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DEGREE PROGRAM **„CIVIL ENGINEERING"**

MASTER THESIS

„From Cybernetics to construction cybernetics"

Submitted in partial fulfillment of the requirements of the academic degree

Dipl.-Ing.

for

„Civil engineering – Project Management"

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Spittal/Drau, September 2010 stamp of study program

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I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

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Introduction

I would first like to thank all of those who contributed to the successful completion of this work. The completion of this paper would not have been possible without the help and support of countless individuals.

I would especially like to mention my supervisors at the Carinthia University of Applied Sciences, Dipl.-Ing. Dr. Otto GREINER (Professor of Construction Project Management), Dipl.-Ing. Dr. Hans STEINER MBA h.c. (Landesinnungsmeister Stv. construction industry, Carinthia) and Prof. PhD. Stuart A. UMPLEBY (Department of Management) at George Washington University, they supported me with their great dedication and many valuable insights. Through lively discussions it was possible to find the right focus for this work and to define its main objective.

I am also very grateful to my parents who both supported me financially during my studies and helped me find solutions to many problems.

I would also like to thank Ms. Simone UNHALLER from the University of Passau (Germany), who was quite helpful in providing me with literature.

The following work was written in the summer semester of 2010 as a master thesis for the Carinthia University of Applied Sciences. In the Construction Engineering Project Management program we were instructed in conventional construction project management and provided with a great deal of technical knowledge on cybernetic construction project management. In the course of this study program a course in cybernetic management was offered in which along with progressive approaches to the steering of construction projects, we also learned about the different elements and cybernetic management principles of company organization.

Driven by the personal goal of completing my degree in a reasonable amount of time despite the intense series of study projects and examinations required, the issue of organization and management was virtually omnipresent throughout my studies.

Subsequently Prof. GREINER made it possible for us to take part in several courses in construction cybernetics at such institutions and events as the MALIK Management Construction Cybernetics Forum in St. Gallen, Switzerland and the Construction Cybernetic Conference in Klagenfurt, Austria. As a result, after an initial examination of construction cybernetics I developed an interest in the field. Using cybernetics as an academic foundation for management seemed like the right approach. My final project for the completion of my studies offers the right medium to intensively explore cybernetics and, in a further stage, construction cybernetics.

Because of the broad thematic spectrum of cybernetics and due to space limitations, in this paper it will not be possible to go into the different dimensions of the subject at full length.

Abstract

This paper focuses on the positive influence of cybernetics on the construction industry and applies the basic ideas and tools of system-oriented management (MALIK Management Zentrum St. Gallen) to both companies and projects in the construction industry. Construction projects are becoming increasingly large and complex, even as the demand for shorter construction times and minimum costs is intensifying. This thesis will thus describe methods for the ideal organization of companies and projects by means of organizational bionics. Organizational bionics refers to natural prototypes like ecological systems and organisms which are used to improve the structural and systemic models of organizations in order to quickly identify the constant changes taking place in the environment and to act and react accordingly, as well as to work more efficiently and (above all) more effectively from the very beginning. This should allow the organization to thrive for as long as possible.

First some important concepts from the field of systems theory and cybernetics will be selected, defined and explained. Then the model generation process will be described, including the structure of the nervous system, which BEER uses as a prototype for his VSM or Viable System Model. A closer look will be taken at the VSM as an exemplary organizational model for companies and projects, before we discuss the application of cybernetics to the construction industry. Here we will introduce the implementation of the KOPF method as applied cybernetics in the construction industry.

The re-orientation taking place in the field of project management – especially in construction project management – in regards to organization and steering will be presented. We will examine the move from constructivistic technomorphic to systemic evolutionary management theory. Within this tendency new approaches and theories are increasingly being used to handle the complex, sophisticated dynamics involved in construction projects, and we will look at the systemic methods now being utilized. Using a recent construction project, this paper will illustrate how a project might be executed using cybernetic-based organization to meet the intensifying demands of new construction projects. The attempt is made to represent the structural organization of the project as a viable system based on the bionic-cybernetic system model of Stafford BEER and to describe the various functional units.

In the final chapter of the paper, recommendations for the implementation of cybernetic structures in projects and/or companies in the construction industry are given. In doing so first the opportunities, risks and difficulties of implementing cybernetic organizational structures are examined, before the necessity and potential of a totally new way of thinking is discussed in conclusion.

Keywords:

Cybernetics, system, systems theory, complexity, self-organization, Sensitivity Model Prof. Vester®, Viable System Model (VSM), KOPF method, cybernetic construction management

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1 Definition of the Problem

In the field of management, and thus also in the area of project management, a new orientation is asserting itself. Conventional management practice is being radically questioned. Authors like Frederic VESTER, Fredmund MALIK, Wolfgang MEWES and researchers from the St. Gallen Institute for Economic and Social Sciences have helped give rise to this new way of thinking in numerous articles and books.

It stands against the form of organization that has developed over the course of 200 years of industrial history. The new perspective is based on connections between and the networking of diverse academic disciplines. This holistic approach attempts to bring together humanistic interests and economic requirements. In the area of project management, the needs for a holistic, networked philosophy and for greater interdisciplinarity and self-organization are also being felt.

In the face of the incredible number of states that can come about in complex systems, it cannot be expected that the limited complexity of an individual human or of a group of humans will be sufficient to steer, regulate and control everything independently. Practically speaking this means that we can never know everything that we need to know to effectively keep an organization under control. One of the most critical challenges in dealing with change is to not just take the idea of the self-organization and self-regulation of systems, organizational learning and evolution seriously, but to utilize these latter phenomena in structuring systems.[1]

All of the above are good reasons why new concepts and methods for the "perfect" performance of managers are constantly being tried out. However, most of these newly developed methods are based on standard project management. In reviewing the different approaches in terms of their most essential characteristics one thing becomes clear – the attempt is made from the very start of projects to define and calculate as precisely as possible every single process. What results is generally missed deadlines and higher costs throughout the run of the project.

Cybernetics works differently. Based on biocybernetics, a system was developed a few years ago that helps make it possible to steer a system in a specific direction without exerting very much direct influence on it. When applied correctly, this results in regulated and targeted project completion. And yet the cybernetic approach still remains marginal in the field of project management, as it is considered controversial and is rarely utilized.

[1] See MALIK, F. (2003): Systemisches Management, Evolution, Selbstorganisation: Grundprobleme, Funktionsmechanismen und Lösungsansätze für komplexe Systeme, pg.25.

1.1 Research goal

After examining the origins and development of cybernetics, this practical science will be applied to the construction industry. From among the various contemporary approaches to management, the cybernetic method will be taken and analyzed in terms of its suitability for construction operations. Special focus will be placed on the relevance of cybernetic principles for the purposes of organization.

With the objective of turning the organization of companies and projects in the construction industry into a viable system, this paper will attempt to find a viable organizational structure based on the insights of cybernetics and the bionic, cybernetic systems model known as the Viable System Model. In addition we will examine to what extent the VSM can be used as a prototype for organizational models in the construction industry. The fields in which organizations are active are becoming increasingly complex and economic disturbances of all sizes are becoming more a rule than an exception. As a result new kinds of organizational forms are needed that quickly recognize constant modifications to the environment as quickly as possible so as to make it possible to act and react accordingly, and to work more efficiently and (above all) more effectively from the very beginning. All of this should allow the organization to thrive for as long as possible.

The various practices and systems for the steering of construction projects must be critically analyzed and evaluated based on the current state of knowledge in the field of systems theory and cybernetics, which will be discussed in this paper. It will also be shown which insights or concrete information should be derived from the system-oriented approach for companies and projects in this sector.

As a result, the question at the center of this master thesis is as follows:

“Which construction cybernetic principles and methods are observable in the structure of organizations and the steering of projects?”

1.2 Structure of the master thesis

The structure and methodological order of this work intended to help achieve its objective will be explained below.

First of all it must be made clear that, although holistic cybernetic construction management relates unquestionably to project development and project completion and, beyond this, to project use and re-use, the focus of this paper will be on project completion.

The paper is divided into three main parts, which may be called Theory, Model Generation and Practical Application (see Figure 1-1).

First there will be an introduction to the science of cybernetics. In this chapter the principles and concepts of cybernetics relevant for this paper will be discussed in a summarized form.

In chapter 2 the necessary foundation for a better understanding of the philosophy and ideas to be applied will be provided. In addition, the terms "system", "cybernetics" and "management" will be defined and delimited, as they are to be applied to the construction industry and used in this paper.

In the second part of the work model generation will be explained as it relates to company and project organization, beginning with management in the specific system-oriented context utilized here. Cybernetics and systems theory will be used as basic concepts and a system-oriented strategy (that is, a strategy derived from the concepts and philosophy of this discipline) will be developed. It will be shown which skills, procedures and structures are necessary at the level of the company and projects in order to have long-term success in an ever changing environment. The VSM provides a general orientation for the integration of the fundamental demands of company leadership and concrete guidelines for the definition of all functions of the company as an organism. The main focus will be placed on the organizational structure of companies and on construction projects, so that the everyday requirements of the company and/or project can be met and these entities can remain viable as a whole.

In the third part the foundation of an understanding of the cybernetic approach to management will be presented. Later the application of these to cybernetics and the construction industry will be attempted. Finally, in this section a standard practical application of the K.O.P.F. method will be introduced as applied cybernetics in the construction industry.

In the following section, the new turn in project management – elicited by the increasing complexity of the field – will be looked at. First there will be a theoretical examination of systems theory in project management, whereby practices and systems for the steering of projects will be analyzed and critically reviewed. As a practical example, the cybernetically oriented organization of the LKH Klagenfurt Neu hospital will be reviewed. Using this project as an example and based on the basic concept of the VSM bionic-cybernetic system model, an attempt will be made to present the structural organization of the LKH Klagenfurt NEU as a viable system and to describe its functional units.

Finally, based on the insights presented, the opportunities, risks and difficulties that can arise in the implementation of cybernetic organizational structures will be scrutinized. In addition, the necessity for and potential of a totally new way of thinking will be discussed.

Figure 1-1 shows the structure of the paper and the different sections as they interrelate and build upon one another.

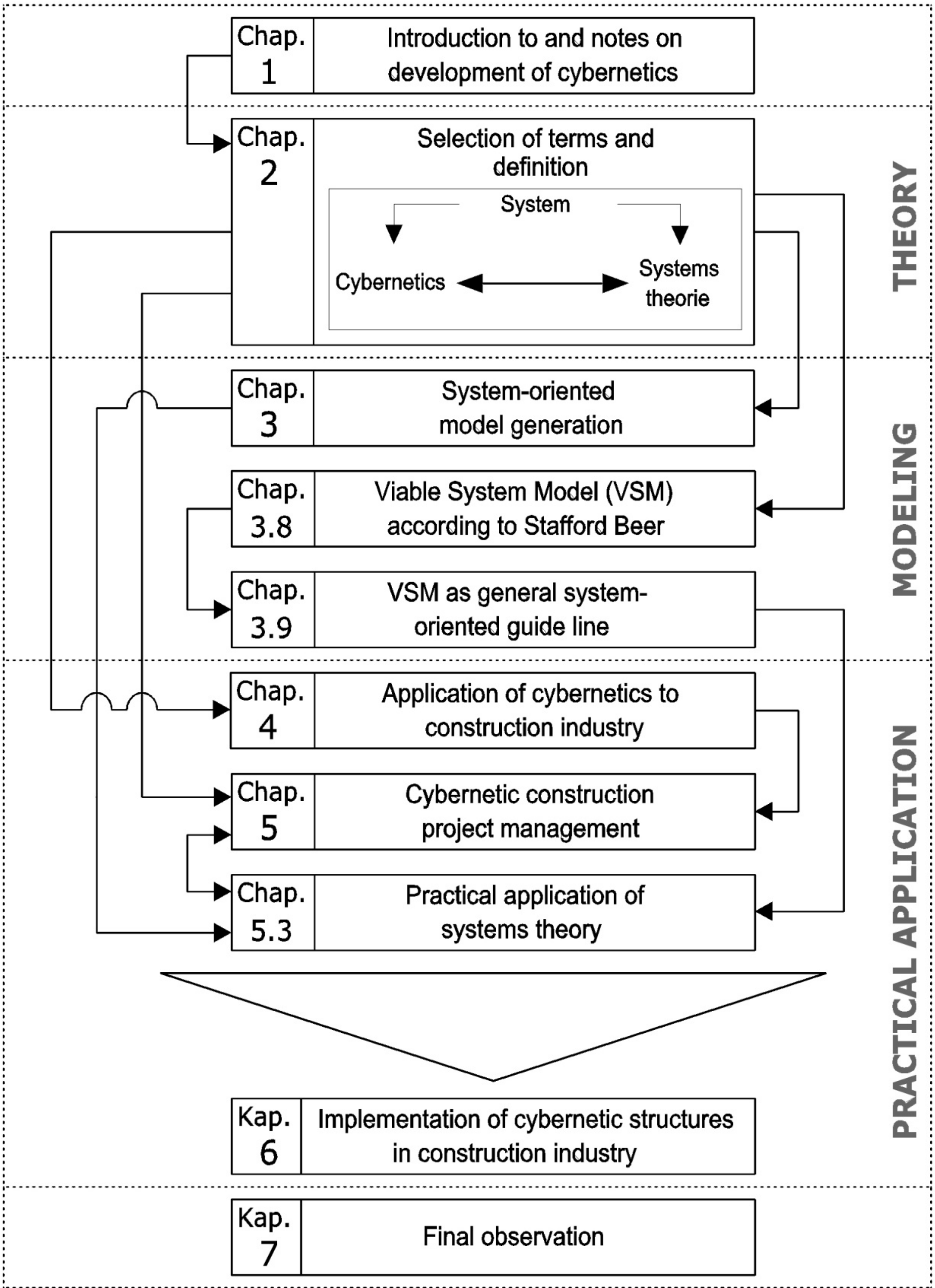

Figure 1-1: Structure of the paper

1.3 Introduction to Cybernetics

"Whatever future developments may come, understanding and designing systems and understanding und taking advantage of the rules that govern them will prove to be an absolutely crucial skill."[2]

With this statement, MALIK directly states the importance of cybernetics as the science of management. This introduction will discuss the principles, findings and context of cybernetics in an abbreviated form. The basic knowledge necessary to ensure an understanding of the application of this science will be presented. After a general description of the field, organizations will be examined from a cybernetic perspective and the most important insights will be applied to the area of management, placing special focus on the construction industry.

1.4 Origins and development of cybernetics

Cybernetics is a new academic field, for which no single definition has generally been accepted.

The term "cybernetics" (in Greek "kybernetike techne" means the art of navigation) was first used in 1948 by Norbert WIENER (1894-1964). In his book *Cybernetics of Control of Communication in Animal and Machine*, the American mathematician established the foundation of an academic discipline that focuses on the regulation and control of processes in dynamic systems based on mathematics and modeling. These dynamic systems are characterized above all by the principle of self-regulation and control, as well as by the transfer, processing and back transfer of information by means of at least one feedback mechanism. WIENER based his ideas on his empirical identification of similarities between organic systems and technical systems, in which information is transferred and processed. Like Hermann SCHMIDT in Germany, he proved that control engineering and the communication of information play a major role in many academic disciplines, and that it would be possible to begin viewing them as a collective phenomenon.[3]

To explain the term, MIROW makes reference to the function of the navigator, who in steering a ship is given the task of holding a predefined course based on various kinds of information continually being given to him. With this insight the author makes reference to the essential importance of information in the control of processes or systems. These reflections on the function of the navigator are intended to illustrate the importance of information: the navigator can only hold to the predetermined course if he has immediate access to all the necessary information. This becomes especially clear if one considers the modern profession of the air traffic controller and views him as a kind of navigator. Information forms the foundation of his activities, which is to safely "guide" hundreds of airplanes of different sizes and speeds onto the runway every minute of every day under changing weather conditions.[4]

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[2] MALIK, F. (2003): Systemisches Management, Evolution, Selbstorganisation, pg.23.

[3] See CUBE, F. (1967): Was ist Kybernetik, pg.34.

[4] See MIROW, H.M. (1969): Kybernetik: Grundlage einer allgemeinen Theorie der Organisation, pg.17.

Yet it should be noted that the laws of cybernetics have been in use for much longer than air traffic control has been around. What was lacking was a general understanding of complex systems, as for a long time this has been concealed by the details of specific problems. The scientific findings of cybernetics are much like those of other scientific fields. Specific uses were made of gravity long before Newton realized that it is a general law of nature.

The foundation of the current understanding of cybernetics was laid by Stafford BEER (*The Irrelevance of Automation*), Gordon PASK (*Organic Control and the Cybernetic Method*), Ross ASHBY (*Design for a Brain*) and Heinz von FOERSTER (*Some Aspects in the Design of Biological Computers*). Works by these authors changed the accepted understanding in German-speaking countries of the field of cybernetics as an engineering theory or methodology. The authors were able to do this by breaking new ground in an area characterized by its great complexity.[5]

1.5 The cybernetic model

Frederic VESTER describes the design of this kind of system in the following manner: the Cybernetic Model is based on a control circuit. It consists of two elements – the controlled variable (for example the amount of petrol in the carburetor) and the regulator, which can change this variable. The regulator measures the controlled variable by means of a sensor.

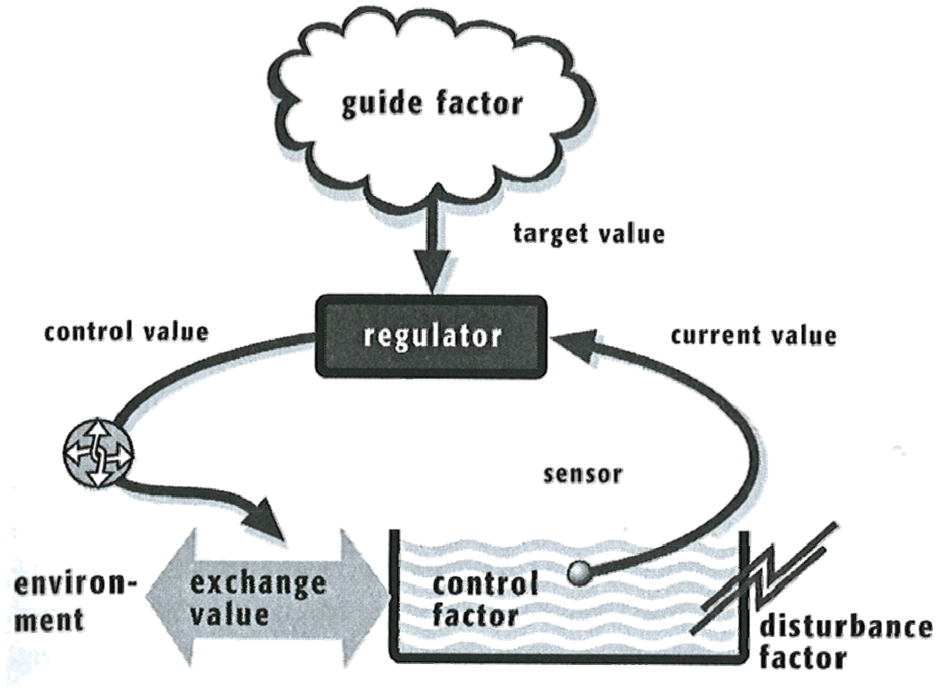

Figure 1-2: Control circuit with standard cybernetic labels. Source: VESTER (2007), pg. 43

If this controlled variable is acted on by a disturbing factor, the disturbance variable, the regulator passes on the appropriate directive (the control value) to an actuator, which then corrects the disturbance by adding or taking out the correct amount of petrol. In this way the system being regulated is connected to itself in a feedback loop. At the same time it is connected

5 See MALIK, F. (2003): Strategie des Managements komplexer Systeme, pg.27.

to the external world by means of the disturbance and corrective measures. If it were a parallel feedback loop (see 3.6.2), an increased measurement would lead the regulator to further increase the value – this would correspond to a positive feedback loop and the system would then shut itself off. For this reason there are no systems that only work on the basis of positive feedback loops – all systems must be stabilized by means of negative feedback loops.[6]

A control circuit is characterized by the fact that the result of a process influences and "navigates" the basic conditions of the system (cybernetics = the art of navigation).

In reality there is no such thing as an isolated, closed control circuit, rather there are only open systems of multiple networked control circuits that are interconnected and interrelated, the optimal values of which are interdependent.

1.6 The eight basic rules of biocybernetics[7]

Living systems, that is animals and plants, automatically learn, grow and automatically adapt themselves to changes in the factors influencing them.

This provides an initial insight into biocybernetics, a field that scientifically explores the organizational forms of nature. The laws contained within nature can be stated in the form of generally valid principles for the capacity of systems to survive.

The principle of the negative feedback loop

This means self-regulation through the use of control circuits instead of unbridled self-propagation or – after collapse – self-destruction. Negative control circuits must therefore predominate over positive control circuits.

The principle of the independence of growth

A system must also be able to function during balance phases, that it must thrive independent of quantitative growth. Because permanent growth can never be more than an illusion for any system.

The principle of independence from the product

Systems that are capable of surviving have to work based on functionality and not production. Products come and go, but functions remain.

[6] See VESTER, F. (2007): The Art of interconnected thinking, pg.42f. and pg.155ff.

[7] See VESTER, F. (2007): The Art of interconnected thinking, pg.153ff.

The Jui-Jitsu principle

Of importance here is the use of existing forces – even disturbing forces – in accordance with the principle of Asian self-defense (the utilization of foreign energy), instead of fighting these forces like a boxer and expending one's own energy.

The principle of multiple use

This applies to products, functions and organizational structures. It leads to multistability by means of bundled solutions and implies a rejection of so-called hundred-percent solutions.

The principle of recycling

This means taking advantage of circuit processes to reuse waste and heat. It helps avoid both shortages and surpluses.

The principle of symbiosis

This implies the reciprocal use of heterogeneity by means of coupling and exchange. This principle, however, requires small-scale links. Monostructures, therefore, cannot profit from the benefits of symbiosis.

The principle of biological design

This rule too can be applied equally to products, processes and organizational forms. It implies feedback planning with the environment and compatibility and resonance with biological structures, especially those involving humans.

Similar to the eight basic rules, there is a further series of additional principles with which the path to viable technology and a viable economic method has in fact long since been sketched out. These basic rules can be most plausibly illustrated in intact, natural systems.

The basic condition for the capability of a system to survive (viability) is in all cases and in all states the best possible self-regulation, not external regulation. This is because all real systems are open to the outside.

2 Cybernetic Terminology

The following notes explain the terminology mentioned above in the context of the field of management and in accordance with the understanding of them derived from cybernetics.

First the following questions in relation to systems must be clarified: What is a system? What are its principle characteristics? What types of systems can be identified? Which of these types are of interest for cybernetics? One other important objective of the following chapter is to delimit the very broad field of cybernetics in a comprehensible manner, so as to make it useful for management.

2.1 System

In the following pages the term "system" is used over and over again, for which reason it requires explanation.

Frederic VESTER defines a complex system as follows:

"Like any organism, a complex system consists of a number of distinct parts (organs) that co-exist in a specific dynamic arrangement. They are connected together in what we call an effect system. In this it is impossible to intervene without altering the relationship of each part to every other and hence the overall character of the system. Furthermore, real systems are always open, maintaining themselves through a constant interchange with their environment."[8]

A pile of sand is thus not a system. Parts of it can be exchanged, a handful can be removed or added, but it will always remain a pile of sand. These types of changes cannot be made to a system without changing its identity or even destroying it. The most important characteristic of a system is that it consists of different parts. The second most important feature of a system is that its parts are not positioned indiscriminately, but are networked together in a certain structural design. In this way a system behaves completely differently from its individual parts. It becomes a whole. A system is always a whole, a unit, and the whole is greater than the sum of its parts.[9]

Two fundamental types of systems can be identified:

- **Static, rigid systems** – In all cases these are theoretical systems devised by human beings, including the following: documentation systems, classification systems, ordering systems, mathematical systems, etc. The term "static structure" is also applied. This model only allows for a certain defined pattern. A single predefined, predictable product (pattern) is created from a model. This type of system must be protected from all forms of environmental influence in order to survive. Such systems are also referred to as object systems.

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[8] VESTER, F. (2007): The Art of interconnected thinking, pg.26.

[9] See VESTER, F. (1991): Neuland des Denkens, pg.27.

- Systems that exist in reality – he systems that make up our world – are dynamic. **Dynamic systems** bear, so to speak, in themselves the program that carries out their own modifications. They are a totality of different units that mutually affect each other – a functional structure. This kind of system assumes the character of a living entity that is organized into a dynamic structure through internal and external communication and information flow. When humans and machines interact, the term socio-technical system is applied. For this reason organizations are generally categorized as dynamic systems.[10] These systems are thus also referred to as operational systems. They are not self-generating, but are rather formed through cooperation between those charged to carry out projects. In contrast to object systems, operational systems are not predictable.

For the discussion to follow, a system should be understood as an aggregate of elements linked together through different relations. In an open system there are relations that lead beyond the boundaries of the system into the system's environment. Systems thinking make it possible to provide a structure for complex conditions. Of utmost importance here is holistic thinking, so that light can be shed on relations and problems of delimitation can be identified. However, it must be remembered that components (or elements – for example relationships) and problems of delineation are dynamic and therefore must be continually re-evaluated until the desired system state has been achieved.[11]

Since there is no way to define a system without defining their boundary, a dividing line is consciously drawn, within which a description is possible. There are of course exterior relations as well as relations extending from the outside inwards, but these are seen as outputs or inputs. In the case of companies, incoming payments are an example of an input and services rendered can be seen as outputs.

When analyzing systems the environment must also be taken into consideration. ASHBY calls the environment "the field" in which the system strives to attain stability.[12]

Figure 2-1 and the following example will help describe the criteria that have been defined for systems thus far.

[10] See VESTER, F. (1999): Unsere Welt – ein vernetztes System, pg.17.

[11] See BRANDENBERGER, J.; RUOSCH E. (1991): Projektmanagement im Bauwesen, pg.11.

[12] ASHBY, W. R. (1970): An Introduction to Cybernetics

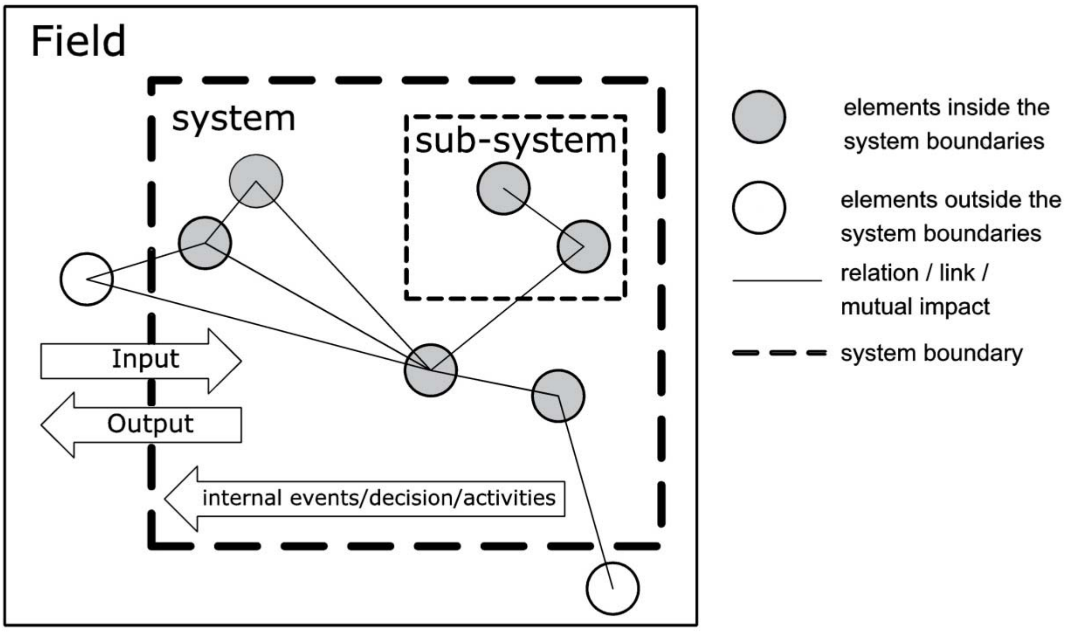

Figure 2-1: Simplified representation of a system. Source, BRANDENBERGER (1996) pg.13.

In itself a steel beam is not a system, assuming the microscopic structure of the steel is not being examined. Once it is put in place, the beam becomes an element within a steel construction system – it is part of the load-bearing structure. It is now the responsibility of the planner (investigator, observer) to draw appropriate boundaries, since the stress resultant of the beam must be determined (its objective or aim). If it is a simple bending beam, then the system can be limited to the beams and the load-bearing dynamics. However if the beam has been integrated into a space frame that is statically highly open-ended, it must be viewed as a part of this space frame. A false ceiling suspended from this support structure can be seen as a sub-system, while external influences like the wind or snow can be interpreted as environmental factors. The system is externally open. It is influenced by energy. Yet in terms of the internal reactions that take place due to various influences (i.e. physical distortions), the system is closed, isolated. In the case of heavy snowfall or tremors it cannot independently add additional supports or vibration dampers. It cannot transform itself from a support structure system into a construction company system. The internal process or the operation by which it reacts to the input (the external disturbance) is the physical deformation.

The focus of this paper, however, is not static but dynamic systems, systems that are continually in motion – that is, companies. Although a support structure is certainly quite sophisticated, it is not nearly as intricate or complex as, for example, a company. What makes this kind of study even more difficult is that in contrast to steel beams (where the quality of the steel, profile, etc. are known), the characteristics of the different elements of a company are partly or entirely unknown (like the performance of employees) or can be incorrectly estimated (like the capabilities of managers). Due to the knowledge of its properties, the behavior of a steel beam can be calculated when subject to various forces (i.e. it will bend 5 mm). The success of newly developed products, however, can hardly be predicted even with the most painstaking research.

2.1.1 Complexity

When looked at more closely it becomes clear that essentially all managerial tasks are intended to deal with complexity. From planning and making decisions to organizing and providing leadership, complex relations have to be handled well. Sensible management is only necessary when complex relationships are present.

The term "complexity" is often used in everyday speech to mean complicated, inscrutable, incomprehensible, etc. This usage is of course correct, but it also expresses a certain amount of impotence on the part of humans in relation to the processes involved – the inability to understand, evaluate and influence certain factors.[13]

It is important to remember that complexity is nearly omni-present in every facet of life and work, a fact that is sometimes quite clear and sometimes less so. Dealing with great complexity requires certain skills, skills that help to reduce the complexity of the environment. For this reason DÖRNER writes that the greater the complexity (be it in a system in general or in the management situation of a company), the greater the demands made on the actor to gather information, to process and integrate this information, and then to make decisions and carry out specific actions.[14]

The complexity of a system is defined by the number of elements involved and the number of potential discreet states of these individual elements. BEER divides systems into three groups based on their levels of complexity.[15]

1. Simple systems:
    - Easy to view and describe.
    - Example: a game of billiards or the arrangement of equipment in a factory.
2. Complex systems:
    - Not easy to view but a description is possible.
    - Example: Newton's planetary system or computer equipment.
3. Highly complex systems:
    - Description of all details not possible.
    - Example: the human brain or a commercial enterprise.

[13] See MALIK, F. (2000): Strategie des Managements komplexer Systeme, pg.185.

[14] See DÖRNER, D. (1989): Die Logik des Misslingens, Strategisches Denken in komplexen Situationen, pg.60.

[15] See BEER, S. (1962): Kybernetik und Management, pg.27-34.

MIROW makes reference to another classification based on the definiteness of a system's behavior.[16] He distinguishes between **determinate** and **probabilistic** systems (see section 2.1). In determinate systems the state of all elements can be precisely determined based on the state of any one element. In a determinate system – for example Newton's planetary system – reactions can also be accurately predicted. Under the conditions generally observable in probabilistic systems, the relationships between elements can involve random factors, for example the behavior of humans in organizations is inherently unpredictable.

According to Beer there are no highly complex determinate systems. Thus for him the following is true: complex probabilistic systems are a part of the field of research known as operational research, while highly complex probabilistic systems pertain to cybernetics.

A final note on this subject: as a property capable of generating new properties, complexity is one of the most important basic requirements for life itself. Furthermore, every system must be capable of developing a certain degree of complexity in order to survive in a highly complex environment. To make the concept of complexity more clear, an example of the complexity of a company is given here.

Example of complexity within a company

In decision making processes within a company, complexity can make its presence felt in a variety of manners. The causes that give rise to this complexity can be found both in the system environment as well as from within the company itself. According to MALIK complexity is evident in company management in that the formal leadership organs of an organization – regardless of their exact relations – never have sufficient information, knowledge, skills or expertise to lead or guide a company beyond the barrier of complexity.[17] KIRCHHOF goes on to state that several determinants for complexity in an enterprise can be identified, such as the increasing number and networking of variables, which range from political, legal and cultural framework conditions; to markets, clients, products and services; to processes, supplier relationships, information systems and organizational form.[18] An example of this is the complexity of the competitive situation, which results from the following factors: 1) the interplay of multiple competitors and their relative power, products and prices; 2) the framework market conditions (as predetermined by nations, contracts and laws); 3) the intensity and kinds of changes that all these factors undergo. Crucial to the level of complexity within a company is also the dynamics of change in the company's internal and external environment, as a result of which new organizational forms and properties (i.e. new corporate identities) can be created.

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[16] See MIROW, H.M. (1969): Kybernetik: Grundlage einer allgemeinen Theorie der Organisation, pg.24f.

[17] See MALIK, F. (2000): Strategie des Managements komplexer Systeme, pg.83.

[18] See KIRCHHOF, R. (2003): Ganzheitliches Komplexitätsmanagement, Grundlagen und Methodik des Umgangs mit Komplexität im Unternehmen, pg.38.

Two manners of viewing complex systems

To effectively deal with complexity two fundamentally different approaches or theories can be used.[19]

From the point of view of cybernetics, commercial enterprises are complex, (probabilistic), dynamic systems. As a rule they can even be said to be highly complex systems, which cannot be described, planned or calculated in complete detail. The cybernetic perspective is only one of two fundamentally different perspectives from which commercial enterprises can be viewed. The first is based on **technomorphic thinking** (also frequently called "constructor thinking") and operates on the assumption that enterprises are systems with planned and consciously designed structures. However as a form of **systemic** or **evolutionary thinking**, the cybernetic theory assumes that enterprises are systems with highly developed and to some extent spontaneously formed structures. The first point of view claims artificial systems as prototypes, like machines. Systemic-cybernetic management theory, however, deals with systems that have formed and evolved naturally, for example organisms. While with some effort machines can be planned to the smallest detail, natural systems require evolutionary processes of self-organization in order to be formed and to exist in their environment.[20] The constructive-technomorphic management theory assumes determinate systems, the behavior of which is predictable in any situation. From MIROW's perspective companies must be assigned to the category of probabilistic systems, the behavior of which cannot be predicted.

For this reason technomorphic management in highly complex systems only yields absurd results, while the systemic-evolutionary – or cybernetic – approach proves to be the only one that can come to terms with the complexity of commercial enterprises. And yet it must be emphasized that the technomorphic method is in fact the most efficient one in those cases where it can be correctly applied. At the same time its use in situations of great complexity is doomed to failure.[21]

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[19] MALIK, F. (2000): Systemisches Management, Evolution, Selbstorganisation, pg.62.

[20] MALIK, F. (2000): Systemisches Management, Evolution, Selbstorganisation, pg.43ff. and 321ff. as well as MALIK, F. (1996): Strategie des Managements komplexer Systeme, pg.36ff. and pg.71ff.

[21] MALIK, F. (2000): Systemisches Management, Evolution, Selbstorganisation, pg.45.f.

Juxtaposition of constructive-technomorphic and systemic-evolutionary premises [22]

Constructive-technomorphic	Systemic-evolutionary
Management…	Management…
1. … implies human leadership	… implies the design and guidance of entire institutions in their environment
2. … leadership by few	… leadership by many
3. … the task of few	… the task of many
4. … direct influence	… indirect influence
5. … geared for optimization	… geared to be controlled or guided
6. … by and large adequate information is available	… adequate information is never available
7. … objective is to maximize profit	… objective is to maximize viability

2.1.2 Law of Requisite Variety

The complexity of sophisticated systems of action is so great that it is no longer possible to describe them in full detail or to predict their behaviors. To determine the degree of complexity of a system, the term variety has been introduced. For static systems, the variety simply expresses the number of different relations between the elements of a system. It must be remembered that different kinds of relations can exist between elements.

Variety depends on the number of elements and the number of different relations between any two elements. Thus for two elements there are only two relations, but for seven elements there are already 42 system states.

$$V = m * n * \frac{n-1}{2}$$

n … number of elements

m … number of elements relations

Since in a dynamic system relations can be turned on and off, a variety of 2 to the 42nd degree would result and thus over 4 billion potential system states. Because a system usually contains more elements than the example above, the variety of most systems increases to astronomical proportions.

„Only variety can destroy variety."[23] With these words the British cybernetics expert ASHBY expresses one of the most important insights to come from this field. Specifically, ASHBY's Law

[22] See MALIK, F. (1993): Systemisches Management, Evolution, Selbstorganisation, pg.71.

[23] ASHBY, W.R. (1970): An Introduction to Cybernetics, pg.207.

of Requisite Variety means that a system with a given complexity can only be controlled by means of a system that is at least as complex.[24]

MALIK demonstrates the natural law-like character of this statement with simple examples: against a football team with a great wealth of potential behaviors another team can only be victorious if it possesses at least the same wealth of possibilities – that is, the same degree of variety. The same is also true for chess players. The requisite variety for extremely complex systems (for example, commercial enterprises) is extremely high.[25]

2.1.3 Control

When control is spoken of in reference to cybernetic systems, it is meant in the sense of having an orchestra "under control" or mastering a sport or foreign language.

Control is the task of reducing the overall variety to an acceptable state, however that may be defined. This reduction can only be achieved if the regulation or control system possesses sufficient variety.

BEER has the following to say about control: *„...the control function is spread through the architecture of the system. It is not an identifiable thing at all, but its existence in some form is inferrend from the systems behavior.*"[26]

And yet control is a function of systems architecture and not an independent phenomenon. The most well known example of a control defined by the structure of a system is Watt's centrifugal governor. This mechanism is coupled to the engine and establishes a connection with a steam generator. If the machine's rotational speed increases, the weight is pushed upwards and the vent limits the steam supply accordingly. This leads to a reduction of speed, and this reduction in speed causes the weight to sink again, thus ensuring even engine operation. Control – in this case even speed – is exercised by means of the system's structure.

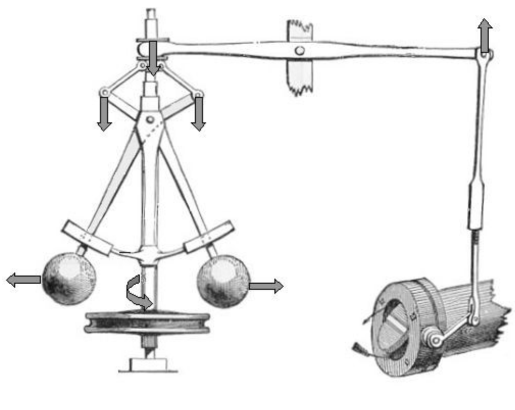

Figure 2-2: Centrifugal governor. Source: http://en.wikipedia.org/wiki/Centrifugal_governor, 7 June 2010

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[24] See MIROW,H.M. (1969): Kybernetik: Grundlage einer allgemeinen Theorie der Organisation, pg.70-77.

[25] See MALIK, F. (2003): Strategie des Managements komplexer Systeme, pg.192.

[26] BEER, S. (1972): Brain of the Firm,

Here control has nothing to do with the general concept of correction of a target-performance deviation. It is the process of "running out of control" itself that activates the control function. Running out of control is already built into the self-regulating control process.

2.1.4 Self-organization or homeostasis

A further property of cybernetic systems is self-regulation or homeostasis.[27] The systems to be regulated are no longer seen as "dead" or purely technical, but as biological. The most important thing is not a central view of all processes but to steer these processes by means of internal autonomous growth. Here nature serves as a model, since all living beings are ruled by this kind of automatism.

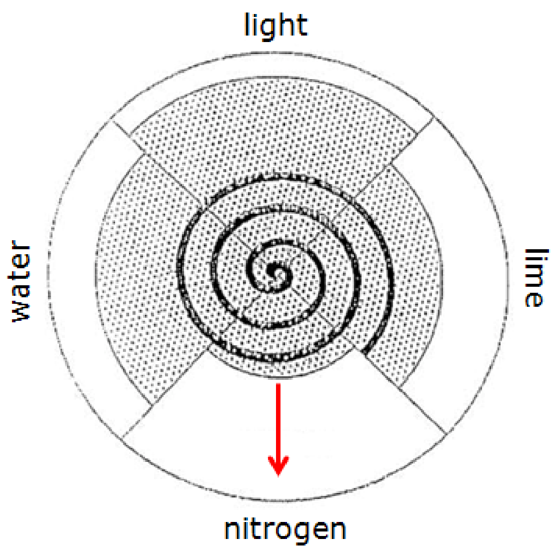

Figure 2-3: Automatism of a flower. Source: GREINER (2006) pg.12

The Figure here shows what is necessary to ensure growth using a plant as a model. This also implies independent development, provided sufficient growth factors are present. If one of these factors is lacking, the development phase is interrupted. Here these factors are water, light, nitrogen and lime. Within each growth cycle, which have a spiral like progression, a sufficient amount of the individual elements must always be present at the correct point in time. If one factor is missing – nitrogen for example – growth is interrupted. Regardless in what quantity the other factors are added to the system (for example giving the plant extra water), there will be no further growth. Only when the shortage – which has now become the system's minimum factor – is removed can growth continue. Later in the process another factor becomes the minimum factor and serves to hinder development. Here lime is missing and the "game" begins all over again. Every self-organizational process, whether it is initiated by an artificial socio-technical system or is the process of natural plant growth, is oriented around the minimum factor. When applied to companies, the deficiency is the factor that is hindering growth and this operational shortage must be found, demonstrated and eliminated. Yet the elimination of this shortage gives

[27] See BEER, S. (1970): Kybernetik und Management, pg.27ff.

rise to other problems. This is an important insight for the "Energo-Cybernetic Strategy" (EKS) discovered by MEWES. The role of this minimum factor in the growth of grain was identified by Justus von LIEBIG in the 19th century.[28]

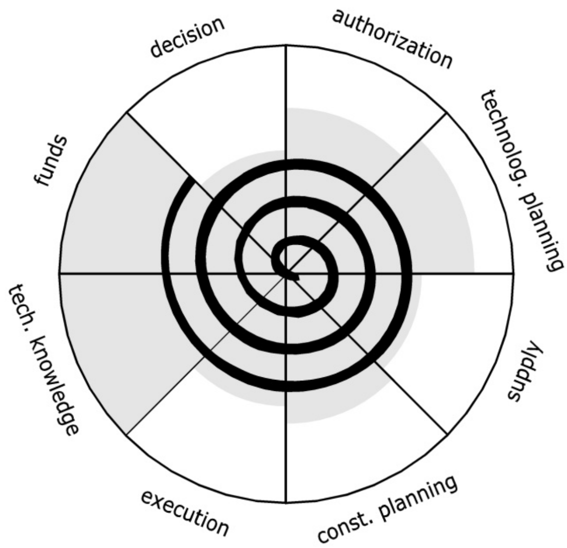

Figure 2-4: Cybernetic spiral of self-organization. Source: GREINER (2006), pg.13

This law of the minimum can also be applied to the development of a project (see Figure 2-4). If even one of the factors critical for development is missing, the others cannot come together to form a development system. All energy must be focused on obtaining the limiting factor. In regards to the completion and management of a project, this means that focus must be placed on deficiencies and blockages in order to ensure regulated, uninterrupted operation. Not allowing shortages to come about is the high art of management.

Explanations of homeostasis and the homeostat

Cybernetics attempts to identify the basic principles of the structure and behavior of any system, paying particular attention to the system's targeted output. The human body is a remarkable example of a self-regulating system, for which reason from the very beginning cybernetic experts made reference to and invented self-regulating machines based on it.

The capacity of a system, in particular of an organism, to maintain a stable state despite disturbances in the environment is referred to as homeostasis. The so-called homeostat is now a famous machine developed by the British scientist Ross ASHBY in the 1940s. Just as the human body maintains a constant temperature, the homeostat can maintain a constant electrical current in the face of outside disturbances by means of different kinds of feedback loops. Homeostasis, or self-regulation, uses the technique of feedback to maintain stability within certain limits. Here it makes no difference how the information is passed on – the only thing that matters is that the regulator receives information regarding changes so that it can make adjustments. As a regulating system, the homeostat forms the fundamental basis of cybernetic analysis and design.

[28] See FRIEDRICH, K. (2010): Das große 1x1 der Erfolgsstrategie, pg.26ff.

The structure of a homeostat as regulating system was demonstrated by ASHBY.[29] With his model he showed how a relatively simple system can be regulated to maintain the desired stability by means of a series of spontaneous behavioral changes. The formal structure of the cybernetic system is that of the homeostat.

ASHBY realized that every system that has the same structure as his model can be described in the following manner:

"Trajectory of a system running to astate of equilibrium."[30]

BEER defines the term homeostasis as follows:

„Homeostasis is the tendency of a complex system to run towards an equilibrial state."[31]

The homeostat, the self-regulator, is the fundamental regulation mechanism used by nature to keep a critical variable stable within physiological limits.[32] Another explanation offered by BEER for the homeostat by way of example is as follows: while the thermostat maintains a temperature within the desired limits, a homeostat is a general form of this kind of device – a regulating apparatus that maintains some variable (not necessarily temperature) within the desired limits by means of a self-regulating mechanism. BEER cites not just body temperature but also the reciprocal interplay of flora and fauna populations (plants – caterpillars – birds) as an example of the homeostat.[33]

MALIK's summarized description is as follows:

"The principle of the homeostasis is that of self-regulation by means of self-organization. The homeostat is the basic element of cybernetic explanation and design. A homeostatic system has the minimum requirements for autonomy, identity and survival. Combinations of more than one homeostatic system – that is, systems of a higher order that are composed of homeostatic sub-systems – make it possible to scientifically and practically explore and explain such phenomena as intelligence, cognition, learning, self-organization and evolution in an interesting manner."[34]

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[29] See ASHBY, W. R. (1970): An Introduction to Cybernetics, pg.83f.

[30] ASHBY, W.R. (1970): An Introduction to Cybernetics, pg.84.

[31] BEER, S. (1994): Platform for change, pg.426.

[32] See BEER, S. (1994): Decision and control, pg.289.

[33] See BEER, S. (1970): Kybernetik und Management, pg.37f. and BEER, S. (1994): Decision and control, pg.289. and BEER, S. (1994): Platform of change, pg.426.

[34] MALIK, F. (2000): Strategie des Managements komplexer Systeme, pg.390.

2.2 Cybernetics

By comparing the different standard definitions of cybernetics put forth by the various fields of research, MIROW has identified that the following common properties are of utmost importance for the entire discipline:

1. Investigation of targeted systems of random composition.
2. Formulation of generally valid statements on the structure and behaviors of these systems relative to a predefined goal.

Figure 2-5 serves to show cybernetics by means of a system (see Figure 2-1).

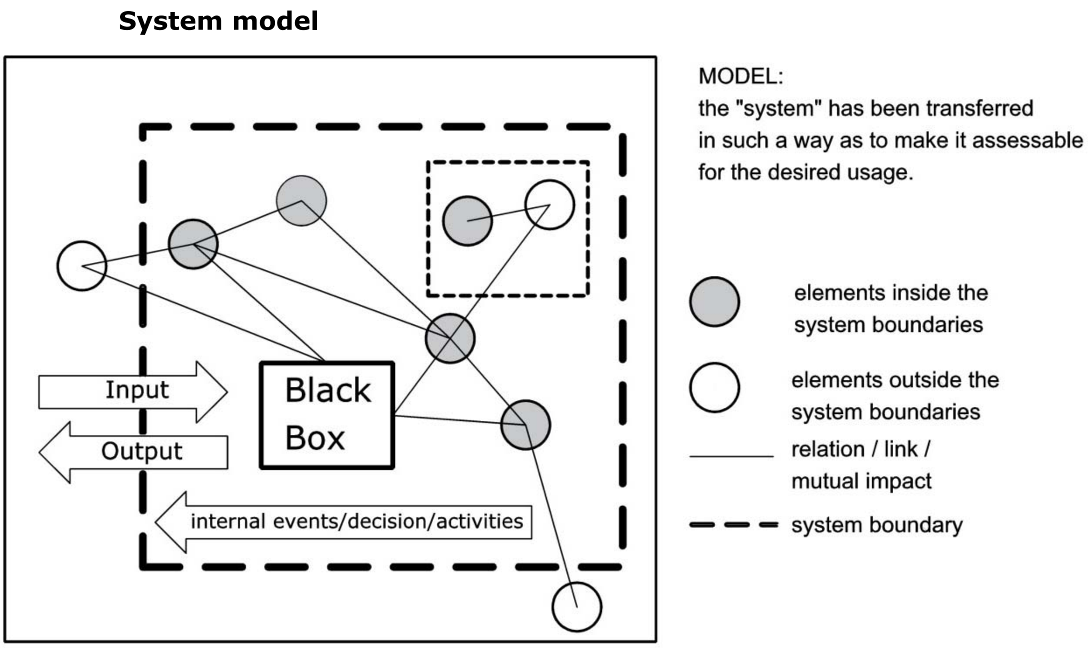

Figure 2-5: Simplified representation of cybernetics

He finally reaches the conclusion that cybernetics can be seen as a general theory of organization, the principles of which are valid for the structure and regulation of organizations of any size or nature.

"*Cybernetics is the formal, interdisciplinary metascience of the structures and message transformations of all imaginable target-oriented, dynamic systems*."[35]

Thus defines KRIEG cybernetics, focusing on the system as the overarching aspect of this broad research field. As a result the investigation of any kind of organization – regardless whether it involve living things, a community of living things or a machine – must be structured around the general principles of cybernetics.[36] The application of the discipline to commercial enterprises is often referred to as management cybernetics. As will be shown later on, construction cybernetics describes the practical application of management cybernetics to the field of construction.

[35] KRIEG, W. (1971): Kybernetische Grundlagen der Unternehmungsgestaltung, pg.27.

[36] See MIROW, H.M. (1969): Kybernetik: Grundlage einer allgemeinen Theorie der Organisation, pg.19ff.

By the term cybernetics, as it is used below, we understand a certain type of cybernetics that represents a continuation of the work by Norbert WIENER and Heinz von FOERSTER, but that has little to do with the regulation methodology or regulation theory that also goes by this name. Two attempts at a definition for this "second-order cybernetics" (see section 3.4) should here be presented:

"Cybernetics is the science and the art of self-organization and target-oriented leadership in complex systems of actions. In a very simplified way, just as physics is the science of forces or (more accurately) of energy, and chemistry is the science of substances, cybernetics is the science of information. Information in the cybernetic sense is the third basic natural scientific substance, which organizes matter and energies into sensible systems."[37]

"By cybernetics we understand the recognition, steering and independent regulation of intermeshing, networked processes using a minimum amount of energy. In the area where cybernetics has functioned since time immemorial – in biological events – it by no means refers to detailed pre-programming or central navigation (the navigator is part of the system), but rather only to impulse guidelines for self-regulation, "tappings" of correlations between an individual and the environment, the stabilization of systems and organisms through flexibility, use of all present forces and energies and constant interaction with them."[38]

Since this paper focuses on the application of cybernetics to the field of construction and goes beyond a pure subject-relevant use of the term to briefly discuss the purpose of construction cybernetics in companies in the construction industry, construction cybernetics can here be summarized as follows:

Construction cybernetics attempts to simulate viable organizational systems in models within the overall field of construction management (ranging from project development to planning to the construction itself), to identify rules and to reach a high degree of self-organization and autonomy.

The goal of construction cybernetics should be to turn a building project into a viable system that can then be integrated into the company, which as a whole functions as a viable organizational system.

How an organizational system can be formed or structured will be discussed in the following sections.

[37] GREINER, O. (2006): Skriptum Projektmanagement – Bau, FH-Kärnten

[38] VESTER, F. (2008): The Art of interconnected thinking, pg.150.

2.3 Management

In addition to the standard view of management as the leadership of commercial enterprises, it can also be seen from a different perspective. Management itself is generally thought of as the design and steering of sociotechnical systems. Since these systems are complex functional structures, in essence management is the ability to deal with complexity.

The complexity of sociotechnical systems is determined by the potential interactions between the system elements and the multiple state configurations resulting from these interactions. The larger the number and multiplicity of the states of a system, the more difficult the task of management becomes. To maintain control over a system it is necessary, as will be shown in section 2.1.1, to avoid potential but unacceptable states and to establish or maintain desired states.

According to BEER, "*The material with which management deals is complexity*"[39]

Money and capital, machines and materials, products, prices, margins and cash flow, profit and investment, employees and clients, etc. – these are all manifestations of complexity, as well as the form in which complexity manifests itself.[40]

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[39] BEER, S. (1975): Platform for Change, pg.221.

[40] See MALIK, F. (1993): Systemisches Management, Evolution, Selbstorganisation, pg.22.

3 Systems Theory and Model Generation

The disciplines of cybernetics and systems theory that will here be discussed revolve around the term "system". The meaning of this concept has already been explained (see section 2.1).

In reviewing the relevant management literature, one often notices that terms from cybernetics and systems theory, which are very similar in their structure but do not always describe the same phenomena, are used synonymously, which sometimes leads to an imprecise understanding. A general review of the field of systems theory and cybernetics is essential for an understanding of systemic management.

3.1 The system-oriented approach to management

The most essential basic concepts of a system-oriented approach to management are systems theory and cybernetics. For an initial classification of the terms the overview provided by Ulrich is helpful (see Figure 3-1). As a comprehensive term, systems theory includes all possible systems (real and imaginary), while cybernetics deals with technical and social systems, as well as living entities. In this sense the terms cybernetics and systems theory are used in a parallel manner. System-oriented management focuses, however, on one aspect of cybernetics – social systems.

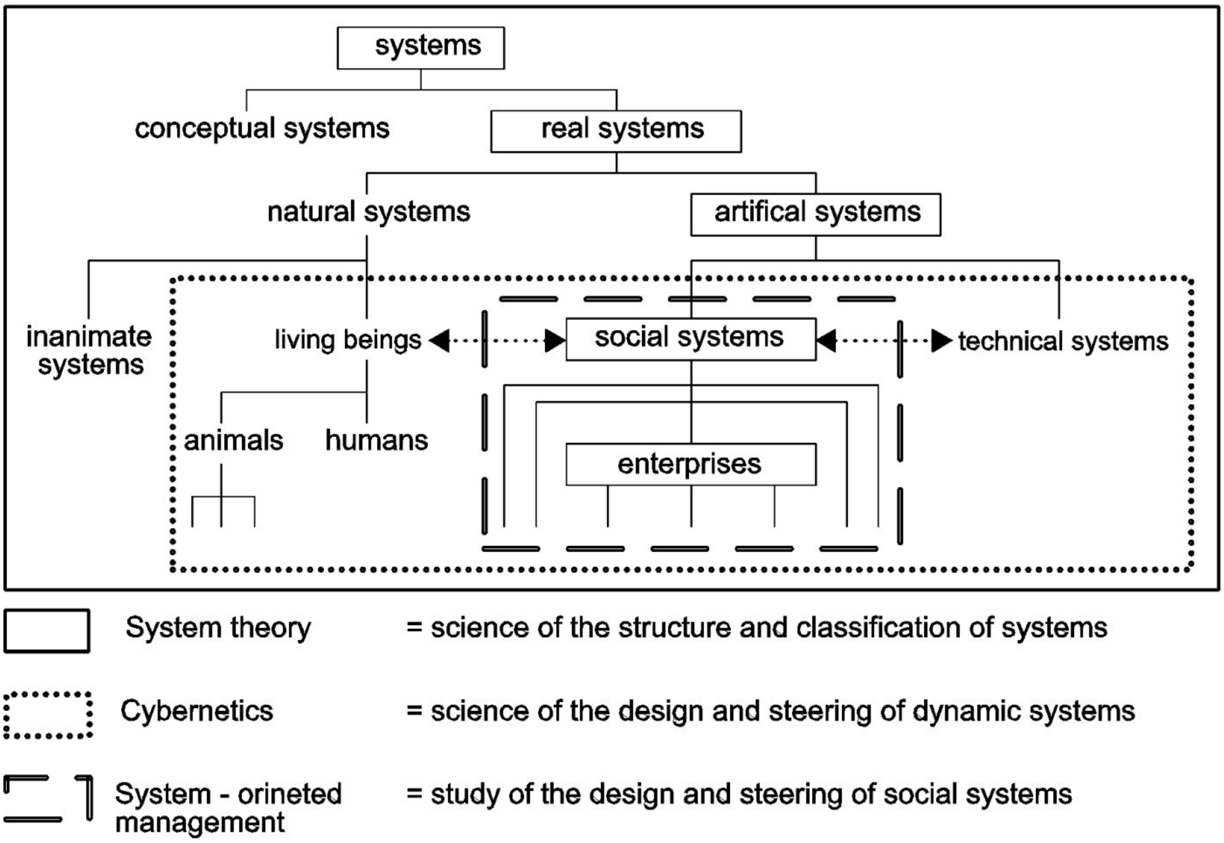

Figure 3-1: Overview of systems, cybernetics, systems theory. Source: ULRICH (2001) pg. 44

In the relatively short time of their existence, cybernetics and systems theory – the foundational phase of both disciplines will be briefly reviewed – have undergone a complex development, branched out in countless directions and seen tremendous conceptional penetration into a wide range of scientific fields.

From the repertoire of system-oriented management tools, two will be chosen that should help turn existing organizational structures in companies in the construction industry into viable systems.

One of these tools is the Viable System Model (VSM) defined by Stafford Beer (see section 3.8). It will be used to demonstrate the necessary general orientation derived from cybernetics and systems theory. In this function VSM provides the basis for the structure of the organization of a company and for the responsibilities of management.

Functional structures as developed by VESTER (system-oriented model generation) will also be introduced. These will be utilized to create transparency for crucial, essentially internal relations. With this type of model generation, the way in which different aspects of a company's policies are related will be illustrated. The results must then be transferred into practical solutions to be applied to common company situations.

The abstract and conceptional basic ideas – the system, cybernetics and systems theory – necessary to use both tools have been or will later be discussed.

In the case of all the issues covered, reference will be made to originators, from which the path to the philosophy and tools applied will be comprehensively described. System-oriented processes (that is, processes based on cybernetics or systems theory) are of importance here and not mathematical, theoretical derivations.

The overview of systems-oriented management will be limited above all to the methods of Stafford BEER, the University St. Gallen, the MALIK Management Center in St. Gallen and Jay W. FORRESTER.

3.2 Basic concepts of system-oriented management[41]

Fredmund MALIK has examined the cybernetic organizational structures of management systems in a series of publications. In the process he has developed three fundamental lines of thought necessary for the understanding of system-oriented management.

- We have to let go of the illusion of predictability and of the more or less unlimited "doability" of all things. Experienced practitioners of management know, of course, that these ideas are false, because they have seen too many prognoses turn out to be wrong or misleading, and too many absolutely perfectly conceived plans fail, and are as a result all too aware of the real limits of such concepts.

- A conscious decision to refrain from regulation of or intervention in details does not lead to a reduction of management potential, but on the contrary to a strengthening and expansion of managerial possibilities. At the same time, this does mean that the function and role of management – its goals and results – change. Of special importance here is the fact that humans are not merely target-oriented creatures, but to a far greater extent rule-oriented creatures. Yet order and organization cannot be understood without knowledge of the special rules that apply to them. Most, however, are not familiar with how rules work or the different kinds of rules and their effects. For this reason no conscious, systematic treatment of rules has been worked out. No organization can work without them, but they are misunderstood and generally poorly documented, for which reason their potential effects are by and large never utilized. Yet rules are the key to the self-organization and self-regulation of systems and thus the most important management mechanism in a complex information organization.

- Distinction between small and large systems, between simple and complex systems. The vast majority of new system-oriented literature is devoted to the way in which small systems or face-to-face groups work – be they work groups, project teams or families. Most writings by organizational psychologists and organizational developers, psychologists, social psychologists, therapists, as well as communications and cognition experts focus on the small system of the face-to-face group. This is generally the specific situation that these researchers face when they work in organizations. Their methods and interaction are almost always related to a relatively small number of physically present human beings who can be observed and who act and react directly. Of course such systems are relatively simple. Systems theory and cybernetics can only reach their full potential in large, very complex systems, and it is here that we most critically need them.

[41] See Malik, F. (1993): Systemisches Management, Evolution, Selbstorganisation, pg.10.

3.3 Systems theory

"First of all there is no systems theory, there are only a lot of systems theories, which in the fields of mathematics, computer science, biology or sociology do not just differ in terms of their applications, but also in their basic conceptions, and that thus are defined and formulated completely differently within their theoretical architecture."[42]

With this statement BAECKER refers to the fundamental problem of systems theory. Furthermore, a strict distinction between cybernetics and systems theory is not very easy, despite the clearly defined dimensions of the two fields (ULRICH's definition, Figure 3-1). Just how difficult it is to distinguish between the two is demonstrated in the collection of essays edited by BAECKER entitled *Schlüsselwerke der Systemtheorie* (Key Works of Systems Theory).

Just as WIENER is considered the originator of cybernetics, Ludwig von BERTALANFFY is seen as the father of systems theory. He called his approach General Systems Theory (GST).

Jay W. FORRESTER calls his systems theory System Dynamics. In the book *Principles of Systems*, he sketched out his program. This book deals with the structure and principles of systems, focusing on the micro and macroeconomic organizations and the social systems that bring together humans, monetary funds and physical elements.[43]

FORRESTER too expands the concept of the system and looks for a least common denominator for all research fields.

"In system concepts we should find a common basic element that unites the natural sciences and humanities."[44]

System Dynamics places focus on practical implementation and success in the application of theory. In contrast to GST, it is presented as a closed process and not as a collection of methods and impulses.

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[42] BAECKER, D. (2005): Schlüsselwerke der Systemtheorie, pg.17.

[43] See FORRESTER, H. (1972): Grundzüge einer Systemtheorie, pg.14

[44] FORRESTER, H. (1972): Grundzüge einer Systemtheorie, pg.14.

3.4 Constructivism (role of the observer)

In terms of the fundamental underlying philosophical issues, systems theory and cybernetics are based on a branch of epistemology referred to as constructivism. The most important proponents are Heinz von FOERSTER, Humberto MATURANA, Gordon PASK, Heinz von GLASERFELD and Stafford BEER.

Stafford BEER was the first to use cybernetic principles and to understand the role of the observer. This was called "second-order cybernetics". While first-order cybernetics focuses on the control of systems and thus generally serves to design systems in such a way that a pre-defined goal can be reached, second-order cybernetics looks at autonomous systems that define their own goals. It concentrates on the question of how goals are constructed.[45]

When cybernetic principles are applied to social systems, the role of the observers of the system must be taken into consideration, as these observers cannot remain outside of the system that they are examining and cannot avoid having an influence on it. Criticism of systems theory and cybernetics also focuses on their philosophical foundations. Without making any final judgment, this author pragmatically accepts and even later presupposes certain consequences of constructivistic reflections along the lines of the following statements by RÜEGG-STÜRM:

„*The way we explain a complex system depends first of all on the section of the system we are observing and above all on the concepts and linguistic possibilities available to us in formulating the description*."[46]

„*Second of all, a system description and thus the perception of a company problem depends to a critical extent on the context in which we interpret our observations*."[47]

For this reason it is best when different individuals study a complex event or system. Only the descriptions of different observers can allow a person find out to what extent that which is being reported is a function of the observer or a function of the events themselves.

[45] See UMPLEBY S. (2006): The History and Development of Cybernetics, pg.166ff.

[46] RÜEGG-STÜRM, J. (2002): Das neue St. Galler Management-Modell, pg.19.

[47] RÜEGG-STÜRM, J. (2002): Das neue St. Galler Management-Modell, pg.19.

3.5 The systemic-cybernetic perspective

Even apparently simple systems are sufficiently complex to make the effect of structural measures uncertain and difficult to calculate or predict. With its explicit focus on problems of guidance, cybernetics warns us of overly hasty assumptions of simplicity or straightforwardness. The variety of symptoms or number of potential states that a system can assume is usually massive. And yet it is only possible to determine what is happening if a system is under control, as this means that not all states that could arise will arise. Only when regulation fails or proves deficient does one become conscious of a system's variety. Cybernetics and systems science teach us that in the final analysis every system is extremely complex and effective control depends on the following factors:[48]

1. Steering always means reducing the total potential states to those that are desired.
2. Every single regulator (whatever relation it might have) must be capable of absorbing undesired states in some form or another. The regulator must be at least as complex as the system to be controlled.
3. Design is also a steering issue, because all that a design process does is select certain states from the entire range of possible states.
4. The regulation mechanisms of truly complex systems cannot be localized, as they are distributed or diffused throughout the system.
5. Processes such as adapting, learning, utilizing experiences or gaining insights are the result of steering processes, but they are also generally part of broader regulation systems.
6. The most effective regulation systems are self-regulating, self-organizing and evolutionary.

Undoubtedly there are many differences between systems (animate vs. inanimate, natural vs. artificial, organic vs. social), and their regulation processes also appear wholly different. Yet despite this variety there are considerable similarities or parallels, which are in turn the focus of the system sciences.

[48] See MALIK, F. (1993): Systemisches Management, Evolution, Selbstorganisation, pg.185.

3.6 Self-organization of systems

In our role as responsible decision makers, we assume that we decide, that we plan, that we organize, and that by and large the results of our actions correspond to our intentions and plans − the premises of currently prevailing management thinking would seem to preclude any doubt that an enterprise is organized and does not organize itself. According to systemic thinking, the very opposite is true and to a surprisingly high degree every enterprise is a self-organizing system. The theory states that we only have enterprises under control to a limited extent, that in reality they have us under their control, regardless how high our position in the hierarchy might be. As previously explained, the systemic-evolutionary management theory assumes that organizations are subject to a self-organizing process. This means that as in accordance with the principle of natural selection, the organization will independently adapt and advance itself under the influence of modified environmental conditions or in accordance with its own experiences and expectations (see section 2.1.4).[49] As proof of the self-organizing nature of enterprises, MALIK cites some simple phenomena:[50]

- For every consciously made decision there is a far greater number of decisions that no one makes, that are made of themselves.
- For every consciously planned event there is a greater number of events that no one has planned, that simply happen.
- The individual dynamic of the system that we are attempting to control is the reason why we are compelled to constantly correct our plans.

The most effective way to intervene in the self-organization process, to steer the system, is to define the framework conditions. The most important thing in organizations is to determine a structure that allows for and promotes self-organization. The process by which organizations adapt evolutionarily to changing conditions is referred to as learning.[51]

The phenomenon of self-organization requires a new leadership culture that does not utilize and command humans, but that strives to promote self-organization. In a brochure by PRO MAN (International Society for Fractal Productivity Management), "to lead" means the following:

"Not to command but to listen and to reach agreements." To lead does not mean to control but to arrange for all work factors reliably and on time and thus to ensure that that which has been agreed upon can take place. One does not lead others, one leads *for* others and is obligated to provide these others with uninterrupted work processes, better working conditions and a high degree of self-organization. Of course the so-called "rules of the game" are also agreed upon together. Then the person leading, like the referee, lets the game take its course. The whistle is only blown if a rule is violated.[52]

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49 See MIROW, H. M. (1969): Kybernetik, pg.87ff. as well as KRIEG, W. (1971): Kybernetische Grundlagen, pg.96ff.

50 See MALIK, F. (2000): Systemisches Management, Evolution, Selbstorganisation, pg.319.

51 See MIROW, H. M. (1969): Kybernetik, pg.112ff.

52 See PRO MAN (2000): Internationale Gesellschaft für fraktales Produktivitätsmanagement

3.7 System-oriented modeling

One of the goals of this work was said to be the creation of transparency in the most critical internal relations, a viable basis for the perception of potential and actual problem areas, and of a procedure for decision making. Here model generation is to be seen as a fundamental element and requirement in preparing for the completion of all the tasks that must be carried out within a company.

3.7.1 Requirements of model generation

In defining the terms cybernetics and system in chapter 2, it was determined that model generation can be a way to make a system capable of assessing a defined problem in relation to a complex task.

Now the specific application of this theoretical concept must be clarified. Into which categories can tasks be divided? How will the most suitable system for each be developed and how will a model then be generated?

Dietrich DÖRNERS classic text *The Logic of Failure – Strategic Thinking in Complex Situations* focuses primarily on behavior-based approaches. We will not examine these here. While he explains and documents the main topics of his book with examples, he also provides step by step instructions for processing complex problems in their totality (see Figure 3-2).

DÖRNER describes the properties of complex problems in the following manner:

„*Complexity, lack of transparency, dynamics, level of networking and incompleteness or incorrectness of knowledge of the respective system – these are the general properties of the action scenarios in dealing with such systems, drawing attention to errors that can come about in the course of processing or searching for solutions*."[53]

The tasks defined by DÖRNER are illustrated and simulated by means of a computer program. The author explains that side and long-distance effects must be taken into consideration. He does not describe how this is to be done. Nor does he present a procedure for generating criteria or the necessary rules. His notes serve as orientation for the partial steps to be completed in solving problems in complex environments.

These notes are extremely comprehensive and useful for the model generation phase. For this reason the following model generation procedures will be looked at in relation to the requirement profile formulated by DÖRNER.

[53] DÖRNER, D. (2003): Die Logik des Misslingens, pg.59.

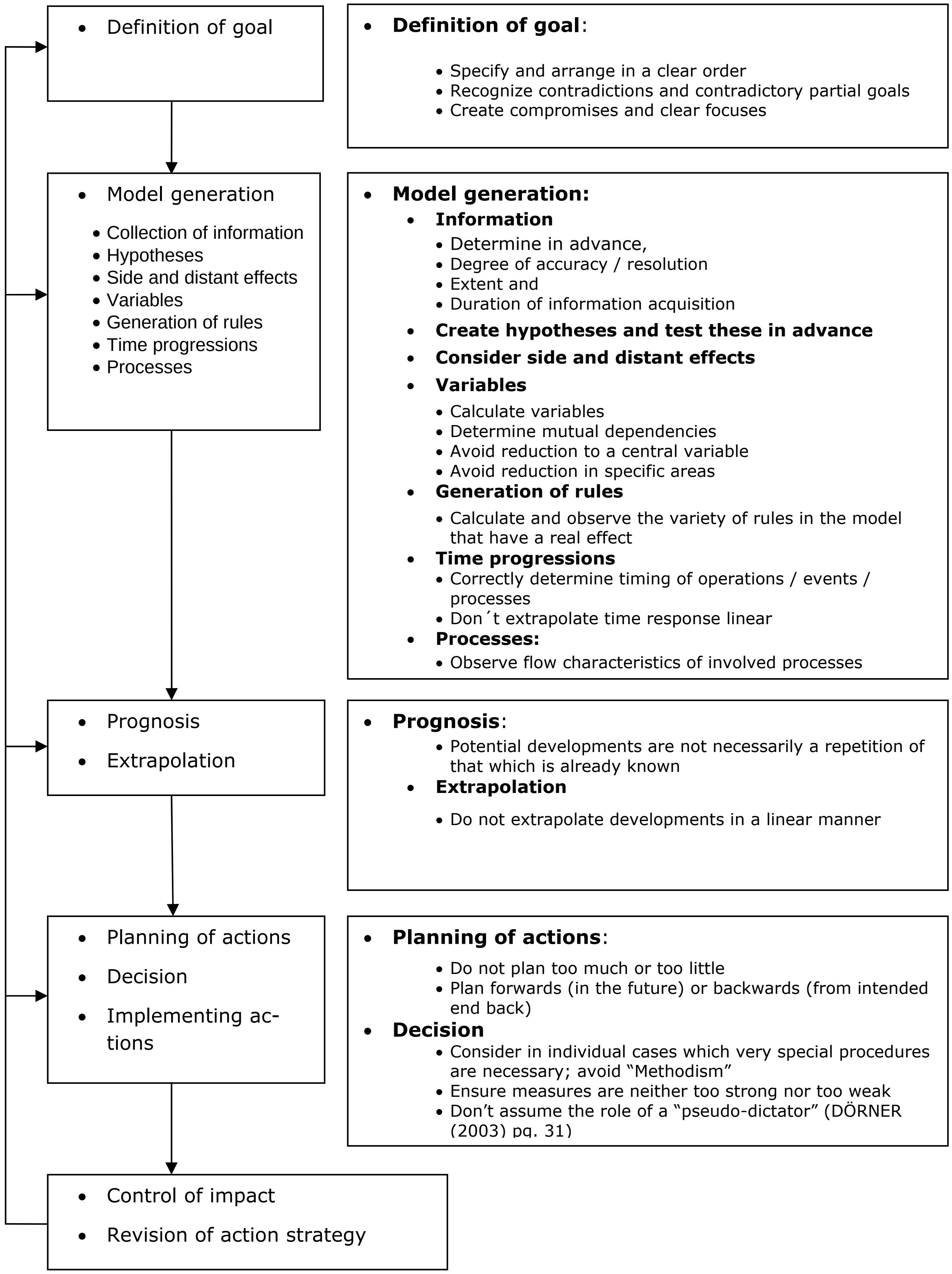


Figure 3-2: Procedures for problem solving, as defined by DÖRNER[54]

[54] See DÖRNER, D. (2003): Die Logik des Misslingens

3.7.2 Qualitative and quantitative model generation

The basis for all forms of graphic model generation is the representation of the system's structure, as seen above in defining a system (see Figure 2-1). Such graphics are called functional structures.[55]

The mathematical basis for this is graph theory. Here the elements are transformed into nodes and the effects of the communication paths become the ends of the effect graph.

The effects are represented as arrows. A full line indicates a concordant effect, and a dotted line a contrary effect. In a fictitious example this would mean the following:

Effect from A to B:

The more employees are permitted to share in the company's success, the greater employees' motivation is.

Effect from A to C:

The more employees are permitted to share in the company's success, the lower the fluctuation rate.

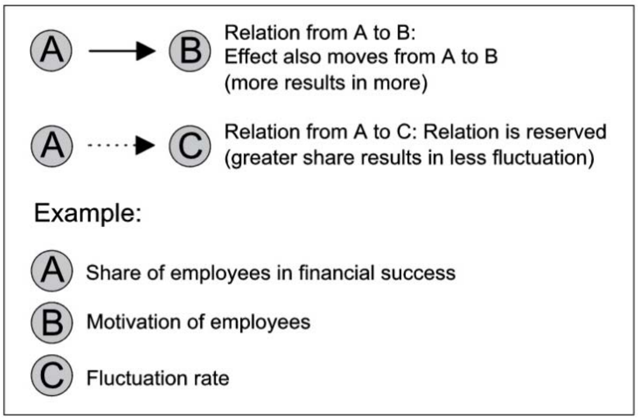


Figure 3-3: Effects in a functional structure with example. Source: VESTER (2008) pg. 233

If effects work in both directions, one speaks of feedback. Negative feedback tends to have a stabilizing (moderating) effect and positive feedback tends to have a destabilizing (amplifying) effect.

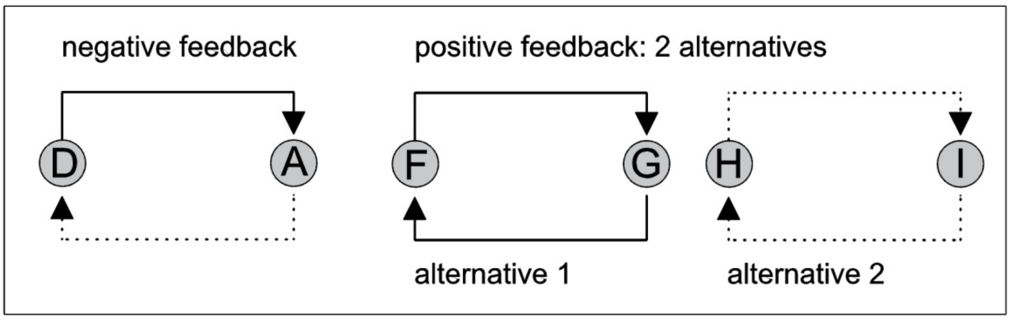


Figure 3-4: Negative and positive feedback. Source: VESTER (2008) pg. 233f.

Positive feedback can be understood as an amplifying loop, which symbolized by a snowball rolling down a slope. On the other hand negative feedback is called a compensatory loop and is symbolized by the arm of a balance. Both the balancing tendency of the contrary effect (in the case of negative feedback) as well as the escalating influence in an upwards or downwards direction (in the case of positive feedback) are quite good. It is important to note here that in the

55 See VESTER, F. (2008): The Art of interconnected thinking, pg.208.

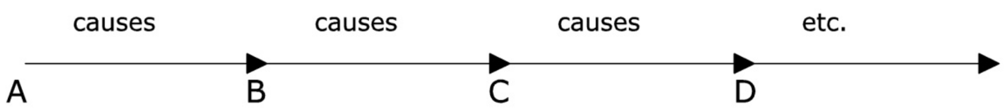
case of positive feedback the elements can move in opposite directions, that is increase and decline at the same time.[56]

In qualitative model generation elements are connected by means of effect arrows, the connections between the elements are, however, not expressed in a mathematical form.

For the formulated task of this analysis the desired statements can be obtained from qualitative model generation.

3.7.2.1 Regulation Systems

A large part of human thought functions on the basis of linear causal chains. An effect is followed by another effect, which then becomes the cause for another effect, etc.



Based on empirical observations of organisms and systems, cybernetics follows a thought scheme based on circular systems that also take feedback into consideration.

Of the two regulation variants – negative, stabilizing feedback and positive, destabilizing feedback – especially the first can be used in a controlled manner.

Control circuits (see section 1.2) are based on the principle of negative feedback. The system reacts to feedback and corrects its behavior in order to reach a given target value. A well-known example is a thermostat, which measures the temperature in a room, compares it to the desired temperature and introduces the corresponding measures in order to attain the final criteria. The thermostat is, so to speak, a system that attempts to maintain a certain order (a constant temperature). It continually compares the environment with the value that has been entered in it and attempts to shape the environment in such a way that it reaches this value, i.e. by decreasing or increasing the heat supply.

3.7.2.2 The regulation system of enterprises[57]

Markets and companies are like biological organisms, that is like networked systems. The modification of one element has effects on the entire system, both positive and negative.

In companies the actual structure of these elements will depend on concrete regulation requirements. Organizations like companies and other similar systems are essentially guided and regulated by means of strategies, their structure, as well as by the culture that prevails in them. The strategy contains the fundamental purposes, tasks and programs of action; the structure determines the distribution of responsibilities, knowledge and above all the flow of information; the culture consists of values, behavioral norms, mentalities and the intellectual focus of the organization's members.

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[56] See VESTER, F. (2008): The Art of interconnected thinking, pg.241.ff.

[57] See MALIK, F. (1993): Systemisches Management, Evolution, Selbstorganisation, pg.226.

3.7.3 Sensitivity Model Prof. VESTER ®[58]

In the over 25 years of work that ended with his death in 2003, the molecular biologist, biochemist and environmental expert Frederic VESTER was continually developing his method of sensitivity analysis – a range of planning tools that first make the creation and evaluation of complex systems user-friendly.

The universality of these tools is evident in the diversity of applications to which they lend themselves, from company strategy and risk management; to training, education and the organization of communal operations; to issues of traffic abatement and waste management; to the electricity industry and sustainable city and regional planning.

How the sensitivity model works

The computer-aided arsenal of tools is "subject neutral", that is it works independent of the nature and problems of the system being analyzed, since it is oriented around fundamental control and regulation processes in complex systems, be it a country, a region, a town, a single company or even a single complex issue. The model allows the user to create and visually represent a system and its socio-economical and ecological environment as a biocybernetic whole, and to scrutinize the system's cybernetics.

Here it is above all the mathematics of "fuzzy logic" (integrated into the process from the very onset) that makes it possible to obtain reliable information about the behavior of the system even from not very relevant data and its order parameters. At the same time, the model offers a way to incorporate not just quantitative inputs but also qualitative relations and to process the two together using various tools. Below an overview of the entire model will be presented and briefly described. Certain aspects of the Prof. VESTER® Sensitivity Model will be looked at in greater detail.

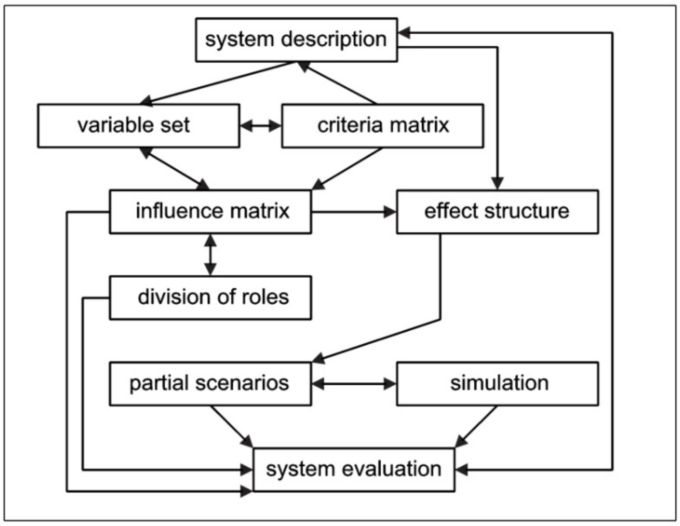

Figure 3-5: Sensitivity Model ® procedure. Source: VESTER (2008) pg.192

58 See VESTER, F. (2008): The Art of interconnected thinking, pg.190ff.

Figure 3-5 shows a rough flow chart of the Prof. VESTER® Sensitivity Model computer program. Similar to the networked approach, digital implementation is characterized by the (in some cases) necessary recurring regressive steps as well as by adjustments to already completed work operations (recursive structure), both of which are taken into consideration in the programming phase.

Departing from the statement made in 2.1, VESTER refers to the units not further categorized within a functional structure not as "elements" but as "variables". This term will be used accordingly in this chapter. The selection of variables will correct the initial system description and its appraisal. The revision of the influence matrix will serve to question the definition of many variables and the simulation of policy tests even within the system description will uncover new aspects, whereby the basic biocybernetic rules will not only be encountered as a first and last authority but over and over again throughout the process. In this way the system is repeatedly being tested against itself until a model is created, and even afterwards as this model is being implemented into a strategy compatible with the system.[59]
When the system is described in words, there is an initial definition of the system's limits. A useful boundary line tends to run along the minimum flows that cross over into other areas.[60]

It must be ensured that in the description the existing layers of a system are also expressed linguistically as separate levels. With a reasonable number of superordinate terms, a system can be roughly described. These terms can than become more detailed, though this explication represents a further level of the system and can contain data, information and opinions. The introductory step is carried out as moderated brainstorming with as representative a random sampling of the disciplines or persons involved as possible.

This still relatively unstructured collection will be more meaningfully formulated in a second processing stage. VESTER calls the descriptive terms a "set of variables" and recommends that these be limited to 20 to 40 items. The observation mentioned above of the levels of a system is now carried out in a thorough manner. The fluctuating sizes are individually classified in the description of the variables and explained in detail, if necessary. All the variables are listed out and evaluated, since only in this way will they be of use in an impact analysis. In this context "evaluate" means that the fluctuating sizes will be qualitatively assessed and not neutrally formulated. One client variable, for example, can be recorded as client satisfaction.

Now the variables will be analyzed for balance and completeness in accordance with a defined catalogue of criteria. This stage is registered in the criteria matrix. The fluctuating dimensions should be assessed in full and factored in (expressed in the sum of the value points) in a consistent manner. VESTER divides the criteria defined for his method into life-related fields (economics, population, land use, human ecology, ecological balance, infrastructure,

[59] See VESTER, F. (2008): The Art of interconnected thinking, pg.168f.

[60] See VESTER, F. (2008): The Art of interconnected thinking, pg.209.

commonwealth); physical criteria (matter, energy, information); dynamic categories (flow size, structural size, temporal dynamic, spatial dynamic); and system relations (opens system through output, opens system through input, can be internally influenced, can be externally influenced). It can, however, be advantageous to revise the criteria matrix for more specific use. For example, to apply the method to a company, it would make sense to replace the life-related fields with business-related fields.[61]

In the Prof. VESTER® Sensitivity Model the selected criteria are applied to every problem. The criteria from the partial matrix certainly cover a wide range of tasks. That is why the different projects feature a similar organizational structure, from which comparable frameworks emerge, so that so-called structural models can be identified.

legend:

● fully applicable (1.0 point)

○ partly applicable (0.5 point)

	criteria 1	criteria 2	criteria x
variable 1	●	●	●
variable 2	○	○	●
variable y		●	
total	1,5	2,5	2,0

Figure 3-6: matrix of criteria. Source: VESTER (2008) pg.216

In an influence matrix, the variables are assessed in terms of their effects on one another. These effects are added up horizontally as the active sum (AS) and vertically as the passive sum (PS). For each variable two indices (the product or quotient times 100) are derived from the AS and PS. Using these indices the properties are classified as active, critical, buffering or reactive (according to the entry in the role assignment matrix).

Influence by ↓ to →	1	2	3	4	5	active total (as)	as x ps
variable 1	0	0	2	1	1	4	20
variable 2	2	0	3	0	0	5	15
variable 3	0	1	0	0	0	1	5
variable 4	0	2	0	0	3	5	5
variable 5	3	0	0	0	0	3	12
passive total (ps)	5	3	5	1	4		
(as/ps)x100	80	167	20	500	75		

Figure 3-7: matrix of consensus. Source: VESTER (2008) pg.221

The parts of the functional structure have already been introduced. Partial scenarios serve for detailed analysis of sections of the overall system.

61 See GOMEZ P. PROBST G. (2004): Die Praxis des ganzheitlichen Problemlösens, pg.49

For the simulation VESTER uses fuzzy logic:

„It seemed to us important in this connection to depart from the usual way of portraying a simulation, which hides its algorithm behind mathematical functions and differential equations in such a way that no one can understand the thinking behind it. In the end, traditional simulations never cease to be 'black boxes'. With the aid of fuzzy logic, at least they can be turned into 'grey boxes'."[62]

The system is evaluated according to the fundamental rules of biocybernetics. Like the criteria from the criteria matrix, the fundamental rules of biocybernetics will be used in every sensitivity analysis.

It only really makes sense to use the entire Prof. VESTER® Sensitivity Model for very complex problems (and only with the aid of software).

The entire requirements profile for the generation of models as defined by DÖRNER (see section 3.7.1) is fulfilled by the Prof. VESTER® Sensitivity Model.

The Sensitivity Model Prof. VESTER ® includes the following:

- Structured procedure for the classification of tasks (system description, set of variables, criteria matrix)
- Qualitative impact analysis with evaluation (influence matrix, role assignment)
- Quantitative impact analysis (mathematical using fuzzy logic)
- Simulation with assessment based on clearly defined indicators (fundamental rules of biocybernetics)

The result of the assessments is not conventional forecasts. The practice of developing future scenarios by means of trend projections or of predicting events is forsaken, as this is not possible in complex systems. Yet it is helpful to recognize the properties and development potential of an existing or planned system and to work with them using policy tests and if-then prognoses of system behavior in such a way that the system is better able to react to unexpected events.

A further advantage of a sensitivity assessment is that the focus is placed not on optimization of a specific desired state but on optimization of skills and faculties, for example the viability of a company or of a habitat. Yet viability in the evolutionary or sustainable sense means that there is potential for development and thus for optimization of the ability to adapt to ever changing conditions, better flexibility and the creation of spaces where free decisions can be made.

[62] VESTER, F. (2008): The Art of interconnected thinking, pg.250.

Assistance in decision making with fuzzy logic

In the early 1970s Prof. Lotfi ZADEH developed the theory of fuzzy logic and "blurred" groups of system elements – so-called fuzzy sets.[63]

In the intervening years fuzzy logic (FL) has come to be used throughout the world in control technology (i.e. camcorders in order to compensate for shaking), data analysis and in systems designed to aid in decision making. For example, in the building industry fuzzy logic is used in constructional engineering,[64] in the process control of construction machinery, in the risk assessment of construction processes and as a supporting tool in software for construction damage prevention.[65]

With imprecise or vague terminology human intelligence is able to grasp conditions and tasks and to derive clear and decisive decisions. If we take "fuzzy" to mean "unclear or out of focus" and reduce the use of fuzzy logic to assistance in making decisions, then FL implies the attempt to express basic conditions, our "unclear world", in a mathematical form.

These terms were introduced for that special kind of imprecision or fluctuation range that cannot be statistically defined – for the lack of clarity, ambivalence, generalization and conflicting criteria that are characteristic of environmental and social systems.

The special thing about fuzzy logic is that it uses the unclear knowledge of real experience, creates a compromise out of contradictory information, and then implements this compromise. The values remain variable, even while taking the individual basic conditions into account. In this way FL makes the kinds of flexible control processes possible that are found in natural ecosystems. Important here are not precise measurements but rules of action. These can be formulated clearly in words (unclear but true).

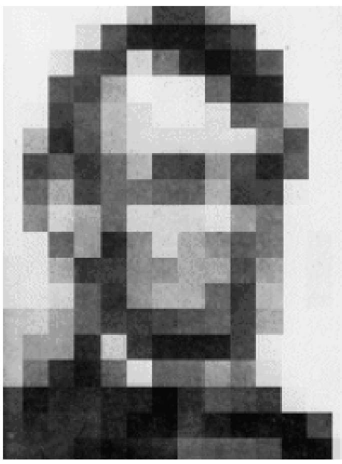

Figure 3-8: Picture of Abraham Lincoln. Source: VESTER (2008) pg. 54

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63 See ZADEH, L. (1965): Information and Control, pg.338-353.

64 See MÖLLER, B. (1997): „Fuzzy" Modellierung in der Baustatik, pg.75-84.

65 See RIZKALLAH, V. / DÖBBELIN, J. (2001): Pluris schätzt das Risiko ab, pg.30-35.

An explanatory model for fuzzy logic used by Frederic VESTER is an image of Abraham Lincoln's head. While fuzziness leads to the recognition of patterns, even the most detailed examination of the squares will not yield anything comparable. The number and sizes of the squares can be measured, the shades of the gray scale can be determined and represented in tables. This is the wrong scientific method to grasp this system, and it does not become more "correct" if it is applied more meticulously. As long as we recognize details clearly, our brains work analytically, registering and interpreting them with certain parts of the cerebral cortex. If the image is seen unclearly, however, the details fade into the background and the relations between them become more apparent. One notices that suddenly completely different brain cells become active. Instead of seeing vertical and horizontal lines and fluctuations in the gray scale, curves and surface proportions are registered, the ability to recognize patterns is activated, so that critical system correlations are seen.[66]

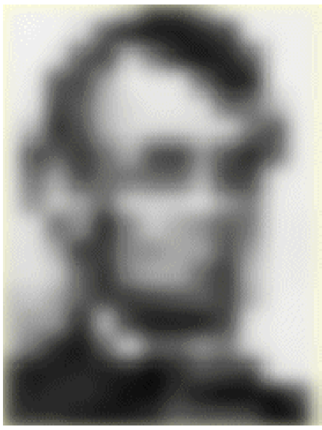

Figure 3-9: Computer image of Abraham Lincoln. Source: VESTER (2008) pg. 54

[66] See VESTER, F. (2008): The Art of interconnected thinking, pg.54f.

3.8 The Viable System Model (VSM) of Stafford BEER

The development of cybernetics was described as the reciprocal fertilization of many difference academic disciplines. Involved were the natural sciences, mathematics, medicine as well as the humanities and social sciences. Attempts were made to verify technical inventions or insights in mathematics by way of similarities with observations made in the field. At the same time observations made of living systems motivated the search for a way to transfer knowledge to the fields of mathematics or engineering.

3.8.1 Advantages of a cybernetic model

From an analytic point of view, the separate parts are most important and the whole is secondary. Yet from a systemic point of view it is the other way around – the whole is primary and the parts secondary. In an exaggerated juxtaposition of the two approaches, one could claim that the analytical approach impedes the system, isolates the fundamental system elements in order to focus on these elements in detail, for which reason it is called a detail view. The systemic approach, however, places greater emphasis on the dynamics, complexity and totality of the system and is thus a global view. The latter "unites" the elements into a whole and focuses more on the relations and reciprocal effects of the elements or on the effects and results of the relations (in contrast to the analytical method, which concentrates on the kinds of relations present). The analytical approach is effective if the relations are weak or linear. Yet as soon as the reciprocal effects are stronger or non-linear, the systemic method provides the better perspective.

According to BEER the advantages of the cybernetic model over the analytical model are based on three features: first, if it is to really exist a model must be subject to several incompatible and even to some extent contradictory performance criteria. Yet BEER claims that an analytical model is less well suited than a cybernetic model to improve multiple incompatible or contradictory criteria, sometimes simultaneously. BEER cites as an example the criteria of profit as opposed to other criteria like reliability, service, etc. Second of all, an open system is needed that is enclosed within a larger open system, which is then enclosed within an even larger open system, etc. The systems are thus open and closed (closed by the larger system) at the same time. In order to be consistent, analytical models must be closed. Thirdly, if the model is to be used by larger, surrounding systems, the control system of the higher levels must use a higher language than the one used in the real situation, since if the same language is used certain processes cannot be described or controlled. Yet an analytical model uses the same language for the control system as for the real situation.[67]

[67] See BEER, S. (1994): Decision and control: the meaning of operational research and management cybernetics, pg.320f.

3.8.2 Systemic point of view using the criterion of viability

All cybernetic systems must fulfill the criterion of viability. This means that just as an organism can survive in its specific environment by means of information, organization and adaptation, cybernetic systems must also be able to survive in their specific environments. That is to say, these systems – for example a commercial enterprise – adapt to the ever changing circumstances of their surroundings, have and evaluate experiences, and learn that they can maintain and develop their identity.[68]

One of the most significant insights of cybernetics is that all viable systems feature a very specific invariant structure, which means that only systems that have precisely this structure are viable. Which components these organizational structures use is of no importance. In different kinds of systems these components can be entirely different, as long as the fundamental structure is maintained. This formal structure is that of the homeostat and the fundamental mechanism is that of homeostasis, which is to be considered one of the most important controlling mechanisms.[69]

3.8.3 General representation of Viable System Model

The viable system model is so characterized by consistent adherence to cybernetic principles that it becomes valid for any kind of system or process, independent of the nature, number or variety of the constituent elements. The complexity and indeterminacy of the systems and processes being examined are accepted in cybernetics not just without reservation, but are even understood as necessary prerequisites for certain kinds of behaviors. The problem that extremely complex, probabilistic systems cannot generally be described (see section 2.1.1) is dealt with by means of model generation.[70]

Models are generally used in the sciences to represent – in a simplified form – complicated processes or relations that really exist. Dependencies on specific magnitudes of influence can, for example, be described in this manner. The model limits itself to those elements of the system relevant to the specific problem or issue. The attempt is thus made to use the abstract process of model generation to at least partially communicate facts and circumstances that due to their great complexity actually exceed human mental capacity.[71]

Knowledge of nerve systems were and are considered an important scientific point of reference. Since in the following section the structure of a model that defines itself as a transfer of the human nerve system to organizations will be described, the interaction of disciplines and

[68] See MALIK, F (1996): Strategie des Managements komplexer Systeme, pg.80.

[69] See MALIK, F (1996): Strategie des Managements komplexer Systeme, pg.81.

[70] See KRIEG, W. (1971): Kybernetische Grundlagen der Unternehmensgestaltung, pg.35ff.

[71] See MÜLLER, K. (1993): Management für Ingenieure: Grundlagen, Techniken, Instrumente, pg.25.

perspectives described above should be looked at once again. To do so we will begin with a quote by MALIK:

„Imagine if living organisms were organized the same way that our social organizations now are. They couldn't function, they wouldn't be viable, wouldn't survive. Precisely because biological systems are so incredibly viable and capable of transforming, do we have to use them for orientation in the creation of man-made organizations and complex systems. ... However it isn't enough to simply compare organisms and organizations. Organisms are in fact organizations, but organizations are not organisms. For this reason knowledge of the biological or neurological sciences cannot – or only very rarely – be directly applied to societal organizations. We will only find reliable help where biological and man-made systems demonstrate adherence to the same laws. These laws have been researched and presented by the field of cybernetics."[72]

The VSM is based essentially on three principles – viability, recursion and autonomy. Before we look at the VSM more closely, we first require a few definitions (the principle of viability was described in 3.8.2).

3.8.3.1 Recursion

The principle of recursion includes two aspects. On the one hand, every level of recursion must be formed with a structure identical to the superordinate system, including all systems 1 through 5. On the other hand, every system 1 must be a viable system in cooperation with the associated division.[73]

BEER compares the system to an example from biology: every cell possesses the "construction plan" – the DNA – for the whole organism. The whole is always encapsulated in each part, says BEER.

If one looks at the model, one sees that the whole VSM scheme is contained in each of the four "divisions". A "whole system" (that is systems 1 to 5) thus yields a system 1 on the next higher level of recursion. If one were to zoom one level further into the division graphic, it would be possible to see that the scheme is contained in each of the four divisions. Here, however, it must be noted that according to BEER the image is only a graphic aid for better understanding. Thus the five systems in one division are not all operational parts of system 1, the circle, rather they belong in part to the directorate (management) and thus are positioned in the boxes, the squares, to the side on the vertical Command Axis. This applies to systems 3, 4 and 5, which on the next level of recursion yield local management of the next highest system 1.

[72] MALIK, F. (2008): Unternehmenspolitik und Corporate Governance, pg.22f.

[73] See BEER, S. (1979): The Heart of Enterprise, pg.11.

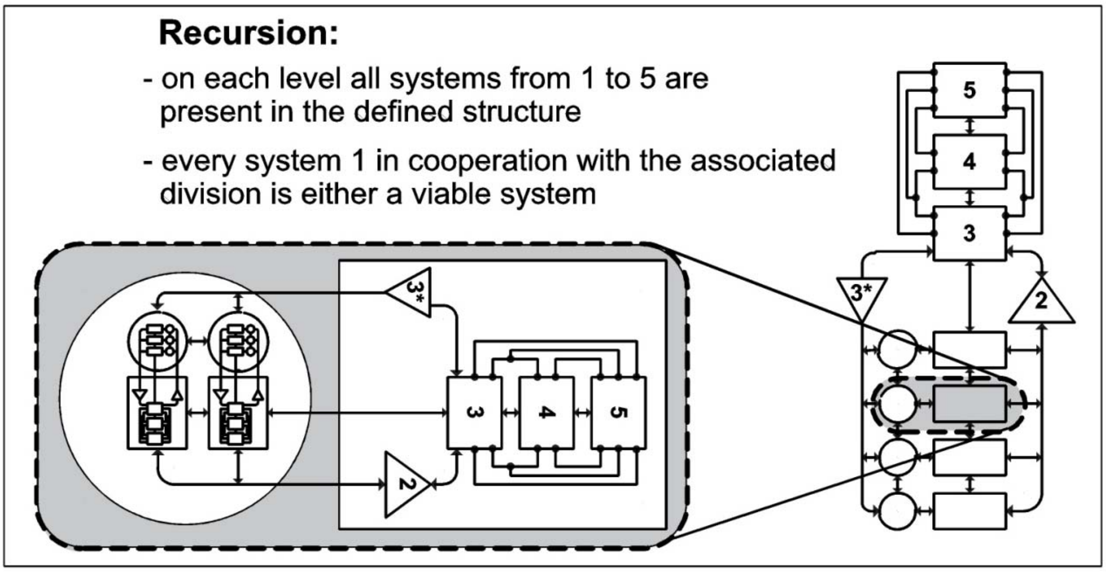

Figure 3-10: The VSM, after Stafford Beer, Recursion.

3.8.3.2 Principle of autonomy

Closely related to the principles of viability and recursivity is the principle of autonomy. From the recursive structure of a complex management system and from the definition of viability as the preservation of a potentially individual existence independent of others results a relative behavioral and/or decision-making freedom for the performance system.

BEER describes autonomy as follows:

„*The word 'autonomy' is pure Greek; it might be freely translated as meaning 'a law unto itself'. So when we speak of autonomy, either in the body or in the firm, we mean that the branch or function indicated is responsible for its own regulation. It is necessary that large areas of any such complex organization should in fact be autonomous*."[74]

The task of the company is, according to MALIK, to ensure

"…*the greatest possible autonomy among parts, while maintaining to as great an extent as possible the integrity of the overall system and achieving a synergy effect*."[75]

The principle of autonomy becomes relevant in regards to the situational structure of the relation between centralization and decentralization. It describes the subsystem's relative freedom as well as the authority and limits in its interventions in the superordinate system for the good of the whole. This kind of fundamental freedom must, however, be understood by the active participants.

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[74] BEER, S. (1973): Brain of the Firm, pg.135.

[75] MALIK, F. (2002): Strategie des Managements komplexer Systeme, pg.108.

3.8.4 Structure of the Viable System Model

The Viable System Model (VSM) was developed by Stafford BEER and published in 1972 in *Brain of the Firm*. This viable system model is the fruit of decades of research work in the field of cybernetics. The result is no longer just a system, but a viable system, which as a whole can be described, as BEER best puts it: *„What I think any organization should look like*."[76]

It is based on the results of biocybernetic and neurocybernetic research and transfers fundamental functions of the central human nervous system to complex living systems, like companies and organizations. Using an example and two diagrams, BEER compares the structure of the nervous system with the Viable System Model (VSM).

The model implies that precisely five different structural elements or sub-systems are to be identified that must fulfill defined tasks, are connected to one another in a very specific manner (lines and arrows) and communicate by using these pathways. Here the structure and interactions are only roughly illustrated.[77]

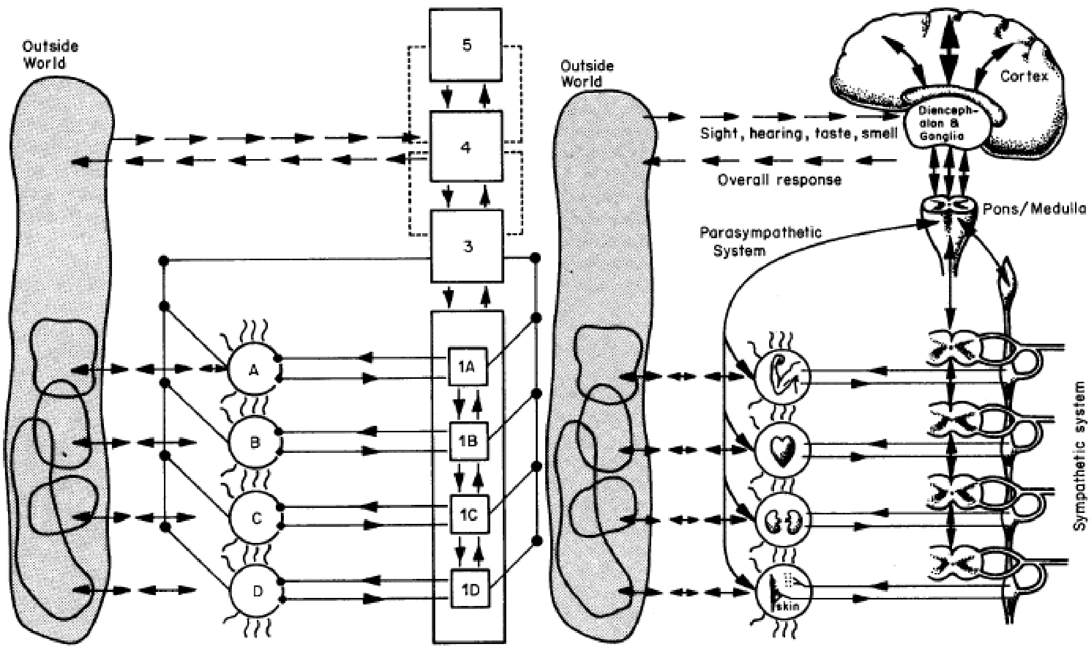

Figure 3-11: Comparison of the VSM with the nervous system. Source: BEER (1972) pg.168 and 170.

BEER refers to the smallest units of an organization as divisions. A company must:

„...divided into parts which themselves are viable, or that can at least theoretically form completely independent systems and exist autonomously in their environment."[78]

[76] BEER, S. (1972): Brain of the Firm, pg.198.

[77] See MALIK, F (1996): Strategie des Managements komplexer Systeme, pg.84-91 and pg.491-511.

[78] MALIK, F. (2002): Strategie des Managements komplexer Systeme, pg.87.

Thus defines MALIK the viability of a system. Divisions are autonomous. The circular symbols show the parts that contribute to the performance of the basic or fundamental units. They stand for their activities and processes. The operative activity of the superordinate unit takes place at the level of the divisions.

3.8.5 General view of the five component systems

Before a detailed explanation of systems 1 through 5 is ventured, a brief overview of the individual systems and their tasks, as well as of the nature of the prevailing information in the individual connections or circuits will be provided. As far as the content of this information is concerned, it must be noted that of course other kinds of information are also transmitted through the individual channels, especially information from the individual upstream or downstream systems.

Of systems 1 through 3 – which focus on the here-and-now, on internal and current factors – system 1 is responsible for the operations, the organization's activities, that which is being done. Information on the work activities, work status, etc. of the operations or information between operation directives and operations will be transferred in the corresponding information channels.

System 2 also focuses on the here-and-now in that it coordinates what the operations do. Here the coordination of the operations is given emphasis, or to be more precise, the coordination of all operations. This is also the main focus in these information channels – everything that is necessary for the coordination of operations.

System 3, still in the here-and-now, is Operative Corporate Management, which focuses on optimization, that is the optimization of all system 1 operations. The information for this optimization of operations is also the prevalent information in the circuits.

Yet the observational field of system 4 includes not only the direct surroundings of the individual operations, which they themselves observe, but the environment of the entire organization, thus more than the sum of the individual operation segments. From this observation of the organizational environment (and of internal organizational information) system 4 gains experiences that are necessary for the development of strategies for the future and for internal organization.

System 5, the Normative Corporate Management, focuses on that which should happen – to be more specific, on that which should always happen, that is identity, rules and values. This task (valuation) includes the creation and monitoring of norms, values and rules and the creation of an identity. That's why the information in these circuits is of a normative nat.[79]

[79] See Cwarel Isaf Institute (2010), http://www.kybernetik.ch/en/fs_methmod.html, viewed on 10 March 2010

3.8.6 Model for potential systems within a company

For this paper, a model (see Figure 3-12) is to be understood as a symbol for the systems possible in this kind of company, specifically companies active in the field of construction project management. Using this viable organization will be developed in the following pages based on the VSM.

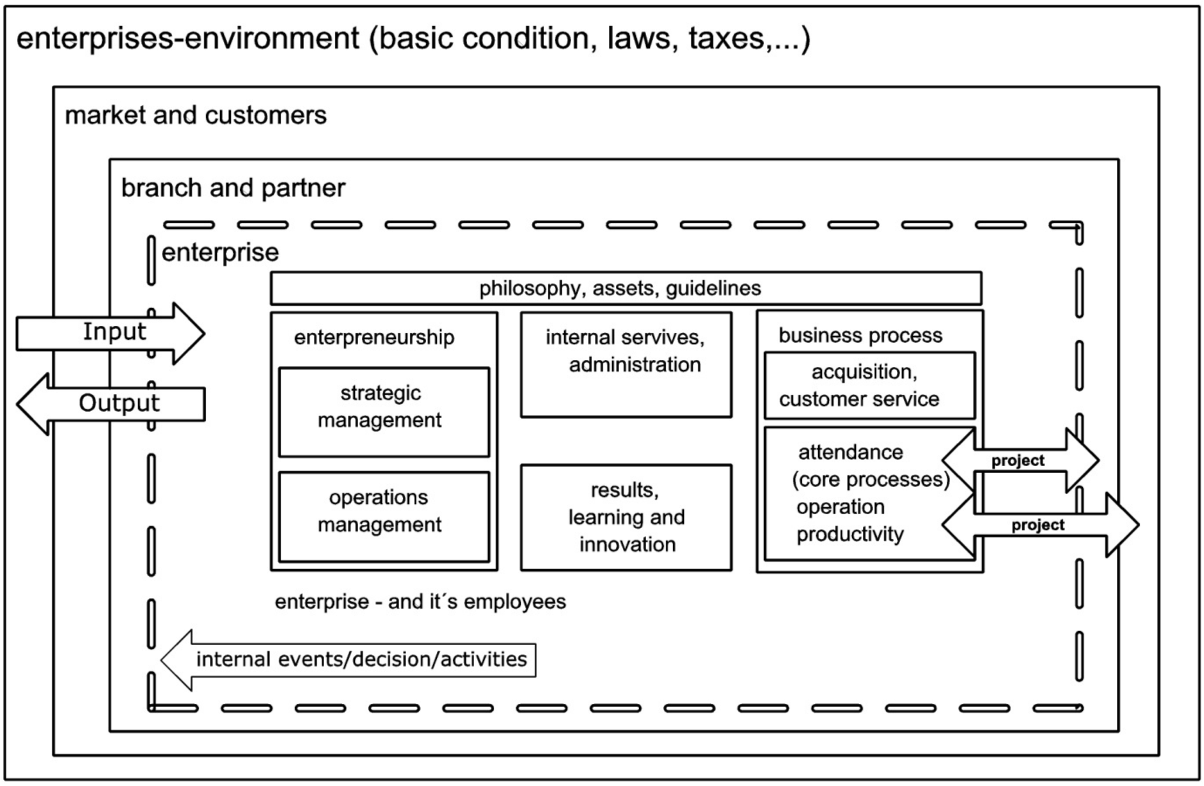

Figure 3-12: Model for potential universal systems of a company

3.8.7 The Viable System Model at the company level [80]

The system of a cybernetic organizational structure with specific tasks and requirements will be described at the level of the company. How the model will be applied to an organizational structure for the steering of construction projects will be explained in section 3.9.

System 1 – Incentive System (direction and steering of projects)

System 1s must be viable, they themselves (or a unit that forms a part of them) have to carry out the company's core value adding process and the proper environment must also exist. System 1s can represent a complete VSM with all systems 1 through 5. Since the completion of projects is also the company's core process, the necessary criteria can be considered to be fulfilled.

[80] For the following discussion see BEER, S. (1972): Brain of the Firm, pg.196ff.

Principal goal:

- To complete projects under the existing conditions and with the resources available in as optimal a manner as possible.
- The classification is not random, System 1s must adhere to the principle of viability as well as the principle of recursion. This means that the divisions themselves must at least in principle be viable as independent systems. In addition, every viable sub-system must be a structural copy of the viable system, of which it forms a part (that is, it must be organized in the same manner as the overall system).

Concrete tasks and completion:

- Planning, execution, follow-up and continual optimization of project processes (with the resources available).
- System 1s steer the basic units. This includes direction and steering functions. Direction is linked directly to the superordinate System 3. The regulation center creates a link to System 2.
- System 1s serve as the individual division management for the company's various product areas (circles A-D).
- Each division operates in the environment that is relevant for it and has its own specific problems.

System 2 – Coordination function (coordination of projects)

System 2 does not exist as an organ or fixed team. It is more a necessary functionality. System 2 coordinates between the System 1s and attempts to create synergies. As a function, System 2 is a great challenge. As such it is part of the company culture, of the "house style".[81]

All forms of communication between System 1s can be understood as System 2s. Speed and unconventional solutions are System 2's strengths. Without a System 2 problems would perhaps be discussed at a weekly project meeting, at which time problems have already emerged or can no longer be avoided. Ways must then be found through System 3 to deal with the inevitable problems.

Principal goal:

- Forestall uncontrolled vacillation between the individual projects and coordinate System 1s = the projects.

Concrete tasks and completion:

[81] See MALIK, F. (2002): Strategie des Managements komplexer Systeme, pg.130.

- System 2 is responsible for harmonizing and coordinating the behaviors of all System 1s in the context of the fundamental behavioral restrictions that are derived from the entire system.
- The difficulties to be coordinated between the divisions depend on the complexity of the environment relevant for the divisions, on the intensity of the mutual dependencies and on the quality of the divisional leadership.
- System 2 should help create synergy effects, which are a priority for the company as a whole.
- These effects include coordination instruments and mechanisms such as committees, conferences, planning and budget control systems as well as informal communication relations between managers and employees.
- Communication takes place through the individual project direction divisions.
- Communications platform include intranet, telephone conversations and visits to work sites.
- Project leaders will inform other projects if short-term deviations from target planning are to be expected.
- Coordination at the level of projects could mean: performance potential not being utilized (unoccupied employees or those not working to their full capacity) can be made available to other projects to correct unexpected problems.
- This coordination may not affect target planning or the other projects' planned resources.
- Information is passed through System 3 (in this case the company) if a problem cannot be solved by means of coordination between projects – that is, if changes to the target planning of the projects is necessary.

System 3 – Operative system management and sporadic monitoring

Principal goal:

- System 3 can be described as Operative Management for the entire company. Its task is to optimize projects (System 1s) with the goal of ensuring that the company performs as effectively as possible. For these purposes all resources and all necessary information from other systems as a control element are made available to System 3.
- This includes information from Systems 4 and 5 as well as from 1 and 2.
- System 3 also has access to the three major communication connections with the individual System 1s, with System 2 and with the individual divisions directly.

Concrete tasks and completion:

- Systems 1 to 3 are obligated to protect the inner stability of the divisions (that is, to maintain their internal balance and harmonize and optimize them internally).

- Controller of the entire company. Planning and control the use of resources in accordance with the guidelines of System 4. Ordering of immediate measures whenever necessary, without exceeding the resources available to the company. Ordering of short-term modifications. Forwarding of alarms issued regarding deviations from target planning from System 2 to System 4.

*System 3**

System 3* contributes an auditing function. In this way unfiltered, non-standardized "real life" information can be obtained from the operations of System 1s.[82]

Concrete tasks and completion:

- Initial plan with specific objectives: advanced planning and assignment of goals as target planning for the entire company = targeted planning (initial plan). The target planning is prepared at the strategy meeting to be held at the beginning of every fiscal year and is adhered to in the financial plan.
- Develop a structural model: which variables must be monitored? The superordinate structural connections of a company are shown in Figure 3-12. The processes upon which these are based are shown as flowcharts or in tables.
- Parametric model: which indices must be created in order to monitor deviations from target planning (initial plan)?
- Parametric model: Following the indices agreed upon: e.g.:
  - Revenue (monthly)
  - Liquidity (monthly)
  - Order intake (monthly)
  - Gross margin (quarterly)

Handling deviations from target planning: there can be no single standard for all the plans available. For this reason trained and experienced staff are required to handle the different possible categories of expected deviations or expected problems. There must be continual training in the handling of these categories.

[82] See HETZLER, S. (2005): *Die Organisation der Zukunft*, pg. 8.

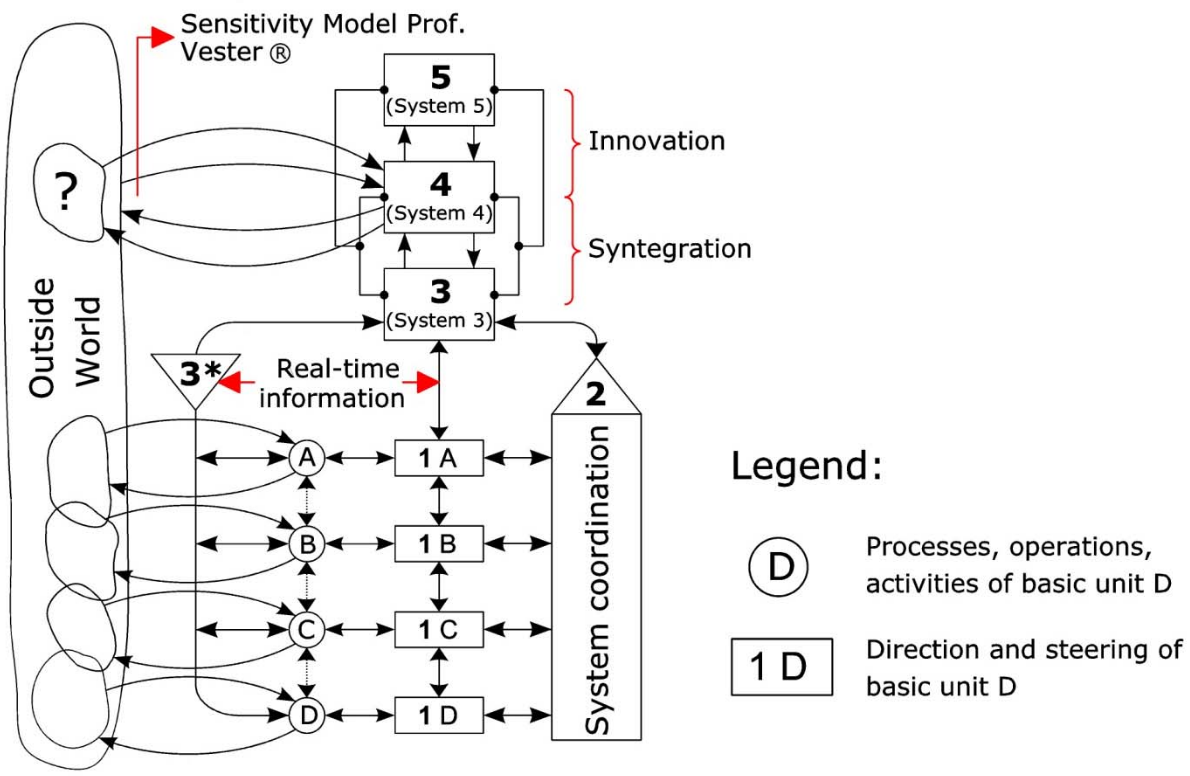

Figure 3-13: VSM, as applied to companies. Source: BEER (1972).

System 4 - Strategic system management (company planning)

System 4 stands for Strategic Management, and focuses on the company environment and on possible future events. BEER has called this the Development Directorate.[83]

He describes System 4 in the following manner:

„For, in managerial terms, the development director himself must exercise control of all those functions needed to acquire information ..., to evaluate information and propose solutions to policy problems ..., and also, arrange all those adaptive planning processes to be agreed with the System 5 and concern the whole company. “[84]

In the neurophysiological model (see Figure 3-11) we see that perception is carried out by means of sight, sound, smell and taste.

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[83] See BEER, S. (1973): Kybernetische Führungslehre, pg.162.

[84] BEER, S. (1972): Brain of the Firm, pg.241f.

Principal goal:

- Strategic management of company = company planning
- Superordinate interface (contact and information) between the company and the environment with a view towards the company as a whole.
- Point of contact for on-going optimization (System 3).
- Preliminary decision-making for System 5 based on internal and external information.

Concrete tasks and completion:

- The task of System 4 is the in-take, processing and forwarding of environmental information, without which the entire system cannot exist in its environment.
- Information is forwarded to both System 5 and System 3.
- The attempt is made to maintain internal and external balance by means of collaboration between System 3 and System 4, as influenced by the monitoring function of System 5.
- Tendencies: to follow technical, social and economic developments (more distant future = over 2 years).
- Obtain, evaluate and prepare information on current market and industry developments.
- Establish contact between management/direction and external decision makers.
- Forward information and, if necessary, forward alarms generated by System 3 to System 5.
- Collect and consolidate internal information.
- Develop functional connections between the elements that affect the company.
- Prepare decisions for System 5 from consolidated internal and evaluated external information based on knowledge of functional connections.

Participants, members of System 4:

- Company management (for smaller companies management will also bear essential responsibility for processes)
- Local office manager
- Project director
- Technical director, technical division director/division director
- Those responsible for externally oriented partial processes, e.g.: Marketing process owner as coordinator and person in charge of all external activities
- Those responsible for internally oriented partial processes, e.g.: Finance process owner as coordinator and controller of finances

System 5 – Normative system management

The focus here is on solving the fundamental problems of balance between present and future and between the company's inner and outer worlds. These problems result from the interaction of System 3 and System 4 and are to resolved by means of the highest, norm-establishing decisions.[85]

Principal goal:

- To ensure the future viability and development potential of the company. To make fundamental, long-term decisions based on norms and values.
- System 5 is the highest decision-making authority when it comes to basic norms, rules and behaviors that actively shape the future of the overall system.

Concrete tasks and completion:

- Develop and update general principles. Evaluate technical, social and economic developments and their effects on the service.
- In System 5 the company's policies (company management) are determined. This takes place in the closest possible collaboration with Systems 3 and 4.
- Here management does not mean controlling, updating and further developing existing procedures and guidelines. Management is always to head in the right direction, to travel new paths (employee participation, etc.) and, if required, to make decisions that are painful (closing local branch offices, dissolving departments, dismissing employees, etc.) or have long-term implications (building up new technical departments, occupying niches, etc.).

Participants, members of System 5:

- Owners/Shareholders (provided they are active in long-term decision making)
- Management
- Representatives of decision makers/direction at each level

Systems 3 to 5 comprise company management. If one compares the tasks of Systems 3, 4 and 5, one sees that these are based on different models. A benefit-cost model that makes it possible to optimize the internal company constellation can be applied to System 3. Tasks related to company marketing can be assigned to System 4, as can its position on the finance market and a range of other environmental aspects. The model in System 5, however, must be capable of illustrating every single important aspect of the company in its environment that could influence its future development.[86]

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[85] See MALIK, F. (2002): Strategie des Managements komplexer Systeme, pg.507.

[86] See MALIK, F. (2002): Strategie des Managements komplexer Systeme, pg.150.

3.9 The VSM as a general, system-oriented set of guidelines for construction projects

The VSM is explained in section 3.8 in a general manner. Here the special circumstances of the industry are considered as well as the implementation of the model for specific use in a construction project. In contrast to section 3.8, where systems 1 to 5 are described at the level of the company, here we find ourselves at the level of the projects, that is within System 1 (the lowest recursion level) in terms of the company.

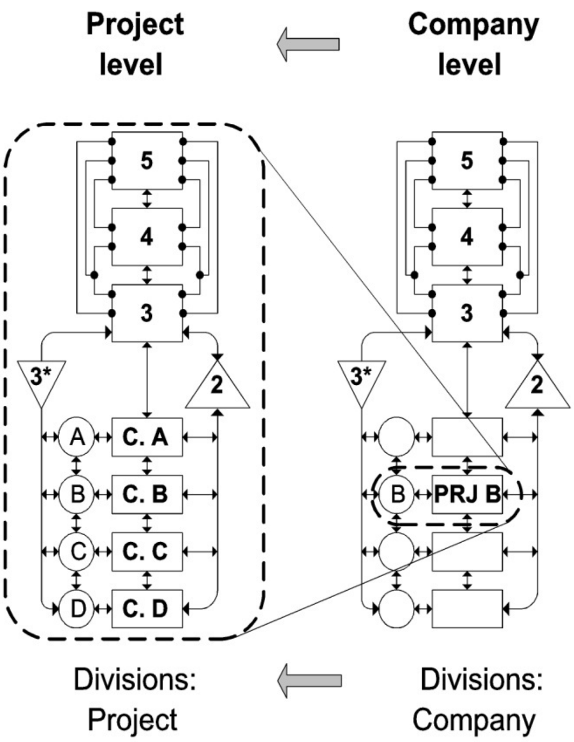

Figure 3-14: Recursion levels of the VSM in a company

Figure 3-14 shows how the entire VSM model can be applied to the structure described above, which consists of company and project levels. The points of contact to the relevant environment are not shown.

The increasing complexity of the individual task areas in the organization of construction projects requires the creation of a new procedure in designing and developing an organizational model that can serve as a grid for the localization and resolution of problems.[87] In this section the attempt will be made to lay a potential organizational model of future construction projects over the grid of the Viable System Model by Stafford BEER. In addition the individual systems and the tasks they must complete will be shown together with the project organization in one potential context.

[87] See MALIK, F. (2003): Strategie des Managements komplexer Systeme, pg.75.

3.9.1 Application of the VSM to the structural organization of construction projects

The applications shown here are not to be understood as recommendations or as general instructions, but as notes that must be interpreted very differently for specific projects and/or companies.

From a cybernetic point of view, the project becomes the essential management task and the most significant factor of success for a company in construction project management.

Difficulties and limiting framework conditions in construction projects:[88]

The success of a project can be made or broken by the organization and leadership of all the individuals involved. Leadership qualities are more essential than ever considering the increasing complexity of our organizations.

Until now we have thought and acted according to the belief that the world can be planned. It was assumed that all necessary information can be obtained and that work bundles can be divided up into individual parts without difficulty. This way of thinking is linear and deterministic. Accordingly, projects generally have rigid, hierarchical organizational structures. This model of thought is outdated and has long since failed to meet the demands of the construction industry, in which too many risks and uncertainties play a role. Additional planning and regulation does not serve to curb unpredictability.

Cybernetic building management effects an important paradigm change. It is accepted that over their entire life cycle construction projects are complex, unplannable and incalculable and the idea of a deterministic world with linear thinking that can be planned and analyzed to the minutest detail is dismissed.

The external framework conditions (established and innovative competitive forms, see section 5.3.8) are the defining criteria for the execution of projects. This can be explained by means of a few examples:

- Departure from standard performance concepts of wage structures, because in future projections for construction almost nothing is "standard" or "simple".
- The established competitive form of specialized contracting is an impediment to the search for an optimal solution for construction projects. Except for specific suggestions the companies involved can only participate in a limited manner to the search for an ideal method of completing the various tasks, since the guidelines for these tasks are based on pre-formulated specifications (on which the individual contracts are based).
- There is a great teamwork problem in the course of construction. In all phases of the construction process companies often find themselves working together for the first time. Friction losses can be expected.

[88] See STEINER, H. (2009): Kybernetische Bauprojektentwicklung, Baukybernetik Forum St. Gallen

3.9.2 Systems of the Viable System Model at the project level [89]

System 1

Circuits A-D shown in Figure 3-11 represents the main activities of the viable system. It would be possible to say that they control daily operational business processes. In the context of projects this would mean that circuits A-D represent semi-autonomous companies (managing and steering themselves) and that systems 1A-1D are the site managers or the responsible leaders of the individual companies.

For this reason individual companies – as System 1s on the deepest recursive level of the project – are chosen that are involved in the realization of the overall objective.

The principle of viability says that the entire system can only be divided into areas which themselves can survive on their own as systems. In this case that means that a company does not directly need the other System 1 companies to survive. To avoid arbitrary division into sub-systems, the principle of recursion is essential.

System 2

Eliminating disruptions – regardless of their source or cause – is the task of System 2. Its functions should help synergy effects be created between companies. System 2 is cannot really be illustrated in a graphic form. It cannot so much be defined as suggested and roughly traced. A viable System 2 can be promoted through the following activities:

- Communication
- Short pathways between System 1s
- Independent decisions made by the leaders of System 1s: there is a rule that the pre-defined target plans of other System 1s cannot be negatively affected or interrupted.
- Self-defined responsibility as laid out in the target planning
- Identification with the common goal of the project

The basis for a vital System 2 is a sense of connection between the employees and the company and/or (at this level) between the employees and the project.

The operations of the individual companies and their management are the responsibility of the companies. The coordination of the different companies and the synergy effects achieved through this coordination are the responsibility of the entire system.

For a better understanding of Systems 3 to 5, the VSM Figure can be supplemented with additional categories as follows:

[89] For the following discussion MALIK, F. (2003): Strategie des Managements komplexer Systeme, detailed references are omitted

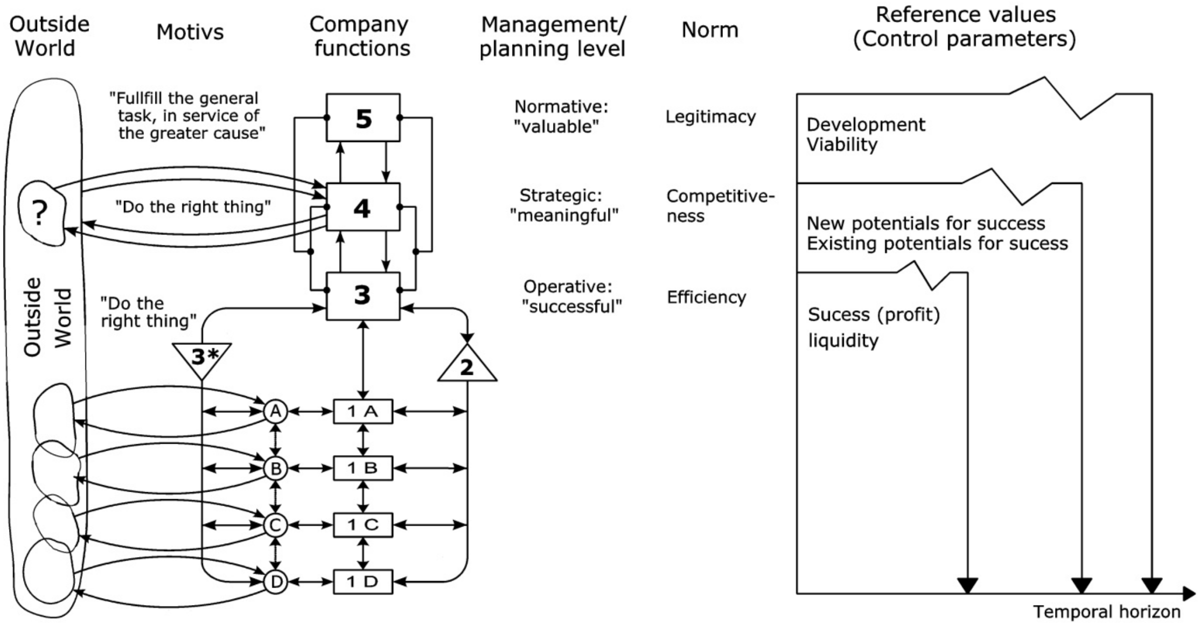

Figure 3-15: VSM combined with an overview of relational sizes. Source: SCHWANINGER (1989) pg. 412.

System 3

The task of System 3 is to plan and assign resources, especially employees, and to react to deviations from the target plan.

System 3 receives the information required to complete these tasks directly from the divisions and from System 2, which provides notification of all deviations from the target plan that cannot be rectified by System 2 itself by means of coordination.

System 3 is not required to optimize the divisions, but it must provide the best possible development of the unit to which the divisions belong. Target planning is a part of System 4's Strategic Planning.

In the context of the project, Project Management (PM) assumes the tasks of System 3, since System 2 is only responsible for coordination.

System 4

System 4 creates links to the relevant environment, receives data from this environment and converts this data into information relevant for the project. System 4 also consolidates the evaluations of all internal processes. System 4 is the interface to the project environment and a contact point for all the information made available through System 3. The goal of System 4 is to establish a basis for long-term decisions. This planning is transferred to System 5 for decision making.

If one imagines a project in which a number of different companies are involved during the planning and construction phases, it becomes clear that the environmental information that is received by the individual companies is completely different from the environmental information that is important for the overall project. In this context it is possible to speak of the completion of an environmental analysis. For this the previously introduced sensitivity model developed by VESTER would be of assistance. It is thus important that all environmental information relevant for the system be integrated into the overall system by System 4.

System 5

System 5 uses the foundation provided by System 4 and pursues the objective of "survival" as the highest long-term goal of the project. The function of System 5 can be generally described as assessment of potential future developments of the project and evaluation of alternative strategies. Monitoring the functions of Systems 3 and 4 and their collaboration is also among System 5's responsibilities.[90]

Since System 5 represents the highest decision-making authority, it can be compared with the responsibilities of the individual site managers. Decisions are made here that are relevant for the project. These, however, should not be made by the individual site managers, but in close interaction with System 3 (PM) and System 4.[91]

Wird nun versucht, jedes System kurz zu charakterisieren und aus der Sicht des Bauherrn darzustellen, so kommt man etwa zu folgendem Schema:

If each system is briefly characterized and illustrated from the point of view of the site manager, we arrive at the following scheme:

System 1:	What is happening right here and right now?
System 2:	Cannot be shown in this scheme, as its responsibility is the coordination of System 1s.
System 3:	What will happen next and in the framework of circumstances that will not change in the short term?
System 4:	What could happen, taking certain vaguely conceivable development tendencies into consideration and assuming all internal deficiencies are rectified?
System 5:	What should happen, taking all these factors into consideration?

Finally, here we see one possible graphic representation for the described application in construction project management, as presented by Hans STEINER at the MALIK Management Construction Cybernetics Forum in St. Gallen on November 24, 2009.

[90] See MALIK, F. (2002): Strategie des Managements komplexer Systeme, pg.150.

[91] See MALIK, F. (2002): Strategie des Managements komplexer Systeme,

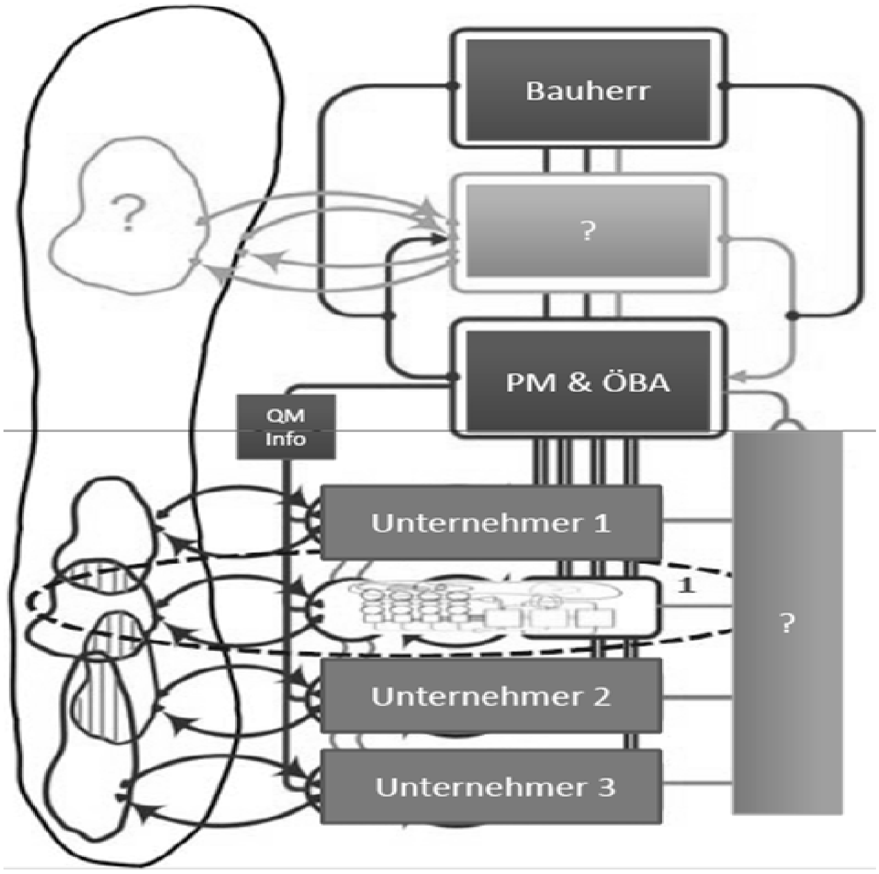

Figure 3-16: The VSM in project organization. Source: Dr. Hans STEINER.

[Bauherr = constructor]

[ÖBA = site supervision]

[Unternehmer = company]

4 Application of Cybernetics to the Construction Industry

The laws of cybernetics have practically been in use for a long time. This usually happens unconsciously and without knowledge of the general adherence to laws of complex systems. Only in rare cases are insights from the science of cybernetics being directly implemented in practical situations to create the proper conditions for self-organization and evolution in complex systems. Only in the relatively recent past has cybernetics aroused interest in the area of company management with the phenomenon of self-organization.[92] The scientific insights of cybernetic research will here be applied to construction management. After introducing management cybernetics as a modern approach to management [93] construction cybernetics as an application of this approach to the construction industry will be attempted.

4.1 Management cybernetics as an applied science

Management cybernetics focuses on the application of cybernetic principles to the field of management. Commercial enterprises or even partial processes within companies can be viewed as cybernetic systems. There is a broad correspondence between the knowledge that cybernetics attempts to ascertain and organizational questions related to the forms and process structures in company systems. In both cases there is an attempt to define the subjection to rules of behavior-regulating structures and element activities in target-oriented dynamic systems and to evaluate them in terms of their design.[94]

Despite the obvious and demonstrated relevance of cybernetics for company organization, KRIEG makes direct reference to the problem of the high level of abstraction and formalization of cybernetic statements. Formal basic conditions, functional requirements and structural principles for the design and control of target-oriented systems are revealed. The most effective procedures and methods are determined. To determine the content of material, social and value-based problem areas, however, enterprise theory and other problem-relevant empirical sciences are absolutely essential.[95]

BEER spent two decades examining the core mechanisms of management and bringing them together in a uniform theory. His results culminated in an overall model of the structure of a single system that is capable of existing in a dynamic environment – that is in an environment that is continually changing in unpredictable manners. Problems like adaptability, flexibility, learning capacity, evolution, self-regulation and self-organization are of central interest. Generally speaking, the central problem of cybernetics is the question as to how systems of all kinds can come to terms with the complexity of their environment, which results above all from

[92] See MALIK, F. (2003): Systemisches Management, Evolution, Selbstorganisation, pg.363ff.

[93] See MÜLLER, K. (1993): Management für Ingenieure, pg.11ff. and pg.25ff.

[94] See KRIEG, W. (1971): Kybernetische Grundlagen der Unternehmensgestaltung, pg.29.

[95] See KRIEG, W. (1971): Kybernetische Grundlagen der Unternehmensgestaltung, pg.31.

continually occurring changes and the speed of these changes. The answer lies in the structure or organization of the system. Organization is the critical means by which explosively increasing complexity can be handled.[96]

The result of BEER's research is the Viable System Model.

4.2 Cybernetic logic

Using current strategies, we always react to real disruptions only after they appear. Yet by this time irreparable damage has almost always already been incurred. A project manager with active network planning methods reacts to real deviations from target values too late and is thus not able to lead in an effective manner.

Cybernetic planning (a prerequisite for effective management behavior) makes use of cybernetic logic. In contrast to causal logic, essential causes for present effects lie in the future. This manner of thinking leads one into a second time dimension in which "objective probabilities" have the same effect on future system situations simulated in the model as causal relationships and the facts known when a decision is being made.

Only when this second time dimension is introduced does a social system become a real action system. It no longer reacts to changes, it does not just adapt, rather it adapts the conditions to its goals and needs. It acts effectively by mentally anticipating potential, desired future states with the help of viable simulation models.[97]

Heinz GROTE writes the following in regards to the K.O.P.F. method: The project leader does not react anymore when the real process is disrupted, rather he is capable of neutralizing potential disturbances before they emerge. Only in this way can the dynamic process be effectively managed, can cost estimates be adhered to and can missed deadlines be avoided. The project leader is constantly simulating future processes with the help of data and the arsenal of instruments derived from the planning section of the KOPF method. The mental system is always a step ahead of reality, for with the KOPF method management decisions are always based on information from the future of the construction process. We refer to this feedback from the future as "positive feedback".[98]

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[96] See MALIK, F. (1996): Strategie des Managements komplexer Systeme, pg. 77.

[97] See GROTE, H. (1978): Bauen mit KOPF, pg.29.

[98] See GROTE, H. (1978): Bauen mit KOPF

4.3 Cybernetic management[99]

With its cornerstones of organization and management, cybernetic management focuses on the natural forces of a system, though this does not mean that the actors must be aware of these forces. On the contrary, it is precisely the mechanisms that are not consciously accessible (or only consciously accessible with proper training) that have the critical regulating power.

MALIK defines cybernetic management in the following manner:

„In the final analysis cybernetic management is a manner of influencing a system to achieve a goal by means of modifying the information basis."[100]

It is a well known fact that humans do not act based on what is real, but based on what they believe is real. Thus the perceptual and communication processes by which system elements become real must be studied. It must be examined how learning and empirical processes change or confirm this reality. It must also be understood how intellectual objects – ideas, rumors, opinions, intrigues, etc. – are formed, changed and promulgated, take on their own lives, etc.

Cybernetic management is based on the explicit recognition and inclusion of the complexity of real systems. This must be given special emphasis because such an approach is, from a certain perspective, not typical of the sciences. According to a view that is still very widely held, scientific processes are aimed at simplification. A limited number of major factors are extracted and examined, while the others are disregarded. If these major factors are not sufficient to obtain the desired results, then a few additional variables are taken into consideration.

Cybernetic management often uses a contrary approach. The assumption is made that when confronted with standard questions, real systems are so complex that it is rarely possible to know everything that has to be known in order to make decisions. This can perhaps best be illustrated in reference to the ***difficulty of making prognoses***.

The standard view is that prognoses are needed in order to be able to plan. Yet it is common knowledge that prognoses are in themselves problematic and that the most important factors cannot be predicted with the necessary accuracy. While researchers are looking for better methods, managers have to act. The special dynamic of systems requires this. Managers do not have the option of taking a step aside until there is better information. Their fundamental consideration is thus not how they can get better prognoses, but how they can approach their work when they (in extreme cases) do not know anything about the future development of the relevant factors.

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[99] See MALIK, F. (2003): Systemisches Management, Evolution, Selbstorganisation, pg.302ff.

[100] MALIK, F. (2003): Systemisches Management, Evolution, Selbstorganisation, pg.302.

A simple example: weather forecasts with questionable reliability. Here essentially two attitudes can be taken. On the one hand one can hope that with more resources and even larger computers the reliability of such forecasts will significantly improve. Or, recognizing the inevitable incorrectness of weather forecasts, one can take an umbrella along so that one is prepared for all eventualities. Here the effects are not so dramatic, but if the risk is serious enough, then we see the value of such ways of thinking and behaving.

Every complex system has a certain time limitation, within which more or less precise predictions can be made regarding the system's development. Any prognoses above and beyond this are only meaningful to a limited extent. Yet this time limitation varies greatly between systems. In the case of the weather system, it is a matter of hours. When it comes to the economy, concrete developments can only be predicted a few days or weeks in advance (depending on the industry), but never years in advance. In the case of football, the time limitation is reduced to seconds.[101]

If it is not really possible to forecast exchange or interest rates, inflation, economic processes, technological advancements, etc., and if there is little hope that this situation will improve (regardless how much is invested), the question emerges: How must an enterprise be organized and managed so that it can nevertheless remain viable? Here it now becomes evident just how important adaptability, flexibility, learning capacity, foresight, self-organization, self-regulation and evolution are.

In this context, Frederic VESTER writes:

„...a project that is deterministically planned and conceived with no feedback with the environment – that is, so to speak, isolated from disturbances – is hardly ever viable and far more at risk than it would be if it were in open contact with the environment. Not the deactivation of disturbances (for example, by ignoring certain interest groups), but rather taking them into account in the conceptional phase will lend the project greater invulnerability to errors."[102]

[101] See VESTER, F. (2008): The Art of interconnected thinking, pg.94.

[102] VESTER, F. (2008): The Art of interconnected thinking, pg.26f.

According to MALIK, within every organization it is necessary to pay special attention to certain factors, regardless of the concrete tasks or the structure of the organization’s regulatory system:[103]

1. Performance orientation

One of the most important tasks of the management staff of any organization is to make clear how the organization’s performance is measured, what is considered good performance and what is unacceptable. It must never be possible to “survive” in an organization without adequate performance. That this can be quite difficult in individual circumstances is self-evident, and yet this is one of the most important prerequisites for creating a self-organization that serves the good of the whole.

2. Feedback

Every organization has countless feedback mechanisms. At least one feedback mechanism must be established between targets and results. This inevitably requires the explicit definition of targets and a measure of results tied to these targets.

3. Penalties and responsibility

A critical element of self-organization and the impact it tends to have is an organization’s reward and penalty mechanisms, and thus the question as to who is responsible for what and what forms this responsibility will take. Monetary rewards undoubtedly play an important role but they are not the only mechanism. Another element is the question as to how the organization handles recognition and what opportunities there are to excel. A third component is the decisions made by humans.

4. Staff decisions

Ultimately the regulation mechanisms of social systems are to be found in the decisions made by humans. Thus the selection of managerial staff, their advancement, the criteria for promotion and demotion, are perhaps the most important factors in determining the direction of self-organization. This is especially the case because these kinds of decisions are visible for all members of the organization and serve to establish precedents. These decisions make it clear to everyone what the rules are to which the system is subject.

[103] See MALIK, F. (2003): Systemisches Management, Evolution, Selbstorganisation, pg.370f.

4.4 Cybernetic Management in the construction industry

Construction cybernetics is the practical application of management cybernetics as a development of self-organization in the networked event structure of the construction industry.[104] Since the early 1970s these insights have been specifically used to handle organizational problems in construction operations. In 1985 the Austrian Society for Construction Cybernetics was founded. It has come to define itself as a forum for future developments in the construction industry. Working very closely with the MALIK Management Center, practice-oriented management systems are developed and actively processed in seminars and symposiums to form and apply cybernetic statements to the field of construction.

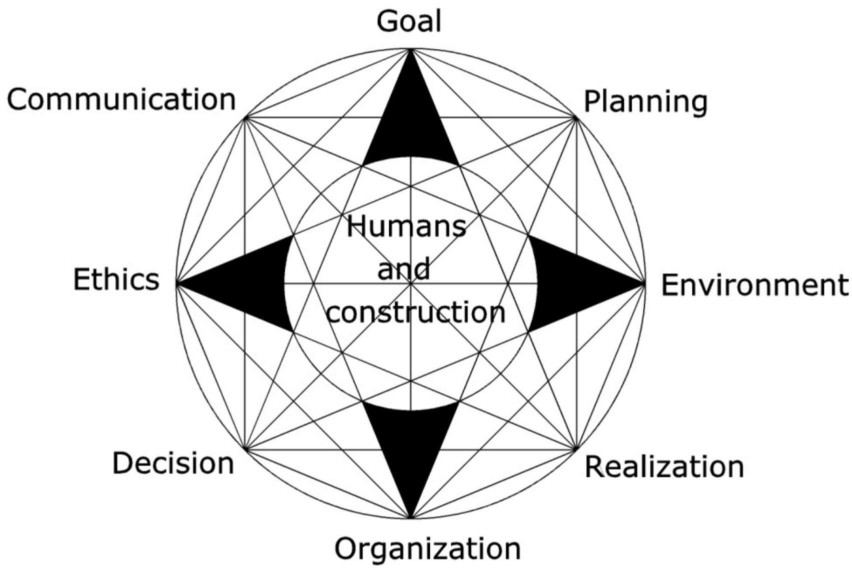

Figure 4-1: Networked Construction System. Source: EFCC (2010), http://www.baukybernetik.at/, 10 March 2010

The society classifies the effect and benefit of cybernetic management principles on three levels:[105]

1. Economic benefit through

- Shorter construction times
- Lower construction costs
- Lower occupancy, operational and maintenance costs

"Every euro invested in the construction industry yields three Euros for the economy."

(GREINER Otto)

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[104] See GROTE, H. (1978): Bauen mit Kopf, pg.15.

[105] See EFCC (2010): European forum for construction cybernetics, http://www.baukybernetik.at/, 10 March 2010

2. Individual benefit through

- Better strategic orientation
- Dramatic increases in productivity, higher net product
- More humane work
- Greater autonomy
- Better professional success
- Less stress
- Positive life attitude

3. Societal benefit through

- Long-term balance of supply and demand fluctuations
- Long-term reduction of fear of crisis

As in general management cybernetics, in construction cybernetics the processes are viewed as a system. In the construction industry there are planning and building processes that as extremely complex systems cannot be described or calculated. The deterministic calculation model on which network planning technology or the standard bar graph method for the planning of construction procedures contain no variety in terms of actions.

New planning methods, however, guarantee the necessary variety of actions, while utilizing cybernetic insights. GROTE describes this in the following manner:

„The most important thing in the process model and in conditioning the steering staff is to provide as much behavioral variety as possible, so that the consequences of disturbances can be compensated for as precisely as possible even in the face of highly complex events."[106]

And Frederic VESTER writes the following about construction cybernetics:

In the building branch a flexible coordination of skills would achieve far more than the standard precise planning that results in chain reactions with even the smallest of disturbances (which are inevitable) and to massive delays and increased costs.

Procedures like the K.O.P.F. method developed by Heinz GROTE, which is based on the bio-cybernetic system approach, create buffer zones and thus save time and money. By introducing a "second time dimension" into the controlling process with the corresponding early warning instrument, flexible balance mechanisms are created for avoiding disturbances at no extra cost. A construction management team that works with these criteria instead of classic project

[106] GROTE, H. (2000): Entscheiden in komplexen Systemen

management techniques becomes, according to GROTE, not a cogwheel-like cooperation of all players, in which every special wish or deviation shuts the whole machinery down, but a model of desired futures with such a large variety of possibilities that it can easily handle any number of special wishes or requirements, as well as the most severe unexpected disturbances.[107]

Both the planning process and the carrying out of the construction work itself can be seen as the production process and thus as a dynamic system. By use of applied construction cybernetics and of the correct structure or organization, adaptability and learning capacity are maximized. The importance of these criteria has been proven in many practical studies and by numerous business consultants. At this point a few examples of the insights provided by business consulting should be mentioned. A clear statement regarding this subject is to be found here:

Under the heading "Human Resources Management", humans and their knowledge potential are treated as the most important capital companies possess. With this special form of management, the human capital of organizations is optimally developed and utilized. Employees that think and act as if they were an integral part of the company – who thus work in a self-organized manner – are seen as the long-term guarantee of a company's success. This is why Porsche became the most profitable car manufacturing company in the world – they made sure that in their Human Resources department the focus was on "human". Committed employees are the source of this company's extraordinary success. The criteria of learning capacity – in relation to both the organization as a whole and the individual employees – is to be seen as very important for the flexible adaptation of a company to future developments. The organization of many companies is still quite bloated, rigid and immobile, as well as inefficient and thus uncompetitive.[108]

This shows that insights from management cybernetics have still not found a foothold in many places. That this is especially true for the construction industry can be seen in current economic developments.

With the resulting increased quality of work through better organization of processes, the symbiosis of productivity and greater humanity can undoubtedly be seen as the ideal result of management cybernetics. The following chapters will feature a more detailed examination of the lack of the practical implementation of construction cybernetics – with the principles of targeted self-organization, cybernetic logic, recognition of the general context, etc. – evident in many places. In chapter 5, we will examine the insights to be gained from these circumstances to a specific construction project.

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[107] See VESTER, F. (2008): Die Kunst vernetzt zu denken, pg.60f.

[108] See HAMANN, A. STRITCH, S. (2000): Aus dem ABC der Unternehmensberatung. pg.509f.

4.5 Known applications

This chapter will conclude with a short introduction to a well-known method that is based on the systemic approach. At this point a discussion of the Prof. VESTER ® Sensitivity Model would be helpful, but this was already examined in section 3.7.3.

4.5.1 Introduction to the K.O.P.F. method

In German, K.O.P.F. stands for "Kybernetische Organisation, Planung und Führung", which translates as 'Cybernetic Organization Planning and Management'. The K.O.P.F. method is the attempt to use cybernetic ideas to structure construction processes in a more fluid, less stressful manner. It is a method of precise management for complex processes, by which lost time and the failure to adhere to costs and deadlines can be avoided or even completely ruled out. The product is a result of the development of self-organization processes and variable balancing mechanisms that counteract disturbances in offices and on production sites. The information that the individuals involved have about all cost-relevant factors leads to a broad self-control that saves central management from overload.[109]

4.5.2 Origins and conception of the K.O.P.F. method

The founder of the method is the architect and construction engineer from Holzminden, Germany, Heinz GROTE. He developed the K.O.P.F. method from 1968 to 1972, based on General Cybernetics. According to him, by using K.O.P.F. projects have reduced costs by an average of 15%.[110]

What motivated GROTE to develop the method was the unsatisfying results of standard planning methods in his construction management experience. The usual deterministic manner of thinking works on the assumption that the processes to be planned – that is construction processes – can be accurately calculated. GROTE sees a fundamental problem in mentality here, since our educational and empirical worlds are still based on a mechanistic view of precisely calculable orbits. This Cartesian way of thinking moves us to try and handle complex events by means of better planning and advanced calculation methods.[111] That mastering extremely complex system – and both commercial enterprises as a whole and building processes are to be seen as such – will always fail is clearly demonstrated by the science of cybernetics (see section 2.1.1). In the case of network planning, the reaction always comes too late. The reaction only comes after the loss of time incurred is virtually impossible to compensate for. Furthermore, network or standard bar graph planning do not take the necessary variety of actions into account (see section 2.1.2). The paths are determined and variable influences with different objectives can hardly be

[109] See PRO MAN (2000): Internationale Gesellschaft für fraktales Produktivitätsmanagement, pg.65.

[110] See GROTE, H. (1996): Die schlanke Baustelle, pg.49.

[111] See GROTE, H. (1996): Die schlanke Baustelle, pg.5f.

accommodated. The self-organization strived for is also not promoted by standard planning methods.

For this reason GROTE used general cybernetics to develop his own method of controlling planning and production processes in the construction industry. His method is essentially based on the implementation of the law of cybernetic logic according to BEER: temporal reversal of the cause-effect chain in mental processes contrary to classical causal logic. This means that significant causes for present effects lie in the future. Thus a second time dimension is introduced, in which for present decision making, objective probabilities are based on the desired future.[112] The circuit-based manner of thinking of biocybernetics as a model for successful management, in which regulation always attempts to intervene in advance and not as a reaction to the effects of disturbances that have already taken place. By following the law of requisite variety, the process model for construction processes is lent an extremely high number of potential paths to a particular goal.

In the K.O.P.F. method, the insights of cybernetics, which GROTE sees as a modern organizational science of targeted action in complex systems, are used to yield above all the fruits of the three principle cybernetic laws for an organization to rise above the competition:[113]

1. Achieve a high degree of self-organization through production plans and early coordination with all parties involved.
2. Create the requisite variety of potential decisions and actions to compensate for lost time. Know the maximum capacity of the employees involved.
3. Avoid undesired developments by basing decisions on information regarding future events.

The creation of production and deadline plans is the basis for the intensive study of construction processes, the required deadline and capacity calculation, process planning, week planning, target-performance comparison and the development of self-organization. The individual levels of productivity are continuously measured during the work process in offices by the employees themselves. This takes place through the agreed upon assignment of the necessary work hours and the comparison of these with the hours actually worked. With this written documentation it is possible to recognize very early on if deadlines are likely to be missed. The principle of cybernetic logic is thus also used in project planning.

112 See GROTE, H. (1996): Die schlanke Baustelle, pg.28, pg.32, pg.45 und pg.191.

113 See GROTE, H. (1996): Die schlanke Baustelle, pg.28 und pg.87.

Not just the planner, but also a construction firm's construction supervisor must determine – by inquiring into the remaining workload and the planning capacity within the planning office – when construction can begin or how the performance capacity is to be curtailed in the initial phases in order to avoid hold-ups.[114]

The foreman and another representative work with the production plan at the construction site. Together the work is planned for the following week. This intensive cooperation makes it possible to avoid the frequent glaring problems of work management.

Self-management by means of continual review of target and performance hours. Workers see the division of hours and the target hours for the individual work section on a form. On this same form they write the performance hours. Self-regulation!

If incentive wage is not standard, to pave the way for this an award can be paid for visible extra performance. The form for recording hours for payroll accounting should be arranged the same way as the form for target and performance hours for each work section, so that there is a simple manner of keeping track of wage bonuses in comprehensive performance wage contracts.[115]

[114] See GROTE H. (1996): Die schlanke Baustelle, pg.99.

[115] See GROTE H. (1989): Spitzenleistungen im Baubetrieb durch komplexe Arbeitstechnik, pg.21.

5 Cybernetic Management in Construction Projects

After the introduction of some basic elements of the K.O.P.F. method in the previous chapter, in this chapter a cybernetic structural organization will be developed based on the VSM and using a running construction project as a model. First, however, an introduction to the different concepts of the project and project management are required for a better understanding above all of the systemic approach to project management.

5.1 Historical development of project management

The basic concepts of modern project management can be traced back to the extensive plans of the U.S. during World War II.[116] Here the ideas were focused mainly on air and space travel. In German-speaking regions the application of ideas of project management was limited for many years to the field of network planning.[117] In both the U.S. and in Europe the pioneers and promoters of systematic management of projects had highly "technocratic" orientations. The technocratic management approach is now being rapidly replaced by a systemic philosophy. Since the 1990s, there has been greater awareness for the importance of project management, however there is currently a paradigm change toward cybernetics and integrated approaches. In this way an attempt is being made to better handle the high complexity of projects as socio-technical systems.

5.2 Re-evaluation of project management

The prevailing form of project management is based on rules of operational research and network planning. And yet these defining operational networks offer hardly any way to represent the dynamics of development processes. Yet if development and self-organization are to become the focus of management and organizational activities softer or more elastic process models will be required. It is not so much a matter of new technologies and methods, but of a re-orientation of our values and attitudes.

„The disturbance is not the exception, the disturbance is the normal case" (Otto GREINER)

From this standpoint project management must always take existing unpredictable factors (feedback, disturbances, shortages, deficiencies, etc.) into consideration. The representatives of the "New Thinking" in project management criticize above all the "over-emphasis placed on planned actions" as well as the "mechanical thinking" of traditional project management.[118] Now a more holistic approach is emerging, which places emphasis on self-organization in projects and to interdisciplinarity. In this context one can speak of an integrating, Unitarian philosophy that is based on a global view and broader connections. This way of thinking takes many different

[116] See MADAUS, B. (1990): Handbuch Projektmanagement

[117] See SCHELLE, H. (1994): Die Lehre vom Projektmanagement

[118] See BALCK, H. (1990): Neuorientierung im Projektmanagement

factors into consideration and is less isolating and disjointed than standard methods.[119] These networked approaches attempt to analyze the relations that exist between the "project" system and its surrounding environment, and to do away with an isolated view of projects.

5.3 Project management terminology

Most terms in the field of project management have been standardized in German. The corresponding definitions are, for example, contained in DIN 69901 "Projektmanagement". According to this norm, the term "project management" refers to the totality of leadership tasks, organizations, techniques and resources required for the successful completion of a project.[120]

5.3.1 Project

In the relevant literature there are different definitions for the term "project".[121] DIN 69901 "Projektmanagement" defines a project as a pursuit that is characterized essentially by the uniqueness of the conditions in their totality, for example:

- Uniqueness of the conditions in their totality
- Specific predefined targets (target assignment)
- Temporal limitation (time)
- Limited financial, staff and other resources
- Limitations on other activities
- Project-specific organization.[122]

The special features of a construction project include:

- Separation of planning and execution (seen only to some extent in innovative competition forms)
- Principle of one-time completion (only in exceptional cases are building projects repeated)
- Overall level of difficulty results from the connection of all individual parts of the abstract coordinate system (see section 5.3.8)

5.3.2 Management

In German, the term "management" is used to refer to leadership and direction. Management can be understood both as an institution and a function. As an institution management represents the group of bearers of dispositive responsibilities, such as the project leaders. Functionally, management refers to the totality of dispositive tasks, the most important of which

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119 See PROBST, G.; GOMEZ, P. (1991): Die Methodik des vernetzten Denkens zur Lösung komplexer Probleme, pg.5.

120 See GREINER, O. (2006): Skriptum Projektmanagement – Bau, FH-Kärnten, and ÖNORM/DIN 69901 (2001): Projekt-wirtschaft - Projektmanagement - Begriffe, pg.1.

121 See LITKE, H.D. (1995): Projektmanagement, and SAYNISCH, H. (1997): Neue Wege im Projektmanagement

122 See DIN 69901 (2001): Projektmanagement - Projektmanagement - Begriffe; Begriffe, pg.1.

are planning, order and control. The goals of these tasks can be defined in terms of service or quality, deadlines and/or costs.[123] In brief, it is the totality of management tasks for the steering of a company or an administration.

5.3.3 Project management

Project management should ensure that the agreed upon project goals are reached in the framework of staffing, technical, scheduling and financial preconditions.[124] The objective around which everything revolves includes the "three essential parameters of project management" – quality, expense and time.

In the relevant literature the term project management (PM) is used in both a functional (management tasks) and organizational (description of groups that carry out PM tasks) sense. [125]

Project management is understood as a directive and organizational unit that attempts to steer the primary project factors according to a specific plan towards the overall goal and not leave these factors to the whims of accident or individual employees.[126]

General systems theory and systems engineering is particularly closely related to project management, as the analysis of projects as complex socio-technical systems has already shown. The application of the methods of systems theory to project management promises an integration of different management-related factors.[127]

In brief, the following theses form the foundation of traditional project management:

- An organized project cycle promotes the fulfillment of project goals far better than an unorganized sequence.
- Increased organization of a project leads to closer adherence to scheduling and cost calculations and to better fulfillment of performance goals.

5.3.4 Construction project management

Construction project management can be equated with short-term company leadership. According to the definition of the Deutscher Verband der Projektsteurer e.V. organization (German Association of Project Controllers), project management includes all financial, technical, legal, organizational and scheduling tasks for the target-oriented completion of a project. These tasks are subdivided into the categories of project direction and project steering. Project direction is responsible for achieving goals and maintains the authority to make decisions, give

[123] See BRANDENBERGER, J. (1991): Projektmanagement im Bauwesen, pg.10.

[124] See LITKE, H. (1995): Projektmanagement

[125] See STAEHLE, W. (1985): Management, pg.54.

[126] See ULRICH, P. (1984): Management - Eine konzentrierte Einführung,

[127] See SCHELLE, H. (1994): Die Lehre vom Projektmanagement

instructions and implement measures. The tasks of project steering can be delegated and serve to assist in making decisions as well as to monitor and document the project

5.3.4.1 Project direction

According to DIN 69901 project management is

„...for the duration of a project created organizational unit, which is responsible for planning, control and monitoring of this project. It can be adapted to the needs of the project."[128]

5.3.4.2 Project steering

Contrary to the DIN standards, the German Official Scale of Wages for Project Steering (HO-PS) states that project management consists of the following elements:[129]

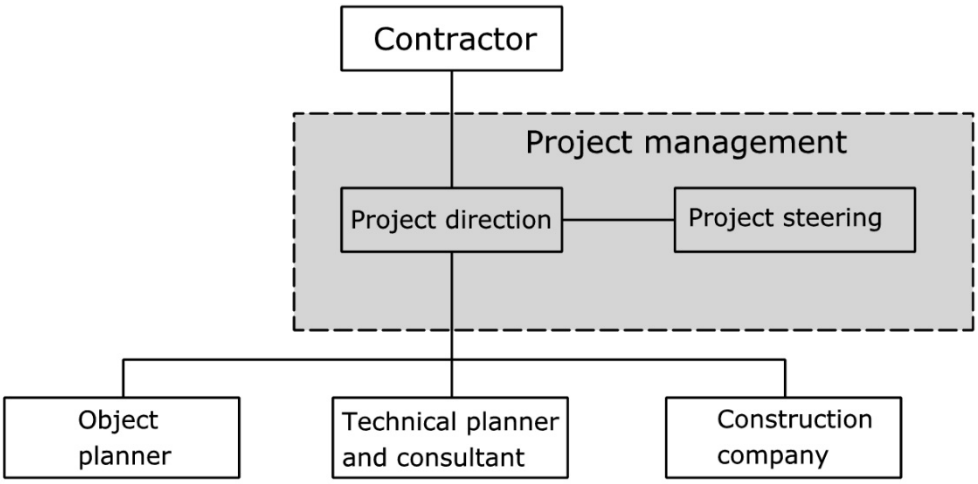

Figure 5-1: Integration of project direction/steering into the contractor organization. Source: KÖCHENDORFER (2007), pg. 10.

The difference between project direction and steering is to be found essentially in the delegation of authority and in their functions within the organization. This division would appear to be more advantageous for construction projects.

The subject of the division of authority and the separation of project direction from project steering will be examined at greater depth in section 5.5.3.

[128] DIN 69901 (2001): Projektmanagement; Begriffe,

[129] See HO-PS (2001): Bundeskammer Architekten und Ingenieurkonsulenten, Honorarordnung für Projektsteuerung,

5.4 Systems theory in project management

5.4.1 Basic principles

The basic premises and theoretical background upon which the systemic approach to project management is based were shown in the previous section of this paper. These theoretically formulated concepts have direct implications for a systemic project management capable of handling the new challenges with which it is confronted.

The systemic approach represents a new approach to project management based on a comprehensive view of the project. The multidimensionality of company processes has been accepted, replacing a single-dimension perspective. The company is not viewed in isolation, rather it is incorporated into its environment and a network of different relationships. Feedback mechanisms, disturbances as well as the importance of information processes are recognized. One-time and unpredictable project events cannot be controlled with organizational and control mechanisms originally developed for static production methods.

System-oriented project management is characterized by the following premises:[130]

- Clear distinction between project organization as an agent, the product as an operative object and the project as a system
- Methodological integration of the project environment in the development of the project target system and in every step of project completion
- The project organization is seen as an open, dynamic, self-organizing system for which the project result as well as the project completion process serves as goals.
- The management function is understood as a complex cybernetic process, divided into planning, steering and monitoring of the actual project work, without assuming a single-cause, mechanistic, cause-effect relationship.
- Subdivision of the overall project management function into deductive pathways (from more general to more detailed), so that a complete project management method can be derived
- The complexity of the interaction of the systems involved and their components (including the system environment) is made easy to comprehend and handle.

Systemic project management conceived on the basis of the systems sciences consciously includes the project environment in the different manners of viewing it. It sees project organization as an open, dynamic (self-organizing) system and it attempts to take the complex network of relationships that emerge in its goals, actions and agents into consideration (as far as this is possible) and deal with them accordingly.[131]

[130] See PATZAK, G. (1989): Systemtheorie und Systemtechnik im Projektmanagement, pg.14.

[131] See PATZAK, G. (1989): Systemtheorie und Systemtechnik im Projektmanagement, pg.40.

5.4.2 Practical application of the systemic approach

Before we look at the practical utilization of the systemic method in the problem solving process, one fundamental insight would seem necessary. In describing the Systemic Approach, the image should not be created that conventional management methods are no longer used. Figure 5-2 is intended to show the way in which different methods interact in the solving of problems.

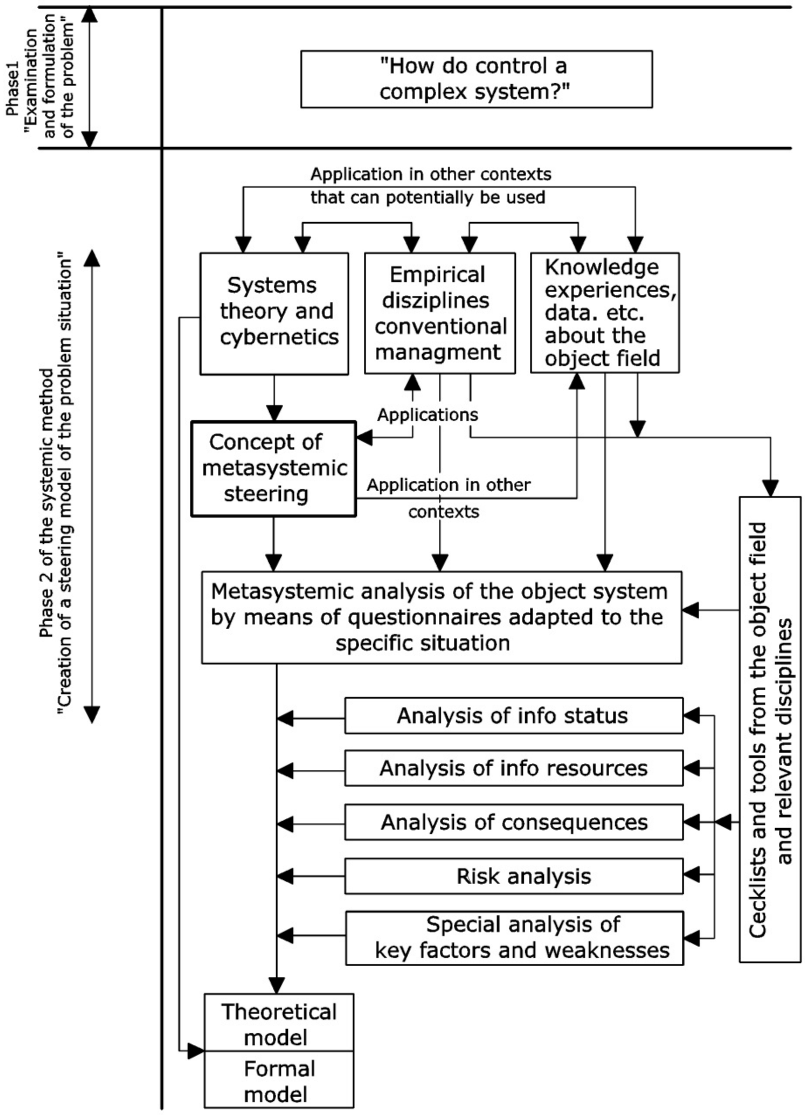

Figure 5-2: System relationships; Source: MALIK (2003) pg.423

The field of knowledge of cybernetics and systems theory is the point of departure. In addition knowledge from various empirical disciplines, especially from the field of conventional management, must also be utilized. The third most important variable is knowledge of the object range that is the focus of the analysis. From cybernetics and systems theory the concept of a systemic control model can be derived. The connecting arrows to the other fields of knowledge signal that under certain circumstances use is made of certain variations of this concept by other disciplines (i.e. management). One goal of this paper is to demonstrate the application of this concept in construction project management.

As explained in previous chapters, a system must be understood as a totality of elements that stand in a relationship to one another, whereby these relationships extend beyond the boundaries of the system itself. For the remainder of this paper the term "system" will be used synonymously with the term "project". Based on this comprehensive view of the problem/project, a problem analysis will be carried out for the sequential series of project phases ("macro strategies"). Each of these phases ("life phases") is understood as its own problem solving process, for which a separate problem solution cycle will be developed.

Figure 5-3 shows a basic integration of the system approach into the problem solving approach.

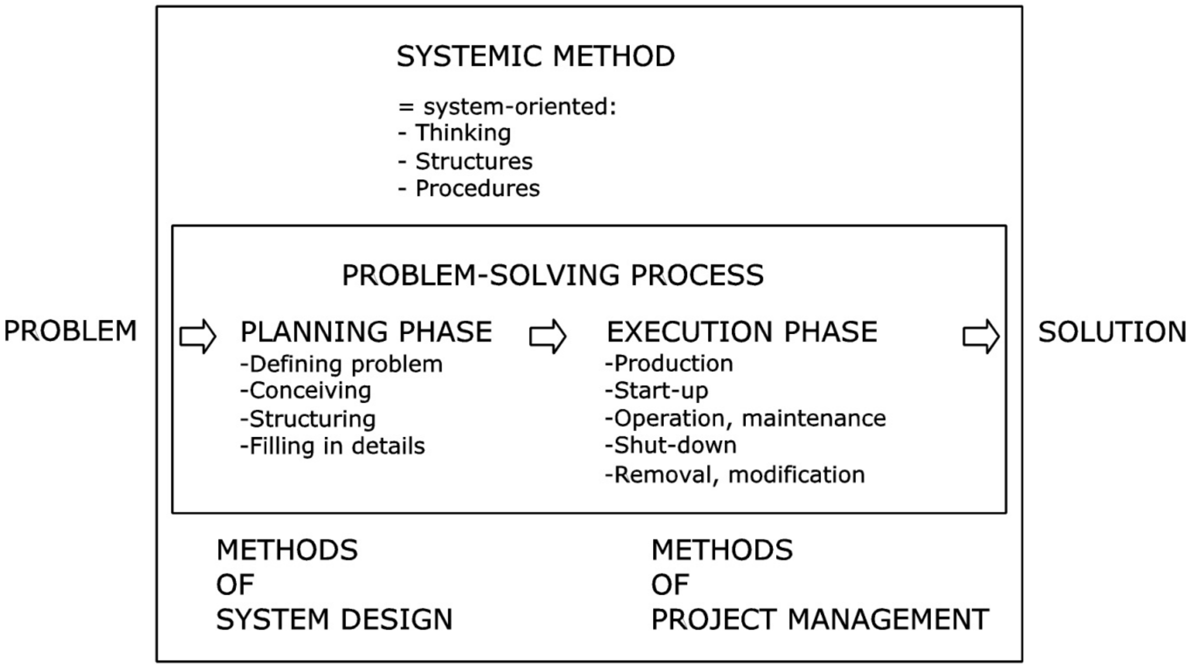

Figure 5-3: Basic model of systemic problem solving. Source: PATZAK (1982), pg. 17.

The following components of Figure 5-3 must be explained:

- The systemic approach serves as a basic philosophy and intellectual superstructure.
- In the center stands the actual problem solving process as a way of transitioning from the original state to a desired one.

  This problem solving process contains two discernible components:

  - Project work itself
  - Project management, that is, the organization and coordination of the problem solving process
- The use of problem solving methods and techniques, as well as the utilization of project management methods and techniques to support the above listed sub-tasks covers the instrumental aspect of problem solving.

5.4.3 Procedural model[132]

The procedural model is based on the following three components:

- From general elements to details
- Structuring into phases (life phases of the project = "macro strategy")
- Problem solving cycle ("micro strategy")

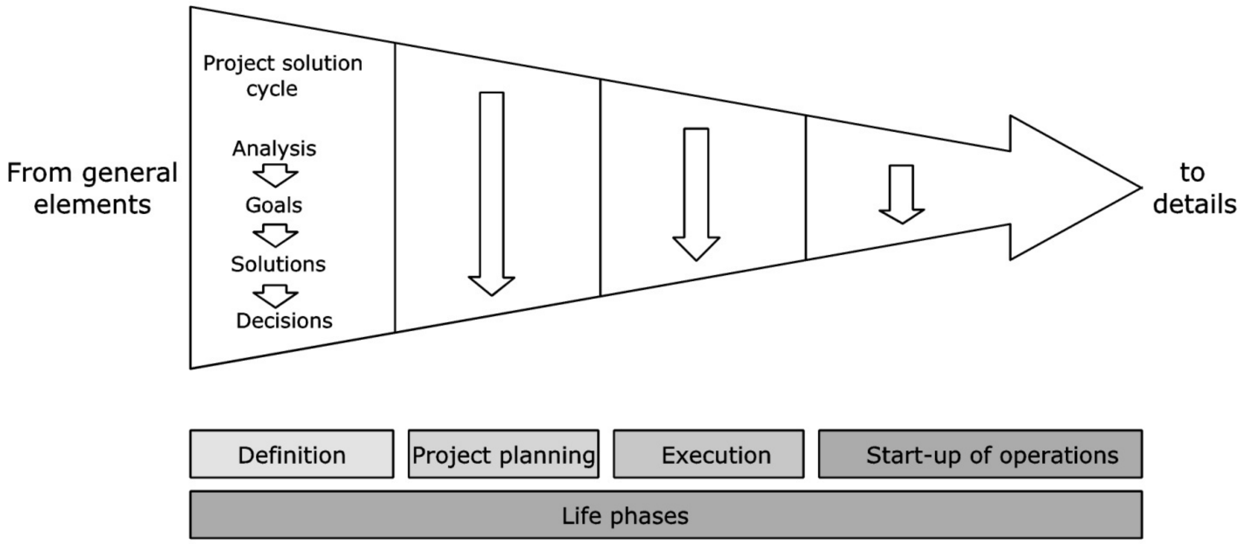

Figure 5-4: System engineering procedural model. Source: BRANDENBERGER (1991), pg. 14.

From general elements to details

It is often most productive to first determine general goals and their rationale and create a solution plan. The project is defined more precisely in several phases, with the details showing whether the goals have to be more closely identified or adapted.

5.4.3.1 Structuring the phases

The development of a project can be described by means of a system timeline, the so-called life phases, and divided into manageable sections. The basic division will remain the same for any system and assume the form shown in Figure 5-3. The following phases must be directly included:[133]

- System development (problem definition)
- System planning (conception, structuring, details)
- System realization (producing components, procurement, assembly)
- System implementation (start of operations)

[132] See BRANDENBERGER, J. (1991): Projektmanagement im Bauwesen, pg.14

[133] See PATZAK, G. (1989): Systemtheorie und Systemtechnik im Projektmanagement, pg. 41

For a more comprehensive view the following phases can be added:

- Preliminary system study (strategic system planning)
- System use (maintaining operations)
- System change (interruption of operations)
- Dismantling of system (recycling, modification)

In practice different terms are used to mean different things depending on the specific technical field. The individual phases exist in an associative relation with sequential logic. From these general phases, construction-specific life cycle phases have been derived are compared in the following Figure to general system phases.

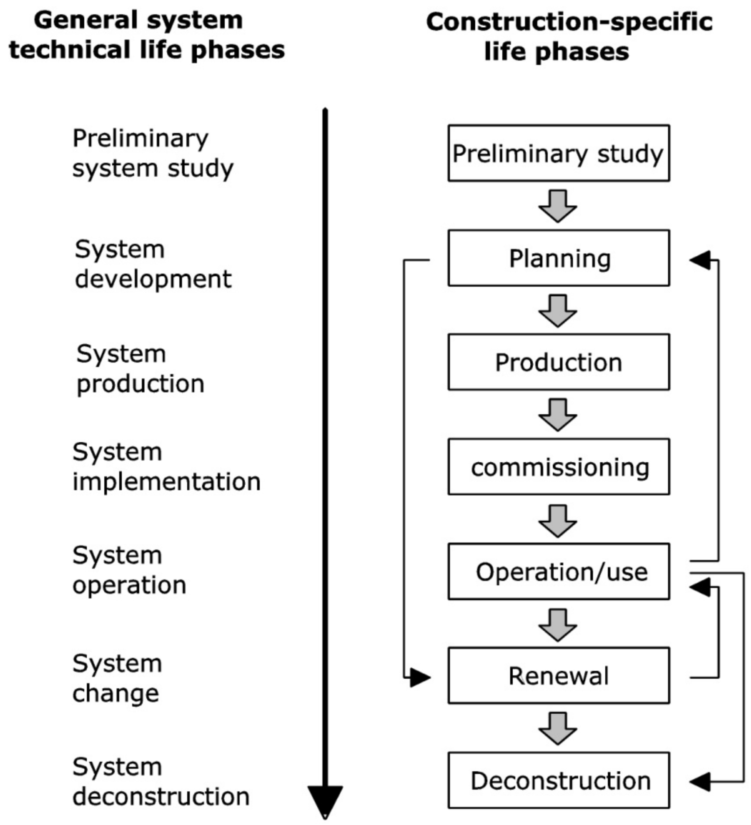

Figure 5-5: Life cycle oriented procedural model

Austrian Norm B 1801-1 could be used as a system for subdividing construction projects. This author, however, prefers instead the subdivision system of the HOAI (Honorarordnung für Architekten- und Ingenieurleistungen – Official Scale of Wages for Architectural and Engineering Services), which is binding in Germany, as well as the non-binding recommendations from other EU countries derived from the German standard (in Austria the Scale of Wages for Architects).

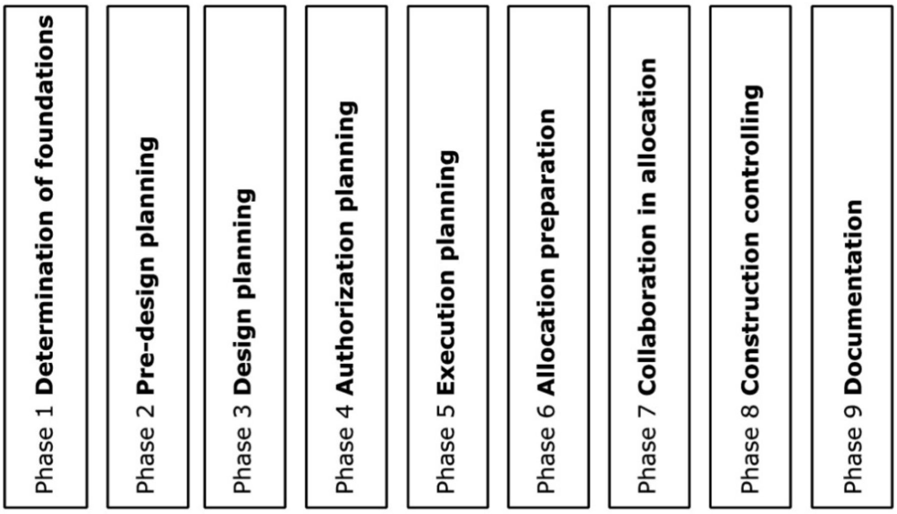

Figure 5-6: The 9 phases. Source: HOAI (2009), pg. 48.

The range of services begins with the communication of basic information on framework conditions (defined tasks, energy requirements) and thus leaves out the crucial foregoing strategic phase of project initialization and development, which from the construction cybernetic point of view must be included. The range of services included in project steering, which in Austria is included in the Scale of Wages for Project Control (Honorarordnung für Projektsteuerung or HO-PS), does include certain aspects of project preparation, but the critical project development phase is also left out. That would mean that the range of services carried out by architects, engineers and project controllers ends when the structure is handed over to the user.
In Austria Norm B1801-1 is used in addition to the HOAI. In this norm more emphasis is placed on the conceptual phase (conceptual phase or project development phase, which consists of need planning and project preparation). Yet even in this norm the phases of demolition and disposal are not included.

Taking into account potential long-term effects on functional and cost optimization as well as a holistic structure life cycle view, the original nine phases of the range of services defined in the HOAI should be supplemented with three additional phases:

- One initial phase:
  - **Phase 0** “Project Development“[134]
- Two phases that round off the structure’s life cycle
  - **Phase 10** “Use Phase“[135] and
  - **Phase 11** “Demolition and Disposal”

[134] See LÖHNERT, G. (2002): Der integrale Planungsprozess, pg.1.

[135] See LÖHNERT, G. (2002): Der integrale Planungsprozess, pg.1.

In the following diagram the service phases of the HOAI are supplemented with project development in the project preparation phase, building management in the operational phase and demolition and disposal in the demolition phase. In this way the entire building life cycle is covered – from project idea to demolition – and thus the prerequisites for a holistic cybernetic perspective are fulfilled.

The diagram also shows that latitude for measures intended to optimize cost-effectiveness and use quality decreases as the project advances. Conversely, as time progresses individual parameters become more precisely defined so that the cost of subsequent planning modifications rises exponentially.[136]

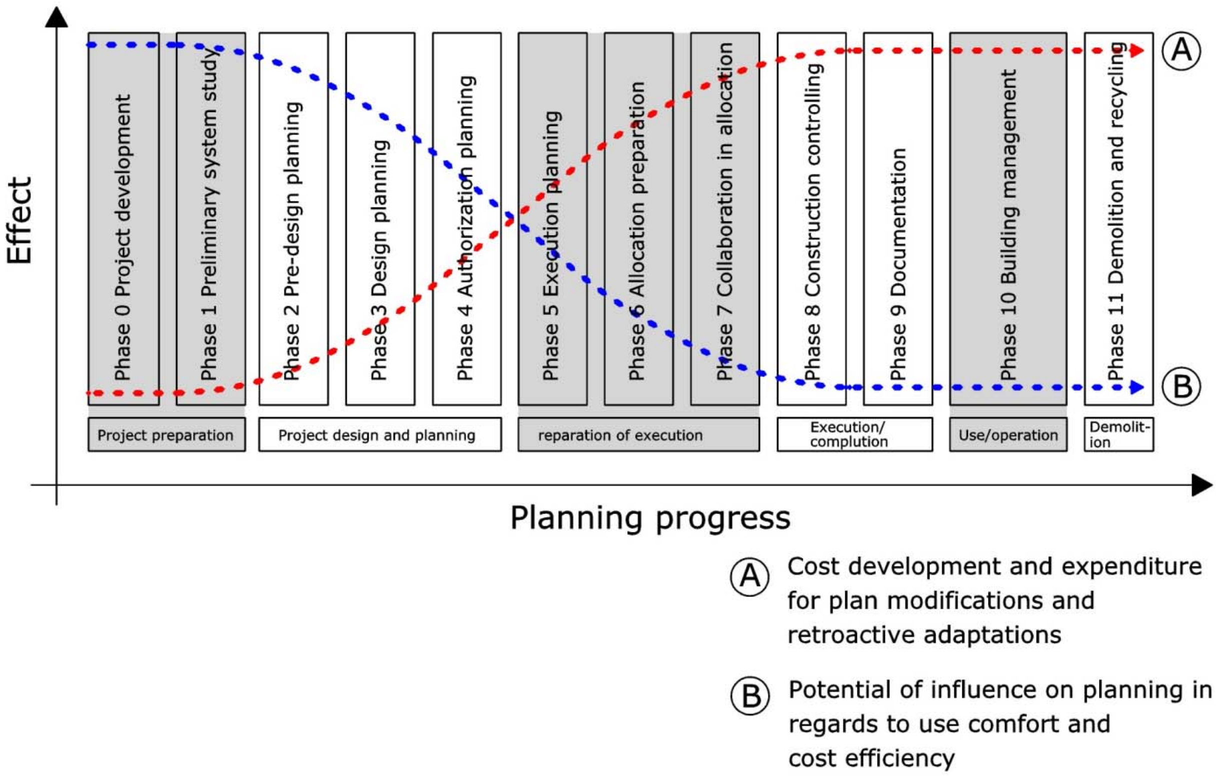

Figure 5-7: Controllability as planning advances. Source: HOAI (2009).

136 See SRIENZ, R. (2003): FM-Bauprojektbegleitung, pg.11f.

5.4.3.2 Problem solving cycle using the systemic method

The problem solving cycle serves as a guideline for the solution of problems in the individual phases of a project. An understanding of the system is not sufficient to solve complex problems. Here the description of a problem solving procedure is needed. It has proven useful to subdivide the processes and to approach the solution step by step. In this way it can be ensured that an overview of the situation is maintained and all potential alternatives can be incrementally tested and implemented. The system dynamic can also be better defined in this manner. The systemic procedural model is based on the "from the general to the more detailed" approach. In the structuring of solutions general goals and an overall solution framework should first be determined, which in the course of further project work are then filled out with more precise details. In this way the problem domain can be embedded before more detailed investigation begins.[137] The procedural model includes a life cycle related model of phases as well problem solving methods that can be used within the phases.

1. Situation analysis – What's wrong?

   - Understand the situation.
   - Define the symptoms of an unsatisfactory situation.
   - Identify potential causes, risks and opportunities.

2. Formulation of goal – What should be achieved?

   - Formulate clear and specific goals.
   - Define requirements, goals must always be quantifiable. Quantifiability is important for specific goals (quality, quantity) as well as scheduling and cost objectives.
   - Consider consequences of not achieving the goal.
   - Distinguish between limiting conditions and goals. Limiting conditions are fixed and predefined.

3. Conceptual draft – Which solutions are possible?

   - Formulate solution methods.
   - Analyze solution methods in terms of the achievement of goals, functionality and completeness.

4. Evaluation – Which solutions make sense?

   - Evaluate solution variants based on weighted criteria.
   - Qualitative and quantitative assessment

5. Decision – How can the solution can be implemented?

   - Selection of the most suitable solution

[137] See BRÜCHNER, S. (2003): System Engineering - Aufbau und Wirkungsweise

The method used is a schedule of actions that describes more the individual solution steps or processes than a real problem.[138]

Here too we can speak of a problem solution strategy that is domain neutral.[139]

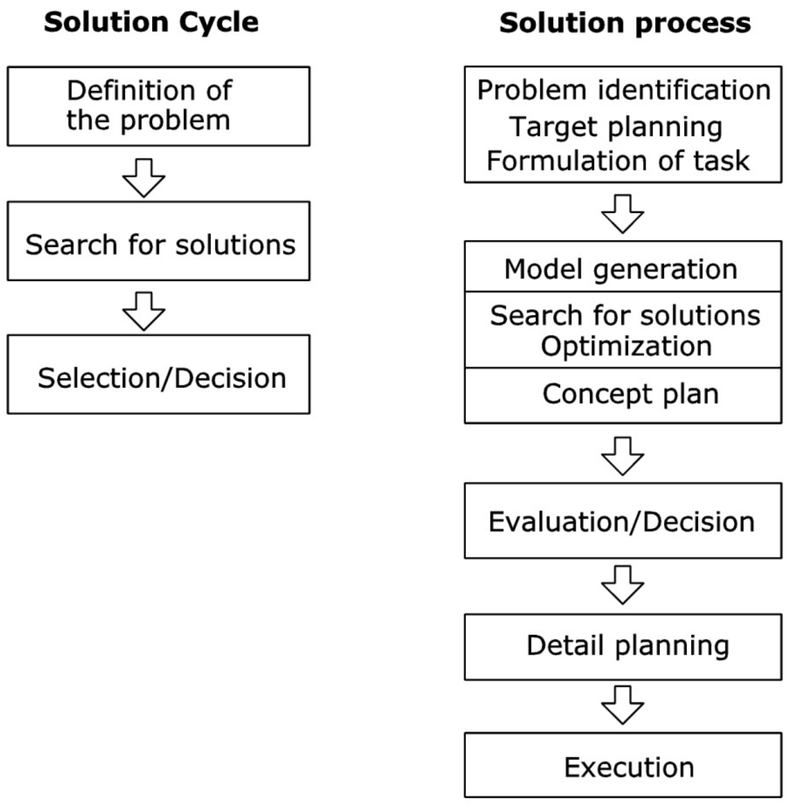

Figure 5-8: Principles of problem solving. Source: AGGTELEKY (1992).

The simplest form of such a problem solving method is the so-called solution cycle (see Figure 5-8), which consists of sequential steps for analyzing the problem, the search itself for a solution and the selection of results or a decision. Complex problems require a solution process with more than one step, in which optimization initially takes place at a conceptual level and details are then planned based on these ideas. The principle of the solution process and solution cycle can be applied to individual phases or to the project as a whole.

[138] See AGGTELEKY, B. (1992): Projektplanung: Ein Handbuch für Führungskräfte

[139] See ALBERS, S. (2001): Erfolgreich Produkte Entwickeln

5.4.4 Defining the project based on the Systemic Approach

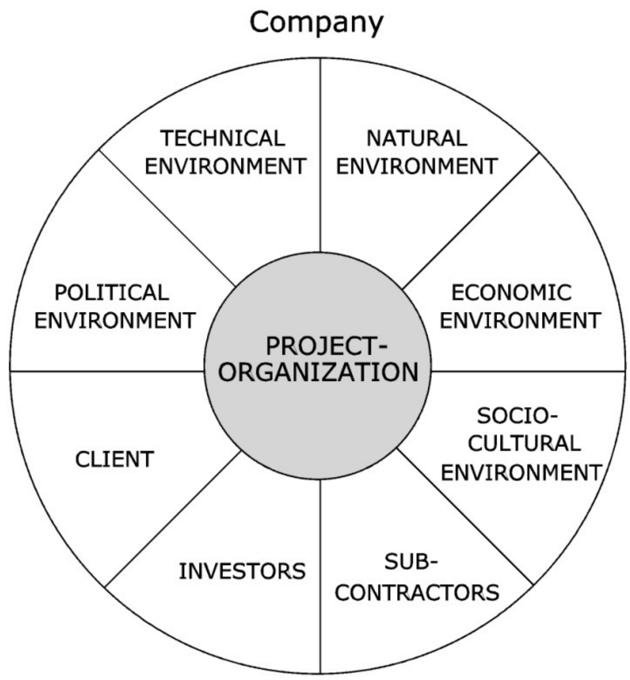

Figure 5-9: System model of relation between the project organization (as institution) and project environment. Source: PATZAK (1989), pg. 43.

Project management and target system[140]

A target system represents an overall project in sub-goals, all the way down to operable individual goals. The overall goal of a project can generally be defined as Optimal Satisfaction of Requirements (maximum system effectiveness) by means of problem solution as a result and as a process. In the systemic approach effectiveness (efficiency) means the total cost-benefit ratio, whereby non-monetary aspects are also taken into consideration.

The relevant requirements are fulfilled and to some extent formulated by all parties directly and indirectly interested in the project. This includes all individuals who have subjective expectations for the project (based on requirement structures, anticipation levels and values) and that belong either to the “Project Organization” agent system or the relevant corresponding project environment.

Expectations and interest on the part of interest groups consciously flow both rationally and emotionally into the project goal system. These are always present and should thus be made clear, expressed and weighed, whereby the power relations of the interested parties determine to what extent expectations and interests are taken into consideration.

[140] See PATZAK, G. (1989): Systemtheorie und Systemtechnik im Projektmanagement, pg.43.

Project definition

Systemic project management is based on the idea that a project target system represents a kind of balance of interest among partners (not adversaries), maintained autonomously for the advancement of the common goal of the greatest possible satisfaction of all individual needs.

The synergistic (collaborative), productive balance of interests is recursive and continues throughout the project (i.e. in the case of changes to client's needs or societal values, advancement of the "state of the art", changes in staff and staff development, new insights gained in the course of the activities, etc.). Thus as a project target system it proves to be dynamic. Systemic project management must take this into account.

The conventional manner of defining a project focuses on a limited view of the project target system. Only the objective goals (object systems – the work result in quantity and quality) and formal goals (intermediate and final deadlines, costs and completion processes) of the client/contractor interest group are set down in writing.

The interests and/or individual goals of the other interest groups shown in Figure 5-9 are not explicitly examined in this kind of project definition.

The project definition that emerges in this phase will serve as a guideline for the following phases: projection, completion, initial operation and use. They are to be set down in the "Project Goals" section of the project handbook in a way that is comprehensible for all parties involved.

5.4.5 Project management tasks and activities (PM and operational system)

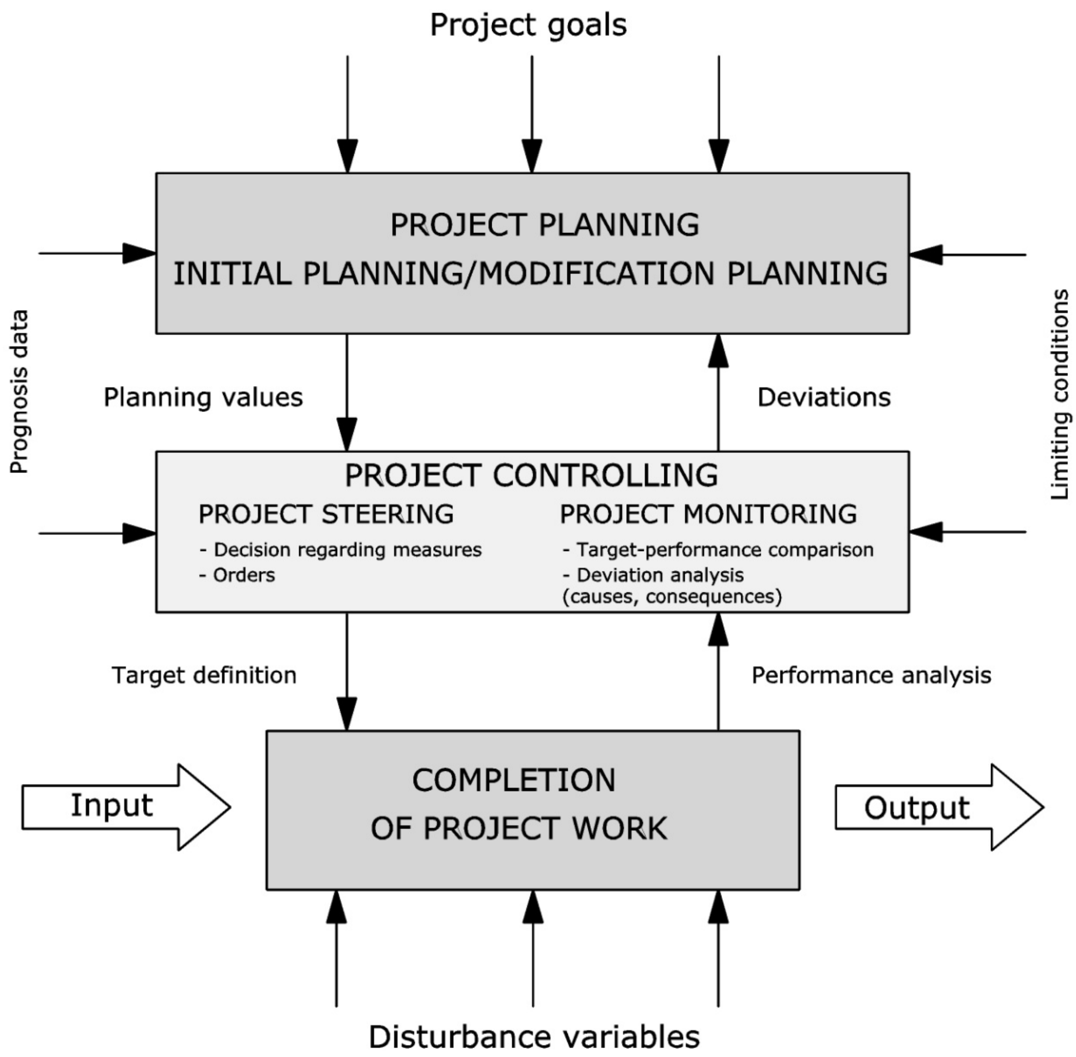

Figure 5-10: Project management control circuit model as operational system. Source: PATZAK (1989), pg. 43

The tasks of project management can be further broken down into direct and indirect tasks.

Direct tasks (main tasks) work as process regulators with main functions from Figure 5.10: planning, steering and monitoring.

The term "project planning" is to be understood here as the planning of project work and not the planning of the object system.

The control circuit model for project management is at the core of the management of complex processes or projects with great variety. This type of process controlling does not involve a traditional form of steering based on constructive, technomorphic theories, according to which a modification of the manipulated variable automatically affects the intended change of the system state.

Instead, by process control the following is meant:[141]

- Communication of orientation towards accepted goals that can change based on system states, defined incentives
- Definition of actuators and stimuli for handling conflicts on the way towards achievement of the goal
- Providing information regarding ways to optimize the process, including staff training

The following object-related factors of the project target system are the variables of direct project management:

- Work result (quantity and quality)
- Deadlines
- Resources/costs
- Risk

The indirect tasks (supporting tasks) include:[142]

1. Inward oriented indirect tasks

These tasks are necessary to be able to carry out the central task of process regulation (project planning and controlling):

- Administration
- Documentation
- Information and communication

2. Outward oriented indirect tasks

These tasks are necessary for successful completion of projects. They can be carried out by project management in full or by another division of the base organization, such as marketing, sales, purchasing, PR, company management (though in some cases only partially):

- Contract design, claims management
- Project reporting
- Project marketing, media contact, PR work
- Procurement and logistics
- Contact with government authorities

[141] See PATZAK, G. (1989): Systemtheorie und Systemtechnik im Projektmanagement, pg.43.

[142] See PATZAK, G. (1989): Systemtheorie und Systemtechnik im Projektmanagement, pg.54.

5.4.6 Management errors in dealing with complex systems[143]

In the mid 1960s DÖRNER performed interesting experiments with complex systems. For example, he had experts in different fields develop a fictitious region by use of computer simulations. From the staggering result he derived the following six errors in dealing with complex systems that can be avoided using cybernetic steering systems. Avoiding these errors is crucial for achieving goals with complex systems.[144]

- *First error: Insufficient identification of goal*

How to avoid: the cybernetic steering system only works in a goal-oriented manner. Insufficient goal identification is impossible, as goals must be determined in all cases.

- *Second error: Limitation to individual parts*

How to avoid: in the cybernetic steering system all information must always be gathered so that the general context is considered even when processing individual parts.

- *Third error: One-sided emphasis*

How to avoid: in the cybernetic steering system all determining factors are always simultaneously included in all project phases, and in this way a one-sided emphasis is avoided.

- *Fourth error: Failure to take side effects into consideration*

How to avoid: the cybernetic steering system only works with information that has been considered from all possible perspectives. Unanticipated side effects are only possible to a small, generally controllable degree. In this context VESTER speaks of so-called "policy tests" (no "what if" test) to evaluate possible strategies.

- *Fifth error: Tendency to oversteer*

How to avoid: the cybernetic steering system regulates itself by means of target-oriented self-organization in control circuits. Oversteering is thus avoided by means of early warning mechanisms.

- *Sixth error: Tendency towards authoritarian behaviors*

How to avoid: the cybernetic steering system functions only with teamwork so that authoritarian behavior is not possible.

[143] See VESTER, F. (2008): The art of interconnected thinking, pg.37f.

[144] See GREINER, O. (2006): Skriptum Projektmanagement – Bau, FH-Kärnten, pg.24.

5.4.7 Requirements of management systems

To avoid these errors in carrying out complex construction projects the management system must be designed in the correct manner. To reach project goals in terms of, for example, use, costs, deadlines, quality, etc. management must satisfy the following five requirements.[145]

1. Target-oriented self-organization

The determination of goals and the identification of limiting conditions for complex systems are only possible with cybernetics, which promotes networked thinking.

GROTE defines this requirement in the following manner:

„*By means of comprehensive, correct and timely information all parties involved in planning and construction processes may be capable of acting independently and in a de-centralized, effective manner. Cybernetic planning provides information that sets the self-organization process in motion*."[146]

2. Target-oriented steering

Target-oriented steering is achieved through the cybernetic control circuit; updated target-performance comparisons provide a basis for analysis and, if necessary, control measures.

3. Early warning

The data critical for construction of a structure is provided in all phases of project completion in the course of planning. Deviations are continually shown, not just in the course of the actual construction work. Warnings are thus issued at the earliest possible moment.

4. Less effort

To achieve this in all areas and phases of project completion the Pareto principle is applied (80/20 rule). According to this all important data is collected in full, but only 20% of the data has to be processed.

5. Simple application and operation

Data and information are only processed to the extent and level of accuracy required for each phase of project completion. Information is shown in a way that best serves and can best be understood by the individual recipient so that he/she can be included in the decision-making process.

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[145] See GREINER, O. (2006): Skriptum Projektmanagement – Bau, FH-Kärnten, pg.25f. and EFCC (2010): European forum for construction cybernetics, http://www.baukybernetik.at/, viewed on 10 March 2010

[146] GROTE, H (1988): Zielgenaues Planen und Steuern

5.4.8 Traditional standard construction industry model

Since this paper presents a new approach to construction management, at this point the "Conceptual Coordinate System" as defined by PFARR should be mentioned as the traditional model for understanding construction industry related issues. In the course of his work PFARR recognized that research on the construction industry provided more and more detailed research, yet an explanation as to how to all the different pieces could be brought together into a single unit was lacking. He helped alleviate this need and provide a solid foundation with his conceptual coordinate system. Thus for the first time a kind of General Introduction to Management was created for the construction industry, which briefly presented the entire construction industry in a systemic manner.[147] The basic features of this introduction will be discussed in the following pages.

As a Conceptual Coordinate System for categorizing different construction industry-related issues, PFARR suggests a division into relevant institutions, structures and processes (see Figure 5-11).[148]

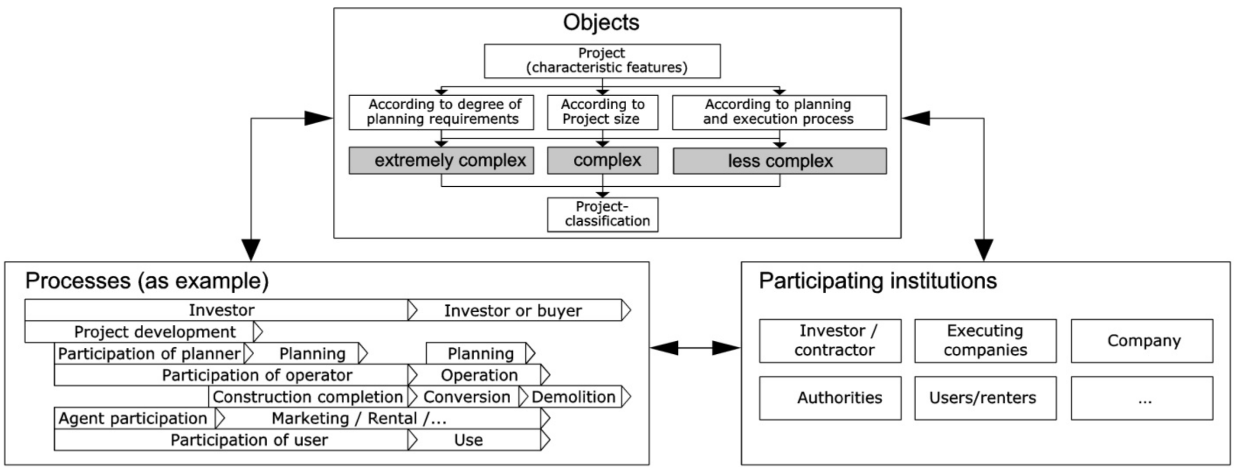

Figure 5-11: Objects-Processes-Relevant Institutions. Source: PFARR (1984), pg.149

Under the category "Objects" there is a very interesting note. Here each project is assigned essential properties – highly complex, complex and less complex. The way this is formulated ties into the subject of this paper, and this differentiation and its effects must be examined in greater detail.

The strength of PFARR's system model lies in the comprehensive view it provides of the temporal feedforward and feedback relationships within the planning and construction process. In this way relations between object, planning, completion and use can be graphically illustrated and precisely numerated, and thus even less experienced users can understand the resulting complexity.

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[147] See PFARR, K. H. (1984): Grundlagen der Bauwirtschaft, pg.5.

[148] See PFARR, K. H. (1984): Grundlagen der Bauwirtschaft, pg.270ff.

This author would make the following modification to PFARR's Conceptual Coordinate System with project management and the competitive model with contract type (see Figure 5-12):

- Eliminate project management at the interface of the coordinate system as the crucial factor for the entire project's success
- Clearly indicate the increasing importance of the competitive model with contract type so that the following items can also be achieved.
- Identify the defining framework conditions of project completion.

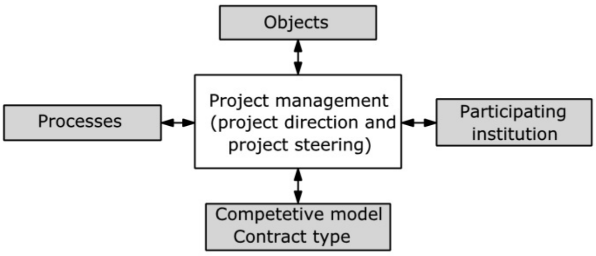

Figure 5-12: "Conceptual Coordinate System" based on PFARR's model with additional components

The competitive model describes how relevant institutions can be integrated in which phases of the work completion (processes), which tasks can be assigned to them and how the various interfaces are to be regulated in relation to one another.

A suitable competitive model will be developed based on the analysis of the object (type of project) and the desires and prerequisites of the investor or contractor (contractor's requirements). Specialized contracting with individual companies as well as complete contracting with the different kinds of general and total contracting companies are considered conventional[149] or established [150] forms. In the future greater attention should be paid to innovative models like construction teams, construction system competitions and target models [151]

Project management is responsible for creating a suitable competitive model with the accompanying contract type. These tasks follow project development and are positioned upstream of the project preparation operational functions created by project steering. The process-related (competitive model) and legal conditions (contract type) that have now been created make it possible for a project organization (hierarchies, authorizations ...) to be set up.

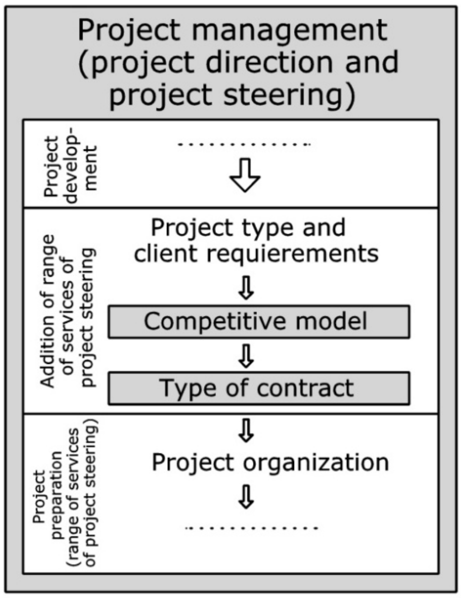

Figure 5-13: Competitive model and contract type as a project management task.

[149] See AHRENS, H. (2004): Handbuch Projektsteuerung – Baumanagement

[150] See BLECKEN, U. (2002): Baukostensenkung durch Anwendung innovativer Wettbewerbsmodelle

[151] See BLECKEN, U. (2002): Baukostensenkung durch Anwendung innovativer Wettbewerbsmodelle

5.5 Structural organization

The following sections on structural organization can be seen as a derivation of the VSM bionic-cybernetic system model that was described in greater detail in section 3.8.

The author ascribes the sub-systems of the cybernetic organizational system to the following levels of the structural organization, which is specially designed for the management of construction projects.

System 5 = Contractor/Investor
System 4 = Steering committee/Construction committee
System 3 = Project director
System 3*= Quality management
System 2 = Project direction team
System 1 = Company (companies carrying out the work)

The insights and background on which this division is based was described in section 3.9 and other sections. In the following pages we will focus on the division chosen by the author with, in conclusion, a practical example.

5.5.1 General considerations

Projects are temporary economic enterprises with a contractual (and not dirigiste) connection between the various parties. For this reason the identification of behavioral rules is especially important in the achievement of project goals, as the "company direction" (= project direction) is also only of a temporary nature and cannot use the kind of hierarchical structures present in permanent companies.[152]
A structural organization is a project-oriented organizational diagram with a limited lifespan. The structural organization shows the static, objective connections of the divisions involved in the creation of a project. It is a function-oriented or object-oriented classification of the divisions, organs and service providers that play an active role. In addition it is intended to illustrate the boundaries of responsibility and authority. In determining the structural organization two factors must be considered:[153]

- Completion of the technical operations necessary to achieve the project goal (development, planning, construction, building tasks, etc.)
- Project-oriented summary of these technical tasks by means of work and process design, coordination as well as project-oriented direction of the internal and external functional units that are to provide the individual technical services

[152] See Bundeskammer der Architekten und Ingenieurkonsulenten (2001): Honorarordnung für Projektsteuerung, HO-PS,

[153] See RESCHKE, H. (1989): Handbuch Projektmanagement, pg.864.

The initiation of large investment projects takes place, of course, with the cooperation of parties from a wide range of fields (investors, users, consultants, planners, contracting companies, etc.). The following operations involve above all the cooperation of these parties. The structural organization of a project can be applied and adapted to the task at hand in various manners, for example quickly or slowly, as a foreign unit or permanently. Critical for success is the question as to how well the company organization and project organization work together.

The form of the organizational models that is applied or derived from the relevant literature varies depending on the kind of projects and the characteristics of the organizations involved. The relation that the contractor desires with the planning and operating parties will also be crucial. Understandably, more occasional contractors will sometimes choose different organizational forms than professional contractors.

5.5.2 Cybernetic structural organization

As explained in section 2.3, managing companies or organizations is about mastering complexity. The organizational form most suited to controlling complexity must be chosen. Regarding the insight that the control behavior of a system is a necessary consequence of the system structure, Fredmund MALIK writes:

„*The steering capacity of a system and thus its ability to control complexity is dependent on its fundamental structures. There are system structures that make handling complexity easier and those that make it difficult or impossible*.“[154]

Since a number of different positions are involved in the solving of problems, satisfactory results are only obtained if the solution created by one position is considered by the other positions, that is, if the state of every position can be communicated in the cybernetic sense to every other.

Beyond that, every adaptation, decision, solution, etc. that takes place or is made at one position must be integrated into the general concept. This general concept can, generally speaking, be a unified strategy or guidelines – in the case of construction projects it is to be understood as optimal achievement of the project goals.

Fredmund MALIK describes this form of problem solving as follows:

„*It is the decentralized problem solving method at the level of the object with centralized steering by means of a meta-system that allows for a coherent orientation with the greatest possible adaptability and flexibility*.“[155]

[154] MALIK, F. (2000): Strategie des Managements komplexer Systeme, pg.173.

[155] MALIK, F. (2000): Strategie des Managements komplexer Systeme, pg.240.

The effects of these diverse problem solving processes on the system's form and the manner in which this form is adapted can be graphically represented in a simple manner:

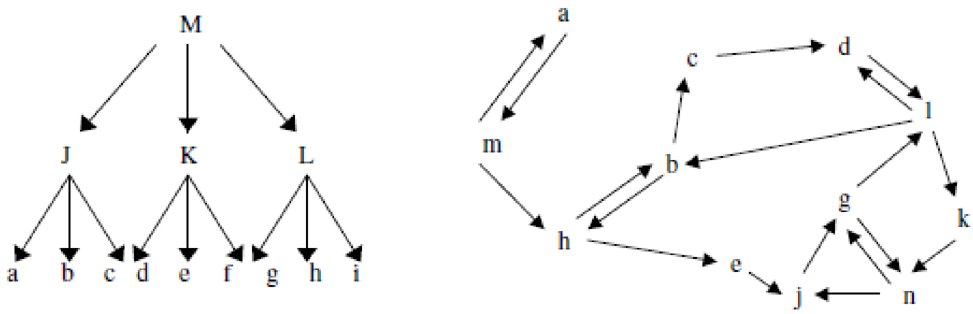

Figure 5-13: Forms of adaptation. Source: MALIK (2003), pg.240.

On the left is the hierarchical system form which is based on central control. On the right is the spontaneous polycentric arrangement, which is based on reciprocal adaptation of the different elements. Each letter represents a problem solver or decision maker. $x \rightarrow y$ means that the decisions or the behavior of the y element is adapted/coordinated to/with the behavior of the x element.

A presentation of this form of thinking and control by way of examples from the context of companies can be seen in the following two representations. Figure 5-15 shows a typical organizational chart which is based on several hierarchical levels (ordered control form).

The organizational chart shown in Figure 5-16 is an excerpt that shows the polycentric control relations between components as they should exist to facilitate adaptations to modified circumstances. A change to any component must result in changes to the other components, though with varying delays and to varying degrees.[156]

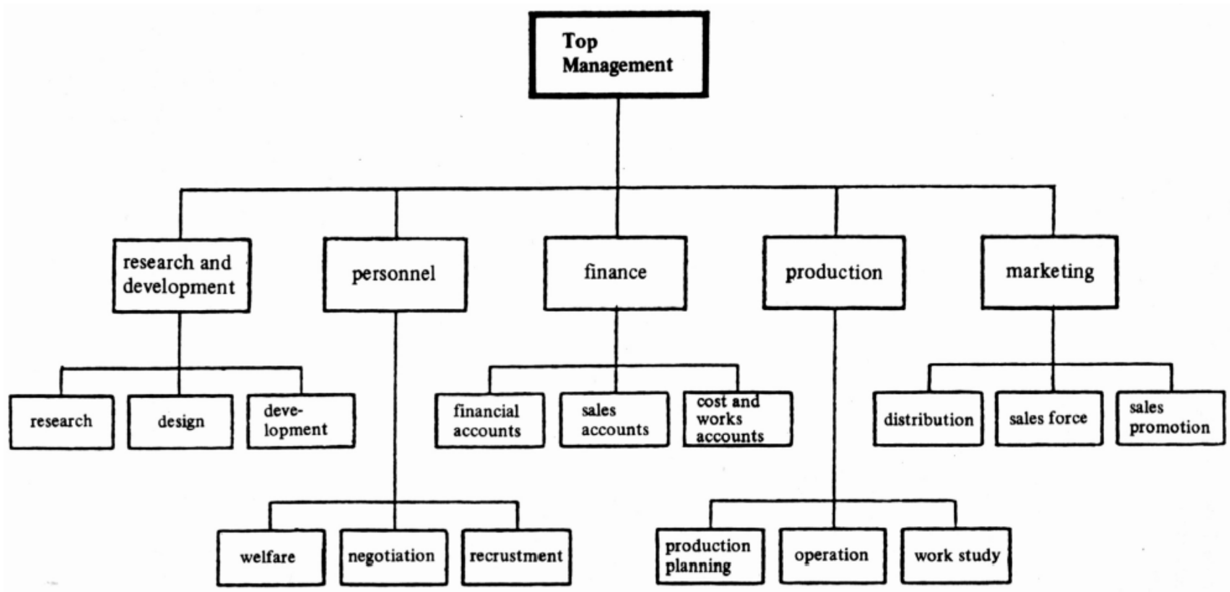

Figure 5-14: Ordered control form. Source: MALIK (2003), pg.242.

[156] See MALIK, F. (2003): Strategie des Managements komplexer Systeme, pg.241.

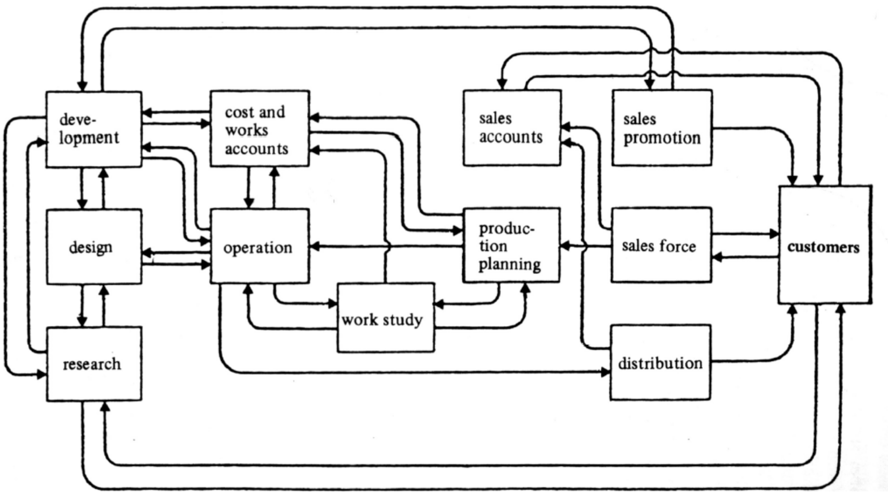

Figure 5-15: Polycentric control form. Source: MALIK (2003), pg.243.

Cybernetically oriented organizational forms are adjusted in the following manner to these circumstances:

The core of cybernetic project organization is the project direction team (System 2). It guarantees quick information distribution and uniform, comprehensive project development and completion.

According to PATZAK a team is characterized by:

„*...when several individuals dependent on one another strive to complete something (that is, when the actions of one member have an influence on the success of all the others). A team is, furthermore, a task-oriented work group with intense personal contact and direct communication. A common goal is therefore required*."[157]

Due to their rigid structures which are designed to handle routine actions, hierarchical line organizations (see Figure 5-15) are less suited to solve new, complex problems with the required flexibility.

Strict hierarchical organizational forms are often characterized by their orientation around the various divisions. Individual divisions do not identify with the overall task. The solutions developed in the individual departments might seem optimal from their point of view, but what results is not necessarily the best solution to the overall problem.

To be able to handle the complex problems that arise in formulating the project, the knowledge and capacity of all positions involved are needed.

For cybernetically oriented organizational forms, the line function is only to be found in the upper decision-making level, as can be seen in the representation of the Viable System Model – that is between Systems 5 to 3 or, applied to the model illustrated, from the contractor sphere to the project director.

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[157] PATZAK, G. (1998): Projekt Management, Leitfaden zum Management von Projekten,

5.5.3 Cybernetically oriented project organization model

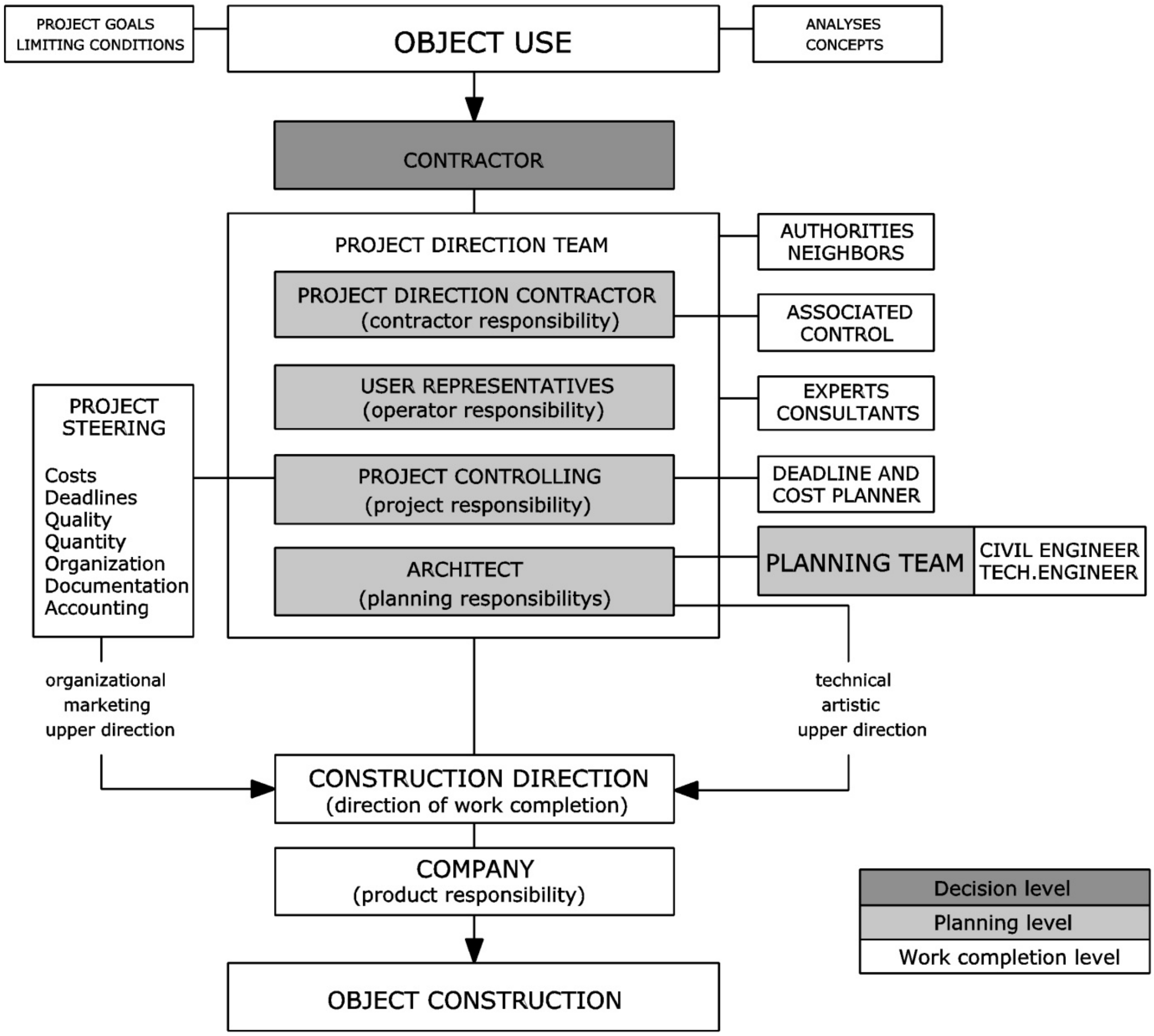

Figure 5-16: Example of structural organization with project direction team.

Similarities to viable systems

In this form of structural organization there are clear resemblances to the viable systems introduced in section 3.8.

The upper decision-making level represents the contractor (System 5). At the very least he/she must complete the contractor operations that cannot be delegated.

For large projects, like the LKH Klagenfurt NEU hospital, the contractor can use a separate organization (System 4) to ensure the contractor’s interests are protected.

This can be a new construction company or a construction committee consisting of members of the contractor organization. This intermediary organization corresponds to the System 4 seen in section 3.8, which functions as a link between the upper decision-making center of the company (System 5) and autonomous management (System 3). A further task is the in-take and processing of information on the company environment and forwarding this information to the upper decision-making center and autonomous management.

The center of cybernetic project organization is the project direction team (System 2), which is organized and coordinated by project controlling (System 3). The team consists of a contractor representative, user representative, planner representative and project controlling. A team that works closely together makes rapid processing of information and comprehensive, interdisciplinary project development and completion possible. This constellation is a reaction to some of the reflections of the previous section.

Functional description – functional boundaries

How the functions, responsibilities and authorizations of the positions involved are delimited depends on the type of project as well as the positions involved (i.e. the contractor's technical knowledge). The range of operations of the relevant positions (contractor, project direction and project steering) must be set down contractually for the various project phases. As a basis for the division of responsibilities and wage levels, the 2001 version of the German Official Scale of Wages for Project Steering (HO-PS) can be used. In addition, independent agreements between client and contractor are possible – for projects not covered by one of the fields of this wage scale (i.e. urban construction projects or product development in high-tech fields) these are even necessary.

Boundaries

Below project steering will be presented as part of project direction, though both can be summarized by the term "project controlling".

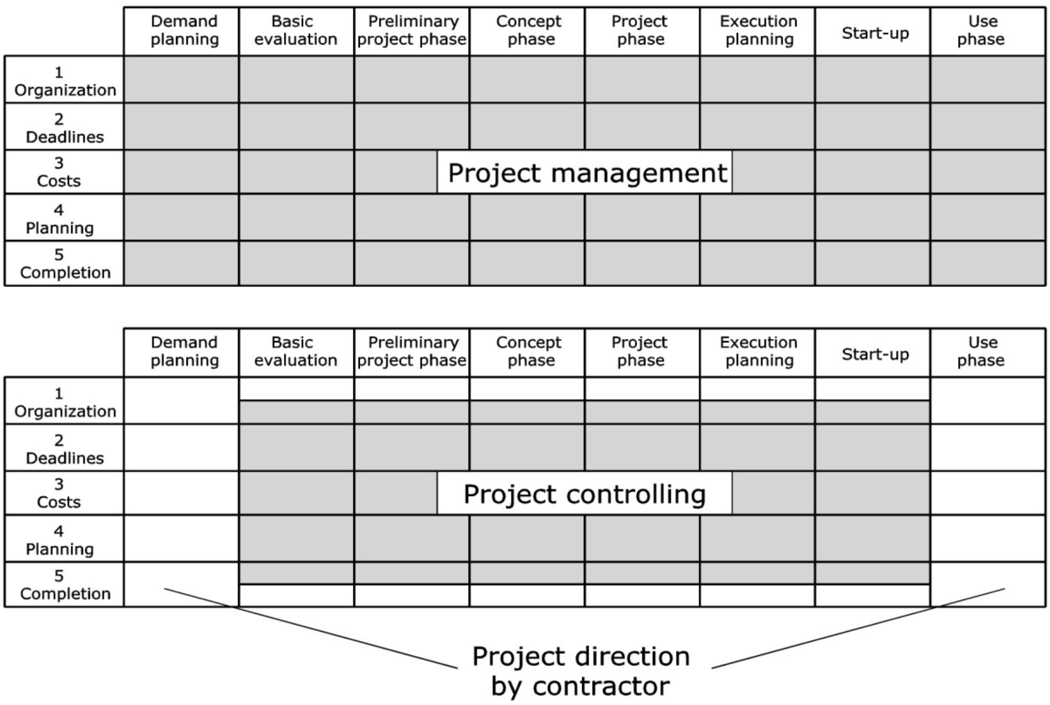

Figure 5-17: Boundaries of project controlling.

Project direction by the contractor

The contractor must carry out contractor operations throughout the project. Some of these tasks can be delegated to technical staff. The HO-PS distinguishes between contractor operations that can and cannot be delegated.

The following operations cannot be delegated:

- Determination of main project goals
- Provision of resources
- Final decisions on planning phases, final completion, etc.
- Conflict management
- Operation of central project contact point
- Project-related representation duties, etc.

In short, according to the HO-PS and the Austrian Association of Construction Project Management (Österreichischer Verein für Bauprojektmanagement) project direction is responsible for achieving the project and contract goals and has the direct power of agency of the contractor overall project contributors. It has a line function and has the authority to make decisions, issue directives and ensure that these are carried out. Project direction represents the central project contact point. It provides reports, puts forth solution suggestions, makes decisions and takes responsibility. It commissions measures to be carried out, gives instructions, issues decisions and authorizations, takes charge of conflict solutions, sees to filing and documentation, provides incentives and consultation, reports, sizes up risk and steers and/or directs strategic discussions.[158]

In contrast to project direction, overall operation of **project steering** is carried out by way of those contractor tasks that can be delegated without authorization. In terms of basic operations these tasks can be divided into the following functional areas:

- Organization, information, coordination and documentation
- Quality and quantity
- Costs and financing
- Deadlines and available capacity

Project steering thus does not have directive authorization but rather a consulting staff function. It prepares the information and/or documents accordingly, provides reports and documentation.[159] This information is relevant to all areas of project management in all project

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[158] See AHRENS, H. (2000): Baumanagement Projekthandbuch, pg.4ff. and STEMPKOOWSKI, R. (2008): Leitfaden zur Kostenabschätzung, pg.4.

[159] See BRAUN, H.P. (2007): Erfolg in der Immobilienbewirtschaftung, pg.49ff. and STEMPKOOWSKI, R. (2008): Leitfaden zur Kostenabschätzung, pg.5f.

phases. Project steering is responsible for communicating and analyzing deviations from targets, but only under the responsibility of project direction.

These operations always contain:

- Target data (planning/calculation)
- Control (evaluation and target-performance comparison)
- Steering (deviation analysis, adaptation, new calculation)

This presentation can be understood in terms of a cybernetic control circuit. From it, as in the identification of the project phases, it is evident that new thoughts on the systemic approach in recent publications on construction project management have been taken into consideration.

Project controlling

With the activation of project controlling the contractor attempts to achieve the following:

- All phases of project completion are to be organized and coordinated as efficiently and optimally as possible in accordance with the target values defined by the contractor.
- In the steering process the selected evaluation criteria and benchmarks are to help ensure that the project goals are achieved.
- A standard target-performance comparison of the defined criteria should help ensure that operational and decision-making processes can be established.
- Construction and use costs should be calculated as precisely as possible in all phases and be prepared as an up-to-date basis for upcoming decisions in planning and completion – these costs represent a reference value in the realization of the building project.
- Optimization in the areas of organization, deadlines, costs, planning and completion should be given emphasis.

As mentioned above, project controlling consists of both project direction and project steering tasks. Here project steering refers to contractor operations that can be delegated without authorization and project direction to contractor operations that cannot be delegated (without authorization). Only when the project steerer also takes on project direction tasks (authorization), do we speak of project management.

The main emphasis of the activity of the project controller lies in the management service function of providing information relevant for decisions, with special focus on the financial effects and the initiation of decisions. The project controller serves as a total information specialist, so to speak, for the project.

5.5.4 Structural organization - LKH-Klagenfurt NEU Hospital

The structural organization of LKH-Klagenfurt Neu, based as it is on Stafford BEER's bionic-cybernetic system model, will be presented here as an example. The structural organization actually applied was analyzed by the author and an attempt was made to transfer it into the VSM. Based on the reflections above it is conceivable that this project organization has applied the five sub-system division put forth by MALIK and is working with a project direction team.

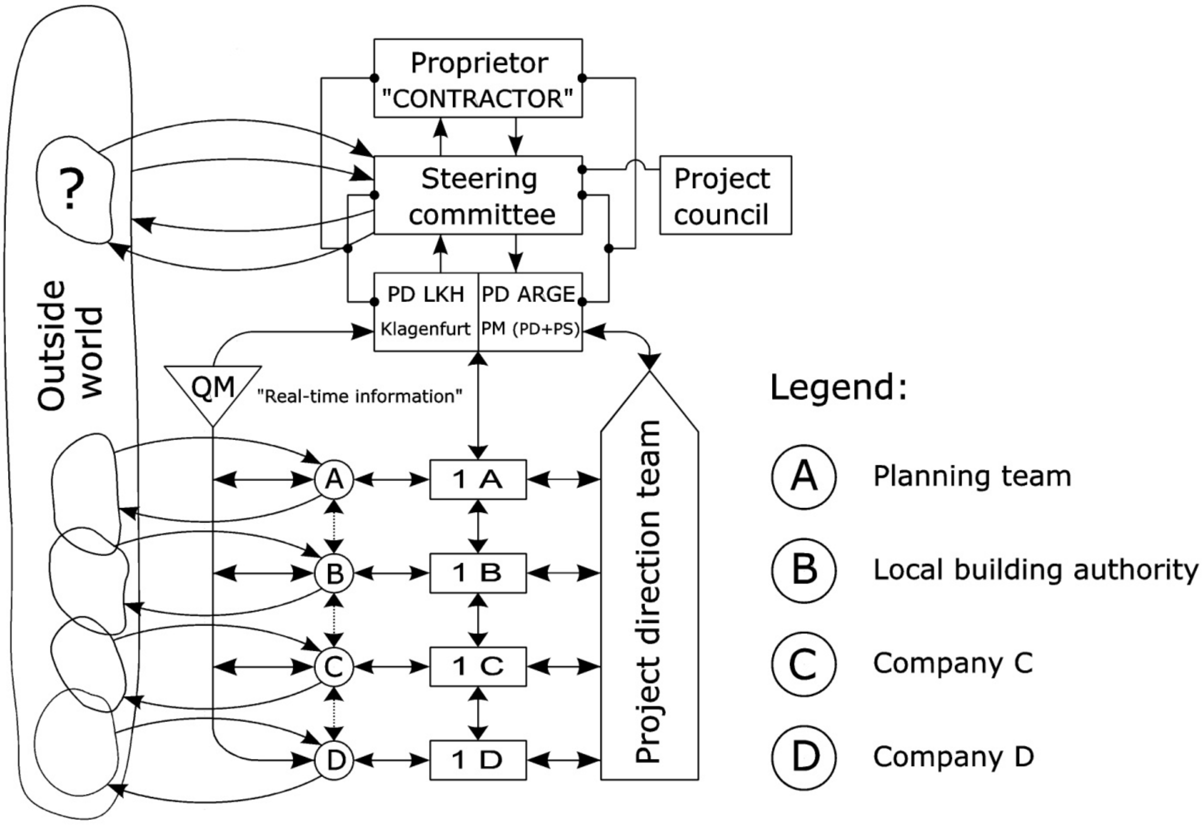

Figure 5-18: Structural organization of LKH-Klagenfurt NEU based on the VSM

The goal of this project is to identify the existing functional weak points of the hospital's design and to optimize organizational processes related to medical care. A comprehensive organizational, construction-oriented, functional restructuring will take place in the course of the project. In the framework of the operations of the KABEG construction company, hereafter referred to as LKH Klagenfurt, the proprietors set cost limits, scheduling parameters and quality requirements. Achieving these goals is only possible with inclusion of and consultation with the project coordinators, planners and future users.

Together with an advanced documentation system, the comprehensive perspective provided by the form of the structural organization makes structured and transparent processes possible. This allows an overview of costs, deadlines and quality to be maintained in each project phase.

5.5.4.1 General principles

The idea essential for the achievement of goals can be briefly described as follows:[160]

Based on the guiding principles and vision of LKH Klagenfurt, the mission and vision of the LKH Klagenfurt NEU project were defined in order to illustrate the overall strategic objective.

Vision of the LKH Klagenfurt NEU project (main project objective)

With LKH Klagenfurt Neu the following will be created or achieved:

- Trust of patients in the expertise of LKH Klagenfurt
- Recognized leadership role in the state of Carinthia and beyond in the institution's areas of medical focus
- Infrastructure and further foundation for beneficial cooperation with other service providers to ensure the operation of the health system

Mission of the LKH Klagenfurt NEU project (main project principles)

Planning, steering and coordination of the team and external partners for the creation of a hospital in which humans are the focus:

- Professional
- Humane
- State-of-the-art

Value system

The interested parties (stakeholders) of the LKH Klagenfurt NEU project are quite diverse and have very different expectations.

They include:

- Patients as end consumers and recipients of the future services of the LKH hospital
- Staff that will provide the complete range of services for patients once the building has been completed
- Proprietors as contractors who have initiated the investment
- Staff who under the supervision of the contractor plan, initiate and direct their visions and goals in the individual steps
- Suppliers and partners in the completion of the project
- Society – the community and public for whom the organization and services are important

For the achievement of the defined project goals there is an attempt to achieve a coordinated collaboration of all project parties with mutual trust and reliability. In an attempt to continually improve the benefits for the client (both internally and externally), mutual loyalty is promoted,

[160] See Projekthandbuch LKH Klagenfurt NEU, Version 5.0, March 2010

motivation is generated and a permanent partnership of all parties involved in the construction process is created.

The success of the project and achievement of all project goals are only possible with collective effort and by avoiding negative effects for all project participants.

5.5.4.2 Description of the functional units

The individual functional units will be described in greater detail for a better understanding of their tasks.

Proprietor/Contractor (System 5)

Owner of the functional unit (project client):

- Contractor is the Austrian state of Carinthia, as represented by KABEG, which is in turn represented by the LKH Klagenfurt

Goal of functional unit:

Protection of the owners' and/or contractors' interests in terms of the project goal (for example, type and size of the functional units), cost, financing and scheduling framework for project realization.

Tasks of functional unit:

- Project initiative through target definition and decision regarding project completion form
- Creation of project organization through issuing of project charter
- Creation and modification of project charter
- Nomination of project director
- Final project completion or revocation of the project charter with dissolution of the project organization

Steering committee (System 4)

Tasks of functional unit:

- Monitoring and steering of project process through the project charter
- Decision-making regarding essential projection modifications (especially deviations from identified quality, cost and scheduling targets)
- Issuing of project contracts to project direction
- Receipt of regular reports by the project direction
- Highest decision-making committee for the LKH Klagenfurt NEU project
- Approval of budgets taking overall cost framework into consideration
- Approval of milestone deadlines taking project scheduling framework into consideration
- Issuing of contracts to project council
- Decision-making authority for resource conflicts and responsibility disputes

Authorization:

- Decision-making within the parameters defined in the project charter
- Issuing of instructions to project director within the scope of the project
- Right to information through project director and project direction team, right to access and evaluate project documentation
- Right to issue mandates to the project council for the testing and assessment of technical issues

Project council (consulting function in System 4)

Tasks:

- Supports the steering committee with technical expertise and by way of a consulting organ
- Tests and assesses technical questions submitted to it and issues recommendations

LKH Klagenfurt project direction, steering and resource distribution (System 3)

The LKH Klagenfurt NEU project direction consists of the LKH Klagenfurt project director and the ARGE project management (PM) project director. It is responsible for the achievement of quality, cost and scheduling objectives for the overall project.

The PM tasks of the contractor that cannot be delegated will be carried out by project direction, the tasks that can be delegated by project steering.

LKH Klagenfurt project director

Tasks:

The tasks and authority of the LKH Klagenfurt project director are related to the steering of the contractor organization and the structuring of interfaces with external project partners.

Planning / Steering:

- Fulfillment of contract in the framework of the defined goals and targets of the client
- Issuing of targets for integrated project planning (quality, deadlines, costs, resources) for the overall project and sub-projects in collaboration with the sub-project directors and external partners
- Commissioning of all necessary planning targets (strategic planning targets, etc.), which are to be made available by the contractor for the purposes of achieving the project goal
- For identified deviations from goals, support or the formulation of alternative, integrated solution possibilities is to be requested in cooperation with the various parties involved in the project
- Timely introduction or determination of decisions, submission of decision and modification proposals
- Coordination of approval of results in the designated committees

- Coordination and steering of project completion (project controlling in terms of quality, deadlines, costs) in the organizational field of the contractor
- Collaboration in the formulation of changes to project charter as related to the targets articulated by the client
- Implementation of the required measures and execution of contracts while respecting the rights and duties of the contractor

Authorization:

- Making decisions within the framework of project costs for reaching project goals in relation to quality, costs, deadlines
- Final decisions on plan approvals, acceptance, etc. as a foundation for approval by the steering committee
- Proposal to steering committee and/or project client in regards to decisions in their area of responsibility
- Directive authority over the members of the contractor's project organization
- Access to project budget in accordance with principles of economy, thrift and purposefulness in the framework of the relevant guidelines and regulations in coordination with the client (steering committee)
- Changes to project goals
- Changes to project structural organization
- Issuing of assignments
- Public relations work (PR) in close collaboration with the executive board of KABEG and the members of the steering committee

Responsibility:

- In the framework of the overall project direction by LKH Klagenfurt Neu and the project client, the project director – LKH Klagenfurt – is responsible for the achievement of project goals in accordance with the project charter.

ARGE Project management (PM) – project director

Tasks:

Project steering is handled by ARGE PM. This includes all activities for achieving the defined goals in the areas of costs, scheduling, quality and quantity.

Planning / Steering:

- Fulfillment of assignment (based on the contract) in the framework of defined goals and targets; acts under the orders and in the interest of the contractor
- Creation and maintenance of integrated project planning in collaboration with the general planner and contractor
- Coordination and steering of project completion (project controlling) for the entire project
- For identified deviations from the goals, formulation of alternative, integrated potential solutions in collaboration with all parties involved in the project

- Execution of quality, deadline and cost monitoring (investment and follow-up costs), assumption of liability (defined in contract)
- Introduction and execution of cost controlling for adherence to approved investment and follow-up costs; creation of continually updated cost reports based on planning documents; wages/invoices of the general planner, specialized technicians and other suppliers
- Test and acceptance of planning services of all suppliers involved in the planning (test for adherence to quality and cost goals)
- Information and reporting to contractors (project progress, results, supplemental costs and supplementary proposals, etc.) at regular intervals defined in collaboration with contractors, in the case of identified deviations and immediately after any significant events
- In the case of identified deviations from the goals of the overall project (contents, deadlines, costs) works in collaboration with the general planner and any specialized technical staff to develop potential solution proposals (including assessment of proposal) and requests decision from the contractor on how to proceed
- Handles modification proposals made by the general planner (processes proposal and basis of decision for the contractor)
- Introduction and maintenance of systematic modification and claim management
- In the case of unclarity, or whenever specifically necessary, acquires services of a neutral test engineer for assessment of specific individual services in coordination with the contractor
- Execution of document management (organization of project archive, archive and care of outcome documents, modifications) and preparation for automatic cyclical data transfer into the contractor's system
- Consolidation and summary of documentation for all materials submitted to the public authorities and audit office
- Creation of plans for the execution phase in coordination with the contractor and general planner

Responsibility:

- In the framework of the overall project direction by LKH Klagenfurt Neu, the project director Arge PM is responsible to the steering committee and the project client for the achievement of project goals in accordance with the project charter.

Quality management QM (System 3)*

All functions within the QM serve to create the organizational conditions needed to ensure the achievement of the defined project goals (quality, deadlines and costs).

For internal quality assurance – in accordance with ÖNORM EN ISO 9001:2008 – a quality officer was named from within the project organization.

Tasks:

- Regularly informs project direction of the effectiveness of the quality management system and has all authorizations and resources necessary for project direction tasks.
- Promotion of quality awareness and training of staff on the subject of quality management and the importance of clients and their satisfaction

In everyday project work this includes the following tasks:

- Analysis of structural and process organization
- Conception and operation of training sessions
- Use of QM tools, including:
  - Collecting data
  - Creating flow charts
- Support of upper direction in all matters of quality management
- Planning of internal audits
- Coordination of management reviews
- Analysis of document control

Internal audit:

The effectiveness of the QM system is tested by means of internal audits. The audit schedule is planned by the QM officer, generally at the beginning of a calendar year. For carrying out the audits use will be made of the services of QM LKH Klagenfurt as an independent office. The audit plan will be created by this office and coordinated with the QM officer. The results and incentives, formulated in the audit report, will be discussed and evaluated with project direction. Measures that may need to be formulated will be assessed for their effectiveness after an appropriate time.

Operative coordination project direction team (System 2)

Parties involved in functional unit:

- Contractor representatives
- Project directors (System 3)
- Operator representatives
- Planner representatives

Goals of functional unit:

- Ensure that the project is completed in accordance with the cost, deadline and quality guidelines of the project charter
- Preparation of bases for contractor decisions
- Execution of operative construction management
- Carrying out the operative measures so that the project is realized in accordance with the conditions determined by the steering committee

Tasks of functional unit:

Contractor representatives

- Making and/or implementing contractor's decisions
- Control of compliance with contractor targets in terms of deadlines, costs, quality and assignment of orders

Project director

- Organization
- Coordination
- Steering of
  - Deadlines and available capacity
  - Costs and finances
  - Quality
- Upper business direction

Operator representatives

- Coordination of operators and users
- Representation of operator and user interests
- Approval of planning foundations and planning for operators and users

Planner representative (architect)

- Overall architectural planning
- Coordination of the planning team
- Representation of planning team
- Technical supervision

Systems 1 represent the service and/or value-added areas

Planning team with following contributors:

- Architect
- Project director
- Cost planners
- Deadline planner
- Statics
- Building services
- Electrical fixtures
- Medical technology
- Cultural technology
- Landscape design
- Hospital hygiene
- Kitchen planning
- Structural physics
- Surveying
- Access planning

Goal of functional unit:

Overall planning services with the goal of realizing the objective in line with deadlines, costs and quality.

On-site construction supervision with the following contributors:

- Project direction
- Technical construction direction

Goal of functional unit:

Execution of on-site construction supervision and technical construction direction for structural engineering, building services, electrical fixtures and medical technology

Tasks of functional unit:

- Assessment of the foundations of the work execution for completeness and economical viability
- Coordination of all deliveries and services
- Keeping construction record and construction site planning record
- Distribution of plans
- Supervision of construction execution, approval of services, controlling measurements, auditing
- Heading construction direction meetings
- Practicing domiciliary rights at the building site
- Collaboration with upper business direction

Executing companies

Tasks are commissioned on a running basis. The status of the work postings will be maintained by means of meeting management. Individuals involved from the executing companies will be included in the list of parties involved in the project. The companies assigned will have the tender acceptance with them in the project area.

5.5.5 Structural organization – conclusion

Project organization in the form of a project direction team is distinct from standard organizations as a result of the intensive collaboration and coordination of all groups involved in the project. Contract, project director, architects, operational staff, specialists and the companies involved form a team that takes all elements of the project into consideration with intensive information exchange.

All phases of the project are planned in an interdisciplinary, holistic and fully coordinated manner. Interdisciplinary interest and dialogue between the various areas is one of the basic principles of the systemic management philosophy. The formation of a project direction team ensures that the project will be viewed and directed not just from the perspective of project direction, but rather the considerations of other roles will also be considered.

6 Implementation of Cybernetic Structures in the Construction Industry

6.1 Opportunities, risks and problems

At this point the opportunities as well as the risks and problems of the targeted integration of cybernetic structures in pre-existing or new organizational models should be examined. Focus here is placed on the practical application of cybernetic principles.

6.1.1 Opening up new opportunities through application of cybernetic principles

The targeted use of cybernetic principles in the organization of economic enterprises and projects can open up a whole new range of potential opportunities. The science of cybernetics provides the framework for a systematic, conscious and targeted optimization of an organization. Yet there can be no guarantee for the success of any measures. First we will again summarize the potential opportunities for a successful application.

Just how valuable an examination of this subject is can be seen in the following list of opportunities:

- Mobilization of the intercultural resources of staff for the benefit of the company and project
- Cost-effective work procedures and use of resources yield economic advantages and long-term competitive power
- The viable system’s self-organization, evolution and ability to learn promote the company’s continual improvement
- Thanks to self-monitoring and the continual improvement it yields, cost and deadline infringements are a thing of the past
- Greater transparency in construction execution makes for more fast reaction to any disturbances
- More autonomy yields greater motivation and fewer missed work days

6.1.2 Risks and problems of implementation of cybernetic principles

The introduction of cybernetic structures into an organization is in itself not enough. Critical is the question whether the organizational system is truly “lived”, that is, whether it is systematically and vigorously implemented. Difficulties can rise in the implementation. For this reason a few additional comments should be made about fundamental risks and problems.

Serious risks lurk in the attempt to optimize an existing organization on one’s own initiative. It is necessary to proceed cautiously in order to avoid destroying the evolved structures of the organization by imposing a theoretical organizational model. Furthermore, broad technical knowledge is required to create a model for one’s own organization – predefined systems are to be seen as templates that must be adapted to the specific conditions of a company and/or project. If too little attention is paid to the potential difficulties to be found in every company and project, there is a risk of – in a worst-case scenario – a total collapse of the internal organization. In this case, instead of bringing relief the new process would yield serious impediments. The following recommendations are intended to help avoid this.

6.1.3 Basic recommendations for the utilization of potential opportunities

Here thoughts will be presented on the most important prerequisites for successful implementation of cybernetic principles within an organizational system. Important here is the change of attitude that must take place. Those who want to utilize the potential opportunities must ensure that staff – or at least the most critical staff members – have understand cybernetic relations and have the right mindset to implement them.

This new orientation or new perspective will be the first, decisive step – otherwise despite one's best efforts one will simply run around in circles. Only when the desire for continual improvement is firmly rooted in the mindset are systematic implementation and the success that comes with it possible. As we will see, the specific requirements of each company must be taken into precise consideration. Adaptation is always necessary, though the basic principles of cybernetic organization must nevertheless be adhered to.

6.2 Establishing a new way of thinking

In this section the fundamental concepts for establishing a new way of thinking will be discussed.

6.2.1 Principles of cybernetic organization

From a cybernetic point of view organizations must satisfy certain conditions to be able to handle the changing requirements in their environment. These conditions will be presented here in a summarized form.

6.2.1.1 Basic features and objectives of cybernetic organizations

The following list contains the most essential characteristics and objectives of cybernetic organizations, which were already presented at length in chapters 2 and 3.

- Natural and evolutionary systems, such as organisms, are prototypes for cybernetic organizations.
- The evolutionary process of self-organization is absolutely critical to be able to exist in a specific environment. In accordance with modified environmental conditions and with experience and expectations, a self-initiated adaptation and enhancement of the organization will take place. For this the criterion of viability has to be fulfilled. To achieve these organizations must maintain an unchanging structure, which formally corresponds to that of the homeostat.
- The complexity of an organization is determined by the number of its elements and their potential states. Only complex organizations offer the necessary variety of behavioral patterns to be able to handle complex processes and adhere to the principle of self-organization.
- The state and behavior of an organization as a dynamic system are influenced by the interaction of the individual elements and their behaviors. Two essential aspects here are the effects of the environment on the organization and the flow of information within the organization.

Cybernetic organizations are goal-oriented. In their structural arrangement the elements work together as a single organization to achieve a goal.[161]

Critical for the implementation of cybernetic principles are adaptability, flexibility, the ability to learn, evolution, self-regulation and self-organization – this is true for both companies and projects as cybernetic organizations.

[161] See MIROW, H. M. (1969): Kybernetik: Grundlage einer allgemeinen Theorie der Organisation, pg.26ff.

6.2.1.2 Basic commitment to the new orientation

Before implementation of cybernetic structures in the construction industry can even be considered, there must be a change in basic attitudes. Furthermore, in management a basic decision regarding this new orientation is necessary. Other industries have already taken this step.

Shortly after the conclusion of World War II Eiji Toyoda, junior partner of the auto manufacturer Toyota (which at the time operated as a handwork enterprise), conceived a totally new management method. It involves the systematic utilization of the creative and intellectual capabilities of all staff members. This so-called "lean" management places focus on reorganization within the company, whereby level hierarchies and tightly-knit project organization are given primary emphasis.[162] There is no doubt that we can here speak of a organizational orientation in line with the insights of cybernetics. With this new orientation begins a totally new chapter in the economic history of the 20th century. What turned the handwork company Toyota into an international corporation is now seen by many companies in the industry as a survival strategy on the competitive market. In the construction industry this survival strategy has until now been integrated into very few operations. Instead of developing long since outdated organizational forms into goal-oriented patterns of action that can keep up with the new information age, the sector goes on complaining about low prices.

Just like back then at Toyota, in the construction industry junior partners – that is, the young generation of managers – are being challenged to replace the dominant constructive, technomorphic management theory, which has long since ceased to be able to keep up with the demands of an increasingly complex environment, with a systemic, evolutionary approach (see section 2.1.1). An enterprise can only be properly understood as a social system – a living, functioning entity. Introducing this new way of thinking is surely no easy task, and much information must be provided in the early phases. At the same time, this does not have to mean that managers of operations in the construction industry have to intensively study system sciences and cybernetics. It is however essential that they always keep an eye out for potential improvements so as to remain competitive. To do this the wheel does not have to be reinvented. There are a sufficient number of predefined organizational systems or approaches that are based on cybernetic principles. The first step is thus keeping continually abreast of the opportunities available. Before a fundamental decision regarding the new orientation of a company organization can be made and committed to, what must first happen is a change of thinking in the area of management.

[162] See SEIFERT, H. (1994): Aufbruch in eine neue Management-Ära: Die Lean-Welle ist keine Modeerscheinung, sondern eine Überlebensübung, pg.12f.

6.2.2 The company as viable system

Standard organizational diagrams provide little information on the actual operation of enterprises. Often one has the impression that companies function not based on but despite such organizational diagrams. For a fundamental understanding of operational processes and a systematic analysis of the organization in place, the Viable System Model by BEER provides an important foundation (see section 3.8).

6.2.2.1 Purpose of understanding the operation as a viable system

The view of a company as a cybernetic organization should help to identify the operational processes that are really taking place and to comprehend how weaknesses in the organizational structure can be spotted. This is based on the insight yielded by cybernetic research that every viable system has to adhere to certain premises in order to maintain its ability to organize itself and remain maneuverable.[163] Thus the model of cybernetic organizational structure can serve as a tool in the goal-oriented development of an operational organization towards self-organization. Self-organization is, in turn, an essential factor for the enhancement of productivity.

6.2.2.2 Application of this philosophy to the analysis of an organization

To analyze the existing organizational structure, first the existing organizational diagram must be transposed into the cybernetic organizational structure model. Focusing on the tasks that the individual sub-systems complete (see section 3.8.7), the organizational diagram is converted item by item to a cybernetic organizational structure. This procedure increases the awareness for real processes in the company.

To orient an organization towards cybernetic principles it is not required to assume a completely new organizational system. As every predefined organizational structure requires certain modifications depending on the specific needs of a company or project, the existing organization can also be directly optimized by means of continual development in accordance with cybernetic requirements. The right attitude is what’s important when it comes to good management of construction projects. What the organizational system is called, whether it has been borrowed or developed independently, would seem to be of secondary importance. Most important is that the principles applied are based on cybernetics and that there is a continual attempt to improve the organization.

[163] See MALIK, F. (2000): Systemisches Management, Evolution, Selbstorganisation, pg.332.

7 Final Observations

In the introduction Fredmund MALIK was quoted as saying that due to their escalating complexity, projects are increasingly subject to decision-making problems that can no longer be handled using linear problem-solving concepts limited to particular fields.

Experience shows that it is now generally overly idealistic to think that projects will be completed as planned. Usually the time or financial expenditures involved are underestimated. With all its different facets, systems theory – including cybernetics – can offer a whole new framework.

When one examines the field more closely one realizes that such complex problems can no longer be dealt with by means of empirical values, routine knowledge and conventional project management methods. Project environments are not static but dynamic. What makes it even more difficult are the changes in the societal, political and technological basic conditions that can set in with longer project running times. For this reason standard, linear thinking must be rejected, and new perspectives are required: thinking in terms of cycles and contexts. Networked thinking takes center stage, pushing out long since outdated linear approaches.

Though the most important information has been given, only a rough overview of the VSM has been presented here. This should be understood as a kind of push in the right direction and all interpretations must be understood as the opinion of the author's. Practical application of the company and project organization methods discussed here reveals that system-oriented thinking and resources can help meet the complex day-to-day requirements of a project and keep companies viable.

And yet a great deal more reflection is required to use the VSM for construction project management. At present not every system can be assigned a direct supervisor (for example Systems 4 and 2). It may be necessary to question even more critically classical project organization and even to redefine the kinds of individuals and institutions that are suitable for the different systems. The structural model of Stafford BEER, the Viable System Model or VSM, can nevertheless be seen as an "ideal model" for a complex organization.

In the future it will be necessary to observe and evaluate the goals of projects and their environments, as these are subject to ever changing dynamics. It is not just important to know a project from the inside, but to observe external influences and to react accordingly.

The dynamics of a project's development and the characteristics of company culture go a long way toward determining the success of any project. Strategies have to be formed, implemented and reviewed in shorter and shorter periods of time. A holistic, networked approach to problem solving is absolutely essential for complex projects.

The use of systems theory makes it clear that in most everyday decision-making situations non-linear elements predominate over linear elements. This paper was intended to provide a useful overview of the potential of systemic, cybernetic project organization.

In the last section an attempt was made to present the relevant insights in accordance with the predefined goal. Yet within the scope of this paper it was possible to discuss the essential basic aspects.

In conclusion it should be noted that the scope of this work is far too limited to portray the full wealth of cybernetics and of construction cybernetics. I hope that it was able to provide the reader with a helpful overview of the fundamentals of cybernetics and cybernetic project organization.

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Abbreviations

i.e.	Id Est (it is); Id Est (Latin: for example)
e.v.	eingetragener Verein [= registered association]
etc.	et cetera
e.g.	Exempli Gratia (for example)
LKH	Landeskrankenhaus [= regional hospital]
ff	and the following pages
f	and the next page
PM	project management
PD	project direction
QM	quality management
ÖBA	örtliche Bauaufsicht [=site supervision]
DIN	Deutsches Institut für Normung [=German Institute for Standard Organization]
HOAI	Honorarordnung für Architekten und Ingenieure [=Official Scale of Wages for Architectural and Engineering Services]
HO-PS	Honorarordnung für Projektsteuerung [=Fee schedule for project steering]
ÖVBPM	Österreichischer Verein für Bau Projekt Management [=Austrian Association of Construction Project Management]

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Normen und Richtlinien

Regarding to construction-specific project management is particular pointed to the following standards and guidelines:

Austrian Standards:

ÖN B 1801-1 (2009): Bauprojekt- und Objektmanagement

German Standards:

DIN 69 901 (2001): Projektmanagement – Begriffe, Verlag DIN, Berlin

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