An interactive decision choice model to support brownfield redevelopment partnerships

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Abstract

The purpose of this paper is to support a better decision regarding the choice of brownfield redevelopment project. In order to achieve that a decision support tool based on the hybrid model has been developed. The possibilities of this interactive hybrid model have been tested on a generic case study. More precise, four possible applications (decision support tools) of the model have been introduced. Although applying decision tools for the brownfield redevelopment projects have been already thoroughly studied there is a little evidence of the interactive (game-theoretical) component built in such decision support tool.

Key words: brownfield redevelopment (BR), public-private partnership (PPP), fuzzy dephi method (FDM), latent class model (LCM), experimental game theory, strategic choice model (SCM)

1. Introduction

Numerous authors [e.g. 1, 2-3] argue that the restoration and redevelopment of a brownfield can provide a range of economic, social, and environmental benefits. Leaving them unmanaged brings the losses of the economic opportunities to the community in which they are present. Some of the benefits are better environment quality, provision of land for housing or commercial purposes, creation of employment opportunities, and especially the reduction in the pressure on urban centers to expand into greenfields. The necessity to deal with these often complex environmental, economic, legal, and social issues for a given property may explain why brownfield problems are not easily resolved.

For example, any transformation has a significant risk related to the multiple actors' involvement and financial challenges due to the long redevelopment time and often high remediation costs. Given only these two risks, brownfield sites within the cities are more likely to be transformed compared to those at the cities' outskirts. The location advantages are recognized since the introduction of the central place theory [4]. Obviously, these advantages apply to the brownfield sites as well. Thus, the central point of this research paper is a generic brownfield located in the urban area including both the urban land and the buildings. Although redevelopment projects have a higher risk compared to greenfield investments [5], redeveloping a brownfield especially with the location advantages can create more value for involved actors [6].

1.1. Multi – actor environment

A decision-making in urban 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 engagements in urban development [7-8]. The new policy implies pluricentric network steering – in which several public and private actors play a role – instead of traditional hierarchical top-down governmental steering.

In this paper, the definition of an actor is "… an individual or an aggregated social entity (collective actor) that has the ability to make autonomous decisions and act as a unit" [9]. For example, a company or an association is a collective actor with overall accepted rules for collective choice and can thus be regarded as a single social entity [9].

In current development projects many actors groups are involved. This involvement is different in each project. The most important actors are municipalities, landowners, end-users, and investors. Furthermore, there are additional actors involved. They either can be seen as sub-groups of already mentioned groups such as independent development companies, contractors or completely new groups with different goals such as designers, consultants, environmental groups and citizens. Urban development cannot proceed without commitment of these actors because the decision processes are interdependent. Therefore, a single actor cannot determine the outcome of the development process. This paper underlines and observes the behavior of two actors: municipality and developers.

Further, the potential multi-actor interest can lead to the creation of a certain form of public-private partnership. Nonrelated to the form, the success of the redevelopment depends largely on the cooperation between at least two participants. Especially important can be defining influences of a future land use that captures the supply and demand of a current property market situation [10-12].

This demands a strategy of different present actors to handle conditions that are more dynamic. In general, there are numerous definitions and various kinds of strategies [e.g. 13]. The strategy in the context of this research addresses the systematic plan of actions that actor does based on its own perspective of the physical, legal and financial structure of the built environment while incorporating reaction(s) of other present actors.

In this paper, second chapter underlines the major problems that confront partnerships in brownfield redevelopment projects. Chapter 3 introduces developed interactive model and its components. On the example of the generic case study, chapter 4 shows the potential of the model by introducing four applications. Finally, chapter 5 summarizes the paper and suggests a prospective future development of this type of models.

2. Major problems confronting partnerships in a brownfield redevelopment (BR) project

2.1. Lack of information

Over the time, local communities have had a difficult time understanding the scope and scale of their brownfield situation. Partly, this is due to the lack of information that has resulted from the property owner reluctance to reveal contamination potential because of liability fears [14]. As a consequence, "… failure to inform creates a debilitating stigma effect, where properties and entire neighborhoods are avoided because of suspected but unknown contamination potential" [15]. Besides soil contamination, there are other physical aspects of a site that define the advantages such as its location, skyline, relief, soil properties, etc. Furthermore, besides the physical aspects also legal and financial aspects play a role in success of a brownfield redevelopment project.

In order to suppress the asymmetric information issue, an author [15] suggested a combination of formal and informal tracking records. Where formal information could be environmental or non-environmental related provided by national or European agencies and informal information is one not found in a governmental agencies. Such a database of combined sources should be followed by developing a brownfield information system to track and assess the impact of all brownfield in one community. Although such a brownfield GIS system can offer planners a powerful set of spatial–analytical tools [16] still legal and cooperation factors can be very project specific.

2.2. Public-private partnership (PPP)

PPP is a concept frequently used in a development practice although uniform definition is still lacking [17]. In most cases, a brownfield redevelopment (BR) seeks a form of partnership. This is particularly the case when circumstances are not favorable for an independent development initiative by the private actors [e.g. 18]. Another important factor for forming partnerships is a limitation of the public funds that have led governments to invite private sector into various long-term arrangements for the capital-intensive projects.

Historically, the first concession was granted in 1782 to Perrier in France for water distribution [19]. From then, there are numerous examples of different public-private arrangements under different perspectives [e.g. 17, 18, 20].

In any partnership, forming principles are the same: (a) a clearly defined goal; (b) without a partnership, the project could not be accomplished; (c) partnership must be accepted by the local community; (d) there must be satisfying interest for both parties; (e) each partner contribute within their field of expertise while forming a team; (f) risks are spread equally. A successful project design requires attention on each of the mentioned principles. That eventually leads to the design of contractual arrangements that allocate the risk burdens appropriately. If not assembled properly or according to the key principles, a partnership could be jeopardized. Risk evaluation in these cases is complex and can be looked from various perspectives [e.g. 18, 21-22] but much of the risk of a PPP projects comes from the complexity of the arrangement itself. This concerns various documentation, financing, taxation, technical details, and sub agreements.

To resolve a conflict based on different parties' interests, negotiation analysis is one of the successful choices where parties try to reach a mutual agreement [23]. Negotiation over brownfield redevelopment is aiming at all actors to share the risks. As in any negotiations, the actors present offers and counter-offers while their objectives and interests are often hidden

[23]. As mentioned previously, there are mainly three parties involved in the funding of a brownfield redevelopment project: (a) current owner of the site; (b) prospective buyer (or developer or investor); and (c) government [24]. They all can be involved in negotiations depending on a development model [25]. As mentioned previously, this research paper focuses on the negotiation between developer and the municipality toward a partnership based on their interests.

2.3. Making an interactive choice

This paper reports on the collaboration and negotiation in a multi-actor environment. The various interdependent relations between actors are investigated and modeled by authors for the purpose of facilitating and stimulating actor's collaboration [26]. Different methods and theories are used while the focal point is the interaction in decision-making. There are already published studies regarding the modeling of negation in the urban development practice [7, 27-30]. Further, there were contributions made in the field of brownfield redevelopment [1, 23-24, 31-41].

No matter who are the present actors, it is methodologically demanding to analyze formally the negotiation process. On the other hand, in order to provide an adequate advice, for example in the form of a decision support tool, that formality is required. Concerning the formal frame within the decision-making theory, negotiations are classified as interactive normative or collaborative prescriptive approach [42]. The interactive normative approach is dominated by the concepts of game theory and the other by negotiation analysis. An application of negotiation analysis studies shows how to reconcile differences and reach consensus in to brownfield redevelopment [e.g. 35]. The concept of merging these two approaches is also investigated [23]. Still, there is a need for further development towards more functionally beneficial tools. Evidently, existing knowledge is conducting to and serving as guidance for modeling in this paper.

This paper describes an interactive hybrid model that can be formally formulated as a prescriptive - interactive decision-making approach, an approach that is barely accomplished.

3. An interactive hybrid model and its components

In the broad sense, the goal of the interactive hybrid model is to analyze the preferences and common and conflicting interests of different actors in brownfield redevelopment process. Further, by developing the hybrid model this research offers recommendations concerning the choice of the best cooperating partner in public-private partnership (PPP), thus potentially accelerating brownfield redevelopment. Therefore, this model addresses three main issues: (a) identifying the attributes of a brownfield; (b) the preferences of actors groups; (c) the characteristics in the negotiation process between the two groups of actors.

3.1. Concept of the model

To deliver the proposed output this model is divided in three procedural phases where each one consists of several steps (Fig. 1).

Initial input. As an initial input, model uses gathered literature to identify important attributes and main actors.

Phase 1. In order to structure and prioritize the attributes the fuzzy Delphi method with similarity aggregation method (FDM - SAM) is used [43]. The first phase explores the attributes that are relevant for the decision to redevelop a brownfield or not. In addition, the first procedural phase indicates the most important actors and makes a distinction between the public and private actors.

Phase 2. In the second procedural phase, this model reveals the utilities of the main actors concerning brownfield redevelopment choice alternatives that are described with previously determined attributes. The utilities indicate the basis of the decision to start a brownfield redevelopment or not. Specifically, a latent class model (LCM) [e.g. 44] derived from stated preference choice experiment provide an insight in the behavior of observed actor groups. Finally, derived utilities of municipalities and developers are used as a part of the finial prescriptive outcome.

Phase 3. The third procedural phase investigates interactive behavior between actors (public and private) since the outcomes of the decision-making process are not depending only on the individual choice, but also include the influence of the choices of an actor's opponent. At first, this phase tests and generates the negotiation procedure or structure in extensive games specifically classical ultimatum game and bargaining game respectively with Game Theory Experiment [e.g. 45]. Secondly, by using backward induction as implementation of a solution concept, this research phase provides insights of the probabilities of certain negotiation outcome and related utilities of both actors with a Strategic Choice Model -SCM [46-47]. The focus is specifically on ultimatum and bargaining games that mimic possible strategies in negotiation issues (set of attributes: building claim, future land use and future parcelation) of a brownfield redevelopment project.

Output. Conclusions that are derived from the SCM are used together with LCM as a calibration to improve a prescriptive feature of the interactive hybrid model. The final output is proposed scenarios for an optimal deal in brownfield redevelopment projects.

Based upon this methodology and gathered data, interaction between the selected actors is modeled. The applications of this interactive hybrid model will assist decision makers to overcome the challenges of conventional negotiation. Little work has been done to develop models that systematically relate the characteristics of the brownfield areas to the behavior of actors thereby giving an insight in the most important points of interest and possible sources of conflicts between two actors. The whole procedure (all three phases) is regarded as newly developed group behavior model that incorporates actors' individual utilities but captures as well the actors' interaction effect in negotiations. Such a hybrid model have an advantage on the choice forecast in brownfield redevelopment projects of a certain actor's group and could be the core model of a future decision support system for finding an optimal PPP agreement.

As referred in previous text, each procedural phase employs different method in order to achieve the expected their inputs and outputs need to be compatible. The most of the links in the flowchart are straightforward (Fig. 1). Therefore, no special attention is required expect for combining LCM and SCM.

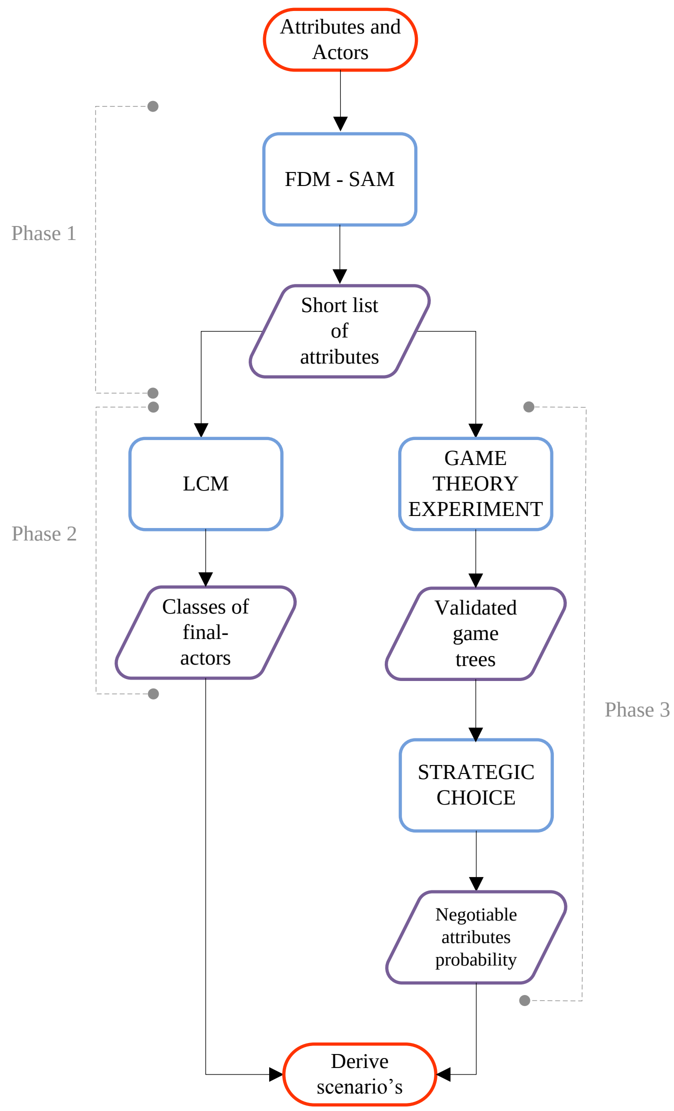

Fig. 1. Interactive hybrid model

3.2. Coupling latent class model (LCM) and strategic choice model (SCM)

One of the ways to improve a what-if scenario is combining the features of different models. Specifically, this hybrid model encourages the parallel use of two models: LCM and SCM.

On one hand, a LCM has the ability to identify and estimate the preferences of different classes of the respondents. Further, by labeling those classes, the analyst is able to identify class respondent preferences in the real market. For example, those preferences could represent the characteristics of the professionals in the brownfield redevelopment. On the other hand, a SCM provides the estimations of the most probable outcome for a certain negotiation attribute (building claim, future land use and parcellation). Such estimation depends on the interaction of two players (municipality and developer). Thus, the ability to incorporate the interaction in estimation is the main feature of a SCM. By combining the features of these two models, an analyst would ideally be able to estimate the real market actors' behavior while incorporating their mutual interactions as well.

The coupling presented in this paper is rather elementary although requires a predesigned compatibility. This compatibility refers to the reflection of the attribute levels in the LCM on the structure of suggested strategic choice models. This is achieved by assigning every attribute level as an action in the structure of the SCM. As a result, the estimated outcome from the SCM can be directly translated into the certain attribute level. Therefore, the most probable result (certain attribute level) is used as an input in to LCM. The other attributes' levels are an additional set of different scenarios. Even with this basic coupling of the two models, it is possible to have different applications and potential decision support tools.

Formally, the coupling of previous models suggested that integration within the discrete choice framework where individual n payoff for strategy j consists of three components. (1) A choice alternative-specific component named $U^{exogenous}$ that expresses the exogenous attractiveness for a given alternative. (2) The second is an interaction component or $U^{endogenous}$ that captures the expected impact of other individuals' choice behavior. (3) Finally, an idiosyncratic error term, ε, treated as an individual and alternative specific random variable whose distribution is common knowledge among all individuals, but whose exact value is private information to the individual n. The previous can be formally expressed as (Han, 2006):

$$U_{nj} = U_j^{exogenous} + U_j^{endogenous} + \varepsilon_{nj} \quad \textbf{(1)}$$

$U^{exogenous}$ represents the traditional attributes of the choice alternatives that affect payoffs. In experimental terms, this component is defined as a condition. This term can be formulated as in the equation:

$$\mathrm{U}^{\mathrm{exogenous}} = \sum_{\mathrm{k}} \beta_{\mathrm{k}} X_{ink} \tag{2}$$

Where $\beta_{\mathrm{k}} X_{ink}$ is known as part-worth utility of alternative *i*; β_k is a parameter indicating the contribution k to the utility of alternative *i*; X_{ink} represents the value of each attribute level *k* of alternative *i* estimated by respondent n.

Here the preference accounts for the variation in utility over a generic brownfield redevelopment project defined by several attributes, and reflect the preference to redevelop a brownfield. There are four attributes included in this component: location, embeddedness, administrative support, synergy with surrounding users.

U endogenous captures the attractiveness of a choice alternative as a function of the behavior of other individuals (Han, 2006). The new element introduced in this section is that there are now multiple decision makers, each of whom must condition their behavior on the expected behavior of the others. Endogenous component consists of different games. Therefore, choice probabilities are based on the choices players are expected to make in equilibrium. Formally, the endogenous component can be regarded as utility related to the equilibrium of Γ games. Let Γ be the class of all games and, for each game $G \in \Gamma$, let S_G be the set of strategy profiles of *G*. A solution concept is then an element of the direct product $\Pi_{G\epsilon\Gamma} 2^{S_G}$:

$$U_j^{endogenous} = \sum U_{G\epsilon\Gamma} 2^{S_G} \tag{3}$$

These two games (ultimatum and bargaining games) are in fact, three negotiable attributes over the future brownfield redevelopment between two players (municipality and developer). These attributes are building claim, future land use and future parcellation. The structure of the game is essential. In this regard, the games are designed to be compatible with discrete choice models such that attributes' levels are present as actions in the game structure. This is done for the practical purposes, necessary to construct a hybrid model. For example, previous example (Figure 1) defines the game structure for the building claim game where actions (X, Y) refers to two attribute levels (having a building claim, not having the building claim).

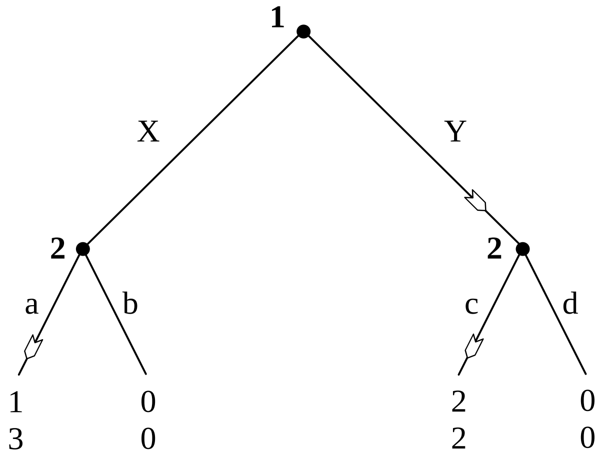

Figure 1. An example of ultimatum game tree

4. A generic case study: applications of the interactive hybrid choice model

In the previous chapter, an interactive hybrid choice model has been introduced as a tool to understand and help tackling the negotiation issues relevant for the urban development. This chapter elaborates on the possible application of the model. All applications introduced in this chapter are presented in the terms of scenarios. These scenarios are related to the different decision-making problems in the brownfield redevelopment processes where two different actors are beneficiary: municipality and developer.

There are many modes of planning that link present to future such as: visioning, forecasting, scenario generation, plan making, development planning [48]. Each mode focuses on making and influencing choices which lead to concrete actions by bringing together information and ideas. In addition, that helps to understand and perceive numerous combinations of actions that can lead to anticipated outcomes. Noteworthy to mention here is that certain mode implies the usage of different tools and techniques. This paper opts for the scenario mode of linking the present and future. In this case, the decision makers generate and select the preferred scenario, where the preferred scenario is chosen from the structurally different scenarios [48]. Scenarios can be deployed in many cases relevant for the urban development practice [e.g. 48, 49, 50-51].

Recently, the most of the applications dealing with the future of a brownfield redevelopment projects are in the form of a decision support tools [1, 23-24, 31-34, 52-53]. This paper emphasizes the possibility of using decision support tools to generate and analyze the scenarios in order to create better public private partnerships (PPP) in the brownfield redevelopment. A decision support system (DSS) is a system that improves and supports decision-making capabilities of an individual [e.g. 54]. Additionally, the term system refers to the information-processing devices (software programs) that actively engage in the decision-making process[55]. Historically, first systems started emerging in the early 1960's and thorough their evolution there was numerous developments [54]. This research in future lies in the branch of negotiation support systems (NSS). Technically specific, the future NSS for brownfield redevelopment would be model-oriented with optimization system type. This specific taxonomy [56] addresses the guidelines for actions by generating the optimal solutions.

4.1. A generic case study description

At first, the controlled settings of this experiment are reached by adopting a proper brownfield definition [57]. In addition, a genric case study has been characterized as: (a) the project in the initiative and land acquisition phase, (b) size of the site is 1-10 hectares, (c) the future land-use is mix-used, (d) site is located in the Netherlands, and (e) municipality owns the land.

4.2. Scenario application

In the paragraphs below, four potential applications are described. They are all in the form of a decision support tool based on the previously described hybrid model. The beneficiary of a decision support tools is either a municipality or a developer.

Application 1: Municipality chooses a policy

The first application is meant for a municipality. Municipality chooses the policy or strategy for a known brownfield. This application requires only implementation of the SCM. By using this model municipality is able to make a tradeoff between the qualities of a known brownfield (described by the four attributes within the given conditions) and influence of a private actor (negotiable attributes). More specific, model provides outcome probabilities of a negotiable attributes (building claim, future land use and parcellation) for a known brownfield through their levels.

An example would be the estimations provided (Table 1) when negotiating about the building claim, and similar table (Table 2) when negotiation about the future land use and parcellation. As an aside, besides suggested nine treatment combinations any combination is possible that describes the best brownfield of the interest.

Table 1. Ultimatum game: Outcome probability for nine treatments

Treatment	Attributes level				Game outcome probabilities			
	L	E	AS	S	pY_1	pY_2	pY_3	pY_4
1	0	0	0	0	0,101	0,393	0,098	0,408
2	0	1	1	2	0,213	0,282	0,193	0,311
3	0	2	2	1	0,207	0,289	0,187	0,317
4	1	0	1	1	0,293	0,211	0,263	0,232
5	1	1	2	0	0,284	0,216	0,258	0,241
6	1	2	0	2	0,271	0,226	0,248	0,255
7	2	0	2	2	0,393	0,116	0,369	0,122
8	2	1	0	1	0,291	0,212	0,262	0,234
9	2	2	1	0	0,343	0,164	0,314	0,179

Table 2a. Bargaining game: Outcome probability for nine treatments

T.	Attribute level				Game outcome probabilities							
	L	E	AS	S	pY_1	pY_2	pY_3	pY_4	pY_5	pY_6	pY_7	pY_8
1	0	0	0	0	0,04	0,17	0,02	0,06	0,01	0,16	0,02	0,06
2	0	1	1	2	0,10	0,13	0,03	0,03	0,04	0,14	0,03	0,03
3	0	2	2	1	0,11	0,13	0,03	0,03	0,05	0,14	0,03	0,03
4	1	0	1	1	0,17	0,10	0,04	0,02	0,08	0,10	0,04	0,03
5	1	1	2	0	0,15	0,10	0,03	0,03	0,07	0,11	0,04	0,03
6	1	2	0	2	0,12	0,10	0,03	0,03	0,06	0,12	0,03	0,03
7	2	0	2	2	0,25	0,07	0,07	0,02	0,11	0,07	0,05	0,01
8	2	1	0	1	0,16	0,10	0,04	0,02	0,07	0,11	0,04	0,03
9	2	2	1	0	0,20	0,08	0,04	0,02	0,09	0,08	0,04	0,02

Table 2b. Bargaining game: Outcome probability for nine treatments

Game outcome probab.			
pY_9	pY_{10}	pY_{11}	pY_{12}
0,03	0,10	0,01	0,32
0,03	0,04	0,02	0,37
0,03	0,04	0,03	0,37
0,03	0,02	0,05	0,32
0,03	0,03	0,05	0,34
0,03	0,04	0,04	0,36
0,03	0,01	0,08	0,23
0,03	0,02	0,05	0,33
0,03	0,02	0,07	0,29

The municipality checks the acceptance probability of a certain brownfield alternative by a developer. The assumption here is that the developer shows the higher probability for choosing the mentioned alternative when it is more attractive to develop that site expressed through the utility function.

Application 2: Municipality chooses a developer

Although the beneficiary is the same as in the previous application, here a municipality deals with another decision problem, choosing a developer for a known brownfield. This procedure has two steps. In the first step, the strategic choice model estimates the probabilities of game outcome for the negotiable attributes (building claim, future land use and parcellation). As a reminder, a game action is an equivalent to a negotiable attribute level in discrete choice model. In this way, it is assured the compatibility between a SCM and LCM. Due to this compatibility, it is possible to use the outcomes of a SCM to generate the most probable set of negotiable attributes' levels. The most probable levels are selected as the highest probability of the game outcome indicated by a SCM. More precisely, a SCM generates the levels of three (building claim, future land use and parcellation) out of total seven attributes. The other attributes (location, administrative support, embeddedness, and synergy) and their levels are given because a brownfield is known. In this way, all of the seven attributes have the specified levels. In the second step a LCM is employed. At this step, a municipality checks the acceptance probability of a previously generated alternative (seven attributes with specific levels) by two different developer types. The assumption here is that the developer showing the higher probability for choosing mentioned alternative is more attract to develop that site. This developer is better partner since municipality can negotiate better "operating" terms.

The table below (Table 3) is an example of a possible two scenarios which developer would accept to join the brownfield redevelopment project, produced in Excel. Starting from the left to right the columns follows. The first group of columns reflects the levels of the attributes in effect codes [e.g. 58]. The second group is the LCM estimation of the variables coefficient. Further columns are the expected part-worth utilities, ending with the probabilities for joining or not a brownfield redevelopment project. Looking at the table top-down, each scenario starts with the names of variables, related coefficients and calculated results. Obviously, within a single scenario levels of the attributes are identical. While the coefficients thus the results vary over two types of developers (traditional and proactive).

Table 3. A scenario for selecting a developer

X_BC	X_LU1	X_LU2	X_P1	X_P2	X_L1	X_L2	X_E1	X_E2	X_AS1	X_AS2	X_S1	X_S2	X_PSC	BC	LU1	LU2	P1	P2	L1	L2	E1	E2	AS1	AS2	S1	S2	PSC	V_B	V_N	expV_B	expV_N	ΣV1	P_B	P_N

X_BC	X_LU1	X_LU2	X_P1	X_P2	X_L1	X_L2	X_E1	X_E2	X_AS1	X_AS2	X_S1	X_S2	X_PSC	BC	LU1	LU2	P1	P2	L1	L2	E1	E2	AS1	AS2	S1	S2	PSC	V_B	V_N	expV_B	expV_N	ΣV1	P_B	P_N

Any combination of levels is possible, only it is important that first the levels for non negotiable attributes (X_L1, X_L2, X_E1, X_E2, X_AS1, X_AS2, X_S1, X_L2) are insert first at the SCM where the most probable levels of negotiable attributes (X_BC, X_LU1, X_LU2, X_P1, X_P2) are estimated. Now with this specified brownfield levels it is possible to estimate the probabilities based on the LCM coefficients. A reader can notice that the probability of accepting the upper scenario is higher for the proactive developer. Still when just the one parameter is changed, (building claim is not available) there is a higher probability that a traditional developer will accept the deal.

Instead of only adopting the game outcomes with the highest probabilities indicating only one alternative, this decision support tool can be improved by introducing the simulation to generate a range of alternatives.

Application 3: Developer chooses a municipality

In this application, a developer can be supported to choose with whom to cooperate for a known brownfield. The procedure is very similar to the one in the previous application, only the beneficiary is changed.

Application 4: Developer chooses a brownfield

One of the applications of interactive hybrid model is decision support tool that helps a developer to choose which brownfield to redevelop. This application consists of two steps as well. Again, in the first step a SCM estimates the probabilities of negotiable attributes (building claim, future land use and parcellation). Although in this application, the most probable outcomes are estimated for two different alternatives (brownfields). At the second step, an analyst compares two different alternatives. Each alternative is defined with the seven attributes and specified levels. Amongst them, a SCM generates the levels of three attributes, while the other four attributes and their levels are known (given condition). The highest probability of choosing certain alternatives of course represent the highest utility (estimated with the LCM) to that developer.

These four applications are worked out in excel and can be potentially transformed in four fully operational decision support tools, for example within the excel interface [58].

5. Conclusions

The shifting planning process also has major implications for the design of decision support systems. Virtually all these systems [59] are based on a planning model that assumes a leading role of government where government institutions are deemed for developing alternative plans or scenarios. In addition, these systems articulate a set of goals or objectives, typically relevant for society. The model underlying the system then simulates or predicts the impact of the alternatives designs, plans or scenarios on human behavior and this information in turn is then used to derive a set of performance indicators.

The goal of this paper is to understand better how the interactive decision-making of main actors in brownfield redevelopment processes can be modeled. A better understanding of these processes is a key requirement for the development of multi-actor planning support systems.

As any DSS future NSS should consist of following main features: (a) the database (or a knowledge base); (b) the model (the decision context and users' criteria); (c) user interface (input and output). This research contributes to developing model base that store and manages the models to support the analysis, design and choice tasks in the decision processes. As mentioned earlier in text, the developed interactive hybrid model (Fig. 1) is optimization driven. It searches for good solutions given the problem of the choosing the partner or optimal agreement in the future PPP for brownfield redevelopment project.

An important part of a successful NSS is the modeling of the actors' interaction and their preferences towards the brownfield redevelopment. Concerning the modeling, an interactive hybrid model has been developed. Prior to this development all the relevant models has been introduced and an integrated approach that consist of three procedural phases has been proposed (Fig. 1).

In brief, these three phases consists of: (a) FDM – SAM is used to structure and proritaized initial set of attributes; (b) LCM has been used to assess the preferences and isolate groups of actors present at the real urban development market; and (c) SCM is design to predict the outcomes of each of the negotiable attributes (building claim, future land use and future parcellation) through their levels. The mentioned procedural phases are referred as an interactive hybrid model because of the usage of different techniques and methods that are linked together. The use of this hybrid model should benefit from the combination of the predictive capabilities of the individual choice on one hand and on the other hand, the interactive analysis based on the game theory. Therefore, this research classifies proposed hybrid model as a quantitative, prescriptive-interactive decision-making approach. As already mentioned previously, this is barely established branch in decision theory, and this thesis contributes in this research direction.

The research suggested some practical implications of as well. There are four possible applications all concerning the negotiation in the brownfield redevelopment. More specific, each of the applications could be a potential decision support tool that helps decision makers to reach the optimal deal in the public private partnerships concerning the brownfield redevelopment. They are shaped as a scenario mode in the planning practice where a beneficiary designs and selects the preferred scenario.

The first necessary improvement is a validation of the proposed hybrid model. It needs to be validated by the experts and consequently adjusted. The validation was not incorporated in this research mainly due to the practical constraint to set up a new survey or a set of individual interviews that also pre-requires generating an additional database of the relevant respondents. By the rule of thumbs, this would be necessary step, since the same respondents cannot be addressed to estimate the proposed models and validate their applicability. Obviously, all of the missing features need to be addressed such as the database and user interface. Regarding the data, a similar survey could be set in future addressing the preferences at a given time. In addition, a program that automates the support system needs to be developed as well. Evidently, further research is needed. However, the idea and the base model modeling part of the future NSS is presented in this paper.

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