captured and delivered on these routes.

A disaster, which can be both natural (earthquakes, floods, hurricanes), man-made (terrorist attacks, chemical leakages), and corruption in the construction sectoris the result of a vast ecological breakdown in the relations between human beings and their environment (Caunhye et al, 2011). In recent years, frequent natural disasters and man-made catastrophic events have brought great loss to human beings. Any occurrence of natural disasters, such as earthquakes, typhoons, floods, or drought, cause huge property damage and human injuries (Yuan and Wang, 2009). As a strongly upcoming area, emergency management is attracting more and more attention of researchers (Chang et al, 2007; Yuan and Wang, 2009).

Logistics is one of the most important tools now in disaster relief operations. The logistic planning is essential and a key component in covering the initial needs in the immediate aftermath of any disaster. Planning is both necessary and practical, as it is generally possible to predict the types of disasters that may affect a given location and the needs that such disasters will be likely to engender. Transport planning, reception and distribution of emergency supplies, type and quantity of the resources, way of procurement and storage of the supplies, tools of tracking and means transportation to the stricken area, specialization of teams participating in the operation and plan of cooperation between these teams, are some vital life-saving coordination roles after natural disasters that are connected directly to logistic planning. The logistics planning model proposed here is intended to be a component of a Logistics Decision Support System linking all relevant databases (stocking units, aid distribution centers, national transportation networks, search and rescue teams, and the central aid coordination centre, etc). The most important issue for the logistic network is how to distribute and transport inventory on time and under stable conditions. The cooperation in SCM can reduce and increase both the logistic network's total cost and gain, respectively (Reyes, 2005).

1.3. Introduction to Game Theory

Game theory is the process of modeling the strategic interaction between two or more players in a position containing rules and specific results. While used in theory in a number of respects, game theory is used in particular as a tool in the study of economics. The economic application of gaming theory can be a valuable tool to help analyze industries and sectors and any strategic interaction between two or more companies. Here, we will take a preliminary look at game theory and conditions.

Game theory is the official study of conflict and cooperation. Game theory concepts provide language for the formulation, analysis and understanding of its structure. Game theory is branch of advanced applied mathematics through ancient and modern studies, has been able to attract many of the world's greatest mathematicians, won two

Nobel Prizes, and even credited for winning the Cold War. The theory of the game dates back to a long time. The mathematician Emile Borel (1871-1956) introduced the notion of a mixed, or randomized, strategy when he investigated some elementary duels around 1920. John von Neumann proved in 1928, that every two-person, zero-sum game must have optimal mixed strategies and an expected value for the game. His result was extended to the existence of equilibrium outcomes in mixed strategies for multi person games that are either constant-sum or variable-sum by John F. Nash Jr. (1931), in 1951. Modern game theory dates from the famous minima theorem that was proven by von Neumann. He gradually expanded his work in game theory, and with co-author Oskar Morgenstern. They wrote the classic text Theory of Games and Economic Behaviour (1944) and introduced the first general model and solution concept for multi person cooperative games, which are primarily concerned with coalition formation (economic, voting blocs, and military alliances) and the resulting distribution of gains or losses. The Nobel Memorial Prize in Economics is awarded to three game theorists in 1994. The recipients were John C. Harsanyi (1920) of the University of California, Berkeley, John F. Nash of Princeton University, and Reinhard Selten (1930) of the University of Bonn, Germany. Game theory has provided important theoretical foundations in economics, political science especially in the study of voting, elections, and international relations. In addition, game theory has contributed major insights in environmental sciences, particularly in understanding the evolution of species and conditions under which animals fight each other for territory or act cooperatively. Conflict has been a major thread throughout human history. It arises when two or more person, with different values, compete to try to control the course of events. Game theory uses mathematical sciences to study cases that contain cooperation and conflict.

Game theory, branch of applied mathematics that provides tools for analyzing situations in which parties, called players, make decisions that are interdependent. This interdependence causes each player to consider the other player's possible decisions, or strategies, in formulating his own strategy. A solution to a game describes the optimal decisions of the players, who may have similar, opposed, or mixed interests, and the outcomes that may result from these decisions.

As a mathematical tool for the decision-maker the strength of game theory is the methodology it provides for structuring and analyzing problems of strategic choice. The process of formally modeling a situation as a game requires the decision-maker to enumerate explicitly the players and their strategic options, and to consider their preferences and reactions. The discipline involved in constructing such a model already has the potential of providing the decision-maker with a clearer and broader view of the situation. This is a prescriptive application of game theory, with the goal of improved strategic decision making. With this perspective in mind, this article explains basic principles of game theory, as an introduction to an interested reader without a background in economics.

Games, which are derived from a flow situation, are called flow games. (Kalai and Zemel, 1982) first introduced a flow game which arises from the revenue distribution problem related to the maximum flow in a network, where arcs are owned by different individuals. In our study, we investigate and handle the cooperative flow game which we construct in the framework of logistic network.

1.4. Cooperative Game Theory

Cooperative game theory focuses on cooperative behavior by analyzing the negotiation process within a group of players in establishing a contract on a joint plan of activities, including an allocation of the correspondingly generated revenues. In particular, the possible joint revenues of each possible coalition (a subgroup of cooperating players) are taken into account so as to allow for a better comparison of each player's role and impact within the group as a whole, and to settle on a compromise allocation (a solution) in an objectively justifiable way. In game theoretical models each player tries to maximize their own value taking into consideration that the other players do the same and that the decisions other players affect each other's values. Cooperative game theory, studies what the players can achieve what coalitions will form, how the formed coalitions divide the outcome, and whether the outcomes are stable and robust (Nagarajan and Sošic, 2008). Cooperative game theory focuses on the outcome of the game, where the outcome is measured in terms of the value created through cooperation of a subset of players (Cachon, 2004).

The payoff of a player in a cooperative game is the value created through the cooperation. The payoff can be represented by a vector. Most cooperative games with three or more players are formulated using the characteristic function form which specifies these payoffs to each coalition (Leng and Parlar , 2005). This is why the cooperative game is sometimes called the game in the characteristic form or the characteristic function game.

Let $N = \{1, 2, .. n\}$ be the set of players i $(i = 1, 2, ... n)$, where n is a positive integer, and $n \geq 2$. any subset $S$of the set N , $i.e.$, $S \subset N$, is called a coalition . $N$is referred to as the Grand coalition. $\emptyset$ is called an empty coalition, i.e. an empty set of players . Usually, we denote the set of coalitions of players in the set N by 2^N.

Denote the set of real numbers by R. A n-person cooperative game is an ordered pair$\langle N, v\rangle$, where $v : 2^N \rightarrow \mathbb{R}$ is the characteristic function which assigns a value $v(s)$ to the coalition $S \in 2^N$, and $v(\emptyset) = 0$. $v(s)$ is called the value of the coalition S. It can be interpreted as the maximal worth (or profit, reward, cost savings) that the players of the coalition S can obtain when they cooperate in the sequent, the n - person cooperative game$\langle N, v\rangle$ usually is referred to as the cooperative game v for short. The set of n– person cooperative games is denoted by G^n.

Definition 1.4.1

A cooperative game in characteristic function form is an ordered pair $\langle N, v\rangle$ consisting of the player set $N = \{1, 2, 3 \dots n\}$ and the characteristic function $v :$ $2^N \rightarrow R$ with $v(\emptyset) = 0$ (Dubey, 1975).

Elements of the set N are called players and the relevant set-function v the characteristic function of the game. A subset S of the player set $N(notation: S \subset N)$ is called a coalition and $v(S)$ the worth of coalition S in the game. The player set N itself is also called the grand coalition, whereas a coalition S is said to be non-trivial if $S \neq N, \emptyset$. The number of players in a coalition S is denoted by $|S|$. Generally, we shall identify the cooperative game $\langle N, v\rangle$ with its characteristic function v. further, the class of all cooperative $n - person$ games with player set N is denoted byG^N. Cooperative game in characteristic function form is usually referred to as a transferable utility game (TU-game).

Example 1.4.1 (Glove Game)

Let $N = \{1, 2, 3\}$ consisting of two disjoint subsets $L = \{1\}$ and $R = \{2, 3\}$ the members of L possess each one left-hand glove, the members of R one right-hand glove. A single glove is worth nothing, a right-left pair of gloves is worth 10 $. This situation can be modeled as a three - person game with $v(1,2) = v(1,3) = v(1,2,3) = 10$ and $v(S) = 0$, otherwise.

The family of cooperative games G^N with player set N forms with the usual operations of addition and scalar multiplication of functions $2^{|N|} - 1$ dimensional lineer space. A basis of this space is supplied by the unanimity games.

1.5. Flow Games

A flow is a way of sending objects from one place to another in a network. The objects that travel or flows through the network are called flow units or units. For example, flow units can be a commodity, finished goods, or information. The nodes from which units enter through a network are called source nodes, and nodes to which the flow units arerouted to are called sink nodes. Source nodes offer a supply, which is represented by the number of units available at the node. Sink nodes usually have demand, which is represented by the number of units that must be routed to them (Reyes, 2005). The network is presented as a graph with a set V whose elements are called vertices, and a set A of pairs of vertices called edges. The graph is denoted $G = (V, A)$. In practice, we specify a flow as a directed graph. The vertices in a directed graph are commonly called nodes, and the directed edges are often called arcs. The nodes from which units enter through a network are called source nodes, and nodes to which the flow units are routed to are called sink nodes. Source nodes offer supply, which is represented by the number of units available at the node. Sink nodes usually have demand, which is represented by the number of units that must be routed to them. A cooperative game in characteristic function form is an ordered pair $\langle N, v\rangle$ where N is a finite set of players and v is a characteristic function $v : 2^N \to R$ that associates to each set $S \subset N$ a real value $v(S)$ satisfying $v(\emptyset) = 0$. this value $v(S)$ shows the joint gain which the players in S can guarantee by themselves if they cooperate independently of what the agents in $N\backslash S$ could do. Hence, $v(S)$ measures the worth of a coalition S. The family of all cooperative games is denoted by G^N(Tijs, 2003). A flow is a way of sending objects from one vertex (place) to another in a network. The objects that travel or flow through the network is called flow units or units. For example, flow units can be a commodity, finished goods, or information. The nodes from which units enter through a network are called source nodes, and nodes to which the flow units are routed to be called sink nodes. Source nodes offer a supply, which is represented by the number of units available at the node. Sink nodes usually have demand, which is represented by the number of units that must be routed to them (Reyes, 2005).

Consider a flow problem between specific nodes (called source and sink) via a given network of arcs, each having its own maximal capacity per time unit. The corresponding optimization problem is to find an optimal flow in which the total inflow for each intermediate node equals the total outflow in such a way that the total flow from source to sink per time unit is maximized. According to the theorem of Ford-Fulkerson, the maximal total flow equals the minimal total capacity of a cut, where a cut is a collection of arcs such that no flow is possible from source to sink within the sub network of all arcs outside the cut. If one assumes that a set of players governs the arcs, i.e. if the use of an arc is restricted to specific coalitions only, then an allocation problem arises. How to allocate the revenues corresponding to a maximal total flow among the players.

Consider a capacitated network (V, E, k) and a set of players $N := \{1,2, \dots \dots \dots . . , n\}$ Suppose that with each edge in E a simple game is associated. The winning coalitions in this simple game are supposed to control the corresponding edge; the capacitated network is called a controlled capacitated network. For any coalition S ⊆ N consider the capacitated network arising from the given network by deleting the edges that are not controlled by S. A game can be defined by letting the worth of S be equal to the value of a maximal flow through this restricted network. The game thus arising is called a flow game.

Example 1.5.1

Consider the 3 - person flow problem as represented in Figure 1.5.1 on each arc the Capacity and corresponding control game are depicted. For the associated flow game v, we find the following coalitional values.

Table 1.5.1. Coalitional values.

S	$\{1\}$	$\{2\}$	$\{3\}$	$\{1,2\}$	$\{1,3\}$	$\{2,3\}$	$\{1,2,3\}$
$v(S)$	0	0	0	6	7	0	10

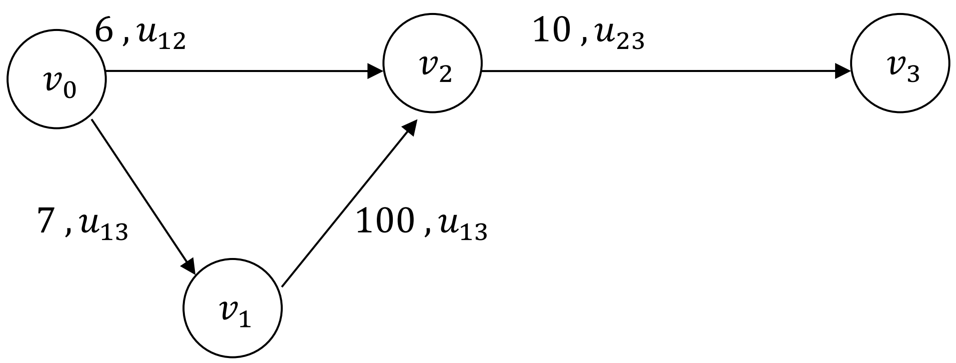

Figure 1.5.1: The flow problem of Example 1.5.1

Example 1.5.2

Consider the network in Figure 1.5.2. with one source one sink and one intermediate node, and three arcs l_1, l_2, l_3 with capacities 4, 5 and 10, respectively, and owners 1, 2 and 3, respectively.

The coalition $\{1, 3\}$ can only use the arcs l_1 and l_3, so the maximal flow (per time unit) for $\{1, 3\}$ is 4. This results in $(\{1, 3\}) = 4$ for the corresponding flow game $\langle N, v \rangle$. This game is given by $N = \{1, 2, 3\}$, $v(\{i\}) = 0$ if $i \in N$, $v(\{1, 2\}) = 0$, $v(\{1, 3\}) = 4$, $v(\{2, 3\}) = 5$ $and v(N) = 9$.

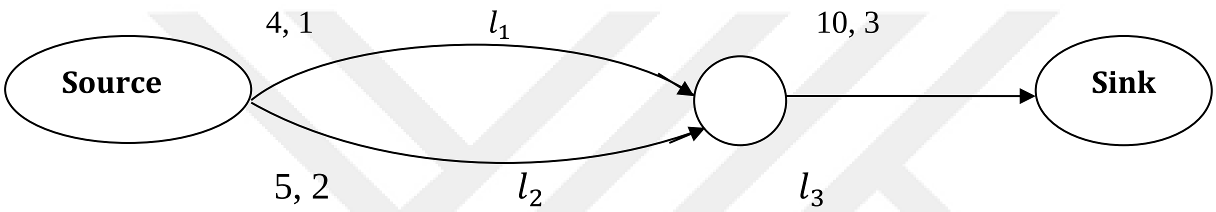

Figure 1.5.2: The flow problem of Example 1.5.2.

Example 1.5.3

Consider the network in Figure 2.4.1with one source one sink and one intermediate node, and three arcs l_1, l_2, l_3 with capacities $40, 60$, and 150, respectively, and owners $1, 2$, and 3 respectively.

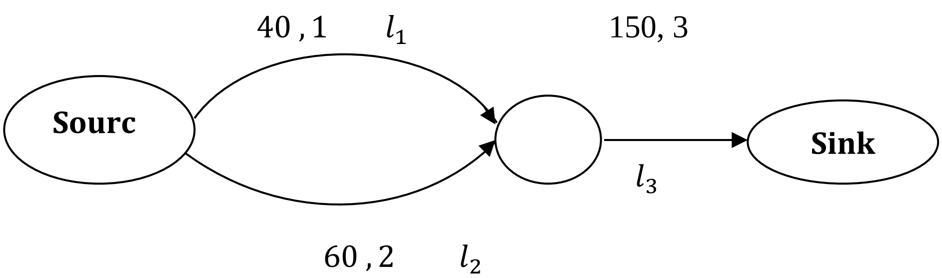

Figure 1.5.3. The flow problem of Example 1.5.3

While modeling the game we find to use maximal flow coming from source and going. The coalition $\{1\ ,3\ \}$ can only use the arcs l_1 and l_3 , so the maximal flow (per time unit) for $\{1\ ,3\}$ is 40 . This results in $(\{1\ ,3\})\ = 40$ for the corresponding flow game $\langle N, v\rangle$. This game is given by $N = \{1\ ,2\ ,3\}$, $v(\{i\}) = 0\ if\ i\ \in N$, $v\ (\{1\ ,2\}) = 0, v\ (\{1\ \ ,3\})\ = 40, v\ (\{2\ ,3\ \})\ = 60,$ and $v(N)\ = v(\{1\ ,2,3\}) = 100.$

Table 1.5.2. Maximal flow (per time unit) for S

S	Φ	**1**	**2**	**3**	$\{1\ ,2\}$	$\{1\ ,3\}$	$\{2\ ,3\}$	$\{1\ ,2\ ,3\}$
$v(s)$	0	0	0	0	0	40	60	100

1.5.1. Cooperative Flow Game

A cooperative flow game is a cooperative game model arising from the maximum flow Problem in a network.Consider a directed network $D = (V, E; \omega; s, t)$, where V is the vertex set, E is the arc set, $\omega: E \to \mathbb{R}^+$ is the arc capacity function, $s \in V$ and $t \in V$ are the 'source 'and the 'sink' of the network, respectively. Given a network $D = (V, E; \omega; s, t)$, let each player control one arc in E. Then the associated flow game $\Gamma_D = (E, v)$ is defined by the player set is E; for each $S \subseteq E, v(S)$ is the value of a maximum flow from s to t in the subnetwork $D[S] = (V, E; \omega; s, t)$, where $\omega_S: E \to \mathbb{R}^+$ is the restriction of ω on S (Deng et al., 2009).

1.6. Literature Review

In this section, we formally give some basic concepts and notions from cooperative games and flow problems, first some definitions of Emergency Management, Emergency Logistics Supply Chain and Supply Chain Management (SCM). Then some of the researches that reviewed the supply chain studies are summarized. As two main elements of supply chain and logistics planning, a brief introduction to facility location problem and vehicle routing are given. We formally give some basic concepts and notions from cooperative games and flow problems in order to provide the readers with all the necessary background to follow this thesis.

1.6.1. Emergency Management

Emergency management (or disaster management) is the discipline of avoiding risks and dealing with risks (Haddow et al. 2007). No country and no community are immune from the risk of disasters. However, it is possible to prepare for, respond to and recover from disasters and limit the destructions to a certain degree. Emergency management is a discipline that involves preparing for disaster before it happens, responding to disasters immediately, as well as supporting, and rebuilding societies after the natural or human made disasters have occurred.

Emergency management is a continuous process. It is essential to have comprehensive Emergency plans and evaluate and improve the plans continuously. The related activities are usually classified as four phases of Preparedness, Response, Recovery, and Mitigation. Figure 1.6.1 illustrates the order of these phases according to the onset of the disaster. A appropriate action at all points in the cycle lead to greater preparedness, better warnings, reduced vulnerability or the prevention of disasters during the next iteration of the cycle.

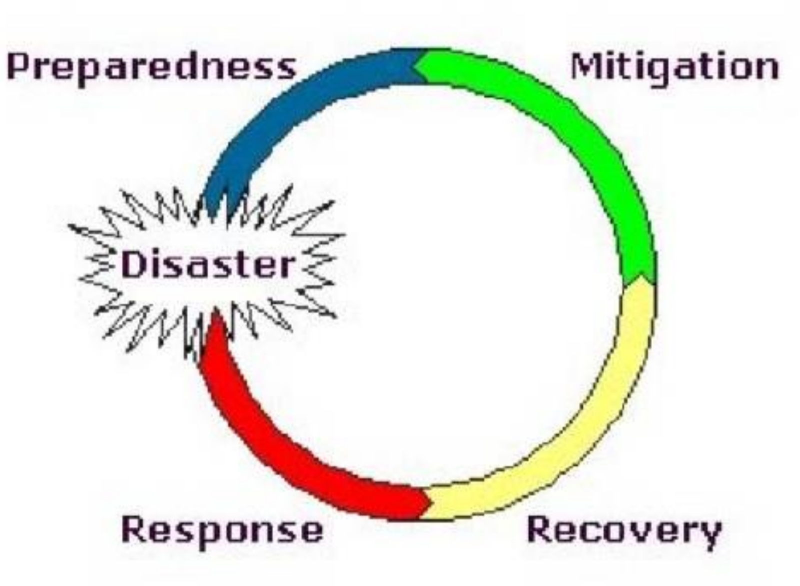

Figure1.6.1 Four Phases of Emergency Management Cycle

Some of the main activities during four phases of emergency management cycle are summarized below:

Preparedness

- The activities needed to improve the response as quickly as possible after the occurrence of any natural or man natural or man – made disaster.
- Including the development of response procedures, the design and development of warning systems, the evacuation planning of affected areas, the conduct of emergency operations testing practices, and the training of emergency response personnel.

Response

- All activities during or immediately after the disaster to meet the needs and urgent needs of disaster victims.
- Including time-sensitive operations such as rescue, search and medical care, including the mobilization of supplies and equipment for emergency personnel, and food programs.

Recovery

- The necessary measures that begin after the disaster, to meet the urgent needs of the injured and residents of affected areas. And work to restore the damaged society to its former status.

- Activities include the repair of public utilities, roads and bridges, the restoration of water, electricity, energy and municipal services necessary for the community.

Mitigation

- All activities that reduce the chances of disasters, reduce the damage and effects caused by disasters and emergencies necessary and unavoidable. Includes all activities that prevent the occurrence of disasters.
- All engineering solutions include dams and barriers. And all the necessary plans for how to use the land and prevent construction in dangerous areas, and proper construction in order to protect the habitat and rehabilitation of damaged structures, conservation of natural environment to resist the effects of danger and awareness of the population about the risks and ways to minimize these risks.

1.7. The Aim of the Thesis

Logistical planning in the event of a disaster can be modeled by using flow games. The logistic planning is essential and a key component in covering the initial needs in the immediate aftermath of any disaster. Planning is both necessary and practical, as it is generally possible to predict the types of disasters that may affect a given location and the needs that such disasters will be likely to engender. Transport planning, reception and distribution of emergency supplies, type and quantity of the resources, way of procurement and storage of the supplies, tools of tracking and means transportation to the stricken area, specialization of teams participating in the operation and plan of cooperation between these teams, are some vital life-saving coordination roles after natural disasters that are connected directly to logistic planning. The aim of this thesis is to introduce a modal for disasters by using cooperative game theory.

2. EMERGENCY LOGISTICS IN DISASTERS

Emergency logistics in disasters is fraught with planning and operational challenges, such as uncertainty about the exact nature and magnitude of the disaster , a lack of reliable information about the location and needs of victims, possible random supplies and donations , precarious transport links, scarcity of resources, and so on . Logistics planning in emergency situations involves dispatching commodities (e.g. medical materials and personnel, specialized rescue equipment and rescue teams, food, etc.) to distribution centers in affected areas as soon as possible so that relief operations are accelerated. In this study, a planning model that is to be integrated into a natural disaster logistics Decision Support System is developed. The model addresses the dynamic time-dependent transportation problem that needs to be solved repetitively at given time intervals during ongoing aid delivery.

2.1. Supply Chain Management

Definition of SCM differs across authors from different fields and there is no explicit and universal description of supply chain management or its activities in the literature (Tan 2001) the literature is full of buzzwords such as: integrated purchasing strategy, integrated logistics supplier integration, buyer-supplier partnerships, supply base management, strategic supplier alliances, supply chain synchronization and supply chain management, to address elements or stages of this phenomenon (New, 1997; La Londe and Masters, 1994).

Another definition of supply chain management emerges from the transportation and logistics literature of the wholesaling and retailing industry, emphasizing the importance of physical distribution and integrated logistics. There is no doubt that logistics is an important function of business and is evolving into strategic supply chain management (New and Payne, 1995). In this definition, the physical transformation of the products is not a critical component of supply chain management. Its primary focus is the efficient physical distribution of final products from the manufacturers to the end users in an attempt to replace inventories with information and reduce transportation costs.

The definition of supply chain (SC) seems to be more common across authors than the definition of supply chain management (Mentzer et al. 2001) proposed that a supply chain is a set of firms that pass materials forward (Eksioglu. 2002) defined a supply chain as an integrated process where different business entities such as suppliers, manufacturers, distributors, and retailers work together to plan, coordinate and control the flow of materials, parts, and finished goods from suppliers to customers. Several independent firms can be involved in manufacturing a product and placing it in the hands of the end user in a supply chain. For example raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies are all members of the supply chain.

Beamon (1998) defined supply chain as an integrated manufacturing process where raw materials are converted into final products, then delivered to customers. At its highest level, a supply chain is comprised of two basic integrated processes: One the Production Planning and Inventory Control Process, and two the Distribution and Logistics Process these Processes define the basic framework for the conversion and movement of raw Materials into final products.

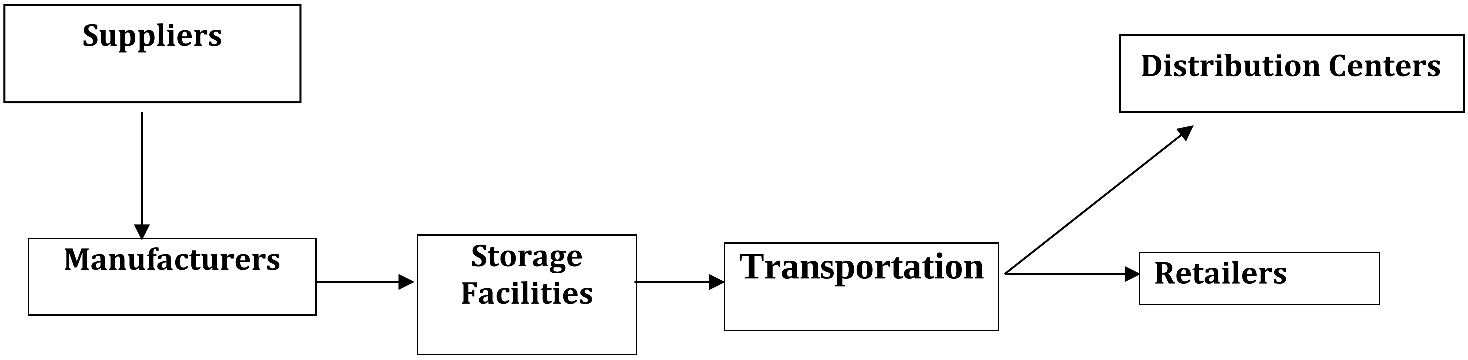

Figure 2.1.1 Supply chain process (Beamon 1998)

3. SOME SOLUTION CONCEPTS FOR COOPERATIVE GAMES

3.1. The Shapley Value

Shapley value is one of the most important solution concepts in cooperative game theory, which tries to capture the idea of fair distribution. It was named after its inventor Lloyd S. Shapley – an American mathematician and Nobel prize winner, who first introduced and axiomatized it (Shapley, 1953). This method defines a way to distribute the value of grand coalition $v(N)$, where each player receives an amount, proportional to his contributions (Chalkiadakis, 2012). Shapley value assigns a unique solution for every player in cost/profit games. Motivated by the need of a theory that would predict a unique expected payoff allocation for every given coalitional game, the concept of Shapley value as a solution concept in cooperative game theory, it considers the relative importance of each player to the game in deciding the payoff to be allocated to the players.

Given a game (N, v) the marginal contribution $m^{\sigma}(v)$ of player i to coalition S $(i \notin S)$is given by $v(S \cup i) - v(S)$. Based on this concept, the Shapley value Φ(v) of a game $v \in G^N$ is defined for each player the Shapley value is the average of each player's possible marginal contributions.The mathematical expression of the Shapley value is the following:

$$\Phi(v) \coloneqq \frac{1}{n!} \sum_{\sigma \epsilon \pi(N)} m^{\sigma}(v) \qquad (3.1.1)$$

Shapley viewed the value as an index for measuring the power of players in a game and presented the value as an operator that assigns an expected marginal contribution to each player in the game with respect to a uniform distribution over the set of all permutations on the set of players. The Shapley value averages to aggregate the power of players in their various cooperation opportunities. Alternatively, one can think of the Shapley value as a measure of the utility of players in a game (Branzei et al., 2008). The basic idea behind the Shapley value is to share the payoff of a game according to the relative importance of the individual players of the game.

One can rewrite (3.1.1) as follows:

$$\Phi_i(v) = \frac{1}{n!} \sum_{\sigma \in \pi(N)} v(p^{\sigma}(i) \cup \{i\}) - v\big(p^{\sigma}(i)\big)$$

The Shapley value has the advantage that it can be computed despite the core being empty and that it offers a unique solution. However, because the Shapley value does not have to be in the core, the stability of the grand coalition cannot be assured. A major drawback of the Shapley value is the exponential number of calculations that are generally necessary to come to solution. Shapley viewed the value as an index for measuring the power of players in a game the value. As an operator that assigns an expected marginal contribution to each player in the game and presented with respect to a uniform distribution over the set of all permutations on the set of players. The Shapley value averages to aggregate the power of players in their various cooperation opportunities. Alternatively, one can think of the Shapley value as a measure of theutility of players in a game (Branzei et al., 2008).The basic idea behind the Shapley value is to sharethe payoff of a game according to the relative importance of the individual players of the game.

Example 3.1.1

Let's see an example of a game with 3 players: We may set 3! = 6 different orderings of the players:

$\{1, 2, 3\}$, $\{1, 3, 2\}$, $\{2, 1, 3\}$, $\{2, 3, 1\}$, $\{3, 1, 2\}$, $\{3, 2, 1\}$.

Suppose that there are three players now and $v(\{1\}) = 100$, $v(\{2\}) = 125$, v({3}) = 50, v({1,2}) = 270, v({1,3}) = 375, v({2,3}) = 350 and v({1,2,3}) = 500. Then we have the following table: $v(\{1\}) = 100, v(\{2\}) = 125, v(\{3\}) = 50, v(\{1,2\}) = 270, v(\{1,3\}) = 375, v(\{2,3\}) = 350$ *and* $v(\{1,2,3\}) = 500$

Now, we compute the marginal vectors of this game. For this, we can check the permutations of N. The permutations of the elements of N is

$\sigma_1 = (1,2,3)$, $\sigma_2 = (1,3,2)$, $\sigma_3 = (2,1,3)$, $\sigma_4 = (2,3,1)$, $\sigma_5 = (3,1,2)$,

$\sigma_6 = (3,2,1)$.

Table 3.1.1.Accounts marginal contribution

Probability	**Order OF Arrival**	**1's Marginal Contribution**	**2's Marginal Contribution**	**3's Marginal Contribution**
$\frac{1}{6}$	first 1 then 2 then 3: 123	$v(\{1\}) = 100$	$v(\{1,2\}) - v(\{1\}) = 270 - 100 = 170$	$v(\{1,2,3\}) - v(\{1,2\}) = 500 - 270 = 230$
$\frac{1}{6}$	first 1 then 3 then 2: 132	$v(\{1\}) = 100$	$v(\{1,2,3\}) - v(\{1,3\}) = 500 - 375 = 125$	$v(\{1,3\}) - v(\{1\}) = 375 - 100 = 275$
$\frac{1}{6}$	first 2 then 1 then 3:213	$v(\{1,2\}) - v(\{2\}) = 270 - 125 = 145$	$v(\{2\}) = 125$	$v(\{1,2,3\}) - v(\{1,2\}) = 500 - 270 = 230$
$\frac{1}{6}$	first 2 then 3 then 1:231	$v(\{1,2,3\}) - (\{2,3\}) = 500 - 350 = 150$	$v(\{2\}) = 125$	$v(\{2,3\}) - v(\{2\}) = 350 - 125 = 225$
$\frac{1}{6}$	first 3 then 1 then 2:321	$v(\{1,3\}) - v(\{3\} = 375 - 50 = 325$	$v(\{1,2,3\}) - v(\{1,3\}) = 500 - 375 = 125$	$v(\{3\}) = 50$
$\frac{1}{6}$	first 3 then 2 then 1: 321	$v(\{1,2,3\}) - v(\{2,3\})$ $500 - 350 = 150$	$v(\{2,3\}) - v(\{3\}) = 350 - 50 = 300$	$v(\{3\}) = 50$

Then the marginal vector for σ_1 is $(100, 170, 230)$

Then the marginal vector for σ_2 is $(100, 125, 275)$

Then the marginal vector for σ_3 is $(145, 125, 230)$

Then the marginal vector for σ_4 is $(150, 125, 225)$

Then the marginal vector for σ_5 is $(325, 125, 50)$

Then the marginal vector for σ_6 is $(150, 300, 50)$

Table 3.1.2. The marginal vector of the Example 3.1.1

σ	m_1^σ	m_2^σ	m_3^σ
$(1, 2, 3)$	100	170	230
$(1, 3, 2)$	100	125	275
$(2, 1, 3)$	145	125	230
$(2, 3, 1)$	150	125	225
$(3, 1, 2)$	325	125	50
$(3, 2, 1)$	150	300	50

3.2. The τ Value

In this section, we also concentrate on another one - point solution, τ *value*, the $\tau -$ *value* is a solution concept for a subclass of games with transferable utility introduced and axiomatized by (Tijs, 1981, 1987). The $\tau -$ *value* is characterized by three axioms. It is shown that the τ-value is the unique solution concept which is efficient and has the minimal right property and the restricted proportionality property. The minimal right property is weaker than the additivity property, which plays a role in the axiomatic characterization of the Shapley value: together with individual rationality and efficiency additively implies the minimal right property. The restricted proportionality property says that for games with minimal right vector zero, the dividend given to the players is proportional to the marginal contribution of the players to the grand coalition .Theτ value is based on the idea of a compromise between an upper and a lower value for each player in the game.

The vector $M(v) \in R^N$ with coordinates $M_i(v) \coloneqq v(N) - v(N\backslash\{i\})$ is called the $upper\ vector$ of v. Here, $M_i(v)$ can be regarded as the maximal payoff that player i can expect to get in the game in the sense that if the player claims more, then it is a dvantageous for the other players to exclude the player from the grand coalition N and to divide the value $v(N)$ among themselves. Moreover, $M_i(v)$ is also called the utopia payoff for player i. The vector $m(v) \in R^N$ with coordinates

$$m_i(v) \coloneqq max_{S:i\in S}(v(S) - \sum_{j\in S\{i\}} M_j\,(v))$$

is called the $lower\ vector$ of v. For each player $i \in N$, the value $m_i(v)$ can be regarded as the minimal right in the sense that the player can guarentee himself/herself this payoff offering the members of a suitable coalition their utopia payoff, which is a good deal to them, and taking the remainder for himself/ herself. It is meaningful to consider a compromise between the lower and the upper vectors if the following two conditions are satisfied:

- $m(v) \leq M(v)$.
- $\sum_{i\in N} m_i\,(v) \leq v(N) \leq \sum_{i\in N} M_i\,(v)$.

In the first condition, “ $\leq$ ”is understood in the componentwise sense. A game $v \in G^N$ which satisfies these two conditions is said to be *quasi-balanced*. The class of quasi-balanced games with player set N is denoted by Q^N. For a quasi-balanced game $c \in Q^N$, the τ value of v, denoted by $\tau(\mathrm{v})$, is the unique compromise between the upper and lower vectors of the game that establishes an allocation of the value $v(N)$.Thus, $\tau(v) \coloneqq m(v) + \alpha(M(v) - m(v))$,where $\alpha \in [0,1]$ and $\sum_{i \in N} \tau_i(v) = v(N)$. It must be noted that τ value is defined only for quasi-balanced games. The class of quasi-balanced games contains all games that have a non-empty so-called core. Now, let us introduce the definitions of some set-valued solutions that we use in this study. A payoff vector $x \in R^n$ is called an imputation for the game $< N, v >$ and the set of imputations of $v \in G^N$ is denoted by $I(v)$. Note that $I(v) = \emptyset$ if and only if $v(N) < \sum_{i \in N} v(\{i\})$.

3.3. The Core

The core of a game $v \in G^N$ is firstly introduced by Gillies (1959), the core of a game is a central set-valued solution concept in game theory. The core of a game $v \in G^N$ is the set

$$C(v) = \left\{ x \in I(v) \middle| \sum_{i \in s} x_i \geq v(s) \; for \; all \; s \in 2^N / \{\emptyset\} \right\}$$

In mathematics the core is a bounded polyhedral set. That is it a polytope. It has extreme points. if $C(v) \neq \emptyset$, then the elements of $C(v)$ can be calculated easily by solving a finite equality and inequalities as follows:

$$min \sum\nolimits_{i \in N} x_i$$

Subject to

$$\begin{cases} \sum\nolimits_{i \in N} x_i = v(N) \\ \sum\nolimits_{i \in S} x_i \geq v(S) \end{cases}$$

If $x \in C(v)$, then no coalition $S \neq N$ has any incentive to split off if x is the proposed reward allocation in N, because the total amount $\sum_{i \in S} x_i$ allocated to S is not smaller than the amount $v(S)$ which the players can obtain by forming some subcoalition. The core may be empty.

Example 3.3.1

$N = \{1,2,3\}, v\,(N) = 11, v\,(2,3) = 8,\ v(1,2) = 10,\ v(1,3) = 5,\ v(i) = 0,\ \forall_i \in N$

$C(v)\{x \in R^3 | x_1 + x_2 + x_3 = 11,\ x_1 + x_2 \geq 10\,, x_1 + x_3 \geq 5, x_2 + x_3 \geq 8,\}$

$x_1 \geq 0\,, x_2 \geq 0\,, x_3 \geq 0$

$x_1 + x_2 \geq 10$

$x_1 + x_3 \geq 5$

$x_2 + x_3 \geq 8$

$x_1 + x_2 + x_3 \geq \frac{23}{2} = 11.5 > v(N)$

Contradicts which efficiency since $x_1 + x_2 + x_3 = 11.$

So $C(v) = \emptyset.$

4. APPLICATION OF LOGISTICS PLANNING MODEL IN IRAN

4.1 Introduction

In this chapter we use cooperative game theory and the Shapley value for emergency logistics planning, after a natural disaster in Iran, we choose the Mediterranean countries as distributors and build the cooperative flow game in the logistics network application. For goods transferred to the affected city (Iran) and allocation of gains among the distributors fairly.

Iran is a country in western Asia. It is the 18 th largest country in the world, with an area of 1648, 195km^2, with a population of about 75 million.

Iran is a distinct country because of the importance of its geopolitical location as a meeting point for three Asian areas (Western, Central, and South Asia). It is bordered to the north by Armenia, Azerbaijan and Turkmenistan. Iran overlooks the Caspian

Sea (an inland sea bordered by Kazakhstan and Russia). It is bordered to the east by Afghanistan and Pakistan, from the south by the Arabian Gulf and the Gulf of Oman, to the west by Iraq and from the north – west by Turkey. Tehran is the capital.

Iran is one of the 10 most vulnerable countries having natural disasters. It is located in one of the most dangerous fault lines in the world, the Anatolian north fault. This puts the entire population at risk of natural disasters.

The objective of this study is to obtain the maximum amount of goods transferred to the affected city (Iran) and to allocate the profits among the distributors fairly

4.2 Our Model

Our model is based on a possible logistic network after a natural disaster occurs in Iran, which is one of the top 10 cities that suffer natural disasters. Suppose there is a natural disaster in Iran and that the goods requested will be sent to Iran. While goods are transported to Iran where the disaster occurred and through the airway.

In our model, we choose these intermediate countries as distributors and construct the cooperative flow game in the application of the logistic network. In this way, the aim of the model is to obtain the transported maximum commodities to the affected city (Iran), and to provide the allocation of gains between the distributors fairly.

For this model, firstly we set the logistic network scenario by using some parameters, and construct the cooperative flow game. To allocate the gains between distributor countries fairly, some solution concepts from cooperative game theory are used. These are the Shapley value, the τ value, and the core. Then we compare the results and determine the solutions which the players want to use.

Consider the logistic network consisting of one supplier that applies the aid materials after natural disasters (D: Deutschland), three countries as distributors (IR: Iraq, T:

Turkey, AZ: Azerbaijan), and one retailer of the country affected by the natural disasters (I: Iran), See the map of Iran city in the Figure 4.2.1.

Figure 4.2.1. Map of Iran city

An illustration of our scenario is presented in Figure 4.2.2

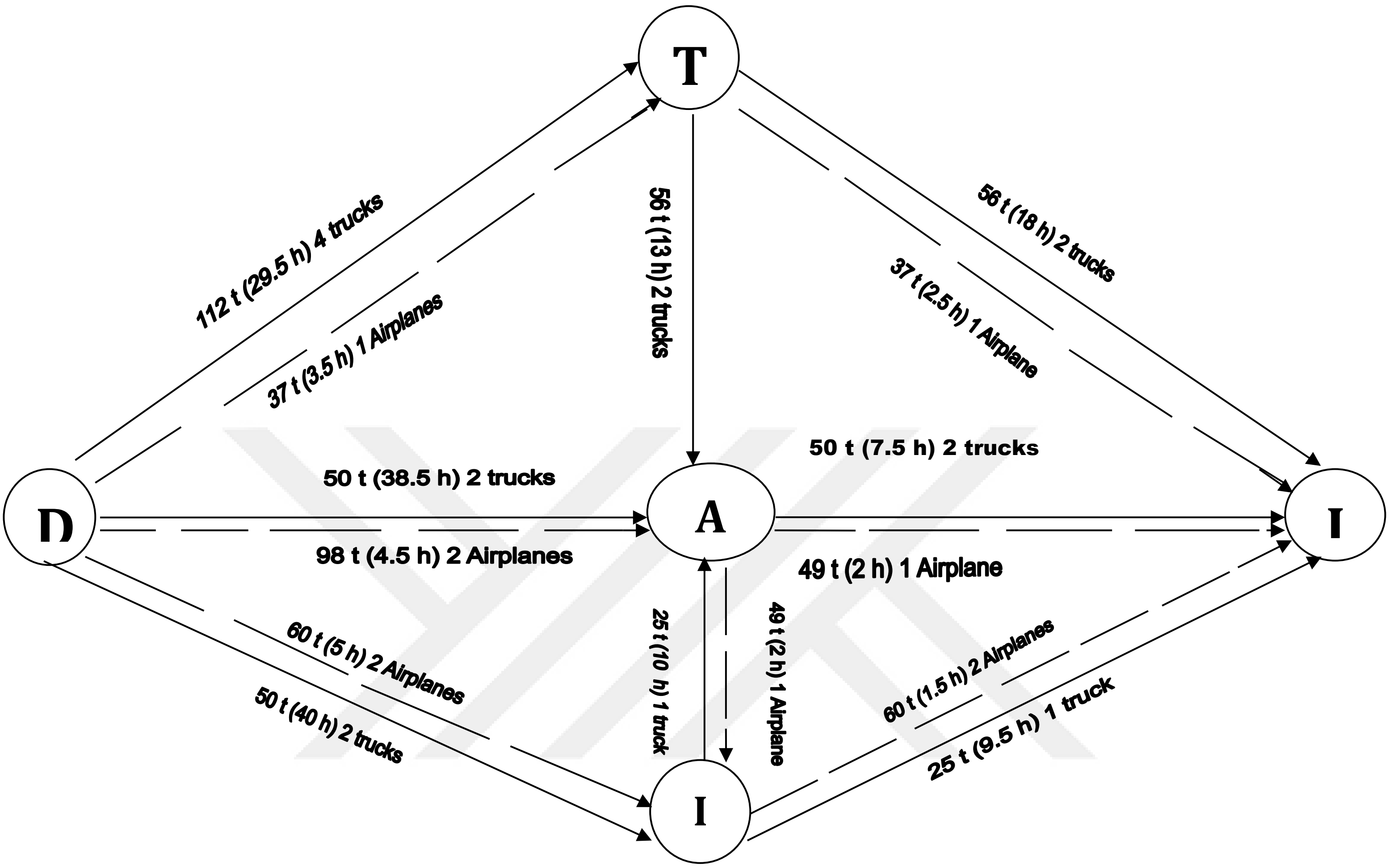

Figure 4.2.2. The illustration of our model.

We have two different paths, namely, as on ground and by airway. Each country has different types of vehicles; these are planes and trucks. Cargo planes supply aid materials and rescue equipment as commodities. Trucks supply commodities of medical, personnel materials, food, etc.

Turkey has a cargo plane carrying 36 tons of capacity and four trucks. Each one has 28 tons of capacity. Azerbaijan has two Boeing 767 cargo planes, each containing 49 tons of capacity; it also has one truck, 50 tons of capacity. Iraq has two cargo planes, one Airbus 321-214 and the other Airbus 320-214, each with 30 tons of capacity. It has two trucks, each with a capacity of 25 tons.

Ground and airway distances between countries (supplier, distributers and retailer) are given in Fig.3.2. The numbers shown on the arcs are the capacities of the vehicles when they use these paths and the times of the transportation. Three countries own the arcs($L_1,\ L_2,\ L_3$). In closer detail, L_1 (the upper arcs) owns the arcs (D, T) and (D, I) with the capacities shown. L_2(the middle arcs) owns the arcs (D, AZ), (AZ, I), (IR, AZ), and (AZ, I) with the capacities. L_3 (the bottom arcs) owns the arcs (D, IR) and (IR, I) with the capacities shown.

In a flow situation there exist arcs, each arcs are owned by one of the players, there are two nodes that distinguished from the others and are called the source *s* and the sink *t*, which have already been previously defined. There is also a finite and non – empty set N understood as the player set. The arcs are considered as owned by the players. Moreover, a coalition owns the arcs of its members. The set of coalition is denoted by C. An *n*- person cooperation flow game is a function v from the set of coalition to the set of real numbers.

For a coalition $S\ \in\ C$, $v(S)$ is defined as the maximum flow value for coalition S and through the network of its members if it operates on its own. This means that $v(S)$

stands for the maximum flow that S can sustain by using its own portion of the network. The function v just defined is called the characteristic function of the game. The flowchart of our model is given in Figure 4.2.3.

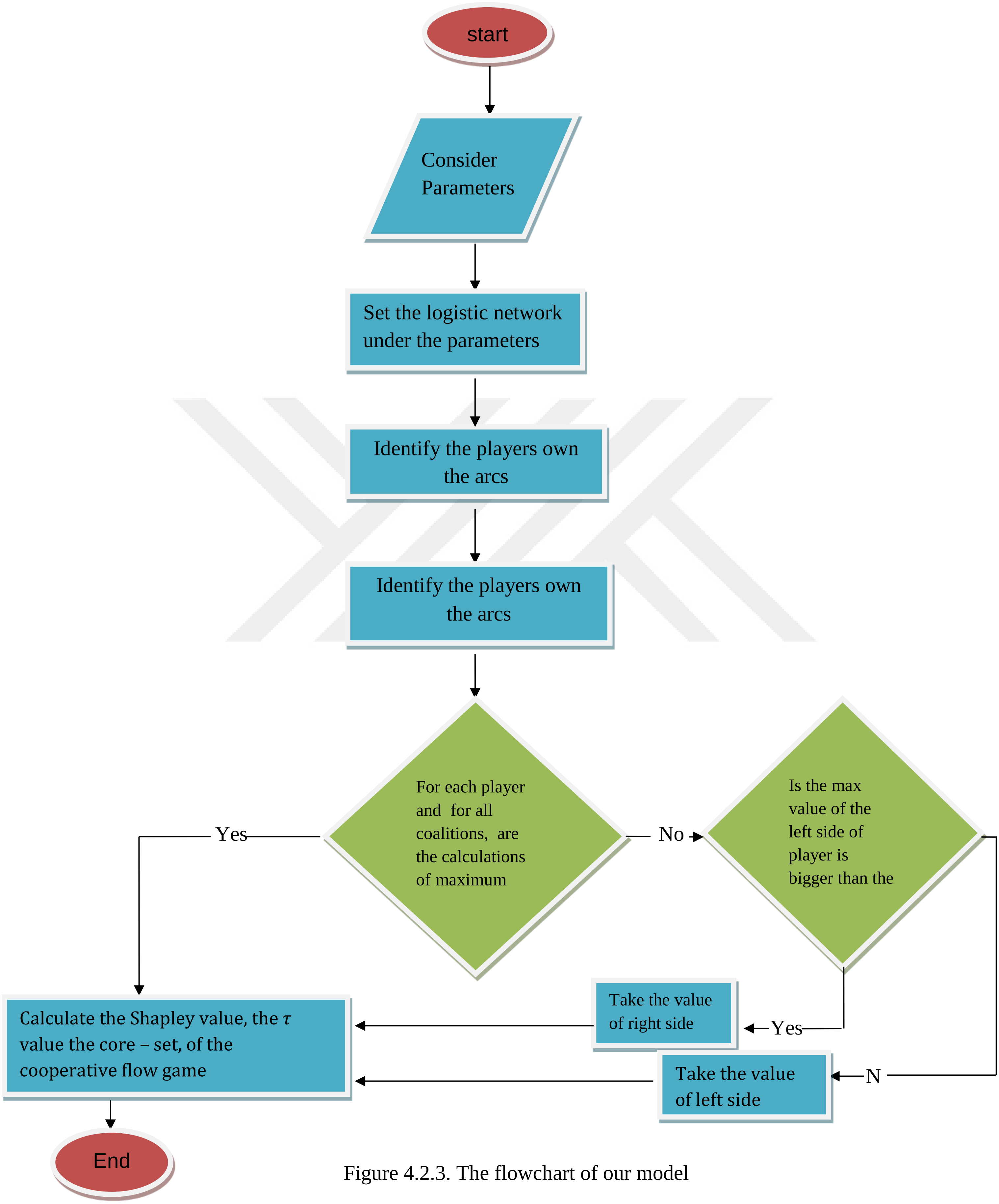

Figure 4.2.3. The flowchart of our model

Let us construct our cooperative flow game. It should not be forgotten that the maximum commodity capacities which can be provided within 1 day are taken into account; but the transport time from supplier to distributors is considered as a separate day. The values obtained from the cooperative flow game associated with the capacities are seen in Table 4.2.1.

Table 4.2.1. The constructed cooperative flow game

S	$\emptyset$	$\{1\}$	$\{2\}$	$\{3\}$	$\{1,2\}$	$\{2,3\}$	$\{1,3\}$	$\{1,2,3\}$
$v(S)$	0	$56 + 37 < 112 + 37 = 93$	$98 < 50 + 49 = 98$	$60 = 60$	$56 + 37 + 50 + 49 < 112 + 37 + 98 = 192$	$49 + 49 + 60 < 50 + 49 + 60 = 158$	$56 + 37 + 60 < 112 + 37 + 60 = 152$	$112 + 37 + 50 + 98 + 60 + 50 = 407$

4.3. Data Concepts and Solution

In this section we want to act with each unit of 407 units by each player and when the distributors are cooperating, they decrease or increase the gains three solutions will be calculated and examined (the Shapley value, the τ value, and the core) are evaluated.

The Shapley value associates each $v \in G^N$, the marginal vectors denoted by $m^\sigma(v)$, and permutations $\sigma : N \to N, \pi(N)$: the family of all permutation of σ of N

The Shapley value $\Phi(v)$ of the game $\langle N, v\rangle$ is the average of the marginal vectors of the game, i.e. $\Phi(v) = \frac{1}{n!}\sum_{\sigma\in\pi(\mathrm{N})} m^\sigma(v)$. The marginal vectors of our model, where $\sigma: N \to N$ consists of three components: defined with $(\sigma(1), \sigma(2), \sigma(3))$.

We call this the marginal contribution of the players. Hence, $m^\sigma(v)$ is the vector in R^n with $m^\sigma_{\sigma 1}(v) = v(\sigma(1) - v(\emptyset))$, $m^\sigma_{\sigma 2}(v) = v(\sigma(1), \sigma(2)) - v\sigma(1)$, $m^\sigma_{\sigma 3} = v\big(\sigma(1), \sigma(2), \sigma(3)\big) - v\big(\sigma(1), \sigma(2)\big)$, $m^\sigma_{\sigma(n)}(v) = v\big(\sigma(1), \dots, \sigma(n)\big) - v\big(\sigma(1), \dots, \sigma(n-1)\big)$.

Our model consists of $N = \{1, 2, 3\}$, with $v(\emptyset) = 0$, $v(1) = 93$, $v(2) = 98$, $v(3) = 60$, $v(1,2) = 192$, $v(1,3) = 152$, $v(2,3) = 158$, $v(1,2,3) = 407$. and $\pi(N) = \{(1,2,3), (1,3,2), (2,1,3), (2,3,1), (3,1,2), (3,2,1)\}$.

Then the marginal vectors of our model are given in Table 4.3, where $\sigma: N \to N$ is identified with $(\sigma(1),\ \sigma(2),\ \sigma(3))$.

Table 4.3.1. The marginal vectors of our model

$\boldsymbol{\sigma}$	$\boldsymbol{m_1^{\sigma}(v)}$	$\boldsymbol{m_2^{\sigma}(v)}$	$\boldsymbol{m_3^{\sigma}(v)}$
$\sigma_1 = (1,2,3)$	$v(1) = 93$	$v(1,2) - v(1) =$ $192 - 93 = 99$	$v(1,2,3) - v(1,2) =$ $407 - 192 = 215$
$\sigma_1 = (1,3,2)$	$v(1) = 93$	$v(1,2,3) - v(1,3) =$ $407 - 152 = 255$	$v(1,3) - v(1) =$ $152 - 93 = 59$
$\sigma_1 = (2,1,3)$	$v(1,2) - v(2) =$ $192 - 98 = 94$	$v(2) = 98$	$v(1,2,3) - v(1,2) =$ $407 - 192 = 215$
$\sigma_1 = (2,3,1)$	$v(1,2,3) - v(2,3) =$ $407 - 158 = 249$	$v(2) = 98$	$v(2,3) - v(2) =$ $158 - 98 = 60$
$\sigma_1 = (3,1,2)$	$v(1,3) - v(3) =$ $152 - 60 = 92$	$v(1,2,3) - v(1,3) =$ $407 - 152 = 255$	$v(3) = 60$
$\sigma_1 = (3,2,1)$	$v(1,2,3) - v(2,3) =$ $407 - 158 = 249$	$v(2,3) - v(3) =$ $158 - 60 = 98$	$v(3) = 60$
sum	870	903	669

The average of the six marginal vectors is the Shapley value of this game which can be calculated as:

$$\Phi(v) = \frac{1}{n!} \sum_{\sigma \in \pi(\mathrm{N})} m^{\sigma}(v)$$

$$\Phi(v) = \frac{1}{3!} (870, 903, 669) .$$

$$\Phi(v) = \frac{1}{6} (870, 903, 669) .$$

$$\Phi(v) = (145, 150.5, 111.5).$$

$\tau -$ value is one – point solution concept in cooperative game theory, $\tau -$ value is based on two vectors, $M(v)$ and $m(v)$, for a game $\langle N, v\rangle$. $\tau -$ value is efficient payoff vector on the closed interval $\left[m\left(v, M(v)\right)\right]$. The vector $M(v)$, called the $N -$ marginal vector, has as $i - th$ coordinate $M_i(v) \coloneqq v(N) - V(N\backslash\{i\})$, which is the marginal contribution of player i to the grand coalition $M_i(v)$ is also called the utopia payoff for player i in the grand coalition. If he wants more, then it is advantageous for the other players in N to throw player i out. The $i - th$ coordinate of the minimum right vector $m(v)$ is defined by:

$m_i(v) := max_{s:i\in s}\left(v(S), -\sum_{j\in s\backslash\{i\}} M_j\,(v)\right)$. In order to find the τ value, we have a look at our game $v \in G^N$ whether it satisfies the two conditions; then it is said to be quasi-balanced. The elements of our utopia payoff vector $M_i(v)$ can be calculated as:

$M_i(v) = v(N) - v(N\backslash i)$.

$M_1(v) = v(N) - v(N\backslash 1)$.

$M_1(v) = v(N) - v(\{2,3\}) = 407 - 158 = 249$.

$M_2(v) = v(N) - v(N\backslash 2)$.

$M_2(v) = v(N) - v(\{1,3\}) = 407 - 152 = 255$.

$M_3(v) = v(N) - v(N\backslash 3)$.

$M_3(v) = v(N) - v(\{1,2\}) = 407 - 192 = 215$.

$M(v) = (M_1(v),\ M_2(v), M_3(v)\ )$.

In our game, the upper vector is calculated $M(v) = (249, 255, 215)$ and the lower vector $m(v) = (m_1(v), m_2(v), m_3(v))$ is calculated as:

$m_i(v) := max_{s:i\in s}\left(v(S), -\sum_{j\in s\backslash\{i\}} M_j\,(v)\right)$.

$m_1(v) = \max_{1\in S}\big(v(\{1\}), v(\{1,2\}) - M_2(v), v(\{1,3\}) - M_3(v), v(\{1,2,3\}) -$

$M_2(v) - M_3(v)\big)$

$m_1(v) = \max(93, 192 - 255, 152 - 215, 407 - 255 - 215).$

$m_1(v) = \max(93, -63, -63, -63)$

$m_1(v) = 93$

$m_2(v) = \max_{2\in S}\big(v(\{2\}), v(\{1,2\}) - M_1(v), v(\{2,3\}) - M_3(v), v(\{1,2,3\}) -$

$M_1(v) - M_3(v)\big)$

$m_2(v) = \max(98, 192 - 249, 158 - 215, 407 - 249 - 215).$

$m_2(v) = \max(98, -57, -57, -57)$

$m_2(v) = 98$

$m_3(v) =$

$\max_{3\in S}\big(v(\{3\}), v(\{1,3\}) - M_1(v), v(\{2,3\}) - M_2(v), v(\{1,2,3\}) - M_1(v) - M_2(v)\big)$

$m_3(v) = \max(60, 152 - 249, 158 - 255, 407 - 249 - 255).$

$m_3(v) = \max(60, -97, -97, -97)$

$m_3(v) = 60$

lower vector $m(v) = \big(m_1(v), m_2(v), m_3(v)\big)$.

$m(v) = (93, 98, 60).$

Since $\tau(v) \coloneqq m(v) + \alpha(M(v) - m(v))$.

$\tau(v) = (93, 98, 60) + \alpha(249, 255, 215) - (93, 98, 60).$

$\tau(v) = (93, 98, 60) + \alpha(156, 157, 155)$

$\tau(v) = (93, 98, 60) + (156\alpha, 157\alpha, 155\alpha)$

$\tau(v) = (156\alpha + 93, 157\alpha + 98, 155\alpha + 60)$

Where $\alpha \in [0,1]$, is such that $\sum_{i\in N} \tau_i\,(v) = v(N)$, α can be calculated as:

$156\alpha + 93, 157\alpha + 98, 155\alpha + 60 = 407$

$468\ \alpha + 251 = 407$

$468\ \alpha$ = 407 – 251

$468\ \alpha = 156$

$\alpha = \frac{156}{407}$, $\alpha = \frac{1}{3}$, $\alpha = 0.3\overline{3}$

$\tau(v) = (156\alpha + 93, 157\alpha + 98, 155\alpha + 60)$

$\tau(v) = \left(156.\frac{1}{3} + 93, 157.\frac{1}{3} + 98, 155.\frac{1}{3} + 60\right)$

$\tau(v) = \left(145, \frac{451}{3}, \frac{335}{3}\right)$.

$\tau(v) = (145, 150.3, 111.7)$

The set of imputations of $\langle N, v\rangle$ is denoted by $I(v)$. An element $x \in I(v)$ can be interpreted as a payoff distribution of the earnings $v(N)$ of the grand coalition N, which give player i a payoff x_i which is at least as much as he can obtain when he operates alone. The imputation set of the model is:

$I(v) = \text{conv}\{(93,98,216), (249, 98, 60), (93, 254,60)\}$.

It is the set of all individually rational and efficient allocations. The core of a game $\langle N, v\rangle$ is the set $(v) := \{x \in\ I(v)\ |\sum_{i\in S} x_i \geq v(S) for\ all\ S \in 2^N \backslash \{\emptyset\}\}$.

The core of the model : consider the following in our model, $v(N) = 407$, $v(1,2) = 192, v(1,3) = 152, v(2,3) = 158, v(1) = 93, v(2) = 98, v(3) = 60$.

$$C(v) := \left\{ \begin{matrix} x \in R^3 |\ x_1 + x_2 + x_3 = 407,\ x_1 + x_2 \geq 192,\ x_1 + x_3 \geq 152, \\ x_2 + x_3 \geq 158 \end{matrix} \right\}$$

The core of the model is $\text{C}(v) :=$

$\text{conv}\{(93, 99, 215), (93, 255, 59), (94, 98, 215), (249,98, 60), (92, 255, 60)\}$

It is the set of all coalitional stable and efficient allocations.

The vertices of core and the imputation set of the flow game can be seen in Figure 4.3. The core consists of all stable imputations. The core allocations provide the players with an incentive to maintain the grand coalition.

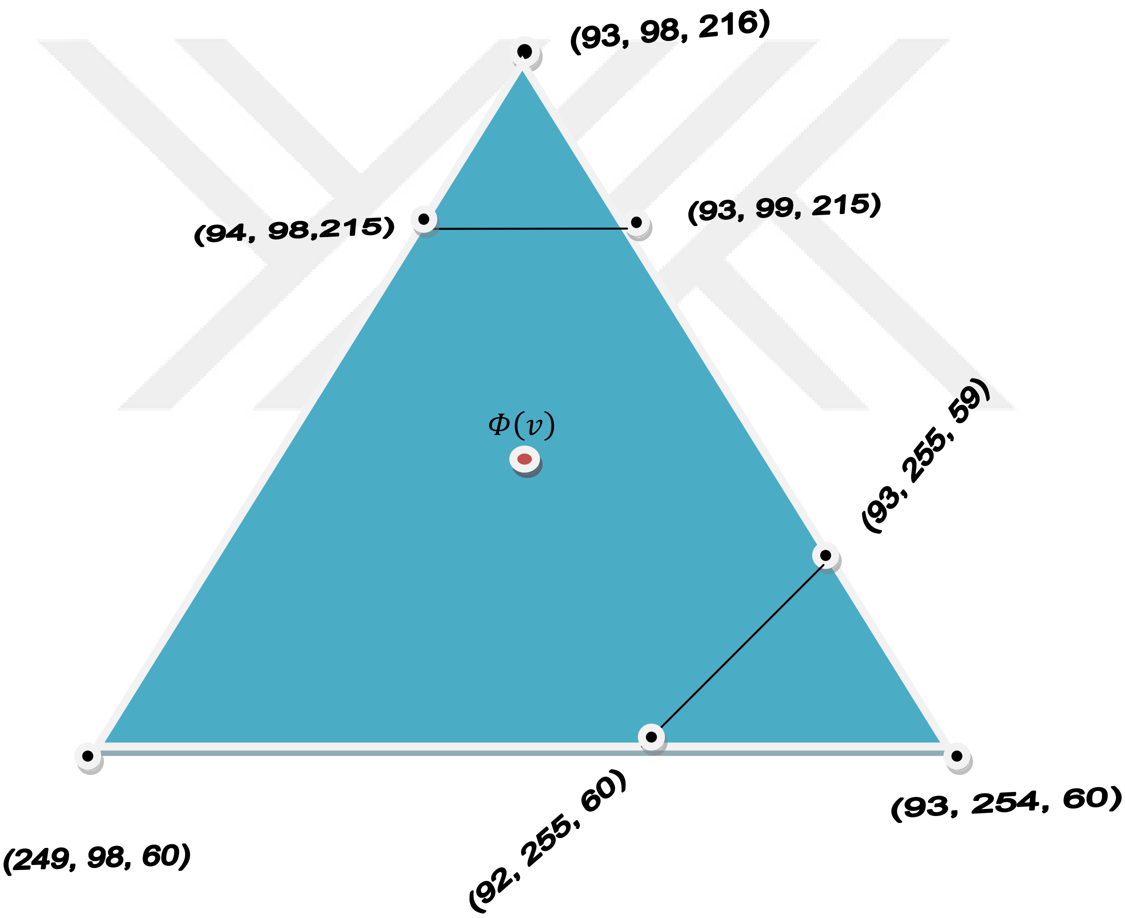

Figure 4.3.1. The core of the cooperative flow game.

5. CONCLUSIONS AND FUTURE STUDIES

In this thesis, we have considered the natural disaster emergency logistic problem for one affected city and one supplier country. We have modeled the emergency problem for the situation given after a natural disaster occurred in Iran by using cooperative game flow games. Several solution concepts are proposed by us for this model.

At the beginning of the disaster, especially large – scale natural disasters such as earthquakes and volcanoes, the demanded emergency supplies often increases dramatically. In many countries, logistics planning to save natural disasters is well formed for the cooperation of rescue organizations. Improving emergency relief efficiency should depend on plans of attention. As natural disasters occur frequently in many countries around the world, governments invest in disaster management systems to minimize loss of life and property. But there often exists shortage or delay of supplies. The road transport network is also extremely crowded because of the damaged roads and the disorderly traffic. In this thesis, we take emergency logistics network as the research object and study it deeply, after the occurrence of natural disaster, in response to urgent relief demands for the affected areas. In this thesis, we have studied the concepts of the main solutions for cooperative game theory, and three different solutions are presented (the Shapley value, the τ value and the core) and evaluated. The emergency logistics distribution using the cooperative game theory has achieved many goals:

Improve the performance of logistics management in emergency situations after natural disasters; logistics planning is essential and important to cover initial needs immediately after a disaster.

We explain the importance of cooperation between countries in the event of a natural disaster and the response of countries to relief and management of the supply chain required.

This thesis offers many open problems, our model and the use of cooperative game theory can be expanded in logistics planning, supply chain management, transportation planning, receiving and distribution of emergency supplies, type and quantity of existing sources, procurement and storage of supplies to cities that are often exposed to natural disasters from earthquakes and volcanoes such as Japan and Indonesia.

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