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# Decision-making in real estate development: application of game theory

Decision making in real estate development projects has generally undergone a number of important changes over the last decades. This transition represented a shift from governmentally dominated top-down spatial planning to bottom-up, public-private engagement schemes in real estate development (Tam et al. 2009). The new policy implies pluricentric network steering – in which several public and private parties play a role – instead of traditional hierarchical top-down governmental steering.



**B. Glumac, dr. ir. E.G.J. Blokhuis & Q. Han**

Brano Glumac<sup>1</sup>, Erik Blokhuis<sup>2</sup> and Qi Han<sup>3</sup> are all working within the group of Construction Management and Urban Development at Eindhoven University of Technology. Brano Glumac's research topic covers the modeling and experimental treatment of the actors' decision making in Brownfield redevelopment. Erik Blokhuis finished his PhD, where the topic of his doctoral thesis was the interaction between stakeholders during the redevelopment of Brownfields. Currently, he is active as researcher within the group of CMUD. Qi Han received her doctoral degree in March 2006. Her research interests are in developing models and experiments for dynamic, strategic behavior and decision process in urban development.

In current real estate development projects many stakeholder groups are involved, and this stakeholder involvement is different in each project. The most important stakeholders are municipalities, land-owners, end-users, financiers, and provincial and national ministries. Furthermore, development companies, building contractors, designers, consultants, environmental groups, and citizens are often involved. Real estate development cannot proceed without commitment of these stakeholders, because the decision processes are interdependent: the outcome of the development process cannot be determined by one player.

Because of the mutual interdependence between these stakeholder groups, there is a necessity to collaborate in order to achieve something. This asks for a new emphasis in how to conceptualize mutual relations, giving attention to mechanisms that coordinate and integrate stakeholders and that promote cooperation. Because of this, many scholars showed an interest in the application of network steering in urban renewal projects, providing for a new stream in literature. This resulted in a search for scientific methods and tools enabling planners to support stakeholders' participative decision making (see Tam et al. 2009). However, the influence of distributional power, hierarchy, and conflict have been relatively neglected in the recent process models, whereas it is still a key component when studying the relation between actors involved in urban redevelopment (Minnery 2007). There have been very few attempts to analyze systematically how *both* relational aspects play a role in multi-actor decision making. Analyses of the structures and processes of real estate development projects will be effective only to the extent that they recognize the roles of both cooperation and conflict. In this article, we expound that game theory which provides a suitable basis for studying interactions in real estate development projects.

## Game Theory

Game theory (e.g. Luce and Raiffa, 1957) is built upon the assumption that the decision making of players is always interdependent. Consequently, players have to think ahead and devise a strategy based on expected countermoves of the other player(s). Basically, game theory deals with the modeling of situations of conflict and cooperation, together with the analysis of these models using mathematical techniques. The principal objective of game theory is to determine what strategies the players ought to choose in order to

pursue their own interests rationally and what outcomes will result if they do so. Because the focus lies on situations in which parties have conflicting and supplementary interests, and interdependency in behavior, game theory is well-suited to describe and analyze real estate development and real estate decision making situations in which two or more actors or decision makers are involved (Samsura et al. 2010).

Basic assumptions that underlie the theory are that decision makers pursue well-defined, exogenous objectives (they are rational and try to maximize their own utility), they have an infinite good memory (perfect recall), and they take their knowledge or expectations of other decision makers' behavior into account (they reason strategically). Game theoretical models are highly abstract representations of real-life situations, which allow them to be used to study a wide range of phenomena. They consist of at least three basic elements in order to predict interaction outcomes: players, strategies, and payoffs.

The players in a game are the decision-makers; a player *i* is assumed to be a solitary actor who makes decisions as a single decision body. Furthermore, the strategy  $S_i$  is a complete plan of possible actions  $A_i = \{a_i\}$ , defining what player *i* might do in any given situation during the game, aiming for utility maximization. The total set of strategies available to player *i* is denoted as the strategy set or strategy space  $S_i = \{s_i\}$ . All players make their own choices by selecting a strategy, but the result for each player is partly dependent on the choice of the other player. This resulting set of strategies for each of the *n* players in the game is denoted as a strategy combination  $s = (s_1, \dots, s_n)$ . The third element in the game theory is payoff. Player *i*'s payoff is denoted as  $\pi_i(s_1, \dots, s_n)$ , and this can be defined as a number associated with each possible outcome resulting from a complete set of strategic selections by all the players in a game. Generally, higher payoff numbers attach to outcomes that are better in the player's rating system.

The conjunction of chosen strategies and related payoffs is defined as the outcome of the game. A clear distinction has to be made between the concepts of outcome and payoff; an outcome is the decision, if any, arrived at by the players collectively, while the definite payoff of an outcome for a player is the value of that outcome for the player. Because players will have different valuation systems over the set of possible outcomes, and hence have different preferences over the outcomes, this is where conflicts can arise. In order to predict the outcome of a game, focus of game theoretic modelers is on possible strategy combinations and on selecting one or more strategy combinations as reflecting the most rational behavior by the players. A strategy combination that consists of the best strategy for each of the *n* players in the game is defined as an equilibrium  $s^* = (s_1^*, \dots, s_n^*)$ ; players choose equilibrium strategies in trying to

maximize their individual payoffs. In order to find equilibriums, the players' most preferred strategies should be defined. Solution concepts are suitable for defining such preferred strategies; a solution concept  $F : \{S_1, \dots, S_n, \pi_1, \dots, \pi_n\}$   $s^*$  is a rule that defines an equilibrium based on the possible strategy combinations and the payoff functions.

## Application

Game theory can be classified into cooperative and non-cooperative game theory, both matching narrowly with real estate development decision making processes. Cooperative game theory deals with situations in which groups of players already agreed to cooperate. These players aim for coordinating their actions, eventually resulting in joint profits. Because these joint profits often exceed the sum of the individual profits, cooperative game theory deals with the question how to divide these joint profits. This might be applicable to situations in which public and private parties negotiate about the division of risks, expenses, and profits in a public-private partnership contract. Non-cooperative game theory primarily deals with the analysis of conflict situations. A conflict can occur when the interests of several decision makers are opposed or only partly coincide. Each decision maker will usually choose an option in his own interest, which need not be in the interest of the others. These individual decisions can result in worse outcomes for all players compared to a coordinated decision. In this section, we will present an example of a non-cooperative game theoretic model, applied on Brownfield Redevelopment.

## Environment of the game

To set up the game, we defined the institutional-economical environment. Therefore, we used the present land development models in the Netherlands (Samsura et al., 2010). All models (Table 1) are characterized by initial situation on the market of ownership, defined parties that acquire the land, the one that service and reparcel the land, and the parties that acquire the building plots. Within these models, the role of the municipality can be active or facilitative. Specifically, we addressed an active approach from the government, and within that group of models a PPP (Public Private Partnership) model. This choice was based upon the fact that active approach is mostly common in the Netherlands and PPPs are common practice.

A common type of PPP is a Joint Venture Company (JVC). In the game we are analyzing a specific decision: to form the JVC or not. The municipality invites a developer to form a JVC for a single project of a Brownfield Redevelopment. In order to simplify the game, we assumed that the land has been already acquired by the municipality. That is an exception of a PPP model since the acquisition is usually conducted by a JVC (see Table 1). When formed, the JVC will service the land and deliver a detailed land use plan and parcellation. Therefore, the final product of the JVC is the urban land with immediate possibility to sell the building plots.

Besides setting the game in a specific institutional-economical environment, the involved players based their decision to form the JVC or not on several other specific contextual conditions. At first, they consider a Brownfield that is: "... any land or premises which has previously been used or developed and is not currently fully in use, although it may be partially occupied or utilized. It may also be vacant, derelict or contaminated. Therefore a Brownfield site is not available for immediate use without intervention" (Alker et al. 2000). Secondly, we have delineated the problem to the initiative phase of a

**TABLE 1**  
Land development models (Samsura et al. 2010)

Land development models	Initial situation on land market	Acquisition of a land	Servicing and reparcelling the land	Acquisition of building plots
Active Land Policy by municipalit				
<b>1. Public land development model</b>	Original owners	Municipality acquires all land	Municipality	Private developers; end users
<b>2. Building claim model</b>	Private developers with intentions to build houses	Municipality acquires all land	Municipality	Private developers with building claim
<b>3. PPP model</b>	Original owners	Joint Venture Company (including landowning private developer)	Joint venture company	Private developers with building claim
	Private developers with intentions to build houses	Joint Venture Company (excluding landowning private developer)		
Facilitating Land Policy by municipality				
<b>4. Private land development model</b>	Original Owners	Private developers; end users	Private developers End users	End users; end users already own building plots

Brownfield Redevelopment on the urban district scale. Thirdly, the size of a Brownfield is in the range of one to ten hectares. Finally, we assumed that different decisions would be more or less present depending on the region of the research (this research focuses on the Netherlands).

#### Game type

We restricted ourselves to analysis in the extensive form or a game tree analysis where the players act sequentially. The extensive form of the game compared to the strategic form brings more realistic representation of the reality. As mentioned before the game is non-cooperative.

#### Players of the game

We focus on two groups of actors in whole Brownfield Redevelopment process. These are the Municipality (*M*) and Developer (*D*) that would potentially form a JVC.

#### Strategy

At first, we will determine the negotiation issues that are treated as strategies in the game. In this game we address two issues: the availability of a building claim and developer's influence on the future land use and parcellation. The building claim is one of the crucial characteristics for any land development model (Samsura et al., 2010). Potential to influence future land use emerged as the most important attribute in our survey (Glumac et al., 2010a). Parcellation together with servicing (land clean-up and infrastructure developing) is a stage characteristic for every land development model (Samsura et al., 2010). Additionally, the selection upon the negotiation issues is reduced to land use mix and density of development (parcellation) at a local neighborhood scale to describe the development typology. Similarly, both the land use and parcellation are used to compose development types.

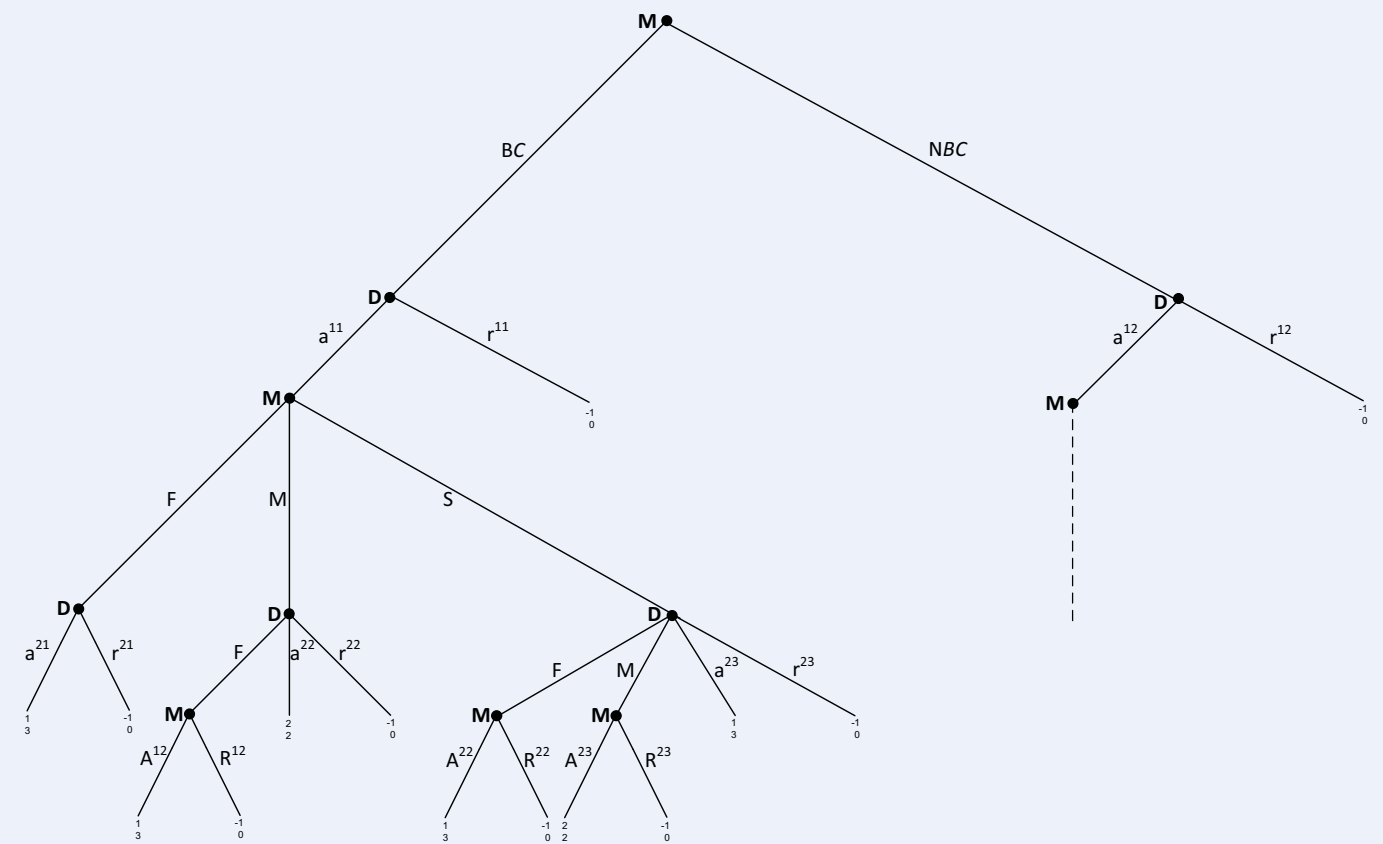
By assigning the levels to these negotiation issues we defined the possible actions  $A_m$  and  $A_d$  of the strategies  $s_m$  and  $s_d$  for player *M* and *D* consecutively. The first negotiation issue, building claim has two levels: *available (BC)*; *not available (NBC)*. These levels are straightforward and we did not provide any additional elaboration. Contrary, the influence on future land-use and parcellation can be perceived arbitrary therefore a further elaboration is necessary. We determined three levels for this issue: *High (H)*, *Medium (M)*, and *Low (L)* influence. High influence means that developer can carry out any land use regulated by mix-use zoning plan and completely determine the size and the shape of any parcel in the land that will be redeveloped. To underline, changing a zoning plan is not an option, but the levels of developer's influence (*H, M, L*) express the potential to adjust the land use ratio within the mix-use zoning. Logically, medium influence grant a developer less and low influence minimal possibilities.

Figure 1 illustrates the game. Player (*M*) is an initiator of the game since we are investigating a type of active land development models. At the first decision node, Player *M* can offers to player *D* either a deal in which building claim is *available (BC)* or *not available (NBC)*. For both possible actions of player *M*, player *D* can *accept* ( $a^{11}$ ,  $a^{12}$ ) or *reject* ( $r^{11}$ ,  $r^{12}$ ) the deal on the next decision node in the game. The game stops when the end nodes are reached.

This procedure practically explains the complete plan of possible actions of the players *M* and *D*. Their actions differ and each action is represented by a branch (Figure 1). A reader can notice that player *M* has 20 possible actions:  $BC, H, M, L, A^{12}, R^{12}, A^{22}, R^{22}, A^{23}, R^{23}$  when starting with the branch (action) *BC*, and similar ten starting with the branch (action) *NBC* that define the set  $A_m = \{a_m\}$ . Similarly, player *D* has 22 possible actions that defines the set  $A_d = \{a_d\}$ .

#### Payoff

Each outcome (end node) has its payoff. Upper number indicates the payoff of a certain outcome for the first player (*M*) and lower number indicated the payoff of the second player (*D*). In this example (figure 1) the payoffs are assumed by the following logic. For every branch ending with action *H* Player *M* will have the smallest payoff (1) while the player *D* will have the highest payoff (3).



**FIGURE 1**  
A game in extensive form: a JVC formation in the land development. (The vertical cut-line represents the repetition of the game identical as the part starting with branch BC)

Contrary, for every branch ending with action *L* Player *M* will have the highest payoff (3) while the player *D* will have the smallest payoff (1). Underlining logic of this statement is: higher developer's influence means higher developer's (*player D*) payoff and contrary the municipality's (*player M*) payoff is smaller. Additionally, for the *NBC* branches the player *D* will have 20 percent less payoffs since it won't participate in building the plots and player *M* will have 10 percent higher payoffs since they can sell the plots to other parties on the market. When the deal is not made (*actions r, R*) payoffs will be the smallest for both players, with 0 and -1 respectively for players *D* and *M*. Built upon the previous notion, the player *M*'s payoff is defined as  $\pi_m(s_1, \dots, s_{26})$  and the player *D*'s payoff as  $\pi_d(s_1, \dots, s_{26})$ .

#### Solution concepts

This game can be solved by backward induction that indicates Sub-Perfect Nash Equilibrium (SPNE). In order to improve the outcomes the interventions derived from the game theory are possible. These interventions in general consist of three elements:  
a) Changing the information for the involved players;  
b) Changing the pay-offs;  
c) Changing the playing rules.  
Based on the outcomes of the analyses, and making the use of the principles of game theory in order to improve game outcomes, various previous interventions can be designed to reduce the number of conflict occurrences and accelerating the real-world realization of the Brownfield Redevelopment projects.

### Perspectives of Game Theory

As decision processes in real estate development projects become more complex, we have to find theories that can support the governance of such processes through interventions. Game theory can be applied to real estate development project environments, resulting in a very basic understanding of players' choice behavior and expected decision outcomes, together with recommendations concerning the application of intervention strategies in conflict situations. However, one should realize that game theory presents an abstraction from reality: not all intricacies of real-life interaction processes in real estate development projects are covered, and deliberately so. The aim is to use the abstract representation of the interaction structure as a tool to understand the behavior of the involved parties a bit better, not to mimic real-life to every detail. Furthermore, a major critic of the classical game theory is the assumption of completely rational players with complete information. To partly overcome the problems related to the assumptions of game theory, the concept of bounded rationality can be introduced. This can be achieved by combining game theory with methods that enable the possibility of having a 'vector' or 'multi-valued' utility function. This is a main subject in the research of the authors, of which the first results can be found in Glumac (2010b) and Blokhuis (2010).

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# Emerging urban futures and opportune repertoires of individual adaptation

This paper summarizes the goals and scope of a new large scale research project, funded by the EEC. The ultimate goal of this research project is to develop the first comprehensive model of *dynamic* activity-travel patterns in the world, expanding and integrating concepts and partial approaches that have been suggested over the last few years. Dynamics pertain to different time horizons. Long-term decisions such as demographic change, changing job or house may also prompt or force people to adapt their activity-travel patterns.



1 2

### Prof. H.J.P. Timmermans & Dr T.A. Arentze

Harry Timmermans<sup>1</sup> is a Professor of Urban Planning at the Eindhoven University of Technology. His main research interests concern the study of human judgement and choice processes, mathematical modelling of urban systems and choice processes and the development of decision support and expert systems for application in urban planning. Theo Arentze<sup>2</sup> is an Associate Professor at the Urban Planning Group at the Eindhoven University of Technology and received a Ph.D. in Decision Support Systems. His research interests include choice modelling, knowledge discovery and learning-based systems, and decision support systems for applications in transportation research, urban planning and consumer research. This research was conducted with the help of Sehnaz Cenani, Helen Ma, Aida Pontez de Aquino, Fariah Sharmeen and Dajuan Yang.

Exogenously triggered change involves change in the urban and/or transportation environment and/or the larger socio-economic institutional contexts. It may be unplanned or planned (policies). The integrated multi-agent model will simulate the primary, secondary and higher order effects of such emerging urban futures on dynamic repertoires of activity-travel patterns. A multi-agent model will be built to capture these dynamics. In addition to the multi-agent model, the PhD/postdoc projects will result in improved understanding of the effects of various policies, based on a variety of statistical analyses, and in guidelines about the most effective (set of) policies in contributing to integrated urban sustainability, and in elaborated theory about spatial dynamic choice behaviour.

**"Activity-based models should be considered as alternatives to spatial interaction models."**

### Introduction

An understanding of complex activity patterns (time-space behaviour) of actors is essential for improving the effectiveness of various kinds of policies and for assessing the market potential of new real estate projects. An activity-based framework constitutes an integrated framework as it (i) combines economic, social and other activities, (ii) is based on a highly detailed, comprehensive spatial and temporal representations (minutes and geocodes/small postal zones), (iii) combines different methods to simulate behaviour, (iv) focuses on the complex interdependencies between activities, household members, time periods, locations, etc., and (v) constitutes the basis for deriving measures of economic, social and environmental impact and feasibility. For these reasons, the activity-based perspective has rapidly gained momentum, especially