

Conference and Seminar: Siantar, Indonesia, February 2019



Optimization for Supply Chain Planning after Disasters with Cooperative Game Theory under Uncertainty



*Gerhard-Wilhelm Weber **

Faculty of Engineering Management, Chair of Marketing and Economic Engineering,
Poznan University of Technology, Poland;
Institute of Applied Mathematics, METU, Ankara, Turkey



Serap Ergün, Pınar Usta, Sırma Zeynep Alparslan Gök

Süleyman Demirel University, Isparta, Turkey



* Faculty of Economics, Management and Law, University of Siegen, Germany
School of Science, Information Technology and Engineering, Federation University, Ballarat, Australia
Center for Research on Optimization and Control, University of Aveiro, Portugal
Universiti Teknologi Malaysia, Skudai, Malaysia
Universitas Sumatera Utara, Medan, Indonesia
Advisor to EURO Conferences



POLITECHNIKA POZNAŃSKA



EURO



I F O R S

International Federation of Operational Research Societies

**Conference and Seminar:
Siantar, Indonesia,
February 2019**



Optimization for Supply Chain Planning after Disasters with Cooperative Game Theory under Uncertainty



**Part 1:
Using Game Theory Applications for Assessment
of Emergency Management Situations**

**Part 2:
A New Approach for Post Disaster Housing Problem
after Earthquake**



POLITECHNIKA POZNAŃSKA



EURO



I F O R S

International Federation of Operational Research Societies

**Conference and Seminar:
Siantar, Indonesia,
February 2019**



Part 1:
**Using Game Theory Applications for Assessment
of Emergency Management Situations**



POLITECHNIKA POZNAŃSKA



EURO



I F O R S

International Federation of Operational Research Societies

Outline

Part 1: Using Game Theory Applications for Assessment of Emergency Management Situations

- Our aim
- Emergency Situations
- Game Theory
- Conclusion



POLITECHNIKA POZNAŃSKA



EURO



I F O R S
International Federation of Operational Research Societies

Our aim

- Research for efficiently planning and responding to emergency situations is of vital interest due to the devastating effects and losses caused by their occurrence, including economic deficiency, casualties, and infrastructure damage.
- Emergency management is the process of preparing for and responding to any emergency or disaster. In emergency situations that may occur in an urban environment, it is significant to perform a fair allocation and scheduling of emergency response units to each emergency, as human lives could be at risk.

Our aim

- The purpose of this presentation is to summarize ways in which game theory has been or could be utilized within emergency situations and to identify future research opportunities in this field. Game theory is a tool for modeling systems in which multiple decision makers act according to their own objectives and where individual choices affect system outcomes. Emergency situations are often characterized by the presence of many such decision makers.
- This presentation also aims to increase comprehension of game theory-based research in disaster management and to provide directions for future research.

Emergency Situations

- Emergency situations can be man-made, intentional, or accidental. Especially hard to plan for is the rare and violent twist of nature, such as the Sumatra–Andaman earthquake of 26 December 2004, with an undersea epicenter off the west coast of Sumatra, Indonesia, triggering a series of devastating tsunamis that spread throughout the Indian Ocean, killing approximately 230,000 people.



Emergency Situations

- By definition, emergency situations are situations we are not familiar with – nor likely to be familiar with – and by their mere happening create acute feelings of stress, anxiety, and uncertainty.
- When confronted with emergency situations, one must not only cope with these feelings, but also make sense of the situation amidst conflicting or missing information during very intense time periods with very short-term deadlines.



Emergency Situations

- Emergency situations present a major global public problem. They strike quickly, often without warning, and are uncontrollable, affecting large populations and leaving injury, death, and destruction in their wake.



POLITECHNIKA POZNAŃSKA



EURO



I F O R S
International Federation of Operational Research Societies

Emergency Situations

- Among other activities and scenarios for mathematical programming problems, the search and rescue activity has acquired popularity in recent years.
- It focuses on models that try to optimize the search and rescue activities in order to save the lives of as many people as possible in the first hours of the disaster.



POLITECHNIKA POZNAŃSKA

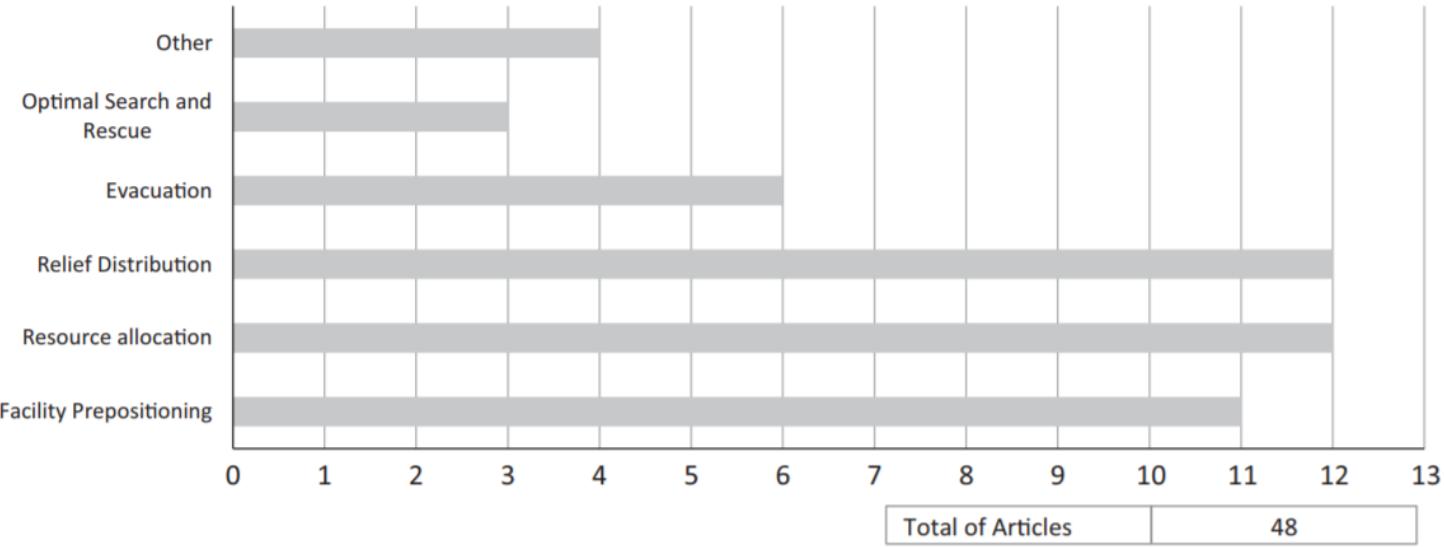


EURO



I F O R S
International Federation of Operational Research Societies

Emergency Situations



Classification of ***Mathematical Programming*** articles by problems to solve.



POLITECHNIKA POZNAŃSKA



EURO



I F O R S
International Federation of Operational Research Societies

Game Theory

- Game theory is a mathematical theory dealing with models of conflict and cooperation.
- Game Theory has many interactions with economics and with other areas such as Operational Research and social sciences.
- A young field of study: The start is considered to be the book *Theory of Games and Economic Behaviour* by von Neumann and Morgenstern.
- Game theory is divided into two parts: **non-cooperative** and **cooperative**.

Game Theory

Game theory is a branch of mathematics devoted to the logic of decision-making in social interactions.

The principal objective of game theory is to determine, through formal reasoning alone, what strategies the players ought to choose in order to pursue their own interests rationally and what outcomes will result if they do so. All players are advisedable and do not know what strategies the other side players choose.

Game theory applications could be used in different emergency situations like, earthquake, flood, evacuate, tsunami, bomb attack, etc.



POLITECHNIKA POZNAŃSKA



EURO



I F O R S
International Federation of Operational Research Societies

Game Theory and Emergency Situations

- Emergency relief is a very important task in emergency management. The components and relations in it construct a complex system which makes it difficult to organize the relief tasks.
- We can use game theory applications for emergency situations like, e.g., earthquakes, bomb attacks, fire, evacuations, floods, etc.



POLITECHNIKA POZNAŃSKA



EURO



I F O R S
International Federation of Operational Research Societies

Conclusions

- The increasing number of affected people due to emergency situations, the complexity and unpredictability of these phenomena and the different problems encountered in the planning and response in different scenarios, establish a need to find better measures and practices in order to reduce the human and economic loss in this kind of events.
- However this is not an easy task considering the great uncertainty these phenomena present including the multiple number of possible scenarios in terms of location, probability of occurrence and impact, the difficulty in estimating the demand and supply, the complexity of determining the number and type of resources both available and needed and the intricacy to establish the exact location of the demand, the supply and the possible damaged infrastructure, among many others.

Conclusions

- Disaster Operations Management has become very popular and, considering the properties of disasters, the use of tools and methodologies such as game theory applications have been given a lot of attention in recent years.
- Game theory could presented a relief-demand management model for dynamically responding to the relief demands of affected people under emergency conditions of a large-scale disaster.
- Game theory can response dynamic relief-demand forecasting, affected-area grouping, and determination of relief-demand urgency problems.
- The contribution of this presentation to the literature is about emergency management.



POLITECHNIKA POZNAŃSKA



EURO



I F O R S
International Federation of Operational Research Societies

**Conference and Seminar:
Medan, Indonesia,
February 2019**



**Part 2:
A New Approach for Post Disaster Housing Problem
after Earthquake**



POLITECHNIKA POZNAŃSKA



EURO



I F O R S

International Federation of Operational Research Societies

Outline

Part 2: A New Approach for Post Disaster Housing Problem after Earthquake

- Our aim...
- Earthquake
- Disaster Housing Problem
- Game Theory and Cooperative Game Theory
- Solution concept: Shapley Value

Earthquake

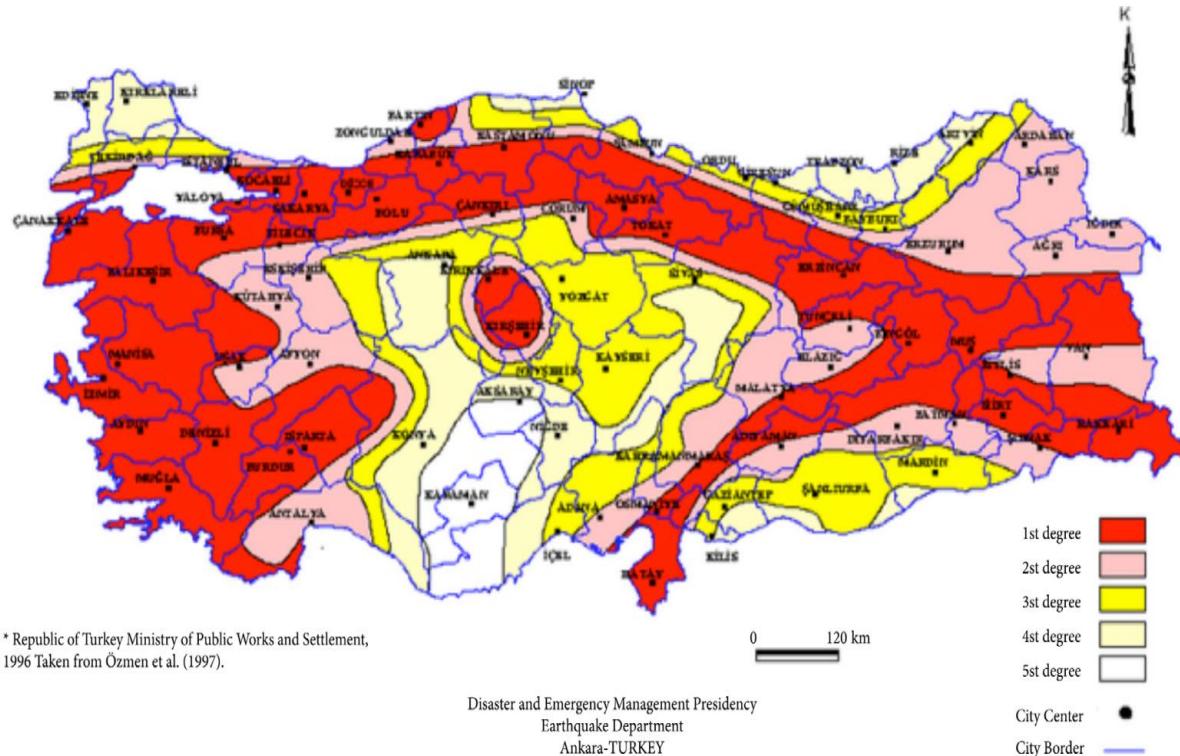


Figure 1. Seismic zones map of Turkey (Özmen et al., 1997).

Game theory

- Game theory is a mathematical theory dealing with models of conflict and cooperation.
- Game Theory has many interactions with economics and with other areas such as Operations Research and social sciences.
- A young field of study: The start is considered to be the book *Theory of Games and Economic Behaviour* by von Neumann and Morgenstern.
- Game theory is divided into two parts: **non-cooperative** and **cooperative**.

Cooperative Game theory

- Cooperative game theory deals with coalitions who coordinate their actions and pool their winnings.
- Natural questions for individuals or businesses when dealing with cooperation are:
 - Which coalitions should form?
 - How to distribute **the collective gains (rewards)** or **costs** among the members of the formed coalition?

Cooperative Game theory

- A **cooperative n -person game** in *coalitional form* (TU (transferable utility) game) is an ordered pair $\langle N, v \rangle$, where
- $N = \{1, 2, \dots, n\}$ (the set of players) and $v : 2^N \rightarrow \mathbb{R}$ is a map, assigning to each *coalition* $S \in 2^N$ a real number, such that $v(\emptyset) = 0$.
- v is the *characteristic function* of the game. $v(S)$ is the *worth* (or value) of coalition S .

Facility location game

- In *facility location situations*, there exists a given cost for constructing a facility.
- Furthermore, *connecting a player to this facility by minimizing the total cost* is necessary.



Facility location game

- In *facility location situations*, two cases may occur:
 - One of them is the case of *public facilities* (such as hospitals, fire stations, etc.).
 - The other one is the case of *private facilities* (such as distribution centers, some stations, etc.).



Facility location game

- In a *facility location game*,
- a set A of *agents* (known as cities),
- a set F of *facilities*, a facility *opening cost* f_i for every facility $i \in F$, and
- a *distance* d_{ij} between every pair (i, j) of points in $A \cup F$ indicating the *cost of connecting* j to i , are given.
- It is assumed that the distances come from a metric space (they are symmetric and obey the triangle inequality).
For a set $S \subseteq A$ of agents, the cost of this set is defined as the minimum cost of opening a set of facilities and connecting every agent in S to an open facility. The *cost function* c is defined by

$$c(S) = \min_{F^* \subseteq F} \{ \sum_{i \in F^*} f_i + \sum_{j \in S} \min_{i \in F^*} d_{ij} \}. \quad (1)$$

Shapley value

Now, let us introduce the definition of set-valued solution that we use in this study.

- Given a game (N, c) the ***marginal contribution*** $m^\sigma(c)$ of player i to coalition S ($i \notin S$) is given by $c(S \cup \{i\}) - c(S)$.
- Based on this concept, the ***Shapley value*** $\Phi(c)$ of a game $c \in G^N$ is defined ([Shapley, 1953](#)).
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:

$$\Phi(c) := \frac{1}{n!} \sum_{\sigma \in \pi(N)} m^\sigma(c).$$

CASE STUDY: TENT CITY DEVELOPMENT AFTER THE EARTHQUAKE IN ISTANBUL

- Our case study is based on a possible facility location after an earthquake in Istanbul, Turkey. Consider that there is an earthquake in Istanbul and after the earthquake, nearly *14000 tents* are distributed. *Three tent cities* are established in Kocaeli, Sakarya and Yalova which are near Istanbul. There are only *8000 tents* in the hands of the Kızılay that is the beneficiary of Turkey. The distribution of the remaining *6000 tents* is undertaken by one local and one foreign company. The *cost* of bringing services to the people living in the tent cities belongs to these companies.

CASE STUDY: TENT CITY DEVELOPMENT AFTER THE EARTHQUAKE IN ISTANBUL

- 50 percent of the 6000 tents are built in Kocaeli,
35 percent of the 6000 tents are built in Sakarya,
and the rest of the tents are built in Yalova.
Three kinds of tent types are distributed (Table 1).
- In Kocaeli, one tent costs 500 Turkish Liras (TL) and
it is for 8 persons.
- In Sakarya, one tent costs 850 TL and is for 15 persons.
- In Yalova, one tent costs 650 TL and is for 10 persons.

CASE STUDY: TENT CITY DEVELOPMENT AFTER THE EARTHQUAKE IN ISTANBUL

Table 1. The costs of building tent cities and some properties.

Tent city no	Tent city name	Property of tent	Number of tents established by companies	Total
1	Kocaeli	1 tent = 500TL and for 8 persons	3000 (by local company)	1500000 TL for 24000 persons
2	Sakarya	1 tent=850TL and for 15 persons	500 (by local company) 1600 (by foreign company)	1785000 TL for 31500 persons (425000 for 500 tents) 1360000 for 1600 tents)
3	Yalova	1 tent = 650TL and for 10 persons	900 (by foreign company)	585000 TL for 9000 persons

CASE STUDY: TENT CITY DEVELOPMENT AFTER THE EARTHQUAKE IN ISTANBUL

Additionally, the bringing services for facility location problems must be given, too.

In our case study, we limit the service cost per person to 50 TL.

In Table 2, the costs of bringing services of companies are given.

Table 2. The costs of bringing services of companies.

Tent city no	Tent city name	The costs of bringing services of local company	The costs of bringing services of foreign company
1	Kocaeli	1200000 TL for 3000 tents	-
2	Sakarya	25000 TL for 500 tents	80000 TL for 1600 tents
3	Yalova	-	45000 TL for 900 tents

CASE STUDY: TENT CITY DEVELOPMENT AFTER THE EARTHQUAKE IN ISTANBUL

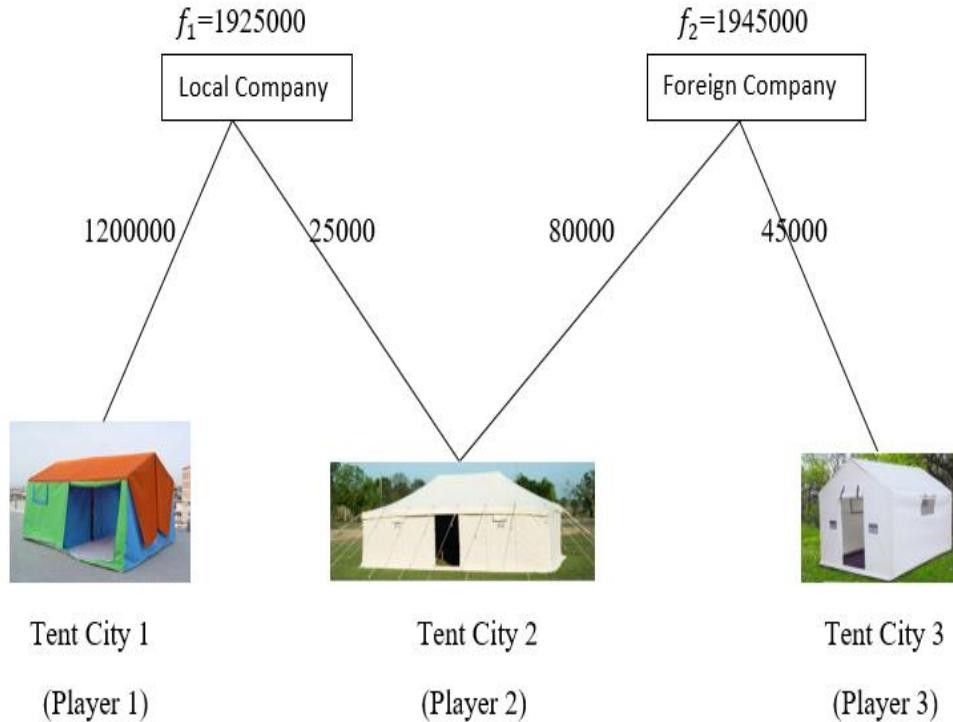


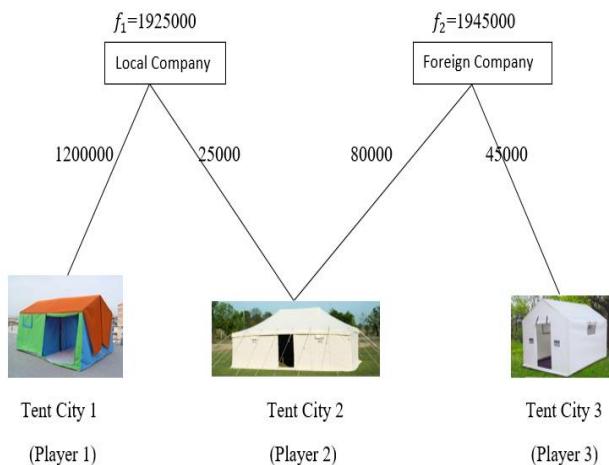
Figure 2 shows a facility location game with **3 cities in Turkey**: Kocaeli (Player 1), Sakarya (Player 2), Yalova (Player 3) and **2 companies**. The cost function is calculated by using (1) as follows:

Figure 2. The illustration of our case study.

CASE STUDY: TENT CITY DEVELOPMENT AFTER THE EARTHQUAKE IN ISTANBUL

Figure 2 shows a facility location game with 3 cities (Kocaeli (Player 1), Sakarya (Player 2), Yalova (Player 3)) in Turkey and 2 companies.

The cost function is calculated by using (1) as follows:



- $c(\{1\}) = 3125000,$
- $c(\{2\}) = 2030000,$
- $c(\{3\}) = 19990000,$
- $c(\{1,2\}) = 3150000,$
- $c(\{1,3\}) = 5115000,$
- $c(\{2,3\}) = 2070000,$
- $c(\{1,2,3\}) = 5140000.$

CASE STUDY: TENT CITY DEVELOPMENT AFTER THE EARTHQUAKE IN ISTANBUL

- Table 3 shows the marginal vectors of our model, where $\sigma: N \rightarrow N$ consists of three components: defined with $(\sigma(1), \sigma(2), \sigma(3))$.
- Table 3.** The marginal vectors of our model.

σ	$m_1^\sigma(c)$	$m_2^\sigma(c)$	$m_3^\sigma(c)$
$\sigma_1 = (1,2,3)$	3125000	25000	1990000
$\sigma_1 = (1,3,2)$	3125000	25000	1990000
$\sigma_1 = (2,1,3)$	1120000	2030000	1990000
$\sigma_1 = (2,3,1)$	3070000	2030000	40000
$\sigma_1 = (3,1,2)$	3125000	25000	1990000
$\sigma_1 = (3,2,1)$	3070000	80000	1990000

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

$$\Phi(c) = (2772500, 7025000, 1665000).$$

Conclusion and outlook

- This presentation has offered a novel facility location planning after natural or societal disasters, responding to the urgent housing problem of the affected areas. In this study, we handle a housing problem after earthquake in Istanbul. Based on the case study, we construct the cooperative facility location game between three cities that the tent cities are built in and we give one solution concept as the **Shapley value** of Cooperative Game Theory.

- Some **uncertainties** can have occurred in facility location situations because of several limitations. Moreover, data may not be available or may not be easy to communicate in large-scale if emergencies are in casualty. For future works, **cooperative games under uncertainty** can be modeled and used in this area.

Conclusion and outlook

Reference:

Usta, P., Ergün, S., and Alparslan-Gök, S. Z., (2018). A Cooperative Game Theory Approach to Post-Disaster Housing Problem.
In *Handbook of Research on Emergent Applications of Optimization Algorithms*, IGI Global (pp. 314-325).

Conference and Seminar: Siantar, Indonesia, February 2019



Thank you very much for your attention!



gerhard.weber@put.poznan.pl



POLITECHNIKA POZNAŃSKA

