The impact of strategic behaviour on an actor model focussed on interdependencies between resources and objectives

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Abstract: Exchange models are adequate actor analysis models to deal with complexities surrounding resource and objective interdependencies among actors. It is expected that these model are highly susceptible for strategic behaviour of actors in an attempt to increase their personal gain, which could be at the cost of the performance of the collective. An exchange model is applied for a case in Curaçao concerning the establishment of an ocean ecopark. In four experiments the interest and control are changes, overestimated or underestimated, to define the impact of strategic behaviour when actors know the outcome of the exchange model and attempt to strengthen their position. The results are that only overstating your resources has a positive effect on one's own utility function, while gaming with your interest can have negative impacts on the personal utility function. Further research could expand on these ideas and define what best strategies are to strengthen one's position in this model.

Keywords: Exchange modelling, Strategic behaviour, Ocean ecopark, Cooperation game

1. Introduction

Interdependencies between actors are part of the difficulty for designing in complex multi actor systems. An actor analysis model can contribute to this by gaining insight in the dependencies between actors. In a context where resources are dispersed within the system and different objectives are present among the actors an exchange model can provide a solution (Timmermans, 2004). It is rooted in the Social Exchange Theory described by James S. Coleman (1990), to gain insight in the behaviour of actors (game theory), and particularly stresses the interdependencies between actors within a system.

In order to represent the behaviour and interdependencies in the system, the actors need to state their control (resources) and interests (objectives) over predefined issues. Although exchange modelling is applied in several cases, only few consist of actual data gathered from the actors. Timmermans (2009) applied it interactively through a workshop for the rural water management policies in The Netherlands. For the development of an urban centre Timmermans and Beroggi (2004) also used the participation of actors to complete the related exchange model. Lastly, Schouten et al. (2001) used the exchange model with the aid of actors to contribute to the development of a land area in Indonesia. Involving actors in this process makes the outcome prone to strategic behaviour of actors. Actors behave self-serving and intentionally try to influence the results and recommendations derived from the model for their own personal benefit. Experts thought that an actor gave strategic answers in the case of Indonesia "to make them seem more concerned with the traditional economic activities in the area" (Schouten, Timmermans, Beroggi, & Douven, 2001, p. 287). Within a pluricentric situation one actor (or player in game theoretical terms) adjusts its behaviour based on the actions another player can take (Schelling, 1960). Within an exchange model an actor could make

misstate its resources, interest or influence the perception of other actors about its own position. Especially, if an actor knows that an action of his will have an increase for its own utility it will take that benefit, without bearing in mind the consequence for the larger situation (ten Heuvelhof, 2008). Although exchange modelling is applied in various situations and one has considered the potential of strategic behaviour, it is difficult to prove and has not been research before for its impact on an exchange model outcome. In this research a case, concerning the establishment of an ocean ecopark in Curaçao, is described to study the impact of strategic behaviour in a laboratory setting by means of a desk research.

In the following sections an elaboration is given on the working of exchange modelling. The third section brings forth a case study for establishing an ocean ecopark to illustrate this research. Based on this case study the effect of strategic behaviour is tested, by assessing the changes in utility for specific actors and the performance of the whole system. In the end conclusions are drawn and a reflection is formulated on the presented research.

2. Exchange modelling in general

The general exchange modelling technique consists of a problem definition, an identification of actors, definition of issues, completing the interest and control matrix, the mathematical construct, and interpretation and evaluation of the results (Schouten, Timmermans, Beroggi, & Douven, 2001). Coleman (1990) identifies a social system by the actors and issues over which actors have control and interest. Therewith issues are considered a set of goals which actors purposively try to influence for their own benefit (Timmermans, 2004). Based on these components transactions of control over issues can take place between actors. A transaction takes place when it is beneficial for the utility function of both actors. This utility function is resembled by the micro-economic Cobb-Douglas utility function (Timmermans & Beroggi, 2004).

$$U_i = c_{i1}^{x_{1i}} * c_{i2}^{x_{2i}} * \dots * c_{im}^{x_{mi}}$$

With

- U_i = total amount of utility by individual actor *I;*
- c_{ij} = control of actor *i* over issue *j;*
- x_{ji} = interest of actor *i* over issue *j.*

The exchange model does not optimize the utility of one specific actor, but the optimal solution for all actors. Thus, actors behave selfishly in their decisions to exchange (Coleman, 1990), and influence each other by making beneficial or not-beneficial actions for other actors, based on the improvements in their own utility function (U_i) (Blau, 1964). These actions consist of exchanging abundant control in issues where they show little interest in for control in issues which they perceive as highly interested (Van der Lei & Herder, 2011). Control is represented by control matrix $C = \|c_{ij}\|$, which shows how much control each actors has for the defined issues in the system. The interest matrix is represented by $X = \|x_{ij}\|$, to show the interest of actors over the issues. Both matrices are subject to the following constraints (Timmermans & Beroggi, 2004):

$$\sum_{j=1}^{n} x_{ji} = 1 \text{ and } x_{ji} \geq 0,$$

$$\sum_{i=1}^{m} c_{ij} = 1 \text{ and } c_{ij} \geq 0$$

Within this system there is a common exchange rate, which resembles the worth (value) of control over an issues compared to control over other issues (Coleman, 1990). The power vector *r* represents the power of the actors, determined by the value of an issue and the amount of control they have over that issue (Timmermans, 2006).

$$v = \|v_j\|, \text{and } r = \|r_i\|$$

Both can be calculated by the following equations:

$$v = (I - XC + E_m)^{-1} e_{m1}, \text{and}$$

$$r = (I - CX + E_n)^{-1} e_{n1}$$

E_n and E_m are square matrices with the respectively the elements of $1/n$ and $1/m$. I represented an identify matrix of ones on the diagonal, and e_{m1} and e_{n1} are *n x 1* and *m x 1* matrices. Where *n* is the number of actors and *m* the number of issues.

The outcome of the exchange model is the equilibrium control (C*) among actors, for which no actor can make another transaction without making another actor worse off, which can be considered the Pareto optimum (Rojer, 1999).

$$C^* = D_r X' D_v^{-1}$$

Where D_r is a diagonal matrix with elements r_i and D_v and a diagonal matrix with elements v_i.

3. Parameterizing the exchange modelling

3.1 Case study

For the purpose of this research a case study is conducted on the establishment of an ocean ecopark in Curaçao. Upon Curaçao there is a high dependency on the import of food, drinking water and fossil fuels. There are limited possibilities to experience economies of scale, a high dependency on foreign investments, environmental impact issues concerning their precious ecosystems, and a large potential of renewable energy systems (Briguglio, 1995) (Weisser, 2004). By using the large potential of energy stored in the ocean one tries to positively affect the conditions on Curaçao in a sustainable way. The ocean ecopark accommodates the cold ocean water (pumped from 800-1000 meters below the ocean) for tenants to use it for their business. The resources to establish such an ocean ecopark are dispersed in the system, and actors are only willing to allocate their resources for the ocean ecopark if they would gain from this concept. To gain insight in this system an exchange model is applied on this system, the conceptualization is presented in table 1.

Table 1: Conceptualization of exchange modelling

Actors	Issues
Project initiator	Business climate
Project developer	Self-sustainable
Government	Employment
Tenants	Economic business case
Other initiatives	Tourism
Environmental interest groups	Environmental impact
Knowledge institutes	R&D

3.2 Conceptualizing and implementing strategic behaviour

An exchange model represents a market place where players can exchange goods (control over issues) if this is beneficial for the utility of both. When negotiating on a market place you will overestimate your losses, while underestimating your gains. Else the price of a product will go up, while you could also have it for less. Similarly, in an exchange model one can think of situations in which it might be in the benefit of an actor to misstate their interest or resources, but only if it is self-serving (Madani, 2010). One could acquire such a situation by convincing other players by for example threatening, or convincingly misstate your own position. The why-question falls outside the scope of this research. To test what the impact of strategic behaviour is on the outcome of an exchange model, the individual utility of the relevant actor, the overall utility, and the potential for exchange are compared for the actual situation and the experimental situation. For four cases a change in the input is made, under the assumption that they have full knowledge of the system and behave on the

basis of this information (Rubinstein & Wolinsky, 1990).

Experiment 1: Overestimating interest

Actors can deliberately misstate their interest to ensure that they gain sufficient control on an issue. In Schelling's book (1960) this is presented as convincingly threatening that you would like something, more than another, and that you are willing to go further than the other party. In this case the actor tries to strengthen its position for a certain topic, by overestimating their interest in one issue to ensure that they receive sufficient control over it.

Hypothesis 1: It is expected that by overestimating the interest in an issue, that actors becomes vulnerable to a higher exchange rate for that issue. Other actors know where your prime focus is, and therefore require extra control, which also could be useful for the relevant actor. In the collective this could also have a negative impact, as the unnecessary high exchanges are made in the system.

Experiment 2: underestimating interest

Stating your position in the system is involved with risks; it brings forth your knowledge, your capabilities, and your preferences (Edmunds & Wollenberg, 2001). One can argue that explicitly the weaker actors or actors with sensitive preferences are not willing to give up their position. It can also be defined as a strategy, to withheld one from the discussion and frustrating it by stalling the discussion. In that case limited decisions are taken, which could be at the benefit of that actor.

Hypothesis 2: If an actor tries to frustrate the negotiations and interactions by underestimating their interest (not willing to make its intentions clear) will have a negative contribution to the overall utility and potential exchanges.

Experiment 3: overestimating resources

In order to show that an actor is important and that everyone should support their solutions and need their help, an actor can overstate their resources in the system. This sounds counter intuitive for a market place, where in this case you overstate your resources, but it also gives your more potential to interact with other actors.

Hypothesis 3: With more resources one can make more transaction within this system for its own benefit, and therewith increase its utility.

Experiment 4: Underestimating resources

A party would like to possess more resources on a subject, because it is very important for this actor. It could suffice in this by stating a low initial control and high interest in that particular issue. The model takes into account their need for control. Many exchanges are proposed with that actor on this particular issue. When an actor has sufficient resources to also make those exchanges, he or she receives more control over an issue. Actually, it already possesses some control and gains an even higher control on that issue. This is quiet similar to what happens when bargaining on a market, where you underestimate your resources to the other parties and convince them to give you more of a resource because you overestimate your losses.

Hypothesis 4: Actors that undervalue their resources, but remain interested in them, gain many resources on that topic.

4. Results

The initial results of this exchange model, based on a desk research to complete the control and interest matrix (appendix A), give insight in the competitive outcome between the actors. Compared with the initial distribution of control it shows where actors can gain beneficial control when cooperating. To define strategic behaviour

this competitive outcome is analysed and changes are made for which it is expected that this would be beneficial for the relevant actor.

Results experiment 1: Overestimating interest

Within the current system the environmental interest groups are small players. Of high importance for them is *environmental impact*. In order to gain more control over this issue they purposefully misstate their preferences in this issue. By knowing the system they, in this theoretical case, state a higher interest (2 times higher) for which they will receive more control as this is how the model operates. The impact of this is that they do receive more control on this issue, and receive less on the other issues (over which the remaining interest was distributed proportionally according the initial interest). Despite this higher control over *environmental impact*, their utility increases only slight compared to their starting utility. The reason for this is that their utility is still calculated by their actual interest (and not their stated interest), and they have received less control on issues they also have interest in. This leads to a situation it would be best to stick to their actual interest distribution, since if this misstated interest would be true it would leave them with a utility increase of 163%.

Table 2: Results experiment 1 overestimating interest

	Initial situation	Experiment 1
Environmental interest groups utility	146%	106%
Overall utility	125%	120%
Potential for exchange	129	108

Results experiment 2: Underestimating interest

The actor group other initiatives can be in a position in which they do not want to make their intentions clear, but do want to be considered at this interactions at decisions made there could influence their business. Theoretically speaking, they could purposefully state their indifference for all the issues, which distributes the interest evenly over all the seven issues.

The effect of this behaviour, taken into account their actual interest distribution, leads to a decrease of utility by this behaviour while the system remains the same. As their control is also equally dispersed over the system (without adjusting it, and with a higher control over *tourism*), this leads to a situation which leads the *other initiatives* worse of. If it would be their actual interest distribution they would have created a situation in which they are better off, although their numerical utility would be lower.

Table 3: Results experiment 2 underestimating interest

	Initial situation	Experiment 2
Other initiatives utility	113%	88%
Overall utility	125%	122%
Potential for exchange	129	125

Results experiment 3: Overestimating resources

The project developer would like to show its worth in the whole system. Especially with its role in this specific system, namely combining all the elements. By overstating their resources, they could be perceived as an important actor which should surely be involved in the project. In this theoretical example they have overestimated their control by three on *R&D*, *business climate*, and *environmental impact*. The rest of the control on these issues is proportionally distributed among the other actors, accordingly to their actual control distribution. It leads to a situation in which the project developer gains a lot of utility, so from this viewpoint it is an excellent step to overestimate its resources. All the other actors are worse of in this situation, although it does not show in the overall utility. Each actor gains less utility than in the situation in which the project developer would have been honest about its position in the system.

Table 4: Results experiment 3 overestimating resources

	Initial situation	Experiment 3
Project developer utility	127%	211%
Overall utility	125%	124%
Potential for exchange	129	121

Results experiment 4: Underestimating resources

Tenants are one of the two powerful actors in this system, which could give them the perception that they could even increase their share. By deliberately stating that they do not possess a lot of control on the *economic business case*, they could try to gain more influence on that (on top of the control they did not present in this system. In this new competitive situation, where they stated their control half as much as it actually is, their utility is calculated, including the control they neglected, and it shows that their utility on slightly changes. Similar conclusion can be drawn for the overall utility of all the actors.

Table 5: Results experiment 4 underestimating resources

	Initial situation	Experiment 4
Tenants utility	153%	150%
Overall utility	125%	127%
Potential for exchange	129	141

5. Discussion

Assessing the situation the goal is to find cooperation in a system which initially focusses on non-cooperation. It shows that within this non-zero-sum game the system always increases in utility by cooperating. This is due to the assumption that an exchange is only made when it is beneficial for both parties. In the competitive situation, without strategic behaviour, this already eliminates the win-lose situations, and draws the focus towards win-win situations. Similarities can be found to a coordination game, which attempts to find an optimal allocation for their resources, where the pay-offs per outcome differ per player.

Table 6: Coordination game

	Left	Right
Up	A, a	C, c
Down	B, b	D, d

With A > C; B>D for player; a>c; d>b for player b.

In this situation actors are trying to convince each other for their specific allocation, which is most beneficial for them. Relating this to the presented system, the exchange model determines in which ideal setting the resources could be allocated for the benefit of all the actors. Not four outcomes are given, but all innumerable win-win situations are acceptable outcomes for the actors. This affects the possibilities you have to convince other actors of the benefits of your proposed outcome (solution).

Still, an actor can attempt to obtain more utility out of the system, at the costs of someone else. In a market place a bilateral bargaining determines the price, and one can behave strategically to influence the exchange rate. It shows from the results in this study that the value vector, which represents the exchange rate, only makes limited changes due to strategic behaviour. Substantiated by experiment 4 is the claim that underestimating your resources, and therewith overestimating your losses, has limited effects for your own utility and the overall utility. Overstating your gains by increasing your utility has a negative effect. The more you express you want something, the more you receive in this model, but at the cost of valuable control over other issues. This claim is substantiated by experiment 1, where the environmental interest group overstates their gains, which actually makes them worse than the original situation.

An exchange model assumes that all the control and interest is dispersed within the system. The implication of this is that when one actor convincingly overestimates its resources, it automatically degrades the resources of other actors. This assumption shows why overstating your resources can be a highly effective strategy for increases one's own utility, see experiment 3. Other implications of this assumption are that there are multiple buyers and sellers represented in this pluricentric system. This is illustrated by experiment 2, where the actor *other initiatives* decreases their potential for exchange in the system, by misstating their interest, without decreasing the potential for exchange in the whole system. Other actors do show interest in certain control and take the place of *other initiatives*, and still require the control from the 'sellers' in this system.

An assumption in this research is that one actually knows the correct situation. Theoretically, it helps to identify if a strategy is beneficial. For the strategies in misstating the interest, one could argue that within this model it is not useful, as that specific actor always knows its own interest function, and therewith hampers itself. In real life, it still could be a useful strategy to learn from others, obstruct the process, or wait until you gain more insight in the system. Relating this to resource strategic behaviour, the effect could be that you exchange control which you do not possess. Where the model perceives that one can exchange that control, the real life situation could be quiet the same. In a negotiation one can overestimate their losses, to ensure that it still receives sufficient. Even, deals could be made where one party already receives the control, in expectation that it receives beneficial control in return, which than does not happen. Therefore the claims made should be nuanced as there are only limited experiments conducted within a controlled environment.

6. Conclusions

This research shows more about how strategic behaviour affects an exchange model, and therewith advancing the methodology. As the model assumes it captures all control and interest within the system, and therewith changes in control and interests automatically affect the other distribution functions of actors or issues. This makes the impact of strategic behaviour rather limited when regarding it as the possibility actors have to know their own situation based on the initial outcomes and make changes to increase their position. Overestimating your own resources is very successful, as it gives you more opportunity to exchange for wanted control, at the costs of the other actors.

Difficulty in generalizing these results is that dependent on the actor, and their related actual interest and control, the outcomes can differ. Advantageous of this view is that it encompasses the whole system. Strategic behaviour automatically influences the other actors, where in two-player games it could only strengthen one player. This gives new advantages for the usages of exchange modelling, as it is less subject to strategic behaviour, although one can only conclude this when the actual true situation is known.

Further research should dedicated to capture strategic behaviour with actual actors, during for example a workshop. Further research can also focus on a more in-depth study towards the effect of input sensitivity of an exchange model. Based on this strategic advice could be given on the tilting point for an actor towards which kind of behaviour could be ideal in achieving its objectives.

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Appendix A: Interest, control and equilibrium matrix

Table 7: Control matrix

Control matrix (= C x 100)	Project initiator	Project developer	Government	Tenants	Other initiatives	Environmental interest groups	Knowledge institutes	Total
Economic business case	14	20	10	37	10	3	7	100
Employment	5	22	18	24	9	5	17	100
R&D	5	9	8	24	6	24	25	100
Self-sustainability	6	25	23	21	8	4	14	100
Business climate	14	7	37	4	7	27	4	100
Environmental impact	4	16	10	24	4	24	19	100
Tourism	17	9	30	5	30	6	3	100
Total control	63	108	135	138	73	94	88	

Table 8: Interest matrix

Interest matrix (= X x 100)	Project initiator	Project developer	Government	Tenants	Other initiatives	Environmental interest groups	Knowledge institutes	Total
Economic business case	10	22	4	20	27	3	6	91
Employment	15	3	25	3	5	9	32	93
R&D	3	9	5	27	12	24	29	109
Self-sustainability	4	14	23	6	4	18	11	81
Business climate	33	25	19	26	9	5	7	125
Environmental impact	12	22	7	14	6	38	11	110
Tourism	24	4	16	5	36	3	3	91
Total control	100	100	100	100	100	100	100	

Table 9: Equilibrium control matrix

Equilibrium control (= C* x 100)	Project initiator	Project developer	Government	Tenants	Other initiatives	Environmental interest groups	Knowledge institutes	Total
Economic business case	7	26	6	30	21	4	6	100
Employment	10	4	36	5	4	10	32	100
R&D	2	8	6	31	7	22	23	100
Self-sustainability	2	16	36	9	3	22	12	100
Business climate	16	21	21	28	5	4	5	100
Environmental impact	6	20	9	17	4	35	9	100
Tourism	19	6	28	9	31	4	4	100
Total control	62	101	142	129	74	100	91	