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Evaluation of Group Decision Process on Enterprise Simulation Model

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Abstract

Decision processes in modern enterprises are primarily based on the participating subjects. The results of choice are therefore not dependent on the individual decision but rather on the group of experts working in the specific field. Their interaction in the process of solving decision problems is supported by group support tools and interactive business simulators, which enable individual and group analysis of problem states. The simulation scenarios considered are made of two subsets: a subset of input that anticipate the impact of the environment such as demand and competitors (exogenous scenarios), and a subset of management decisions influencing production, quality of products, capacity development and other parameters that represent endogenous scenarios. Each member of the experimental group, who participated in the described experiment, can evaluate different alternatives for given input scenario in order to get the highest score for criteria function. The evaluation of scenarios was treated using two different methods: 1. Each subject had own feedback information provided by the simulator while, method 2. implemented group feedback connection. In the case of method 2. subjects had the opportunity to compare their decisions made by using method 1. with the group decision gained by the same method. Group feedback information has caused a faster convergence of decision process. The methodology was tested in an experimental environment and in the real case.

Key words: GDSS, System Dynamics, Simulation Scenarios, Group Decision Experiment

1. Introduction

Decisions involving large financial, technological and logistic resources require decision makers to simulate before taking any action in the production process (Kljajić, et al., 1998). The decision-makers in the production process are supported by the simulator, which enables the testing of decisions associated with business plan. As in all organizational systems the subjective factors such as human skills and creativity play important roles in efficient problem solving. The participation of the team in the decision process is therefore of major importance for making the "optimal" decision. The simulation model included in the user-friendly simulator enables decision-makers to explore different simulation scenarios. Implementation of the Group Support Decision System (GDSS) enables the participants in the decision process to test various business scenarios and share a common view on the problem state. The repercussions of the test scenarios are understood in a risk-free environment prior to any actual implementation in the production process.

The use of the simulation as the base for the decision support gives new quality to anticipated information, which facilitates the adaptive nature of the decision process. Figure 1 represents the process of using the simulation scenario.

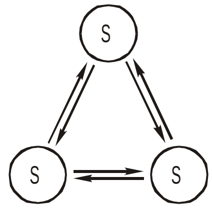

Figure 1: Simulation, Scenario and Selection

The main goal is solving practical control problems via the simulation by following the main virtual reality paradigm as shown in Figure 1. Three entities of Simulation, Scenario and Selection are interconnected in the process of searching the desired result. Consequently, decisions made with the aid of organizational simulation models are not only concerned with the feedback dynamics but also with possible inputs into the system at the prescribed criteria (Kljajić et al., 1998).

System dynamics, multiple-criteria decision methods and decision support systems interconnection field had many researches (Chuang and Yadav, 1998; Karim *et al.*, 1998; Richardson and Andersen, 1995; Larsen, 1997; Ruth and Hannon, 1997; Kwok and Khalifa, 1998; Vennix, 1996), but the methodology should be further developed and integrated for implementation for real application in practice. The reason lies in the complexity of the decision-making task in organizational systems. The proposed methodology integrates system dynamics models and group support systems, enabling users to gain useful information about the considered real system in the form of scenarios and different simulation models.

2. Methodology

Decisions in complex systems require a decision team (team approach) and system approach methodology (Kljajić, 1995). From the decision point of view, the organizational system is defined as $S = (P, D)$, if mapping exists (Mesarović and Takahara, 1989) $P : X \times U \to Y$ and $D : X \times Y \to U$ such that it satisfies $G : X \times Y \times U \to V \in R$ and $E : X \times Y \times V \to U$, where X and Y represent the input and output of the system, P process, D decision process, G objective function and E evaluation strategy, Figure 2.

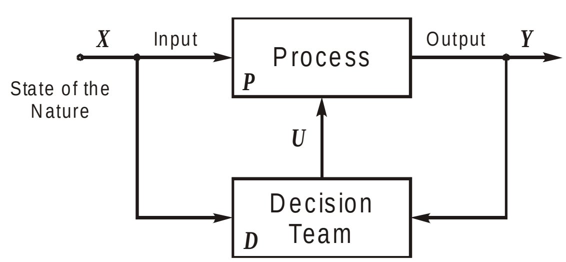

Figure 2: General model of a goal oriented system

Note that G represents the objective of an alternative, while E represents the subjective evaluation of the decision. Consequently, the decision in an enterprise is not primarily concerned only with feedback dynamics (selecting of proper parameters of rate elements), but with rate elements matched with possible input into the system and defined criteria. The following three basic feed-back loops of learning through the simulation method are highlighted in Kljajić (1994):

a) the causal or feed-back loop represents the business result as a consequence of former decision-making, and being a part of management experiences and the history of the system,
b) the aposteriori information about model applicability and former decision-making, and
c) the anticipation or intellectual loop provides the feed-forward information which is essential for the formulation of the system strategy obtained through simulation.

In this context a simulation model of the organisational system can be divided into two parts: the subsystem of the basic model (production process and finance) and the decision model. The problem was stratified from the individual goal, group goal, economy, technological and environmental aspects. Taking in account the goals, objectives and restrictions, the model was built to meet these requirements: to predict and gain an insight into production processes for planning purposes.

3. Application of System Dynamics Model

The business simulation system used in the experiment consists of a production model, raw material ordering model, marketing model considering different demand functions and a financial section. The three different end products modeled are made from different raw materials. Each of the products has it's own marketing demand function which is subject to market assimilation. Modeling of different productions and demand functions permits an analysis of different marketing and production mixes. The general simulation model of a business system is described by the System Dynamics methodology.

In the simulation process, market demand is the parameter, which is determined heuristically by an expert group in the form of a demand function. The model enables price changes for different products, management costs, labor costs, raw material costs, warehousing costs, use of different marketing costs depending on market acceptance, and investment analysis. The demand function is modeled in three different ways: as an active marketing function, non-cyclic step and random function. The work on the model was supported by the Group Support System (GSS) as described in (Kljajić at al.,1998a). Users have the opportunity to actively participate in the decision process by defining relevant criteria and their importance, in spite of the large number of different simulation scenarios. The decision process is clear, intuitive and creative. The user-friendly interface of the developed simulator allows the user to perform the tests easily. Different simulation scenarios are tested in groups to find the preferred solution. The process of scenario evaluation is conducted with the multicriteria decision function and expert judgment of the users. The chosen scenario provides the basis for the actual execution of the decision.

The basic component captured in the proposed decision support system is the dynamics of the system as a reflection of the structure. In modern organizational systems the complexity is the main attribute, therefore an important decision always involves a group of experts who must share the same view on the decision problem in order to obtain a proper decision. The System Dynamics (SD) model provides information about the structure and dynamics of business processes. The process of modeling and validation of the model contributes to the overall awareness of the real system structure and behavior. New information is obtained mainly in the process of experimentation with the model. Different scenarios provide a tool for structuring the information of the system's behavior. Information outputs generated with the aid of the proposed methodology are captured with GDSS in the form of scenarios and multi-criteria function. While the decision maker is the only one who can select the 'best' alternative and who has the final word, it is the process by which the decision is made that science can judge (Henig and Buchanan, 1996).

3.1 Group Decision Process Experiment

Our goal was to obtain a relevant evaluation of the simulation scenarios through the participation of actors in the business system who are most acquainted with the business processes and entities. The simulation scenarios are made of two subsets: a subset of input that anticipates the impact of the environment such as demand and competitors (exogenous scenarios) or the state of nature, and a subset of management decisions influencing production, product quality, capacity development and other parameters that represent endogenous scenarios. They give the answer to the basic question of system effectiveness with regard to the problem of proper resource allocation. The procedure of choosing the best scenario is known as the "what-if" analysis. The generation of scenarios of the simulation system that respond to the "what-if" is based on the variation of parameters of the basic scenario for the extrapolation of past behavior and expert evaluation of development targets with the Brainstorming method. Variants of business scenarios are evaluated with the linearly weighted sum of the multi-criteria decision function. The state analysis and decision-making is constrained on account of the complexity and large number of parameters incorporated in the models of organizational systems. Multiple criteria functions enhance the level of the model abstraction and partially avoid the complexity of decision processes. Subjects involved in the decision process (S_1, S_2, ... S_n) use individual decision support systems marked as (IS_{n1}, IS_{n2}, ... IS_n), providing them with the possibility to test different scenarios on the model. Individual decision support systems feed the data into the GSS, providing the informational feedback about the group's common view of the problem state, which can be established by many different methods, e.g. averaging.

Different simulation scenarios were tested on the simulator providing new views of the organization. Each member of the expert group can test different alternatives in order to obtain a better insight of the problem state. The experts themselves generate a large set of different scenarios, which must be discussed in the group. Participants involved in the group decision experiment were last year students of the graduate study. There were 71 students involved in the experiment, divided into seven groups. Eight different scenarios were presented to the participants in the experiment. The scenarios were formed by the variation of different business parameters. An experiment applying the proposed methodology was conducted in a computer laboratory equipped with twenty networked computers each providing a system simulator and net access, which was used for passing the feedback information to subjects. Participants were familiar with SD methodology and computer technology. The experiment conducted on the proposed system (with a test group) started with an introduction to the business simulator application. The model used in the experiment had the following six different user-definable parameters: price of products, price of raw materials, administrative expenses, cost of goods, cost of workforce, and warehouse costs. The participants monitored the results from the simulator showing there financial parameters: net sales revenues, gross profit from sales, operating profit, total profit/loss, operating effectiveness ratio, participation rate of administrative costs, and net return on capital. The group task was to select from eight different business scenarios which were verbally presented. The evaluation of different scenarios was achieved using two different methods: 1) expert evaluation supported with the simulation model – the participants at this stage used the simulator individually to evaluate scenarios, and 2) expert evaluation supported with the simulation model and group feedback information – the evaluation was supported with the simulation as in the previous case, enhanced with feedback information passed through the network about the group decision. The difference between method 1 and method 2 was in the type of feed-back information. Method 1 had individual feed-back information provided by the simulator while method 2 implemented the group feedback connection. The subjects applying method 2 had the opportunity to compare their decisions made using method 1 with the group decision gained by the same method. Group feedback information created a faster convergence of the decision process as can be seen in the next chapter, an analysis of the results. These were analyzed in terms of the information feedback on the decision process according to the next hypothesis: 'The acceptable solution is the average score of the scenario range of the group assuming that there is no bias in the decision process and that all decision-makers, i.e. subjects, act rationally.' Let us also assume that the coherence of the decision depends on the deviation of individual decisions from the group mean. The deviation from the group mean should therefore be smaller in the case of implementing group feedback information.

4. RESULTS

The evaluation of scenarios was conducted at a scale of 1-10 (1=worst, 10=best). Each of the participating subjects evaluated scenarios with the appropriate number of points. The mean of the scenario evaluation $\bar{x}_i, i = 1,..8$ was computed in order to gain the group evaluation of the particular scenario. The mean deviation for each subject was computed as: $MD = (n^{-1}\sum_{i=1}^{n}(x_i - \bar{x}_i)^2)^{1/2}$ representing the deviation between an individual evaluation of a particular scenario x_i and the group evaluation of scenarios where n is the number of scenarios, in our case, 8.

The mean deviation is represented in the form of a continuous distribution showing that using a decision supported with the simulator deviates from the decision gained by using the simulator with the group information feedback since the mean differences are 1.73 and 1.30. The effect is represented with the smallest mean deviation from the graph. Figure 3 shows the effect of information feedback in the decision process conducted by the proposed methodology under two previously described conditions: 1) Expert evaluation supported with the simulation model (marked as Sim. on the graph), and 2) Expert evaluation supported with the simulation model and feedback information (marked as Sim. Feedback I on the graph). The X-axis represents the rank of differences from the mean, i.e. group decision. The smaller the deviation, the more convergent is the decision process.

The X-axis represents the mean deviation, while the Y-axis represents the cumulative ratio of subjects who evaluated the scenarios. The upper curve on the graph is the evaluation with the aid of simulation and group information feedback. It reveals that the decision subject evaluation is less divergent than in the case of the evaluation supported only with the simulation model.

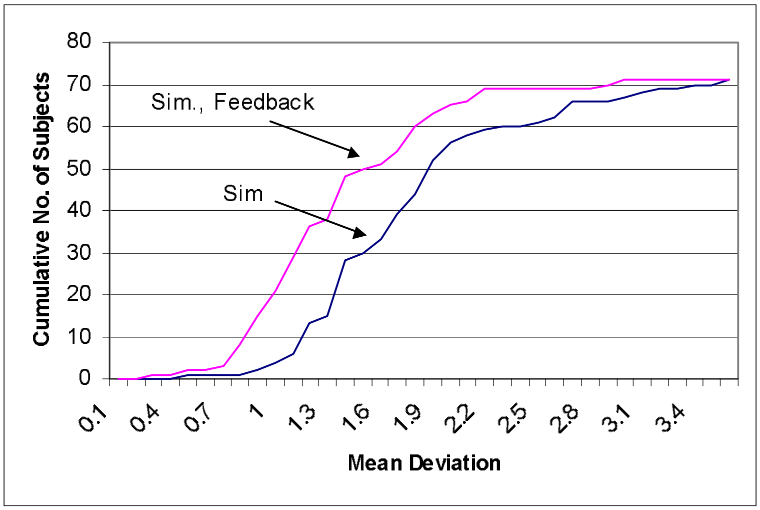

Figure 3: Convergence of the decision process

The significance of the difference between group decisions was tested with the t-Test. The hypothesis H1 was stated as: "*Evaluation of scenario change with group feedback information.*" Results of the t-Test between the evaluation under the first testing condition, i.e. use of the simulator, and the second testing condition, i.e. applying feedback information, showed that the hypothesis is accepted at the critical level of p=0.01 for all scenarios except: SC2, SC5, and SC7, where the deviation of group decisions was not significant on account of the consensus of the group about a particular scenario. The hypothesis of the influence of informational feedback passed to the group of decision subjects on the convergence of the decision process can therefore be accepted.

The Chi square test of independence of deviations from the 1st and 2nd experiment showed that $\chi^2 = 13.94$, which is higher than $\chi^2{}_c = 12.84$ required for significance deviation at the p=0.005 level. The hypothesis of smaller differences among in-group decisions when group feedback information is applied can therefore also be accepted.

5. DISCUSSION

The methodology was implemented in the real case in the reengineering of production and the production planning process. The implemented model built on the SD methodology included the financial aspect of investment in new equipment. In the implementation of the methodology in a real case five members of the management structure were involved in working with the system. The group consisted of one business manager, two production managers and two financial experts. The group worked in interaction among its members, similar to the previously described experiment where convergence in the decision process was expected. Structural changes and changes of different parameters in the model reflect a certain management of knowledge incorporated in the model structure. The expert group estimated different business parameters. The model generates results as shown in Figure 4. Five of the different expert-defined scenarios were tested on the model. The X-axis represents simulation time while the Y-axis represents Profit on the left-hand side of Figure 4 and the Operational Effectiveness Ratio (OER) stated as: $OER = opereting\ revenues / opereting\ \exp enses$,on the right-hand side of Figure 4. In the estimation of investment profitability the prediction for the next 10 years was used on the basis of past data and an expert estimation of future demand. Different investment arrangements were modeled and tested. The expert group conducted a validation of the model. Different simulation scenarios were run on the model too. In the process of validation some parameters were adapted according to the suggestions of the experts.

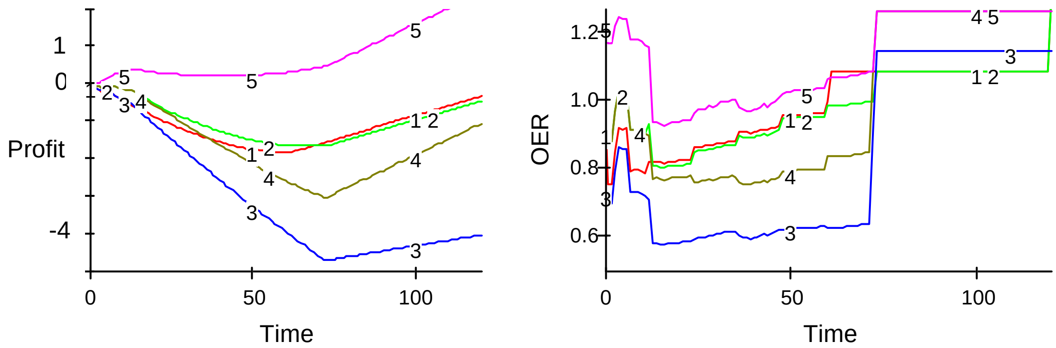

Figure 4: Different business scenarios created by the expert group in a real case

The model of financial flows enables the user to analyze the effectiveness of different business scenarios. The model is connected to active production data providing dynamic analysis and development control. The influence of investment costs, depreciation plan, risk of market demand, prices and sales can be observed on the model. The future may lead to unpredictable conditions, which could be anticipated with the use of a simulation on the model. In the case of large deviations in production the proper solutions are found using the simulation model. Proper business measures are taken in order to optimize the overall effectiveness ratio. The system enables the user to test a set of different scenarios with the purpose of conducting investment analysis and controlling the development of the business according to market demand. Implementation of the model enables a “what-if” analysis. The model is connected to the actual database of the company. With simulation the positive trend of development was indicated according to current investment and anticipated production. The expected profit of the company is considerably large after investment costs drop. The model showed that the decision to invest in new equipment has a positive financial effect on the company. In the process of validation of the simulation system many different scenarios were tested. The knowledge about the systems was gained through working on the model and group interaction. As a result, the new definition of fixed and variable costs was established and the new depreciation costs were stated.

6. CONCLUSION

Developed methodology implements business models as a tool for decision support in the form of a model structure and set of scenarios, which are determined by the expert group. Different expert views are standardized with the implementation of the business scenario design methods, which form an adequate basis for executing coherent strategic operations. The approach presented connects the methodology of system dynamics by allowing experimentation on business simulation models and multiple criteria group decision problems.

As in all processes, the information gathered by the decision-maker defines the quality of the decision. The feedback effect of using a simulator with the information feedback was analyzed with the preliminary experiment indicating that the informational feedback connection enhances decision process convergence.

The proposed methodology was also implemented in a realistic case where the results demonstrate the suitability for group decision process support. The knowledge captured in the model structure and defined by scenarios is the transformation of group perception of the real process and its future behavior. Understanding the model is dependent on all participants in the production process, therefore group modeling and scenario testing represent one of the methods to enhance and manage the considered system.

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