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Modeling Multi-Actor Decision Process in Conflict Situation: A case of Community Disaster Risk Mitigation in Ichinose Community, Tottori Prefecture, Japan

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Synopsis

This paper intends to illustrate the conflict in decision making process in case of Ichinose community, Chizu, Tottori prefecture where landslides and floods are major problems. In order to resolve their problems different actors are identified in this decision- making process. The GMCR model (Graph Model for Conflict Resolution) is used to systematically describe the process of changes in the structure of this conflict. Sensitivity analysis is also performed to assess the robustness of stability results. It is proposed to create a participatory platform where each actor can convey their opinions. This could help to find an effective way to resolve the conflict.

Keywords: conflict; graph model; participatory platform

1. Introduction

In decision making process, the most important aspect is to consider each of actor's preferences and bringing them in a common platform. Often multiple players with different interests evolve in conflicts. That is why conflict resolution is a significant task for planners, engineers, social scientists and decision makers.

The Graph Model for Conflict Resolution (GMCR) is used to understand and to structure the conflicts in our proposed case study area. It is based on game theory which is further extended by Fraser and Hipel. This model gives some insights to understand the problems within which the possible strategic interaction among the decision makers (DMs) can be systematically analyzed in order to ascertain the possible compromise resolutions, or equlibria.

2. Modeling

The Graph Model for Conflict Resolution (Fang et al, 1993) is founded upon a rigorous mathematical frame work utilizing concepts from graph theory, set theory and logical reasoning. Graph Model for Conflict Resolution represents a conflict as moving from a state to an other state (the vertices of a graph) via transmissions (the arcs of the graph) controlled by the decision makers. Mathematically this multi-player conflict game can present in the following way:

Let N= {1, 2…, n} be the set of players and K= $\{K_{1,}K_{2,...,}K_u\}$ be the set of states of the conflict and n-tuple $\{D_i\}$ (i =1, 2…, n) as the set of directed graph that D_i = (K, V_i). The set of arcs V_i means player i 's possible move between states. Let $k_l k_m$ be the arc from the state k_l to the state K_m. If $k_l k_m \in V_i$,it implies that player i can move from the state k_l to the state k_m, unilaterally. The payoff function Pi specifies the player i 's preference order for states. If $P_i(k_l) > P_i(k_m)$, player i prefers the state k_l to the state k_m .The Graph for Conflict Resolution (GMCR) is presented by 4 -tuple $\{N, K, V, P\}$, where,

$N = \{1, 2, ..., n\}, K = \{k_1 k_{2,...} k_u\}, V = \{V_{1,} V_{2,...,} V_n\}$ and $P = \{P_i \setminus i \in N\}$.

One advantage of graph model over more traditional game theoretical approaches is that it can represent irreversible moves. In such cases, a decision maker can unilaterally move from state *k* to state *q* but not from *q* to *k*.

DM i 's graph can be represented by i 's reachability matrix, R_i, which displays the unilateral moves available to DM i from each state. For $i \in N, R_i$ is the u x u matrix defined by

$$R_i(k,q) = \begin{cases} 1 \text{ if DM } i \text{ can move (in one step)} \\ \text{from state k to state q} \\ 0 \text{ otherwise} \end{cases}$$

where $k \neq q$, and by convention

$$R_i(k,k) = 0$$

The GMCRII (Hipel et al. 1997; Hipel, Kilgour, Fang and Peng, 2001) provides a simple strategic representation of conflict, with minimal information requirements which can be analyzed for a range of stability patterns that represent different styles of decision making under a real world conflict (Fig.1).

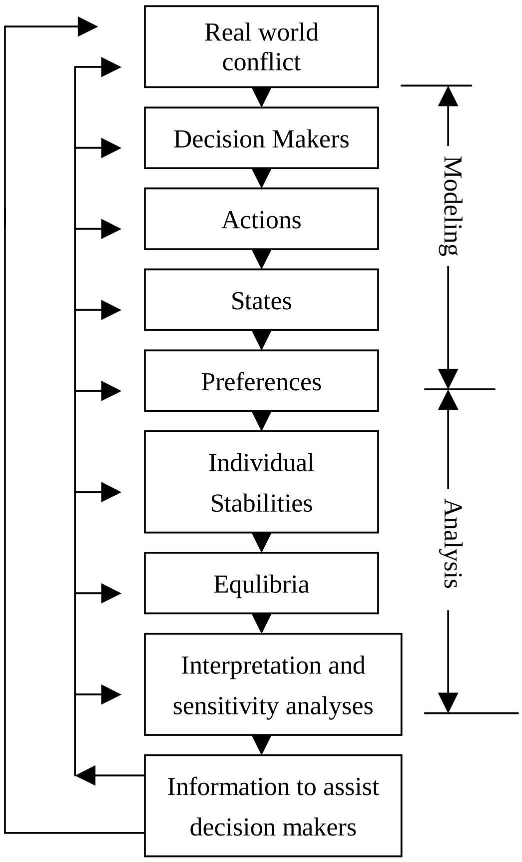

Fig. 1 Applying Graph Model for conflict resolution
Source: Fang et al, 1993

3. Applying GMCR II in the Ichinose community disaster mitigation conflict

3.1. Background of the conflict

Ichinose, a mountainous community is located in Chizu (Tottori prefecture) in Japan (Fig.2). It is a very small community having 33 population. In this area one local company (Hisamoto Company) was engaged to collect the rocks from the mountainous site. In 2004, October the area was badly devastated due to landslides.

After this event it is discovered that the landslides happened due to excessive rock quarry from the mountainous site. Immediately after this disaster it was needed to clean up the rocks and debris from the site. In order to the clean up order of the rocks and debris by the local government the local company refused to do probably because their quarry work had been officially registered by the tottori prefecture government and also their work continuously monitored by them. The tottori city office has also started to enquire this fact. The local people were not ready to move from their site. So they asked the local government to clear the rocks and debris from the site and also to operate an early warning system (EWS). Still, the local company is not ready to do, so the local government took legal steps. The history of the conflict is outlined in Table 1.

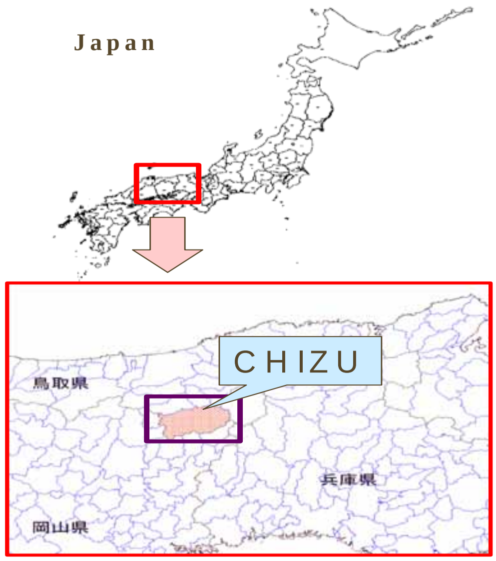

Fig. 2. Location Map

Table1 Chronology of the Conflict

Year	Event
September , 1996	The Tottori prefecture ordered the Hisamoto company to stop the rock quarry and asked them to remove the rocks and debris caused by the landslide.
January, February, 2002	The Hisamoto company got license to quarry in Ichinose area again, but they did not operate the proper way of rock quarry and as a result about 140,000 m^3 earth dammed up in to the Sendai River, and Ichiose village was flooded. The tottori prefecture ordered the Hisamoto company to stop quarry again, but soon in February, the third landslide occurred. Tottori prefecture urgently ordered the Hisamoto company to remove the rocks and debris caused by the landslide.
October, 2004	After the last accident, Hisamoto company did not remove the rocks. Consequently when the fourth landslide occurred, the debris also felt into the river and the damage was enlarged. The Sendai River was dammed up and the Ichinose village was flooded.

4. Model of the Conflict

4.1 Two phases of the conflict

This conflict is modeled by use of GMCR II. September 1996 has taken the point in time for which the modeling and analysis has started. The two decision makers have identified in this conflict, i.e., the local company and the local government. The local government consists of the prefecture government and the town office. Just after the last landslide in October, 2004 the local community became more actively involved in this conflict and they also started to take part in this game.

4.1.1 Phase I

Decision makers and their relative preferences

Decision makers and their relative options and the Status Quo state are listed below: (Table. 2)

Table 2 Player and their options in Ichinose Community Disaster Mitigation Conflict, 1996

Players and their options	Status Quo State
Local company	
1.Rock quarry & dumping at the site	**Y**
2.Operate and maintain the EWS	**N**
Local government	
3.Assisting local company for rock dumping	**Y**
4.Operate and maintain the EWS	**N**
5.Monitoring	**Y**
State number	**9**

The desirability of each state of each player is structured in the following way. A positive number means that a player prefers that option is taken, and negative number is that a player does not prefer that the option is taken.

Players have the following options.

Local Company's desirability

- Local company wants to quarry rock deposit. (1)
- Local company does not want to operate and maintain the EWS. (-2)
- Local government can help them for rock dumping at the site. (3)
- Local government can operate and maintain the EWS. (4)
- Local company does not want to monitor their work by the local government. (-5)

Local Government's desirability

- Local company can quarry rock deposit and dump at the another site. (1)
- Local company can operate and maintain the EWS. (2)
- Local government can help the community for rock dumping at the site. (3)
- Local government does not want to operate and maintain the EWS. (- 4)
- Local government wants to monitor the local company's work. (5)

The table 3 shows the feasible states of this conflict and table 4 shows players' preferences states. Here we obtained only one equilibrium which was also the Status Quo state (Table 5) at that time.

Table 3 Feasible states of the conflict

Option	States	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Local company	**1**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
	2	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**
Local government	**3**	**Y**	**Y**	**N**	**N**	**Y**	**Y**	**N**	**N**	**Y**	**Y**	**N**	**N**	**Y**	**Y**
	4	**N**	**N**	**Y**	**Y**	**Y**	**Y**	**N**	**N**	**N**	**N**	**Y**	**Y**	**Y**	**Y**
	5	**N**	**N**	**N**	**N**	**N**	**N**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**

Table 4 Players' preference order

Local company	**Local government**
5	10
1	8
13	9
9	7
3	14
11	12
7	13
6	11
2	2
14	1
10	6
4	4
12	5
8	3

Table 5 Equlibria state

Players and their options	
Local company	
1. Rock quarry and dumping at the another site	**Y**
2.Operate and maintain the EWS	**N**
Local government	
3.Assisting local company for rock dumping	**Y**
4.Operate and maintain the EWS	**N**
5.Monitoring	**Y**
State number	**9**

4.1.2 Phase 11

Decision makers and their relative preferences

Decision makers and their options and the Status Quo state are listed below. (Table.6)

Table 6 Player and their options in the Ichinose community disaster mitigation conflict, 2004

Players and their options	Status Quo State
Local community	
1.To stay in the same village with disaster preparedness	**Y**
2.Shifting the village with public facilities	**N**
Local company	
3.Rocks and debris clearance from the site	**N**
4.Operate and maintain the EWS	**N**
Local government	
5.Assisting the local community for shifting the village	**N**
6.Rocks and debris clearance from the site	**Y**
7.Operate and maintain the EWS	**N**
8.Go to court	**Y**

Local community's Strategy

Local company's Strategy

Local government's Strategy

The option representation of a state is presented by indicating ''Y''and''N'', where ''Y'' indicates yes, the option is taken by decision maker and''N'' means no that is the option is not taken. Here strategy means choice of decision makers for his or her options to invoke. States are defined as the combination decision makers' strategy.

In this conflict, there is a total 256 states (2^8=256).But many of the states are not feasible for actual conflict for different reasons. For example, the local community has two options, to stay in the same village with disaster preparedness and shifting the village with public facilities. Both are mutually exclusive, so they are infeasible options. But in case of local government, out of four options, two options, i.e., rocks and debris clearance from the site and operate and maintain the EWS which is mutually exclusive for the local company. This may be possible with coordination of both players. So, in this case it is regarded as a feasible state for both players. After removing the infeasible options, a total of 18 states have been identified for this conflict (Table7). While ranking the preferences, option prioritization method has employed in this case (Table.8). The desirability state of each player is assumed as follows.

Table 7 Feasible states in the conflict

States / options		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Local Community	**1**	**Y**	**Y**	**Y**	**N**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**N**	**Y**	**Y**	**Y**
	2	**N**	**N**	**N**	**Y**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**Y**	**N**	**N**	**N**
Local Company	**3**	**N**	**Y**	**N**	**N**	**N**	**Y**	**N**	**N**	**Y**	**N**	**N**	**Y**	**N**	**N**	**N**	**N**	**N**	**N**
	4	**N**	**N**	**Y**	**N**	**N**	**N**	**Y**	**N**	**N**	**Y**	**N**	**N**	**Y**	**N**	**N**	**N**	**N**	**N**
Local Government	**5**	**N**	**N**	**N**	**Y**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**Y**	**N**	**N**	**N**
	6	**N**	**N**	**N**	**N**	**Y**	**Y**	**Y**	**N**	**N**	**N**	**Y**	**Y**	**Y**	**N**	**N**	**Y**	**N**	**Y**
	7	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**N**	**N**	**N**	**Y**	**Y**
	8	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**Y**	**Y**	**Y**	**Y**	**Y**

Local Community's desirability

- Community wants to stay in the same village with disaster preparedness. (1)
- Community does not want to shift from their place (-2)
- Local company should clear the rocks and debris from the site (3)
- Local company should operate and maintain the EWS (4)
- Local government should not assist the local community to shift the village (-5)
- Local government should clear the rocks and debris from the site (6)
- Local government can operate and maintain the EWS (7)
- Local government can go to court if local company does not take any initiatives (8)

Local company's desirability

- Local community does not want to stay in the same village with disaster preparedness (-1)
- Local community wants to shift the village (2)
- Local company does not want to clear the rocks and debris from the site (-3)
- Local company does not want to operate and maintain the EWS (-4)
- Local government can help the local community for shifting the village (5)
- Local government can clear the rocks and debris from the site (6)
- Local government can operate and maintain the EWS. (7)
- Local government should not go to court. (-8)

Local government's desirability

- Local community does not want to stay in the same village with disaster preparedness. (-1)
- Local community can shift their village. (2)
- Local company can clear the rocks and debris from the site. (3)
- Local company can operate and maintain the EWS. (4)
- Local government can assist the local community to shift their village. (5)
- Local government can clear the rocks and debris from the site. (6)

- Local government can introduce and monitor the EWS. (7)
- If the local company does not do anything they can go to court. (8)

4.1.3 Allowable state transitions

GMCR allows calculating all possible state transitions (Table 9).Decision makers may be able to unilaterally cause a transition from the current to another state by changing his or her options.

Table 8 Option prioritizing

Local Community	Local company	Local government
1	-3	2
-2	-4	5
6	-8	-1
7	-1	3
-5	2	4
3	5	8
4	6	6
8	7	7

Table 9 Transition from Status Quo to the equilibrium state

Players and their options			
Local Community			
To stay in the same village with disaster preparedness	**Y** →	**N** →	**Y**
Shifting the village with public facilities	**N** →	**Y** →	**N**
Local company			
Rocks and debris clearance from the site	**N**	**N**	**N**
Operate and maintain the EWS	**N**	**N**	**N**
Local government			
Assisting the local community for shifting the village	**N** →	**Y** →	**N**
Rocks and debris clearance from the site	**Y** →	**N** →	**Y**
Operate and maintain the EWS	**N**	**N** →	**Y**
Go to court	**Y**	**Y**	**Y**
State number		**15**	**18**

4.1.4 Stability analysis and solution concepts

To understand the behavior of each decision makers in this conflict situation stability analysis has been conducted and the following Table 11 explains the different solution concepts implemented in this conflict. Table 10 explains the overall stability for decision makers.

Table11 Equlibria State

State	Equlibria
15	R (Nash),SEQ(Sequential)
18	R (Nash),SEQ(Sequential)

In this analysis the Status Quo state is not to appear as an equilibrium state. States 15 and 18 are the equilibria or solution points. So conflict resolution may not be possible at this point. Like the local community is not ready to move from their location. So, state 15 is not a possible equilibrium. The sate 18 is also not a possible equilibrium for this game because at this moment local government is not ready to operate and maintain the EWS. May be the local government can work in collaboration with the local company. So, further sensitivity analysis is done to assess the robustness of stability results. Sensitivity analysis in the graph model will also help to carry out further analysis by asking what-if questions.

4.2 Sensitivity analysis

In order to carry out sensitivity analysis players' preference order is modified but the desirability of state is not changed. A number or preference statement located higher in a column is more preferred than those appearing below it (Table.12). The same option prioritizing technique applied is applied to a set of players' preferences (Table.13). Further stability analysis shows the possible equilibrium (Table 14).

Table 10 Solution concepts and human behavior

Solution concepts	References	Foresight	Disimprovements	Stability descriptions
Nash stability (R)	Nash (1950,1951);Von Neumann and Morgenstern (1953)	Low	Never	Focal decision makers (DM) can't move unilaterally to a more preferred state.
Sequential stability (SEQ)	Fraser and Hipel (1979,1984)	Medium	Never	All focal DMs unilaterally improvements are sanctioned by subsequent unilateral improvements by others.

Table 12 Option prioritizing

Local Community	**Local company**		**Local government**	
Initial and altered preference	Initial Preference	Altered Preference	Initial Preference	Altered Preference
1	-3	-8	2	6
-2	-4	6	5	7
6	-8	7	-1	-1
7	-1	-3	3	3
-5	2	-4	4	4
3	5	2	8	2
4	6	5	6	5
8	7	-1	7	8

(Number in the table mean option)

Table 13 Payers' preference order

Local Community	**Local company**		**Local government**	
Initial and altered preference	Initial preference	Altered preference	Initial preference	Altered preference
12	4	11	15	12
13	11	13	4	13
18	5	12	12	18
11	8	5	6	11
6	1	7	9	6
7	15	6	2	7
16	18	8	13	16
5	16	10	7	5
9	17	9	10	9
10	14	4	3	10
17	13	1	18	17
2	7	3	16	8
8	10	2	17	15
3	3	18	14	4
14	12	16	11	3
1	6	17	5	2
15	9	15	8	14
4	2	14	1	1

Table 14 Equlibria State

State	Equlibria
13	SEQ(Sequential)
15	R (Nash),SEQ(Sequential)
18	R (Nash),SEQ(Sequential)

Here we obtained 3 equlibria States 13, 15 and 18. Here state 13 is a new equlibrium where the local company can operate and maintain the EWS and thus local government will not go to court. This is different from other equlibria state 15 and 18. But the local company seems is not ready at this moment to cooperate with the local government.

5. Conclusion

The conflict is still in progress. Though the conflict resolution is not possible for these equilibria points, this basic structure of conflict model provides us with a simplified analytical framework, in order to obtain a better understanding of how decision makers behave and which course of resolution are most likely to occur. It seems that the conflict structure be further modified to identify other players and their role in this conflict. The conflict is more crucial from the prefecture government and the town office points of view because the local company has been registered by the prefecture government. For instance, it is necessary to understand what kind of agreement and monitoring has been done by the prefecture government and the local town office also. The communication between different actors is very weak. Even the local Community has not much power to take decision about their welfare. It is urgent to create a participatory platform where each actor can convey their opinions. This could help to find a more effective way to resolve the conflict. In case of negotiation, it will be appropriate to use an asymmetric equilibrium model, where one of the players has ability to force once decision to the other. This is known as Stackelberg Equilibrium where the player who holds the powerful position is called the leader and the other player who react the leader decision is called the follower.

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コンフリクト状況下における複数当事者の意見決定問題のモデル化: 日本鳥取県市瀬集落の災難危険緩和の事例

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要旨

本稿は, 地すべりと洪水対策に関わる鳥取県智頭町市瀬地区をめぐるコンフリクトの意思決定プロセスを取り上げる。まず，コンフリクト問題の当事者を明らかにするとともに, ＧＭＣＲモデルを用いて当該コンフリクト問題の措置とその変化の過程をモデル化する。均衡解の安定性分析を行い，得られた解がどの程度の頑健性を示すかを明らかにする。参加型のコミュニケーションの場を設営することにより，当事者が意見を表明しあうことが可能になるような仕組みを作ることが必要であることに言及する。これにより, 本コンフリクトをより効果的に解決する方式を見出すことが可能になることを指摘する。

キーワード：コンフリクト，グラフモデル，参加型場作り