A NEW LOOK INTO GARBAGE CANS - PETRI NETS AND ORGANISATIONAL CHOICE

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Abstract

Understanding how organisations make decisions is a crucial step towards understanding organisations. Seeing organisations as a place of structure and rationality led to unsatisfying results. The "Garbage Can Model of Organizational Choice" of Cohen, March, and Olsen (1972), fundamental to behaviouristic organisational theory, looks at "organized anarchies" and opens eyes for ambiguous and unpredictable decision situations. Reference Nets, a high-level Petri net formalism, offer formal semantics, graphical representation, means to model concurrency, and immediate executability, and, thus, seem to meet basic requirements to model and present sociological theories. In this paper Petri nets are used to formalise the Garbage Can Model and expose its implicit assumptions. The resulting model serves as a basis for interdisciplinary collaboration. Weaknesses of the original theory are laid open leading to new sociological considerations.

1 Introduction

Usually sociological theories are available as natural language texts and, thus, elude from formal analysis. To find clear semantics which is a prerequisite for formal analysis, verification of consistence, and executability, often is difficult. This paper reports on approaching a sociological model of organisational decision making with means of Petri net theory. In the socionics project at the University of Hamburg the emphasis lies in the modelling and analysis of sociological scenarios, aiming at evaluation and improvement of different theories. Both, for advancement in sociology and for better understanding of artificial societies (also see Sozionik@UHH, 2000).

Our chosen example of a sociological theory, namely the "Garbage Can Model of Organizational Choice", deals with decision making processes in organisations. And the way Cohen, March and Olsen (1972) do that, marks a point of changing the common view to such processes. This change of view refers to the *context* and the *order* - or better: the absence of order - in decision making processes. Here promising points for the actual research on organisations are touched which will be discussed later in the paper.

The “Garbage Can Model” is a fundamental and often cited contribution to behaviouristic organisation theory. The model combines empirical characteristics, theory, and simulational aspects. It also deals with the essential sociological task how organisations can survive while struggling with ambiguous and complex problems just as an unpredictable environment. The Garbage Can Model turns away from the common view that organisations are the right place for rational, intentional and well structured decision making. Rather there are seemingly a lot of incoherent actions and the results are not as intentional and desirable as they might be. The issue, whether this interpretation is a grounded one or a question of perspective, will be taken up later in this paper. At least, it is argued by the authors, that parts of any organisation can be described with this model at various times.

Originally, C. A. Petri (1962) intended to introduce a universal formalism for complex systems, offering formal semantics, explicit means to model concurrency, graphical representation, and executability. Elementary Petri nets consist of three static elements: places and transitions which are connected by arcs. Anonymous tokens represent the dynamic aspects by being moved from one place to another through switching transitions.

The high-level paradigm of "nets in nets" by Valk (1987, 1998) allows the tokens to be Petri nets themselves. This idea is incorporated and extended in Reference Nets by Kummer (1998). Each Petri net can be seen as an object (or even agent) in a Petri net environment.

This paper is based on a case study approaching the sociological theory (CMO, 1972) with Reference Nets. The emphasis is in the construction of an executable model which serves as a starting point for interdisciplinary collaboration and the validation and evaluation of the sociological theory. The Petri net model delivers new insights to strengths and weaknesses of the original contribution about organisational decision making. It provides a base point for connecting reflections which are new to the sociological discourse.

Other studies which are regarding the Garbage Can Model in a computational way have focused on artificial intelligence and simulational aspects (see Masuch and LaPotin, 1989).

The following section introduces the basic concepts of the Garbage Can Model of Organizational Choice. Section 3 gives a brief overview on the Reference Nets which are used as the modelling technique of the nets of section 4. In Section 5 the implications and results of this work are discussed. The last section concludes the paper and takes an outlook on relevant topics in the near future.

2 The "Garbage Can Model of Organizational Choice"

This section introduces the Garbage Can Model of Organizational Choice by Cohen, March, and Olsen (1972). Then a generalised version of the original work is presented. This will be the basis for the executable object Reference Net model of section 4.

The "Garbage Can Model of Organizational Choice" (1972) still is a relevant contribution to organisation theory because of the remaining actuality and applicability for present organisational processes. The authors led various research projects on universities, motivated by the student demonstrations at the end of the sixties. Based on these studies, Cohen, March and Olsen developed the notion of the Garbage Can Model.

An organisation is characterised by three general properties: problematic preferences (goals of organisation and participants are inconsistent and ill-defined), unclear technologies (organisation's processes are not understood by members), and fluid participation (time and effort of participants vary).

In sociology decisions are seen as one of the main outcomes of organisations (Luhmann, 1988). The Garbage Can Model discovers, describes and explains failures in organisational decision making processes. It is argued that a decision is the outcome or interpretation of several relatively independent streams within an organisation:

- A stream of problems: Problems are determined by inner and outer organisational circumstances and require attention of participants. Problems are looking for situations in which they might be raised.
- A stream of energy from participants: Participants come and go. It is assumed that they provide energy for organisational decision making.
- A stream of solutions: Members of the organisation produce solutions. Solutions move around, actively looking for questions to which they might be an answer.
- A stream of choices: Choice opportunities represent the point of time when a decision is required by the organisation. Each choice opportunity can be seen as a garbage can into which diverse problems and solutions are dumped.

A special feature of the Garbage Can Model is that not only the participants interact with each other, but also the remaining components of the decision process (problems, choices, solutions) can become active, attract each other, and move away. Thus, this kind of organisation can be viewed as a collection of choices, problems, and solutions. Each component looks for matching other components. According to the Garbage Can Model many different actions are taking place at the same time independently. This provides the model with a high dynamic style.

Now it is time for a few words concerning the striking metaphoric and the main notions Cohen, March and Olsen conceptualised in their model. Firstly the organisation, described as a "collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision-makers looking for work" (CMO, 1972, p. 2), is called "organized anarchy". Secondly the decision making process takes place in a "garbage can", because one may consider each choice situation as a garbage can into which problems and solutions are dumped by the participants. They do it by chance and with no well-defined intention. Solutions and problems can migrate between the different garbage cans. If a solution meets a choice in the right context and at the

right time, a decision can be made. But the emerging outcomes are diverse and not always as desirable. They can be summarised under three decision styles: (1) If there is at least one problem attached to the choice, the making of a decision leads to a rational outcome (decision by resolution), the problem is solved. (2) Or the making of a decision takes too long and no problems are solved (decision by flight). (3) If the decision is made so quickly that no problem has the chance to come up, it was made by oversight.

The speciality of the Garbage Can Model is not only the comic and pointed name. It deals with the essential sociological task how organisations can survive while struggling with ambiguous and complex problems and an unpredictable environment. The Garbage Can Model turns away from the common view that organisations are the right place for rational, intentional and well-structured decision making in the favour of time and context sensitive behaviour. It is argued that at least parts of any organisation can be described with this model at various times. And in fact, Hickson et al. analysed 150 decisions in British organisations and came to the conclusion, that the form of organisation "is not the primary factor affecting how decisions are made ... More important are the complexity and the policality of the matters under decision" (Hickson et al., 1995, p. 53). Or so to speak, "the matter for decision matters most" (Hickson et al., 1986, p. 248)].

To make a long story short, this is how Masuch and LaPotin (1989) put it: «... reconsider the finale of the James Bond movie 'A view to kill'. Agent 007 balances on the main cable of the Golden Gate Bridge, a woman in distress clinging to his arm, a blimp approaching for rescue. In terms of the Garbage Can Model, the blimp is a solution, Agent 007 a choice opportunity, and the woman a problem. In the picture's happy ending, the hero is finally picked up, together with the woman, and a solution by resolution takes place; the problem is solved. Now imagine numerous blimps, women, and heroes, all arriving out of the blue in random sequence. Heroes take their positions on the main cable. Women cling to heroes, blimps hover above the scene. Heroes may or may not be able to hold an unlimited number of women, but the blimps' carrying capacity is limited; heroes with too many women cannot be rescued. Blimps are retrieving rescuable, i. e., not-too-heavy, heroes. Women in distress are aware of that and switch heroes opportunistically, choosing the hero closest to retrieval. As women, as well as blimps, make their choices independently of each other, a light hero, on the verge of rescue, may suddenly find himself overburdened. Heavy heroes, in turn, may become rescuable all of a sudden as their women desert them.«

This coming and going is the mechanism called fluid participation. Women may not be saved at all if they change between heroes disadvantageously and all of their heroes of choice turn out to be too heavy; then, these problems are not solved. Heroes may be saved when all women just have left; this is called a decision by flight. Also, heroes can be rescued before any distressed woman was able to hold on to them; then, a decision by oversight has occurred.

Let us come back to the sober grounds of organisational theory and sum up the terminology: the bridge is an organisation, heroes are choices, women are problems, and blimps are solutions. Choices attract problems and solutions. A choice is made if there is an appropriate solution to its problems.[1] Three styles of decision making may appear, but only one of them solves problems.

3 Basic Notions of Reference Nets

Since Petri's thesis (Petri, 1962) many different dialects of Petri nets have been introduced. The basic concepts are concurrency and conflicts, active and passive parts, and the movement of tokens. The few concepts of active (transitions) and passive (places) parts of a Petri Net-system with the restricted relation between them is straightforward and intuitive.

Reference Nets are a high-level Petri net formalism that uses Java as an inscription language. High level-Petri nets are extended by dynamic creation of net instances, references to other net references as tokens, and dynamic transition synchronisation and communication via synchronous channels (Kummer, 1998). They are designed and executed with Renew, the Reference Net Workshop (Renew, 1999), according to Aalst et al. (1999) the only tool supporting the execution of any kinds of nets in nets.

Reference Nets (as Petri nets) consist of three types of elements: places, transitions, and arcs. Semantic inscriptions can be added to each net element. Places can have a place type and arbitrary number of initialisation expressions. On creation of a net instance the initialisation expression is evaluated and leads to the initial marking of the net. Arcs can have arc inscriptions. The arc inscriptions are evaluated when a transition fires and the results leads to the consumption and creation of tokens. Transition may carry diverse inscriptions. There are expression inscriptions which are performed when the transitions fires[2]. Guard

[1] One might wonder where the participants have gone. In this version participants are not mentioned explicitly. They remain backstage. Now and then they throw solutions into the scene.

[2] Actually the expression inscriptions are evaluated during the search for a binding of the transition. In case the transition does not fire, the result is discarded.

inscriptions are preconditions to the transitions, i. e. the transition is only activated if all attached guard expressions evaluate to true. Action inscriptions start with the keyword *action* and are only evaluated when the transition fires. Creation inscriptions (consisting of a variable name, a colon, the reserved word *new* and the name of a class net) create new instances of nets.

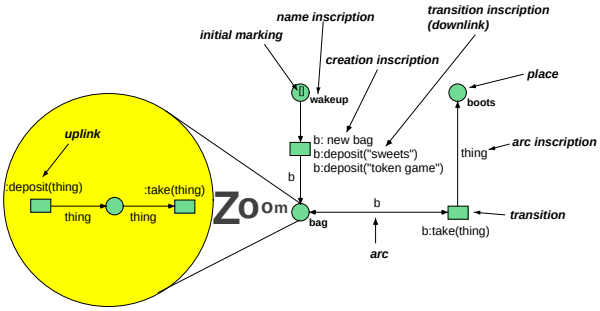

Fig. 1: Sample Reference Net

As known from programming languages function calls can be used for synchronisation and communication. Christensen and Hansen (1992) combined this mechanism with Petri nets by introducing typed communication through synchronous channels for Petri nets. Synchronous channels allow different transitions to be synchronised and exchange data. Both transitions must agree on the name of the channel and on a set of parameters before they can synchronise. This concept is generalised by allowing transitions in different net instances to synchronise. This can only be done, if the initiator of a synchronisation knows the other net instance.

Fig. 1 shows two nets which communicate. The outer net represents the basic schedule of Santa Claus on the night before Christmas. After waking up he takes a new bag and deposits "sweets" and a "token game" into it. Later he can take things out of the bag and put them into children's boots. (Renew, 1999)

The initiating transition must have a special inscription, a so-called *downlink*, specified as a *netexpr:channelname(expr, expr,..)*, which makes a request at a designated subordinate net. The requested transition must have an *uplink* (*:channelname(expr, expr,...)*) as an inscription which serves requests from other net instances. Every time a synchronous channel is invoked, the channel expressions on both sides are evaluated and unified.

Whenever a simulation is started, new instances of each involved net are created. For any further access on those new net instances now their *references*, which are tokens of other nets, are used.

Reference Nets have successfully been used for system modelling, for agent systems, and business applications, especially workflow systems (e. g. Aalst et al., 1999, Laue et al., 2000, Rölke, 1999).

4 The Garbage Can Reference Net

The Garbage Can Reference Net consists of four net classes: Organisation, Choices, Solutions, and Problems. The *Organisation* (Fig. 2) which is the stage for the elements involved in decision making. It represents the bridge and keeps track of the other net instances and controls the interactions among them. Looking at the *Organisation* the main features of a garbage can decision process become clear: there are the three streams of problems, choices, and solutions pouring into the system. Problems are free until they cling to an available choice. Then switching between different choices is possible. If a solution is obtainable, a decision can be made by removing one choice with an arbitrary number of problems.

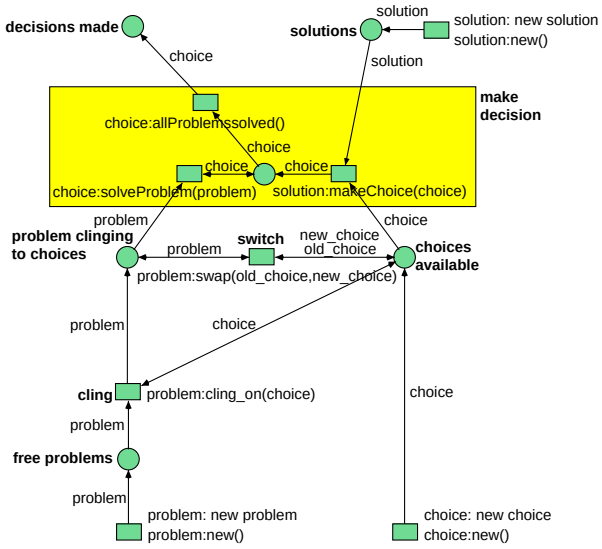

Fig. 2: Reference Net *Organisation*

The *Choices* (the heroes) are the crucial elements of the decision making process and which bring together problems and solutions. The *Solutions* (blimps in the sky, Fig. 3) which bring relief to the distressed situation and lead to decision making. The *Problems* (called women in (Masuch and LaPotin, 1989), Fig. 4) which attach themselves to choices and may be solved eventually. If one takes a look into the net *Problem* (Fig. 5), one can see how a problem can be *free*, *clinging to choice*, or *solved* and how states are changed by the transitions *cling_on*, *swap* and *be_solved*.

Concurrency can be found in the transitions *cling*, *switch*, *make decision*, and all the *new*-transitions. They

behave totally independently to each other and can switch concurrently to themselves. For sociological theory this means that there is no predefined order in which choices, problems, and solutions appear and interact.

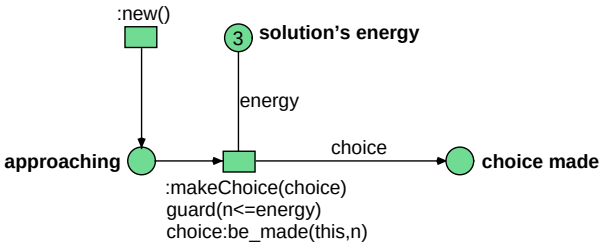

Fig. 3: Reference Net *Solution*

Non-determinism is a key concept of Petri nets. At a given point of time it cannot be determined neither which of the enabled transitions will fire next nor which tokens will be used for the bindings of a transition's variables. In the Petri net formalism for transitions to be enabled it is sufficient that all direct preconditions are satisfied. Thus, information other than local does not need to be considered.

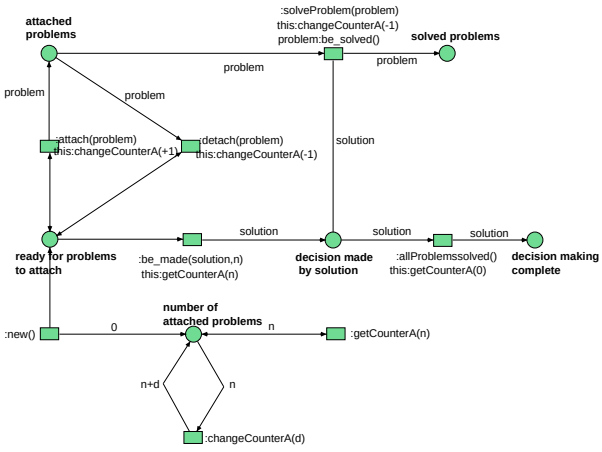

Fig. 4: Reference Net *Choice*

These nets represent a very generalised view on the Garbage Can Model. Apart from the basic behaviour seen here, (CMO, 1972) incorporate aspects of organisational structure, energy distribution among participants and problems, and search strategies for the most attractive choice available. Taking all these features into consideration led to an extended net model with up to 10 net classes (see Heitsch et al., 2000).

Organisational structure controls the access of problems towards choices (which problems may effect which choices) and of participants towards choices (which participants are allowed by the organisation's structure to make which decisions). These regulations give a rudimentary pattern of behaviour to the organisation, but still are far away from total rationality. In a Petri net model these structures limit the amount of possible bindings leading to situations in which a choice can be made, but the available participant is not authorised by the organisation's rules. The problems attached to the choice remain unsolved.

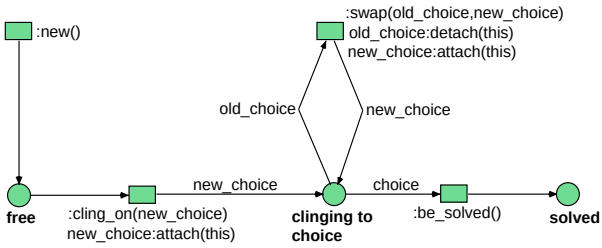

Fig. 5: Reference Net *Problem*

The distribution of energy takes into account the different complexities of problems and the variant skills of participants. On the one hand each problem requires a certain amount of energy to be solved, on the other hand each participant provides energy for problem solving. When the amount of energy available exceeds the energy required, a decision can be made. This aspect is captured technically by changing states of objects which describe if a choice can be made or not.

Search strategies are used to determine which choice problems and participants will select at a given point of time. Problems as well as participants chose the choice closest to decision, i. e. the choice with the least difference of required and available energy. This leads to a »tug of war« between problems and participants. Choices close to decision can either suddenly can be clung to by a large number of problems which prevents decision making or can be processed by too many participants which leads to a decision, but with a waste of energy. Technically, such a search strategy can be implemented by global knowledge of all other objects or by a central instance which acts as a coordinator. (CMO, 1972) require that each problem and participant always is aware of the optimal choice. In the original FORTRAN simulation this was implemented by a simple loop which processes *all* available elements. In a concurrent system like a Petri net it is more difficult to process all available elements atomically. Tokens move non-deterministically and concurrently through the Petri net (similar to a distributed system). In order to find the optimal choice at each given point of time, a coordinating instance has references to *all* active choices and returns the current »most attractive« choice to the problems and the participants. The global form of

knowledge is assumed in (CMO, 1972). Nevertheless, a rather local representation of knowledge as in Petri net semantics seems to be more intuitive for organisations and its members.

In conclusion the Petri net model applies concurrency and non-determinism to the Garbage Can Model and dismisses the necessity of a global clock. Observations of the many different version of the Petri net models result in semantic questions (inspired by terms of Petri nets theory) toward the original sociological theory.

5 Sociological Implications

Cohen, March and Olsen intended to gain new discoveries about decision making processes and their failure in so called “organized anarchies”. Their “Garbage Can Model” is laid out as a triad of empirical, theoretical and computational components. Already forty years ago, the authors detected the contribution a computational model can make to the creation of theory. In the words of their research colleagues Kalman C. Cohen and Richard M. Cyert, going back to the year 1961: “The basic advantage of computer models is that they provide a language within which complex dynamic models can be constructed.” (Cohen and Cyert 1961, p. 127). But compared with the original simulation of the Garbage Can Model, carried out with FORTRAN by Cohen, March and Olsen (1972) themselves, by all means there are several advantages of the Petri net model. Letting the Petri net model run and taking a look at the outcome allows new insights into for example implicit presumptions of the Garbage Can Model and its link to reality in organisations. In fact, the emerging sociological implications can be classified in four categories, all of them referring to the question of a “good creation of organisation theory”.

- The right perspective to organisations, here presented in the form of the sharpened question, how long, how intensive and how extensive an organisation or the respective part of it must be observed?

- The reasonable reference to the reality of the organisational processes taking place and the context of the decision situation. This point deals with the question of taking into account all relevant aspects and not to neglect important issues from the start.

- The formalisation of the theory is the next crucial aspect of theory building. In order to analyse the theory for example with regard to its strong and weak points, it is necessary to decompose the theory in its single components. This is also a prerequisite for the validation of the units in an executable model.

- The possibility to vary the model can lead to new conclusions, relevant to the sociological discourse. For example, the sensibly chosen variation of theoretical assumptions might aim to integrate them in an extended model or mark the boundary of it.

Now let us put these general characteristics in some concrete terms, which emerged from this special approach:

1. One of the main criticism of the Garbage Can Model is addressed to the *inclusion of structures, modes of functioning and patterns of interaction* in the organisation as a whole. Or with the words of Christine Musselin "the organizational context is ignored" (Musselin, 1995, p. 60). Musselin wonders about that matter, because we have not the case "where participants ... have never cooperated with each other before and face a new choice opportunity for the first time" (Musselin, 1995, p. 60). In fact, to isolate the single decision processes from the rest involves some risks. Namely the neglect of "the structure of the relationships between the actors and the possible links between the decisions studied and other decisions” (Musselin, 1995, p. 61). They might then appear not as disorderly as they are regarded now. Furthermore there are no processes like the question of how decision situations and choice opportunities are generated to come into the focus, when dealing with the organisation like Cohen, March and Olsen do. One might get the impression, that Cohen, March and Olsen watched only parts of the 'organized anarchy' and observed the decision making process in the short run. Maybe they decided to do so in order to avoid high complexity. But the reverse of the medal is that many aspects are left out of sight. To sharpen the problematic one might say, that the look Cohen, March and Olsen took to the organisations studied was (1) too short, (2) too partial and (3) too superficial. Dealing with many aspects in this context, which are removing themselves from the directly observation, the modelling with Petri nets comes at the right time. Petri nets can bridge the gap between the theoretical and empirical work in organisational research by providing a tool with the ability to handle special implicit processes and suggestions and even execute this hidden aspects. This is not a substitution for the proper empirical research but can lead to then definable questions and suggestions and may make the approach to the things happening unintentionally and seemingly unstructured easier.

2. One above mentioned speciality of the Garbage Can Model is the *dynamic aspect* of making a decision, due to the many parallel interactions taking place. Surely there are many actions, which seem to happen unnecessarily and to make no sense. But there is also something like a so-called "power of parallel search" by Cohen (1981): "highly uncertain and equivocal situations can be better explored by boundedly rational agents attacking the problem from multiple perspectives and selecting the best emergent solutions" (Warglien and Masuch, 1995, p. 7). And this phenomena is not an unknown although there are different names given. Lindblom (1959, 1964) chose the name "pluralism" and Thompson (1967) the term "intensive technologies" for almost the same thing. And all of them consider this kind of searching for an solution as a dynamic and creative one. Thus, further research is very promising for the progress in studies of organisational behaviour and can start up with the Petri net formalism supporting the concurrent and non-deterministic aspects. Maybe there will arise something like an "shaped disorder" and an unusual form of "situative social intelligence".

3. The Petri net formalism provides a view to decision processes studied, which is much more true to the theory than the original simulation. For example the fact that new problems and solutions appear by chance, choices are made unpredictable. This view is getting much closer to the implication of the theoretical model, which describes the interactions in a similar way. Beyond, in the original simulation model decisions are always made, when there is enough energy of the participants available. However, in the Petri net model some problems stay unsolved, which one might consider as the consequent pursuance of the principle of non-determinism.

4. There is a big question about processes taking place either in a totally irrational, or in a limited rational, or in a certain rational way according to the Garbage Can Model. Cohen, March and Olsen themselves are dealing with *rationality only implicitly*. Musselin for example interprets the reading of the term of rationality by the Garbage Can researchers as not existing. "To emphasize variations in actors‘ intentions, suggests that J.G. March et al. concluded that it is pointless to seek rationality in the actions of participants during the decision process" (Musselin, 1995, p. 62). From this statement Musselin derives the criticism that Cohen, March and Olsen deny any kind of rational behaviour from the beginning. So even if there is some, there is no chance to discover it. In Musselin’s opinion the term of rationality is understood in a far too narrow way. "Nevertheless, while it is actually harder for participants facing complex situations to elaborate long-term strategies or to anticipate the future, it seems fair to assume rationality in the actor’s behaviour, that is, his ability to reformulate the issues at hand in order to have some influence on the process, to seize opportunities or take advantage of the situation whilst it is changing" (Musselin, 1995, p. 63). One can understand and call such behaviour as a *"local" or "situative rationality*". Petri nets of the Garbage Can model in Heitsch et al. (2000) make the difference between "local" and the common sense of "global" rational behaviour clear respectively discovers an inherent contradiction between the theory and the original computational model itself.

6 Conclusions and Outlook

Computer models provide a bridge between empirical and theoretical work. The requirements of a computer model can provide a theoretical framework for an empirical investigation, and, in return, the empirical information is utilised in developing a flow diagram for the model. Through this process of working back and forth, it is possible to know when enough empirical information had been gathered and whether it is of the proper quality” (Cohen and Cyert, 1961, p. 127). These are again some wise and far-sighted words of Kalman Cohen and Richard Cyert, formulated in 1961.

By applying Petri nets operational semantics were given to the sociological theory. Formal modelling gave explicit meaning to behavioural assumptions which were only made implicitly in the original model by Cohen, March and Olsen. Thus, the formal approach leads to new views on the Garbage Can Model. New ideas of concurrent and non-deterministic behaviour as well as aspects of structure and rationality emerge. If one pursues the goal to deconstruct an existing theoretical model by going into its details and coming out with some new insight to its implications, the Petri net model provides the basis for interdisciplinary discussions, modifications, improvements to the theory, and, lastly, a better understanding how organisations work.

The presented work is one attempt to put a sociological model into a Petri net model. This approach is to be continued. What we explored by applying Reference Nets to the Garbage Can Model can be extended to other organisation theories and the prevailing views to organisations in common.

Relevant aspects for our view on good socionical theory building are:

- the nature of the view taken on the organisation,

- the dynamic aspects of decision making, which might express themselves as so far unknown "logics of action and interaction",
- the relation between action and structure in organisational decision processes.

The Petri net formalism involves the corresponding flexibility to all these aspects and can help to get this undertaking going. Also Petri nets can be regarded as a relevant and promising tool for the project work coming up. They bring to bear a mode, which is not popular to sociologists and their concepts, even though many of them would like to have it.

As well an organisation as a whole, as a matter of decision, as a group or a single actor can be modelled as a Petri net respectively a Petri net. The impact of organisation theory and connecting ideas to the sociological discourse will be a main challenge we will accept in our future co-operation.

For future research the organisation stands as a relevant miniature of society. Adding the Petri net formalism helps to model, formalise, and verify our theory of organisation sociology.

Acknowledgements

Thanks to O. Kummer, R. Langer, R. von Lüde, M. J. Macdonald, D. Moldt, L. Spresny, R. Valk, and F. Wienberg for the fruitful discussion of our work.

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