Roberto Moreno-Díaz Franz Pichler (Eds.)

Computer Aided Systems Theory – EUROCAST 2003

9th International Workshop on Computer Aided Systems Theory
Las Palmas de Gran Canaria, Spain, February 24-28, 2003
Revised Selected Papers

Springer

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Cataloging-in-Publication Data applied for

A catalog record for this book is available from the Library of Congress

Bibliographic information published by Die Deutsche Bibliothek
Die Deutsche Bibliothek lists this publication in the Deutsche Nationalbibliografie;
detailed bibliographic data is available in the Internet at <<http://dnb.ddb.de>>.

CR Subject Classification (1998): J.6, I.6, I.2, J.7, J.3, C.1.m, F.4, F.3

ISSN 0302-9743

ISBN 3-540-20221-8 Springer-Verlag Berlin Heidelberg New York

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Springer-Verlag Berlin Heidelberg New York
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www.springeronline.com

© Springer-Verlag Berlin Heidelberg 2003
Printed in Germany

Typesetting: Camera-ready by author, data conversion by PTP-Berlin GmbH
Printed on acid-free paper SPIN 10949948 06/3142 5 4 3 2 1 0

Modeling with Archetypes: An Effective Approach to Dealing with Complexity

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Abstract. In the face of growing complexities, agents who lead or manage organizations must revert to better models. This proposition is based on the Conant/Ashby Theorem, which says that the results of a management process are determined by the quality of the model on which that process is based. The author proposes that archetype-based modeling is a promising way to enhance the behavioral repertory of agents in organizations and society: It aids in achieving better models and thus in coping with complexity more effectively. Experiences with System Dynamics modeling of real-world issues and problems as well as the pertinent results achieved are reported. The special flavor of the cases described lies in a new quality and speed of learning-by-modeling, which was unachievable a few years ago. This is now enabled by a) an advanced methodology of modeling and model validation, b) the conceptual maturity of systems archetypes, and c) the availability of powerful simulation software.

1 Introduction: Objectives and Motivation

The speed and uncertainty of events have grown, and with them the need for a better understanding of dynamic complexity as a basis for managerial action. Therefore, models of complex systems which link qualitative reasoning and quantitative decision support have become increasingly necessary in the domain of management. However, areas such as strategic management and organization design have been dominated by verbal argumentation. These fields have shown resistance to quantitative modeling. One of the reasons is that many researchers and practitioners have considered the path toward solid, quantitative decision support too difficult or even impossible in the face of organizational complexity.

The purpose of this paper is to show that "systemic archetypes", as proposed by Senge [14] and Wolstenholme [18], can open a new way to deal with such complexity effectively and efficiently.

This paper emanates from the tradition of System Dynamics modeling and simulation, a powerful stream of the Systems Approach [cf. 13]. In section 2, an overview of modeling and simulation with System Dynamics will be presented. The theoretical basis of the postulate for better models, which has motivated this paper, is the *Conant-Ashby-Theorem*. This theorem will be expounded on – in connection with the concepts of *essential variables* and *archetypes* – in section 3. An account of the

applications of archetype-based modeling and simulation – the core of this paper – will be provided in section 4. The paper is finalized with a discussion in section 5 and the conclusions in section 6.

2 System Dynamics Modeling and Simulation

System Theory has bred a very powerful approach for enabling a better understanding of dynamic complexity in organizations and society – System Dynamics (SD). With "SD", the author refers to a modeling and simulation methodology which originated from M.I.T.-Massachusetts Institute of Technology, where it was invented by Professor Jay W. Forrester [6,7,8].

In SD, systems are modeled as closed loop systems, which largely generate their dynamics internally. They are essentially made up of stocks and flows (→ differential equations); temporal delays are carefully modeled. Given its generic features and the strong software tools available (Stella/Ithink, VENSIM, Powersim, MyStrategy, Jitia), the SD methodology is extraordinarily efficient at grasping the dynamics of complex systems and exhibits exceptional strengths for modeling and policy analysis with regard to socio-technical systems. Applications in organizations have been subject to sustained growth. Factors which appear to restrict the diffusion of SD are a somewhat limited availability of conceptual knowledge leading to good models and a certain resistance on the part of practitioners to engage in comprehensive, methodologically rigorous "modeling exercises".

Recent developments in literature, software technology, and the worldwide exchange of knowledge across the growing community of system dynamicists will gradually eliminate these restrictions. In addition to the journal of that community, the System Dynamics Review, the cumulated knowledge on System Dynamics modeling and simulation is made available in excellent introductions [e.g. 12, 10], text and handbooks [e.g. 15, 11, 16], as well as by means of a continuously updated bibliography edited by the International System Dynamics Society [17]. Standard software packages – Stella/Ithink, Vensim, PowerSim, MyStrategy and Jitia – facilitate the access to the modeling and simulation technology. Generally, the software enables the design of user-friendly interfaces ("cockpits"). The packages also provide features with varying emphases, enabling careful model validation. Certain packages include modules with standard models for specific purposes, optimization heuristics, etc.

3 Modes of Coping with Complexity

Why is the quality of models so important? The answer is given by the Conant/Ashby Theorem from Cybernetics. It says: "Every good regulator of a system must be a model of that system." [5] In other words, the results of a management process cannot be better than the model on which it is based, except by chance. In their work, Conant and Ashby provide the proof of the claim that model quality is crucial. Consequently, the Conant-Ashby-Theorem is as important for management as are the Laws of Thermodynamics are for Mechanical Engineering.

Yet, the use of trivial models in organizational practice still abounds. Models tend to be static; dynamic complexity is not adequately taken into account. Arguments tend to lack clarity; they are not sufficiently underpinned by explicit models. Vagueness often dominates strategy discussions. Hypotheses, if there are any, are not properly tested.

When confronting complex issues, the discussions tend to mire down in two classical traps. The first trap manifests itself in the shape of a symptom *sweeping arguments*, such as: "This issue is highly complex. Therefore, let us simply assume that ..." This is the trap of *trivialization*. The second trap is accompanied by a syndrome, – the illusion of "mastering complexity", expressed in language figures such as: "To capture the complexity of the real system, we need complex models", meaning large numbers of variables and formulas. This is the trap of *model complexity*.

Risk Management Theory has developed a rigorous approach for dealing with the risks of model complexity, expressed in the construct of *model risk*. System Theory offers two major strategies for dealing with the challenge of modeling complex systems adequately. One is Ross Ashby's notion of *essential variables*. Essential variables are those "which are closely related to the survival [of the system under study] and which are closely linked dynamically so that marked changes in any one leads sooner or later to marked changes in the others." [1: 42]

The other is the concept of *Systemic Archetypes*. The term comes from the Greek *arché* – very old, original, and *typos* – type. Archetypes in the sense used here are ideal-typical (in the sense of the sociologist Max Weber's *Idealtypen*) patterns which can be repeatedly discerned in the structures of organizations. These archetypes are a kind of pattern language, similar to those used in architecture and software engineering. In all these cases they are conceptual tools, heuristic devices for coping with real-life complexities: for the sake of both, understanding a complex, dynamical system or situation under study and, if necessary, changing it by means of a systemic design. The SD view emphasizes that events are mere instances of larger patterns of behavior, which on their part, are brought forth by underlying structures.

Both of these strategies are connected, in that a) proper use of archetypes is always grounded in understanding essential variables and their interrelationships, and probably b) essential variables are to a great extent of an archetypal nature. Validation, the process by which confidence is built into models, is at the heart of both modeling approaches, essential variables and archetypes.

The emphasis of this paper is on archetypes, a complete list of which does not exist. However, Wolstenholme has come up with the most complete and generic typology of archetypes to date [18], embracing more specific archetypes, such as those expounded by Senge [14] at an earlier stage. An overview of Wolstenholme's four generic archetypes, as well as their semi-specific subclasses and specific cases are expounded in Table 1.

A generic solution archetype exists for each generic problem archetype; a detailed treatment is beyond the scope of this paper. The next two sections contain an account on how some of these archetypes have been used and which lessons were learned.

Table 1. Summary of systemic archetypes after Wolstenholme [18]

Generic Problem Archetype	Semi-Generic Archetype	Specific Case
“Underachievement” Archetype	Limits to success, Tragedy of the Commons	Growth and Underinvestment
“Out-of-Control” Archetype	Fixes that Fail, Shifting the Burden, Accidental Adversaries	Criminal Justice, Problem Child Walmart vs. P & G ¹
“Relative Achievement” Archetype	Success to the Successful	VHS vs. Betamax
“Relative Control” Archetype	Escalation, Drifting Goals	Arms Race, Quality Improvement

4 Applications of Archetype-Based Modeling and Simulation

The author recently pursued a path of using System Dynamics, which led to promising results. Together with MBA (Master of Business Administration) students, SD has been used in project seminars to tackle relatively complex issues faced by real-world organizations. These seminars have been held at two Universities, one being the University of St. Gallen, Switzerland, where the students were newcomers to complex systems modeling but had some practical business experience in business or the public sector. The other is an MBA program at the Universidad de los Andes, Bogotá, Colombia, with participants who already had substantial experience in management or engineering.

As the students in these seminars had not been exposed to SD in earlier courses, the following approach was adopted. The objective of the course was that participants a) should enhance their skills in order to gain insight into the structures underlying typical patterns of behavior exposed by organizations and to model them properly, b) they should reach a better understanding of the dynamics of organizations as well as the consequences of interventions, and c) they should get a grasp of the potential as well as the limitations of SD as a tool for the design of solutions. Early on, the students studied Senge's "archetypal" system structures, which stimulated them to a new perception of issues encountered in the real world. Using this, they chose their own cases, learned how to model, validate models, proceed with policy analysis etc., and finally came up with proposals for the improvement of the systems under study.

To date, four seminars of this kind have been held, three at the University of St. Gallen and one at the Universidad de los Andes. Altogether, 13 cases were studied. Three of them proved to be so rich that the work groups have continued to study them in a second seminar, during the following semester. This seminar is still continuing in the 2003 summer term. In the next section, one of the cases studied will be expounded in sufficient detail, and with the dynamics it exhibits, as well as the policy analyses and recommendations made. The rest of the cases will be summarized.

¹ P&G stands for Procter and Gamble.

Fig. 1. Loop A – Marketing enhances business

4.1 Exemplary Case: Growth and Underinvestment

The firm studied was a young company – a job agency for university students, an electronic business in Germany. The purpose of the project was to understand the problem of the hampered evolution of the business manifest in that small firm, and to improve resource allocation. Early on the project team identified an instance of growth and underinvestment [cf. 14: 389f.].

The three constituent parts of the stocks-and-flows diagram for the model (elaborated by means of the VENSIM software) illustrates the problem which occurred – a pattern of growth phases alternating with set-backs. The structure is made up of three loops, one of them of the self-reinforcing type (Figure 1), and two of the balancing (self-attenuating) type (Figures 2 and 3). On the one hand, the job agency boosted growth by marketing its services to both, students interested in finding jobs and companies who would offer positions (Figure 1).

On the other hand, the growth was hampered by bottlenecks in the server capacity, which eventually led to frustration and departure by some of the users (Figure 2).

The deeper cause can be found in the third loop, which unveils a problem of lagging investments leading to temporal capacity shortages (Figure 3). The need to invest is perceived too late, and availability of additional servers only materializes after a time lag. As a consequence, the ensuing growth of capacity is poorly

Fig. 2. Loop B - Bottlenecks hamper growth

synchronized with the growing demand. This is the cause of intermittent phases of server underperformance, with the consequences already indicated: Applicants left unattended leave the loop after some time, – normally after a week.

The model was thoroughly validated by means of standard tests for structural and behavior validity, i.e. the test if the model replicated the behavior of the real system under study [cf. 3].

Figure 4 summarizes the *diagnosis* realized by the project team. It shows the evolution of the total number of registered client companies. The bold curve exhibits the actual numbers over time (bold line), with the kinks representing the setbacks. The punctuated line is a realistic projection into the future on the actual numbers of client companies registered. The attenuation of this S-curve produces a kink in the trend due to the temporal server underperformance. The faint line shows a projection of the potential evolution of the business if these technical barriers to growth did not exist. The shapes of the analogous curves for the numbers of registered students exhibit the same pattern.

After this diagnosis, a number of *scenarios* were explored. Different policies for the elimination of growth barriers were tested. These indicated two directions for improved performance – a more prospective or at least more adaptive investment policy and the deployment of resources on smaller servers. The Investment Policy parameter is a measure of the level of capacity utilization (in terms of the percentage/100), which a new server would reach immediately given the current level

Fig. 3. Loop C – Inadequate Investment Policy

Total registered Companies :

- Actual number
- Projected number
- Potential number

Fig. 4. Number of Registered Companies

Cumulated Net Revenue in Thousand (M) Euro:

Status Quo (Investment Policy=1.0, Capacity per Server=200) —————

Optimum (Investment Policy =0.45, Capacity per Server=130) - - - - -

Fig. 5. Investment Strategy - Status Quo versus Optimum

of demand. The Capacity per Server is defined as the number of students that can simultaneously log into a server.

The final *policy recommendation* was elaborated by means of a multiple parameter optimization heuristic, which the VENSIM software makes available on the basis of the Powell algorithm. The parameters jointly optimized were Investment Policy and Capacity per Server. The final policy recommendations are synthesized in Figure 5.

The *optimal strategy* is defined by a more proactive Investment Policy (parameter set at 0.45 instead of 1.0) and the use of smaller servers (capacity for 130 simultaneous users instead of 200). As the rental cost remains invariable for smaller servers, this strategy is counterintuitive: students and participants of executive seminars to whom the model has been demonstrated mostly opted for larger servers in their first guesses.

According to the comments obtained from the project group's internal partners in the firm under study, the model and the policy recommendations assisted the management enormously in gaining an in-depth understanding of the problems they were wrestling with. The model proved very useful as a vehicle for discussions among the people involved.² For that purpose, the process of developing the model, elaborating and validating its structure, as well as exploring its dynamics playfully, was more important than the detailed simulation outcomes were. Several durable insights were gained. Mutual interdependencies, e.g. between internal and external variables, the factors driving and hampering the development path of the company, and the levers of change which could be influenced, became clearer. The building of and the interaction with the model triggered a thinking and communication process which enabled team learning, a process for ultimately and more robustly weathering

² On the part of the firm two managing directors, the CIO (Chief Information Officer) and two further members of the Information Technology department were involved in the project. Altogether, the company has roughly 25 associates, i.e. besides our students about 20% of the staff were involved in the project.

the challenges faced. Today, 15 months after the conclusion of the project, the firm under study appears to have gained in strength and found its place in a highly competitive market. As a supporting factor, this model was one, albeit not the only contribution.

4.2 Further Cases

It is worthwhile enumerating the other cases which were subject to modeling and simulation exercises in the three seminars mentioned. These were³:

Case 2: Tax Competition between Swiss Cantons	I
Case 3: Lake Sempach – Farming and Fishing (Ecological Problem)	I
Case 4: Arms Race during the Cold War	I
Case 5: Dental Clinic – Flow of Patients	II
Case 6: Reorganizing Sales in a Software Distribution Company	II
Case 7: The Problem of Cheating – A Quality Problem in a University	II
Case 8: Marketing Initiatives in a Decentral Organization	II
Case 9: Information Technology – Release Policy in St. Gallen State Government	II
Case 10: Consulting Services during Recession – The Human Resources Issue	III
Case 11: Micro-Mobility: Overshoot and Collapse of a Microscooter Producer	III/IV
Case 12: Pension Funds: Financing and Risk Issues	III/IV
Case 13: Pension Funds: Financing and Risk Issues II	III/IV

Not all of these models achieved the same level in terms of validity, relevance, and usefulness, but all of them improved a great deal as the projects advanced. Several of these cases led to models useful enough to support and probably improve real-life decision-making in the real systems under study. This was the case at least in cases 6 (a problem of the Limits-to-growth type) and 9 (a situation of the Fixes-that-fail-type). Others at least led to insightful improvements of mental models-in-use (Cases 10 and 11). The last three cases were so complex and the students so highly motivated, that the author offered to accompany them for a second seminar in the ensuing term. This seminar is close to completion, as this paper is written. The models have been greatly improved and submitted to thorough validation procedures, which in one case included a readjustment of model boundaries.

5 Discussion

The results achieved with archetype-based modeling in the experiences outlined have been a most positive surprise. The quality of the modeling and simulation work done

³ Cases marked with ,I‘ are from the St. Gallen seminar in Winter 2001/2, with ,II‘ from the Bogotá seminar in Summer 2002, with ,III‘ from the St.Gallen seminar in Winter 2002/3, and with ,IV‘ from the St. Gallen seminar in Summer 2003.

and the strength of the policy recommendations elaborated were astonishingly high, given the short duration of the courses and the limited resources available. The speed of learning of the teams was far superior to cases of comparable traditional courses.

This feature was particularly salient in the Seminar with Colombia, which had to be carried out in a "virtual" mode, using of the new StudyNet platform of the University of St. Gallen. The following communication channels were used: 1. & 2. Audio and video, 3. Application sharing, 4. Chat function, 5. E-mail, 6. Telephone. Despite all the restrictions imposed by these mediated forms of interaction, the students came up with remarkable models, and their recommendations even had some impact on the organizations under study (a University, a software company, a dental clinic etc.).

How was it possible to achieve these results? First of all, the students generally showed excellent motivation and commitment. Second, the archetypes were used as conceptual stimuli to help the phases of issue identification and diagnosis. To avoid constricting the students' thinking it was emphasized, however, from the start that real-life issues may exhibit features which transcend the bounds of one archetype – for example in cases where a combination of archetypes applies. Consequently, the cases listed in the section above are not always as closely confined to one archetype as was the case in the account of the growth and underinvestment example.

Third, throughout the process, the conceptual and methodological guidance of the students was crucial. At the outset, conceptual input and training in the use of the software were provided. Thereupon the emphasis was on learning-by-doing, which was backed by intensive support. Several learning loops were built into the process. Student groups submitted partial results along a schedule followed rather tightly – causal loop diagrams, stock-and-flow diagrams, models at different stages of accomplishment, validation steps and results, setups and results of scenarios, policy tests etc. These were examined by the author or his assistant, and then discussed with the groups. The doors of the supporters were open for consultation. Hands-on support for the groups was provided whenever necessary. Intensive help was needed, for example, for more sophisticated applications such as the use of the optimization heuristics. In each seminar, the intermediate and final results of all groups were presented and discussed in plenary sessions. A rather extensive documentation of the model, the process of diagnosis, design and validation, as well as the final recommendations was handed in by each group, and made available to the partnering firms after the end of the term.

Altogether, this design of the process led to an extensive learning experience for all subjects involved. Perhaps not all of the members of a group were in a position to master the methodology and the techniques of modeling and simulation at the end. However, the opinion leaders in the groups were, and the rest had obtained a good feeling of what can be achieved by means of System Dynamics modeling and simulation, and where the limits of the chosen approach are.

6 Conclusions

The compelling conclusion of this paper is that the SD methodology supported by powerful software and conveyed by a didactically effective (self-)education – learning-by-modeling (and simulation) – can open new dimensions, not only to

coursework in strategy and organization. As the case study above shows, these advantages are now available also to practitioners of management. The stimulation through the initial study of archetypes proved most useful in this context. The motor of the effectiveness of these ventures, however, was in each case a set of powerful brains triggered by appropriate methodological (plus technical) support and coaching on behalf of experienced instructors.

Moreover, this innovative approach shows a new path to anyone – practitioner or theoretician – who deals with the issue of organizational complexity: dynamic modeling is now within easy reach, and it can be put in practice at stunning levels of quality. Generic archetypes are available [14, 18] for facilitating the qualitative understanding of dynamical systems. The methodology of System Dynamics modeling and simulation has matured – generally (cf. 15), and with respect to the improvement of model quality, i.e. model validation (cf. 9, 3, 4). Finally, software technology has advanced enormously, facilitating model building and simulation. Some packages (Vensim, Powersim) close the gap between simulation and optimization (in the sense of optimization heuristics). State-of-the-art software also contains inbuilt features dedicated to supporting model validation (e.g. consistency checks, Reality Check®).

As in computer science, where software developers caught in the complexity trap are increasingly reverting to the use of generic "patterns" in diagnosis and design, and in architecture, where Christopher Alexander already suggested a "pattern language" a generation ago [2], management scientists can finally reach new horizons through the use of generic "archetypes", in their quest for better models.

Acknowledgements. The author extends his thanks to Messrs. Kristjan Ambroz and Camilo Olaya. They assisted him in teaching the seminars and supported the students in St. Gallen and Bogotá with the utmost care and effectiveness. The author is also grateful to the students for their outstanding commitment and enthusiasm in delivering high quality work. The group members for the model referred in section 4.1. were: Clemens Mueller, Anatol Pante, Philipp Tuertscher, Boris Doeblen, Sven Graber. Special thanks go to Dr. Bob Eberlein, Ventana Systems, for valuable software support, and to Kristjan Ambroz, who read the manuscript of this paper, for his helpful comments.

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