The Use of Game Theory in Voluntary Urban Readjustment Measures

Anja JESCHKE and Alexandra WEITKAMP, Germany

Keywords: Decision-Making Process, Game Theory, Strategic Form, Extensive Form, Prisoner's Dilemma, Dominant Strategy, Equilibrium, Nash Equilibrium, Pareto Efficiency, Urban Remodelling, Voluntary Urban Readjustment Measures

SUMMARY

Many fields of land management contain processes of decisions: for example in planning of new building land, in rural readjustment measures or in urban development. Normally, different stakeholders from administration, economy and citizenship are involved. Their objectives differ between emotional aspects and rational choice. It is rarely predictable, in which way the participation processes proceed, which aspects will be picked up and which results can be received.

Game theoretical models could be very helpful in this context. Both, decision theory and game theory could be used as decision support tools. While decision support theory is focused on one stakeholder, the game theory has the possibility to model the decision behaviour of multiple stakeholders (players) in interaction. The behaviour of different stakeholders can be modelled by the game theory, so the significant parameters of future processes can be predicted.

Within game theory, the decision of a stakeholder is correlated with the actions of the other players. Game theory knows many kinds of games, e.g. if the stakeholders communicate with each other or if a repeat of the decision is possible. Precondition of the game theory is the knowledge about all of the stakeholders. Groups of stakeholders can be interpreted as one stakeholder, if they have the same objectives and behaviour.

This paper contains game theoretical modelling of decision processes in context of voluntary urban readjustment measures. The adaptation of the game theory for this field of action is focused in the analysis. Therefore, the stakeholders, their aims, possible force proportions (public-private also as private-private), the extent of knowledge of each stakeholder and finally the results (payoffs) of the decisions should be identified. On this base different constellations of games are tested for their applicability within voluntary urban readjustment measures. Last but not least, possibilities and limits of modelling by existing constellations of games are presented.

The Use of Game Theory in Voluntary Urban Readjustment Measures

Anja JESCHKE and Alexandra WEITKAMP, Germany

1. INTRODUCTION

Decision-making processes can be found in many areas of land management. In most cases, different stakeholders from administration, economy and citizens are involved. Normally, they pursue different objectives. It is rarely predictable, in which way the urban processes proceed, which aspects are addressed in the decision-making process and which results can be received. Here, the game theory can be very helpful. It offers a possibility to analyse decision-making processes where the result does not depend only on the own decision but the stakeholders are influenced by the decisions of the other stakeholders.
The following paper contains the game theoretical basics. The different kinds of games and different forms of presentation are presented. Based on this, the game theoretical modelling is presented by using the Prisoner's Dilemma exemplary for the urban modelling. Finally, the academic added value for land management will be derived.

2. DECISION THEORY VERSUS GAME THEORY

Both, decision theory and game theory, are concerned with decisions of individuals. The decision theory deals with decision-making processes, where the result depends on the own decision and unsure environmental conditions (ORTMANNS & ALBERT 2008, 14). Here the environmental conditions should be modelled and provide with probabilities.
In contrast, the game theory analyses strategic decision-making processes. Here, the result depends on the own decision and the decision of the other stakeholders. A single stakeholder is not able to determine independently the decision of the choice of the other stakeholders. Each stakeholder is aware of this interdependence and can assume, that the others are aware of this, too. Any stakeholder will consider these characteristics of strategic decision-making processes (HOLLER & ILLING 2006, 1).
Such decision-making processes are known from many strategy games, for example chess or poker. Therefore, the name of game theory has been established. Overall, it can be resumed that game theory is a special part of decision theory (RIECHMANN 2014, 1).

3. BASICS OF GAME THEORY

For using the game theory as a tool for analysis, it is important to have a fundamental basis of definitions and concepts in game theoretical modelling. The starting point of a strategic decision-making processes are the players (P_n) with their several strategies (s_{ni}) to solve the problem. Each player has at least two strategies. Even doing nothing in a decision-making process represent a strategy. The results of the chosen strategy of each player are named payoffs (ORTMANNS & ALBERT 2008, 15).

3.1 Forms of Representation

Different forms of representation illustrate a game theoretical situation.
Figure 1 shows a simple game with only two players P_n (with n = 1, 2) in a so-called game matrix. The player P_1 is also called the column player and player P_2 the row player. Both have two strategies s_{ni}. In relation to the choice of each player, there are (2x2)-combination of strategies. The set of all combination of strategies describes the strategic space S (HOLLER & ILLING 2006, p. 2). Each combination of strategies causes a payoff of a player E_{im}. This form of representation is the **strategic (or normal) form** (ORTMANNS & ALBERT 2008, 72).

Player P_1 / Player P_2	Strategy s_{11}	Strategy s_{12}
Strategy s_{21}	S_1 $E_{21} \mid E_{11}$	S_2 $E_{22} \mid E_{12}$
Strategy s_{22}	S_3 $E_{23} \mid E_{13}$	S_4 $E_{24} \mid E_{14}$

Strategic Space

Figure 1: Game matrix (strategic form)

Another form of representing a game is the game tree (figure 2). There are two players P_n (with n = 1, 2) given in the example. A game tree consists of two elements, the nodes and the branches. The nodes A, B and C are decision nodes. Here, the player P_1 (decision node A) and the player P_2 (decision nodes B and C) have to make a choice. Node A is the root of the game tree. The nodes at the end of the tree are called terminal nodes S_1, S_2, S_3 and S_4 (combination of strategies). Here, the payoffs are attached. The set of all possible combination of strategies is called the strategic space S. The branches of the tree are representing the possible strategies s_{ni} of each player. This form of representation is the **extensive (or sequential) form**. In addition to the detailed description of each game, it is possible to represent the temporal structure of the individual features of the players (HOLLER & ILLING 2006, pp. 12; RIECK 2010, pp. 120; RIECHMANN 2014, pp. 47).

3.2 Types of Games

For analysing strategic decision-making processes with the help of the game theory, the rules of the game and the resulting types of games must be known.

3.2.1 Cooperative versus non-cooperative games

In cooperative games, arrangements between players are allowed. They meet each other and agree on realizing a special result of a game. This type of game allows binding arrangements between the players. They agree to act according these arrangements. In contrast, in non-cooperative games, arrangements between the players are not allowed. Their information only contains playing the same game and the individual assessment about the outcome. In non-

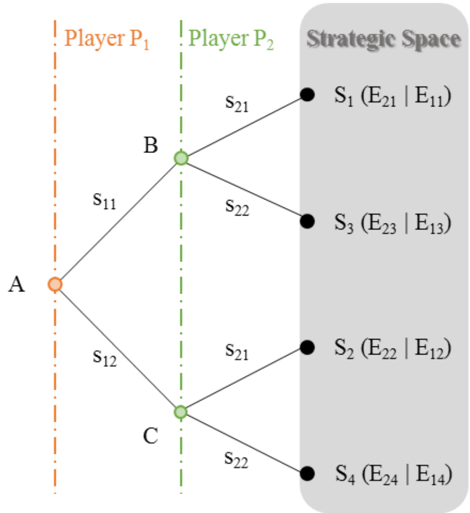

Figure 2: Game tree (extensive form)

cooperative games, there are no possibilities to make binding arrangements (ORTMANNS & ALBERT 2008, 74; RIECK 2010, pp. 35).

3.2.2 Static versus dynamic games

In a static game, all players decide simultaneously and without knowledge of the strategic choices of the other players. These games also called simultaneous games and represented by the strategic form with the game matrix, whereby the simultaneous decision of the players is shown. In a dynamic (or sequential) game, the players choose their strategy on by one. In this case, the second player knows the choice of the first player. Here, the extensive form is the best way of representing such games, because it shows the temporal order of the individual players (ORTMANNS & ALBERT 2008, 74; RIECHMANN 2014, 22 und 47).

3.2.3 One-shot versus repeated games

One-shot games are played only once, repeated games are played several times or even indefinitely (so-called super games) (ORTMANNS & ALBERT 2008, 74).

3.2.4 Symmetric versus asymmetric games

These two types of games differ on the level of information of each player at the time of decision. In symmetric games, all players have the same information. In asymmetric games, one player has any information, a so-called private information, in addition. Private information is for example the environmental condition, which is unknown for the other players (ORTMANNS & ALBERT 2008, 74; RIECK 2010, pp. 129).

3.2.5 Games with perfect (complete) information versus games with imperfect (incomplete) information

These two types deal with the level of information of each player, too. More specifically, it is about the information regarding to the payoffs of each player. Within the game with perfect (or complete) information, each player knows the payoffs of the others. If any players do not know the payoffs of the others, the game is called game with imperfect (or incomplete) information. A static game is a game with imperfect information, because all players decide at the same time. If all players decide simultaneously, no player may have the knowledge about the payoffs (RIECK 2010, pp. 129).

4. APPLICATION OF GAME THEORY IN AREAS OF URBAN REMODELLING

4.1 The Prisoner's Dilemma

After the discussion of game theoretical basics, the application of game theory in field of land management is presented in the following chapter. Bernt picks up the best know game of game theory: the prisoner's dilemma (BERNT 2005, pp. 109). Literature discusses various modifications of this game[1]. In the following remarks, the explanations of Bernt are presented (BERNT 2005, 115). Following situation is defined: Two persons are suspected of a common crime. They are arrested in solitary confinement with no means of speaking to or exchanging messages with each other. Each of them has to decide, if they want to betray or not. Cooperation is not possible. Both of them know:

- If prisoner 1 betrays and burdens prisoner 2, while prisoner 2 remains silent, prisoner 1 will not be punished and the other one will serve 5 years in prison.
- If both remain silent, they get both a mildly serve of 2 years in prison.
- If both betrays, both get 4 years in prison.

Both prisoners decide simultaneous and without knowing the strategy of the other one. It is a simultaneous game. The game situation is not cooperative, because they cannot make binding arrangements. The matrix of the game is presented in figure 3.
In the game theory, the different solutions base on an individual rational action of the players. They switch a strategy, which maximises the expected benefit (BISCHOFF 2014, 23). The best fitting situation of prisoner 1 is to betray (0 years) while prisoner 2 stays silent (5 years). Same situation vice versa is the best fitting one for prisoner 2. "Betraying" as strategy leads to the highest benefit for both of them. Such strategy is called a **dominant strategy** (HOLLER & ILLING 2006, 54).

Prisoner 1 / Prisoner 2	Staying silent s_{11}	Betraying s_{12}
Staying silent s_{21}	2 years | 2 years	5 years | 0 years
Betraying s_{22}	0 years | 5 years	4 years | 4 years

Figure 1: Matrix of the prisoner's dilemma (according to BERNT 2005, 116)

[1] The prisoner's dilemma is presented in ORTMANNS & ALBERT 2008, p. 76; RIECK 2010, pp. 46; RIECHMANN 2014, pp. 42; HOLLER & ILLING 2006, pp. 2.

For both prisoners it would be the best, if both stay silent (2 years for both). This strategy do not correspond with rational behaviour, because it is a non-cooperative game. Binding arrangements cannot be made. Thereby, the risk is high, that one prisoner betrays and achieves a favourable result in the decision (HOLLER & ILLING 2006, p. 5).
If both prisoners act individual rational, they will follow their dominant strategy and choose betraying. Then a worse situation occurs with 4 years in prison. This could be assessed as a dilemma.
Solutions of non-cooperative games, like the prisoner's dilemma, are characterized by a missing incentive for both to choose another strategy, if one player gives the strategy (HOLLER & ILLING 2006, 6). The game theory calls it equilibrium[2]. If both prisoners chose the dominant strategy "betraying", the solution is called equilibrium in dominant strategies (HOLLER & ILLING 2006, p. 54). If the expected benefit of each player will be maximized in addition and under the premise that all other players also chose the corresponding equilibrium strategy, a Nash equilibrium is achieved (also strategic equilibrium) (HOLLER & ILLING 2006, 10). The strategy combination of "betraying | betraying" is a Nash equilibrium; both get a penalty of 4 years prison. The maximized benefit of each is an imprisonment, which is not the maximum penalty.
A criterion of assessing the result is the "**Pareto Efficiency**[3]". A game output is called pareto efficient, if none of the players can be made better off without worsen the other one (RIECK 2010, 39). The pareto efficient solution of the prisoner's dilemma is the solution "betraying | betraying". The actual output of the prisoner's dilemma game (both betray) is obviously pareto inefficient, because of at least one of the two prisoners could provide better, also if it is at the expense of the other one (RIECHMANN 2014, 43).

4.2 The Prisoner's Dilemma in Urban Remodelling

Bernt transferred the idea of the prisoner's dilemma on German urban remodelling. He designed a "demolition-game" between two housing associations A and B. Figure 4 presents the game matrix. Both associations have property in an area with a high vacancy quota. Both would benefit in case of demolition, because vacant flats cause costs. The demolition is assessed positively with 1 point. Demolition causes costs, which should be spread evenly on both players. If only one housing association will demolish, he would have to bear all costs (-1 point). The other one would have the whole benefit. He would not have to bear costs and benefits of the changes of tenants, who cannot live in the flats to demolish. The player, who has no costs for demolishing (1 point), has the advantage of renting his vacant flats in the remaining buildings (1 point; in total: 2 points for the beneficiary association). If both decide against the demolishing, no further actions of urban remodelling will take place. Both players will neither win nor loose anything (0 points) (BERNT 2005, p. 116).
The results are similar to the origin prisoner's dilemma. It is a non-cooperative game. Both housing associations act individual rational and chose each dominant strategy "not demolishing" with the objective not to provide an advantage to the other one. Thus, an action blockade in urban remodelling would be the consequence (BERNT 2005, 117). However, this

[2] The strategy combination "staying silent | staying silent" is not an equilibrium. Each prisoner would have the incentive to change the strategy to get a better result.
[3] In literature also called: pareto optimality or pareto superior.

Housing Association 2 \ Housing Association 1	Demolishing s_{11}	Not Demolishing s_{12}
Demolishing s_{21}	1 | 1	-1 | 2
Not Demolishing s_{22}	2 | -1	0 | 0

Figure 2: Matrix of the prisoner's dilemma in urban remodelling (according to BERNT 2005, 117)

is not the case, fortunately. The normal case of prisoner's dilemma is based on a non-cooperative game. In reality, agreements are possible in urban remodelling. Especially in Eastern Germany, housing associations have a lot of problems (e.g. population decrease, shrinking demand, declining revenues). Thus, they are forced to find a collective solution (BERNT 2005, 117).
Bernt deals with three types of proprietors in urban remodelling (BERNT 2005, pp. 120).

<u>Private, entrepreneurial proprietors</u>
They recently bought the real estates quite and often paid high price. They had modernized and repaired the building. Their commitment will be low in urban remodelling, because they would lose the housing stock by demolishing, but at the same time they would keep their debt from buying and modernization costs.

<u>Small private proprietors</u>
This group of stakeholders will also show little commitment to the urban remodelling. They have only minor equity or securities for loan financing. Thus, they are not able to modernize their buildings. In addition, they do not have the ability for housing management issues. They are interested in removing the market overhangs without doing anything by themselves.

<u>Municipal or cooperative housing associations</u>
In the context of the existing debt repayment[4], this stakeholders are the only, who would have a relief by demolishing their stocks. The municipal or cooperative housing associations have advantages by the size of their stock and the possibility to compensate losses by benefits with other buildings or by transferring tenants within their own stock.
The group of municipal or cooperative housing associations advance the urban remodelling. Other groups make benefits by demolishing vacancies, but do not participate actively. As a result, a misalignment arises. Public subsidies, like programme "Urban Remodelling East", had helped to confine the prisoner's dilemma of the housing associations. Other results arises with changed strategies.

In practice of urban remodelling, Bernt mentions a modified prisoner's dilemma (BERNT 2005, 126). The demolishment is passed on demolishment-willing housing associations. In

[4] Until 2003, municipal or cooperative housing associations got an issued debt, if a vacant stock were demolished.

general, the housing association act cooperatively. According to Bernt, the cooperation bases on a distribution of losses combined with a compensation by public subsidies.

5. GAME THEORETICAL MODELLING IN VOLUNTARY URBAN READJUSTMENT MEASURES

How can the game theory provide an academic added value in the field of land management?

This is shown further on by giving an example of voluntary urban readjustment measures. Three adjacent owners A, B and C are given (figure 5). The situation of the property boundaries is rather unfavourable. Owner A and C are restricted in their open space in the rear section of the property. Owner B wants to build on his previously undeveloped land. All in all, the three owners could be interested in the change of the property boundaries. However, the advantage of each owner should be assess in different ways. This is a simple problem of voluntary urban readjustment measures and in fact a decision-making process.
The first step of the game theoretical modelling is to occupy with the stakeholders. This includes the identification of the participants of the game (players) and considerations of existing of background knowledge, the objectives and options in action (strategy) of each player. In addition, the benefit of each player for each chosen strategy is a part of the modulation. According to the pre-analysis of participants in decision-making process, a grouping of stakeholders is possible to simplify the model. In figure 5, owners A and C can be grouped. It can be assumed, that A and C have a minor benefit within voluntary readjustment compared with owner B. B would get a building lot afterwards, which is missing know. His benefit is higher, than the own of owner A and C.
In a further step, the situation of decision should be analysed. The analysis deals with the rules of the game and leads to nature of the game. Within the analysis, several questions must

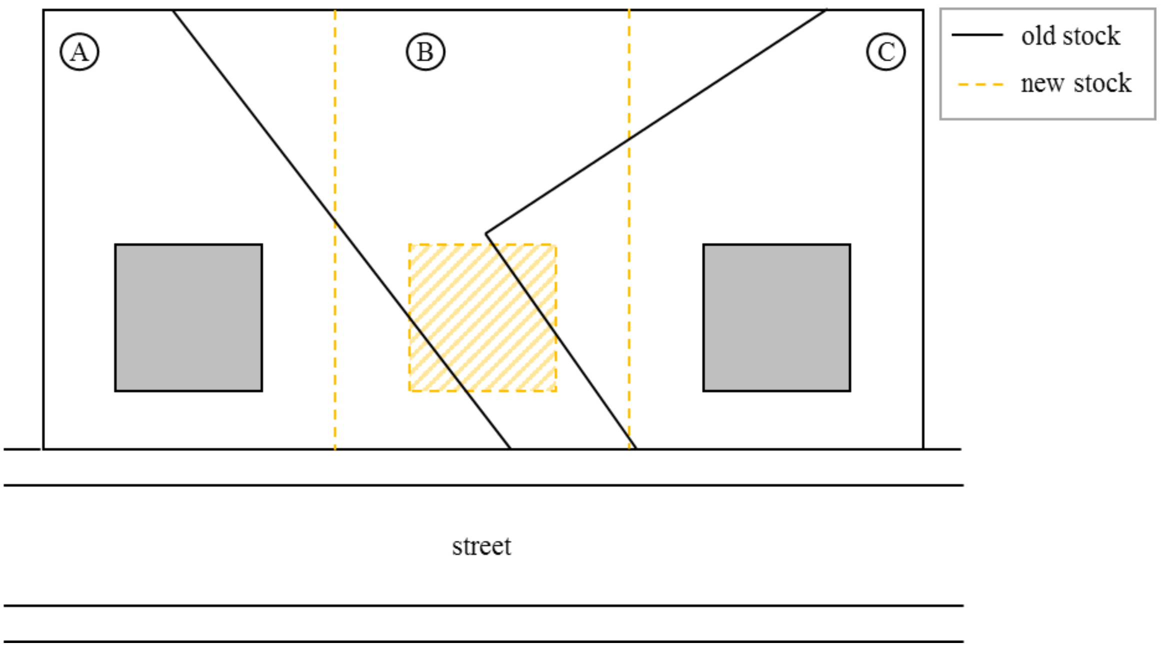

Figure 3: Example of a decision-making process in voluntary urban readjustment measures

be answered:

- Can binding agreements between players be made?
- Do the players play simultaneously or one after another?
- Which information do the players have and is the amount of information similar for each player?
- In which order information became known?

The presentation in the extensive or normal form of the decision is helpful. Basing on the analysis of the nature of the game, solutions can be found. A solution is favourable, if no player has a self-interest to change his strategy: an equilibrium (see above), more precisely a Nash-equilibrium is needed. Then, the equilibrium strategy of all players leads to a maximized benefit.

6. OUTLOOK AND CONCLUSION

A strong need for actions within the game theoretical modelling is doubtless the analysis of the stakeholders in the decision-making process. Then the game theory has some application fields. For existing decision-making processes with given rules, solutions can be named. That means, if the type of the game in chapter 5 is known, you can derive the decision for a rational decision-maker. If the rules of the game are not known, different games can be modelled with the help of the game theory. Afterwards, a particular choice can be made to get the desired results.
According to a certain question, the game theory may be an analytical tool for decision-making processes in land management. At first, the game theory offers a possibility to model and evaluate such processes. Based on this, recommendations for similar decision processes derived and adjustments are named.

REFERENCES

ORTMANNS, Wolfgang & ALBERT, Anke, 2008: Entscheidungs- und Spieltheorie. Eine anwendungsbezogene Einführung. Sternenfels: Verlag Wissenschaft und Praxis.

HOLLER, Manfred J. & ILLING, Gerhard, 2006: Einführung in die Spieltheorie.6. edition, Berlin: Springer Verlag.

RIECK, Christian, 2010: Spieltheorie. Eine Einführung. 10. edition, Eschborn: Christian Rieck Verlag.

BERNT, Matthias, 2005: Stadtumbau im Gefangenendilemma. In: Weiske, Ch., Kabisch S. und Hannemann Ch. (Hrsg.): Kommunikative Steuerung des Stadtumbaus. Interessengegensätze, Koalitionen und Entscheidungsstrukturen in schrumpfenden Städten. 109-130, Wiesbaden: VS Verlag für Sozialwissenschaften.

RIECHMANN, Thomas, 2014: Spieltheorie. 4. edition, München: Verlag Franz Vahlen GmbH.

BISCHOFF, Ivo, 2014: Einführung in die Spieltheorie. In: Geodätisches Institut der Leibnitz Universität Hannover (Hrsg.): Modellierung von Akteursverhalten in der aktiven räumlichen Planung auf lokaler und regionaler Ebene. 23-25. Hannover.

BIOGRAPHICAL NOTES

Dipl.-Ing. Anja **Jeschke** received her diploma (Dipl.-Ing.) in "Geodesy" at the Technical University of Dresden in 2010. Since September 2010, she works at the Geodetic Institute of the Technical University of Dresden at Chair of Land Management. Her research focus refer to the determination of standard land values in areas with low information and the analysis of decision-making processes especially in area of game theory.

Prof. Dr.-Ing. Alexandra **Weitkamp** received her diploma (Dipl.-Ing.) in "Geodesy" at the University of Hanover in 1999. She passed the highest level state certification as "Graduate Civil Servant for Surveying and Real Estates" in Lower Saxony in 2001. After two-year experience at Bayer AG, she returns to Leibniz Universitaet Hannover. In 2008 received her Ph.D. in "Geodesy and Geoinformatics" at the University of Bonn. Until 2014, she has been postdoctoral fellow at the Geodetic Institute at the Leibniz Universitaet Hannover. Since October 2014, she became Chair of Land Management at Technical University of Dresden. Her main research interests are: adaption of innovative evaluation methods for valuation, stakeholders in rural and urban development, and decision-making methods.

CONTACTS

Dipl.-Ing. Anja Jeschke; Prof. Dr.-Ing. Alexandra Weitkamp
Technical University of Dresden
Helmholtzstraße 10
01069 Dresden
GERMANY
Tel. + 49 351 463-33921; -37115
Fax +49 351 463-37190
Email: isabelle.klein@tu-dresden.de; alexandra.weitkamp@tu-dresden.de
Web site: http://tu-dresden.de/gi/lm