Simulation-Based Decision Support Modeling and Validation of Weak Anticipative Systems

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Abstract
Organizational systems are one of the more remarkable classes of weak anticipative systems in which decision making is the main force for its functioning and development. Simulation-based decision support is a holistic methodology for decision assessment in organizations. System dynamics is a proper methodology for modeling and testing the dynamic hypotheses of organizational systems. The role of subjects in model development and its validation from cybernetic, psychological and cognitive perspectives are discussed in this paper. Group participation in model building and validation is suggested in order to prevent the manipulation of dominant subjects and/or implicit dictators during modeling. This paper concludes with some useful examples of systems simulation in solving real problems.
Keywords: Decision Support, Simulation, Modeling, Validation, Learning

1 Introduction

Organizational systems (OS) are one of the more remarkable classes of weak anticipative systems in which decision making (DM) is the main force for its functioning and development. For these purposes, decision-makers need a different kind of object model and environment model in order to reach their goals and/or maintain the values of their variables. Simulation models, ICT and the systems approach provide direct inspection of different vision-based anticipation impacts on the future behavior of the system. However, a central part of the methodology is represented by model building and its validation and, therefore, the role of modelers in the model development. The model of OS consists of two parts: the model of the process itself and the model of the environment/state of the nature. While the object model could be more or less validated based on the structure, and the goal of the OS with its DM attributes, the model of the environment remains in the area of expectation. Therefore, the DM of such systems is based on utility function and risk acceptance. Due to the complexity of OS, there are many methodologies for DM purposes. It seems that the methodology based on simulation is one of the more holistic ones, which directly transfers to the idea of DM in a simulation laboratory providing experimentations on the basis of a what-if

International Journal of Computing Anticipatory Systems, Volume 26, 2014
Edited by D. M. Dubois, CHAOS, Liège, Belgium, ISSN 1373-5411 ISBN 2-930396-15-6

analysis beforehand certain strategy is selected. However, appropriate models are of primary importance for using this method. In general, three classes of complex systems can be identified: natural systems, biological systems (living systems) and organizational systems (human systems). All have certain structural similarities, yet there are huge differences in our understanding of their behavior. We will consider organizational systems as complex because of the different relations among subsystems, such as: psychological, social, political, material, financial, informational, etc. Their structure and functioning are changed because of changing relations among participants and the environment due to changes in information technology. In this case, the information-based decision represents the prevalent force of development. Computer simulation is one of the important methods for the studying, understanding and controlling series of organizational processes. Integration of simulation methods and artificial intelligence with a system for decision assessment provides a complex insight into business events, whereas a person with his/her ability to anticipate future decisions gains a new quality of decision. However, use of simulation in understanding complex system behavior is rather modest; nevertheless, the influence of the observer in the process of modeling the complex system is of primary importance.

In this paper, we discuss the role of subjects in model development and validation from a psychological perspective and the clarity of methodology from a cognitive perspective. This paper concludes with some example of usefulness of systems simulation in solving OS problems as well as development of model of learning using simulation model.

2 General Approach to Complex Systems Modeling Paradigm and Role of the Subject

In order to clarify the assertion that modeling methodology is an inseparable part of the context of the problem and can be described from the different perspectives of a modeler, we will start with a general definition of the word "systems". It is derived from ancient Greek and means a whole that consists of elements and is greater than the sum of its elements. An element is the smallest part of the whole, necessary for the system described, that cannot or will not be divided any further. From a formal point of view, a system is defined by the pair

$$S = (E, R) \tag{1}$$

in which $E_i \in E \subset U, i = 1,2,.n$ represents the set of elements and $R \subseteq E \times E$ the binary relation between the elements, and U the universal set. Each element $E_i \in E$ can be further set as well and $R_j \in R, j = 1,2,...m$ defining different relations between the elements. In general, three classes of complex systems can be identified: Natural Systems (mechanical systems), Biological Systems (living systems) and Organizational Systems (human systems). We will consider OS as complex because of the different relations among subsystems, such as psychological, social, political, material, financial, informational, etc. Their structure and functioning are changed because of changing relations among participants and the environment due to change in information technology. From the research perspective, human activity in order to gather new knowledge can be considered from two aspects: the subject of the research itself (process) and the methodology using different methods, tools and techniques for process analyses. Research methods are sets of rule-based knowledge by which we can consistently describe some process described by Equation 1 or a test hypothesis. Therefore, there are many different approaches and consequently descriptions of such a system.

There are three main concepts in the modeling approach to real world (Myers, 2009): a)Positivistic, which supposes that (1) the external world exists independently from the observer, (2) this world is not directly observable, and (3) for its representation, we develop simplified models. b) Interpretative, which starts with the assumption that social reality is a social construct and its understanding and interpretation is only possible through language, consciousness and shared meanings. c) Critical, in which researchers assume that social reality (realized reality), is historically constituted and that it is produced and reproduced by people.

The modeling paradigm can be stated (Kljajić, 1994) with a triad (O, S, M). O represents the real object; S represents the observer (subject) and M the model of the object as the consequence of observed knowledge, intention, interest etc. The relation between the observer, S, and the object, O, is of essential significance. The observer is a person, with all his cognitive qualities, while the object of research is the manifested world, which exists by itself, regardless of how it can be described. The third article of the triad M is the consecutive one and represents a model or a picture of the analyzed system O. The $O \leftrightarrow S$ relation indicates the reflection of human experiences to concrete reality. This cognitive consciousness represents our mental model. The relationship $M \leftrightarrow S$ represents the problem of knowledge presentation, i.e. the translation of the mental model into the actual model. The $O \leftrightarrow M$ relation represents the phase of model validation or proof of correspondence between theory and practice, which renders possible the generalization of experiences into rules and laws. The $S \rightarrow O \rightarrow M$ relationship is simply an active relation of the subject in the phase of the object's cognition. The $M \rightarrow O \rightarrow S$ relation is the process of learning and generalization. A theory is an intellectual construct enabling us to obtain a more generalized form of the phenomena of the research and direct results of the experiment. In the cognitive process, the value standpoints of subject Sv are far more important to us in relation to the object of research in the modeling process. This can be stated in the following equations: (2) and (3).

$$S_v \cap (O \cap M) = 0 \tag{2}$$

$$S_v \cap (O \cap M) \neq 0 \tag{3}$$

In the second parts of Equations (2) and (3), $O \cap M \leq 1$ are always fulfilled. (In the case of $O \cap M = 1$, the model and original are identical. This statement is valid for abstract, i.e. formal, knowledge). Equation (2) is valid for formal and natural sciences, where $S_v = \varnothing$ (empty set). This means that it is impossible to find any link between the axiom and the hypothesis linked to model M and the value standpoints of the subject. That is, of course, not valid for the scientific hypothesis in the process of modeling; this is always the product of the intellect and historically conditioned by the progress of science. Such hypotheses may always be rejected (Popper, 1973). In the case of organizational sciences and humanities in Equation (3), the value standpoints of the researcher and the object of the research are always $S_v \neq \varnothing$. Some qualities, which are not provable, are always added to the description of the observer in question. The conditions expressed by (2) and (3) have a key meaning in the choice of research methodology and for the scientific value of the statement. The first expression allows the establishing of the principle testable hypothesis by means of active experiments with the subject, while the second cannot and is not allowed to prove the hypothesis through experimentation, but by observation and generalization dependent on the qualities of the observer. This conclusion is similar to that of C. S. Peirce, (Peirce, 1931) and his three categories of being: *Firstness, Secondness,* and *Thirdness*. This means there is a triadic relation between the Sign, the Object, and the Interpretant and is not reducible to a set of dyadic relations between a sign and an object or between an object and an interpretant. Meaning is never reducible to *Firstness* or *Secondness,* but can always be found in genuine triadic relations. From the above elaboration, we can conclude that modeling is always context dependent, conditioned with the problem and the goal. The Subject, with his perception and perspective, has the main role in the modeling process. With complex systems, according Equation (3), the Systems approach is a holistic methodology to overcome different point perspectives of the modeler. With model-based control (weak anticipative systems), the Systems approach is other name for the process of modeling.

3 Anticipative Concept of Organizational System Within System Dynamics

Organizational systems are complex artificial goal-oriented systems designed by people to achieve certain purposes. Past states determine the system's memory: biological, social, cultural and historical (which is immanent and non-destructive for those systems, in contrast to computer memory), and together with the vision of individuals/groups of people who are part of the system strongly influence the future state. It was shown that a system's anticipatory essence and its development as well as growth are consequences of decision-making (Rosen, 1985). Therefore, the basic principle of its control is feedback and feed-forward information. For decision-making in an organizational system, information from the model, which represents the anticipation of the future state of the nature, is necessary. Such anticipation is known as weak anticipation (Dubois, 2000) and is an important part of the strategy of goal-oriented systems. The relation between feedback and feed-forward information (Kljajić, 2000) in the course of time in decision-making can be described as:

$$S(t+T) = F(S(t), M(t+T)) \quad (4)$$

$$M(t+T) = \Phi(S(t-\tau), M(t), E(t+T)) \quad (5)$$

in which S(t+T) and M(t+T) represent the state of the system and state of the model, respectively, at time horizon t+T and time history t-τ. F and Φ represent the mapping of the system $F: S(t) \times M(t+T) \rightarrow S(t+T)$ and the model $\Phi: S(t-\tau) \times M(t) \times E(t+T) \rightarrow M(t+T)$. The state of the environment E (t+T) is usually estimated as the state of the nature. One promising methodology for modeling organizational phenomena is system dynamics (Forrester, 1958). The idea of modeling is based on the supposition that every real system, as well as any business system, could be described by the system of equations that is represented by the interconnected flows or Rates and Storages i.e. Levels:

$$S = (L_j, R_i, A_r)\, j = 1,2,..n,\, i = 1,2,..m, r = 1,2,.l \quad (6)$$

Here L_j represents the set of Levels (stocks) and R_i the set of Rates (flows) and A_r the Auxiliary expression by which we can express arithmetic relation among L and R. Each level, L, or state element has its own input i.e. input rate R_{in} and its own output Rate, R_{out}. Figure 1 shows symbolic representation of described elements.

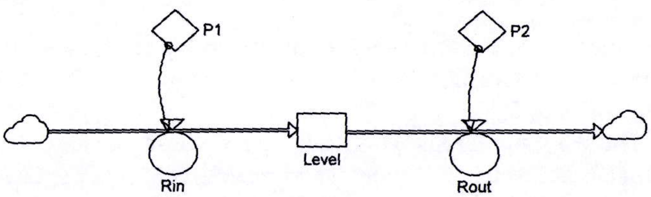

Figure 1. Basic elements of System Dynamics

The conservation of mass principle for the above model could be described by the dynamics equation in the form of difference equation:

$$L(k+1) = L(k) + \Delta t(R_{in}(k) - R_{out}(k)) \quad k = 0,1,2,..n \quad (7)$$

in which k represents discrete time, Δt is the time interval of computation. Each entrepreneur understands that the value of Level element $L(k+1)$ increases if $R_{in}(k) > R_{out}(k)$; it is unchanged if $R_{in}(k) = R_{out}(k)$, and decreases if $R_{in}(k) < R_{out}(k)$. In Figure 1, P1 and P2 represent the decision parameters by which the flows are regulated to and from the Level element. The clouds at the beginning and at the end represent the environment of the model. This is therefore our boundary of modeling of the addressed model. From the formal viewpoint, this method is indeed straightforward and clear, as well as understandable. In case of a concrete problem, the possible meaning of L and R elements are obtained. There are several methodologies for complex problem solving similar to System Dynamics, such as the Systems Approach and Systems Thinking. All three procedures are almost the same; small differences can be observed only on the lexical level (Kljajić, Fahr, 2010).

The first step is defining or stating problem, or describing the system. When we talk about the problem, we anticipate part of the process (or the systems) with whose functioning or behavior we are not satisfied. From an engineering perspective, it means deviation of the state of reference variables values.

The next step is determination of the desired value of the state variables, i.e. the goal of the problem to be solved. Following this step is the dynamic hypothesis or a theory how to reach this goal, i.e. by changing parameters or structure of the systems (process part or control). Of course, SD (or modeling in general) does not deal only with solving problems. Weak anticipation also means foreseeing potential problems and preventing undesired behavior with different vision-based scenarios and structures. In his methodology, Forrester (1994) emphasized the step "Educate and debate". Without users' participation and their understanding of the problem in the course of SD (or any other) methodology, there can be no successful results.

4 The Modeling of Organizational System in the Psychological Framework

Who then is the person, who is aware of himself and his environment and who tries to understand reason and consequence as well as predict the future? Consciousness is one of the main attributes of the person who takes part in the modeling as well as the decision-making process. There are numerous works devoted to consciousness from philosophical, psychological, social as well as biological perspectives. For its unconventional yet important approach to accessing human subjects in the modeling process, we will mention the work of Stevanić (1996): *Psychological Theory of Quantum* (PTQ). The psychological part of the book treats the individual in the interaction with the environment. A man is an *Ego Quantum of will for power* consisting of a Real Ego and an Imaginary Ego defined as:

$$\text{Ego Quantum} = \text{Real Ego} + \text{Imaginary Ego} \qquad (8)$$

Consciousness is derived from both mind and body and is indivisible. A similar concept but in different context, unity of body and mind and technique can be found in the method of Zen way to the martial arts (Deshimaru, 1999). However, the contest of mind can consist of truths and untruths. Therefore, consciousness is divided into a consciousness of a Real and an Imaginary Ego. In Stevanić (1996), Ego Quantum is a constant psychological unity, while Real Ego and Imaginary Ego are changeable within expression (8). Indeed, we are always a whole person, no matter if we lose some part of the body or damage part of the brain (observable from the outside) but the ratio between the Real and Imaginary consciousness is changed, which can't be observed from outside. Real Ego or reality consists of the consciousness of Real Ego and soma, which are indivisible. Both contain truths and in the Ego Quantum frame represents truths directed toward progress and the realization of the human essence. We can write: Real Ego = soma ⊕ consciousness of the Real Ego (the sign ⊕ signifies this is not the case of an algebraic sum). Greater consciousness of Real Ego means greater Real Ego and the inverse. For the soma, it is valid that a stronger soma is reflected on the greater Real Ego, which means a smaller Imaginary Ego. And the inverse: illness, exhaustion and advanced years weaken the soma and the Real Ego; therefore, the consequence is the strengthening of the Imaginary Ego. According to the PTQ, even lies, fear, ideology etc. weaken the Real Ego and consequently strengthen the Imaginary Ego.

Causal loop diagram CLD of the Ego Quantum in interaction with the environment is illustrated in Figure 2. Positive change in the environment on the person's intention ***c*** causes the person's satisfaction and rise of Real Ego (positive feedback) and automatically lessens the Imaginary Ego. The resistance of the environment to the person's intention ***c***, whose ambition is to win, modifies its concept of defeat by "trick of mind" in increasing Imaginary Ego and in this way changes "the defeat" into a success. It is obvious that subject intention ***c*** is a vector composed from numbers of attributes of Ego Quantum willpower (Stevanić, 1996).

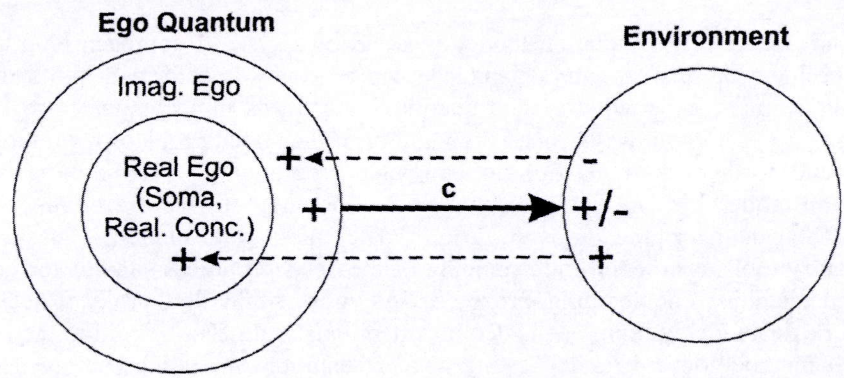

Figure 2. CLD of the Ego Quantum of will for power in its surrounding: intention ***c***→ + change of environment → + increase of Real Ego, intention ***c*** → - resistance of environment → + increase of Imaginary Ego.

The Real Ego in the frame of Ego Quantum of will for power produces an Imaginary Ego, which is just appropriate to compensate failure of real ego in order to maintain its biological integrity. It tries to conceive information in a way to correspond to the Ego Quantum and not to reality. One example to illustrate that and support Equation (8) is anorexia, a very difficult contemporary disease. From different causes in the environment, the subject rejects eating food and loses body mass, yet the subject perceives this as beautiful. The Imaginary Ego is that part of the human psyche, which is subjugated to manipulation and create an "inner shadow" as consequence of the Imaginary Ego preventing objectivity in researching society.

If we collect group of subjects to model some part of the environment, so cold group model building we will obtain a different view on the model due to variety of Real and Imaginary Egos. For example, if the problem of interest is objective then the model are coherent. However, if the problem of interest is society or ecology then the model as the result of group building is rather spread. Imaginary Ego is ideal media for social manipulation. This fact clarifies Arrow's 5^{th} axiom (Arrow, 1951) of the presence of dictators (even implicit) through social manipulation. On the basis of social identification through the Imaginary Ego, we can measure power for the will of a group, directed by leadership towards another group. That is the reason for different world views on complex systems modeling, although we used the systems approach as an example. Although there are several methodologies, many of them are "whole-ing the parts and righting the wrongs" as remarked by Ackoff (1995). This is why society has to ensure conditions and freedom in educating people in order to develop and perform creative abilities of their Real Egos. Only in this way will new education and people become less receptive to manipulation (Kljajić, 2000). One of the promising approaches is System Dynamics and the Systems approach from elementary school to university.

5 Simulation Model As a Tool for Decision Support

The advantage of a simulation model as a part of a systems approach is in the fact that a problem defined in natural language can be easily transformed into a directed graph, convenient for qualitative and quantitative analysis in a computer program. In this case, the user can always check the validity of the stated problem within a certain theory and further its translation to computer programming. Furthermore, with a simulation model one can, with a tentative set of assumptions, verify the model-based theory (Schwaninger and Grösser, 2008). The simulation model is used as an explanatory tool for a better understanding of the decision process and/or for defining and understanding the learning processes. As most simulation projects necessitate teamwork for model building, considerable attention should also be paid to the issue of research methodology of model testing and presentation of findings before decision-making process (Andersen et al, 1997). This problem of group model building we discussed in section 4. In order to test the hypothesis concerning the impact of the simulation models on the decision-making process, a business simulator was developed (Škraba *et al.*, 2003). The model consists of production, workforce and marketing segments. The subjects in the performed experiment had to find the proper values of simulator parameters, $P_i \in P$ in order to optimize criteria function CF. The role of the participants was to change the parameter values via the user interface, which incorporated sliders and input fields for adjusting the values. They could monitor the simulator response on the output graphs showing the four decision criteria (Capital Return Ratio, Overall Effectiveness Ratio, Workforce Effectiveness Ratio, and Inventory Income Ratio) as dependent variables or any other state variables of the model. With this, in contrary with group model building, we researched impact of model on decision support.

A total of 147 senior undergraduate management students were randomly assigned to work on three experimental conditions.

a_1) Determination of strategy on the basis of a subjective judgment of the task.

a_2) Individual determination of strategy supported by a simulation model.

a_3) Individual determination of strategy supported by a simulation model and Group Information Feedback.

The results of the decision process gathered when group feedback information was introduced revealed that the Criteria Function values of Group a_3 were higher than in cases where the decision was based only on individual experience with a simulation model (Group a_2), and the lowest Criteria Function values were achieved on the basis of subjective judgment (Group a_1). These results were confirmed on a $p=.01$ level of significance. In order to explain the influence of individual information feedback (assured by the simulation model) and group information feedback (introduced by GSS) on the efficacy of problem solving, we have developed a causal loop diagram (CLD) of learning during the decision-making process. The model shown in Figure 3 was modified according to (Lizeo, 2005, Kljajić Borštnar, 2006) and consists of three B (balancing) and one R (reinforcing) loops. Loop B1 represents the decision-making process supported by just a formal CLD model, and a paper and pen (Škraba *et al.*, 2003; Škraba *et al.*, 2007). The decision maker solves the problem by understanding the problem and the task. The higher the gap between the task performance and performance, the more effort should put into understanding of the problem and find appropriate parameter value P_i.

Loop B2 represents decision-making supported by a simulation model and corresponds to experimental conditions a_2 and a_3 (groups supported by just individual feedback information of a simulation model). The higher the gap between the goal and performance is, the higher the frequency of simulation runs is. The search for the optimal parameter values is based upon trial and error. The more simulation runs that the decision maker performs, the more he or she learns (on an individual level), and the smaller the gap between performance and goal is (in our case the optimized CF). We have named this loop "Individual Learning Supported by Simulator".

Loop B3 represents the direct contribution of group information feedback, while loop R suggests the reinforcing effects of group influence on problem solving in Groups a_3 (groups supported by individual feedback information of a simulation model and group information feedback provided by GSS). The decision maker at a_3 experimental condition with Loop B3 understands better the problem and the goal. He or she is supported by both simulator and group information feedback. While the use of the simulator supports individual learning, the introduced group information feedback enhances the group performance. Consequently, the increased group performance reduces the need to experiment on the simulator (try and error). In other words, a decision maker supported by group information feedback has a broader view of the problem, insight into new ideas and needs to put less effort into problem understanding. In contrast, the group information feedback stimulates group members to actively participate in problem solving, so that they perform more insight into results of group information in the process of searching for the solution (Kljajić Borštnar, 2006). Loop R can be further explained by interaction between group information feedback and facilitation of the decision-making process. As we observed in (Kljajić Borštnar *et al.*, 2011), the group information feedback with facilitation contributes to higher feedback seeking behavior and higher commitment to problem solving. Facilitation in this case serves as motivation and orientation towards the goal and was discussed in detail in (Kljajić Borštnar *et al.*, 2011). When the group is satisfied with its performance, the frequency of simulation runs decreases with time.

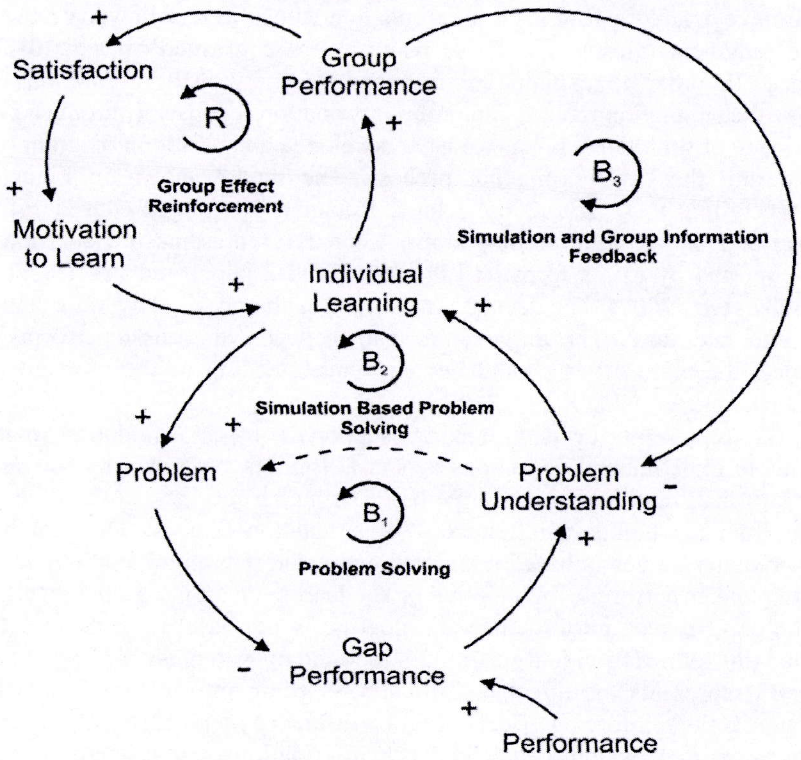

Figure 3. Causal loop diagram of group problem solving and learning using GDS adapted from (Kljajić Borštnar, 2006)

Participants' opinions about participation in the experiment have been solicited by questionnaires. Participants completed the questionnaires via a web application. Questions were posed in the form of a statement, and agreement to the statement was measured on a 7-point Likert type scale, in which 1 represents very weak agreement, 4 a neutral opinion, and 7 perfect agreement with the statement. There were 10 basic questions about the experiment. The ANOVA test showed high agreement in opinion between groups. From the questionnaires, we can gather some general observations:

1) 99% of the participants agreed that the experiment was of high quality,
2) 83% of all participants agreed that the decision problem was correctly presented,
3) 68% of all participants agreed that they understood the presented decision problem,
4) 93% of all participants agreed that the simulator was easy to use,
5) 84% of all participants agreed that the use of simulator contributed to understanding of the problem,
6) 70% of all participants agreed that there was enough time for decision making,
7) 63% of all participants agreed that they were motivated for solving the problem,
8) 88% of all participants agreed that they benefit from participating in the experiment,
9) 97% of all participants agreed that experiment was well organized,
10) 92% of all participants agreed that use of the simulator contributed to a better decision-making.

6 Conclusion

Our goal was to highlight the usefulness of SD methodology in research and implementation in management IS, particularly in decision support systems. SD was considered from general system theory. Model-based control is other name for weak anticipative systems. The subject, with his perception and perspective, has the main role in the modeling process of complex systems. His property so far has been discussed from psychological aspect and CLD of his behavior was developed. The Systems approach is a holistic methodology to overcome different point perspectives of the modeler in group model building.

Developed CLD model on Figure 3 represents common background of three experimental groups with regard to group problem solving and learning. All participants in cases a_2 and a_3 agree that clear presentation of the problem motivates participants to find the solution. The use of realistic yet sufficiently simple business models and GDS technology is essential, if one wishes to close the gap between business processes understanding and the role of modeling and simulation in problem solving. Developed CLD model could be usefull in any case of complex problem solving.

The advantage of SD as a part of Systems Approach is in the fact that a problem defined in natural language can be easily transformed into a directed graph convenient for qualitative and quantitative analysis in computer programs. In this case, the user can always check the validity of the stated problem and the model developed. SD enables studying the behavior of complex dynamic systems as a feedback process of reinforcing and balancing loops. As a methodology, applying SD in analyzing complex system behavior is very important for several reasons: It is **simple,** because it is based on the natural laws of Rate and Storage that describe relations between elements in quantitative/qualitative relation; it is **transparent,** because it allows unique discussions about elements relations defining problem; it is **coherent,** because it consists of simulation tools harmonized with methodology and the problem to be solved. Human knowledge and the simulation methodology combined in decision support systems offer new levels of quality in decision making and research. In the future, we expect that the methodologies of Simulation and the Systems Approach should be more intensively fused into one holistic methodology, the System Simulation methodology, and more intensively applied to social and ecological systems.

Acknowledgements

This research was supported by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia (Contract No. P5-0018).

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