Systems, Organisations, Management

Hans-Gert Gräbe

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1 Once more about the Goal of the Seminar

Systematic innovation methodologies such as TRIZ are essentially based on a better understanding of the development dynamics of corresponding (technical and non-technical) *systems*. The results are rooted in engineering experience from structured processes of planning, implementation and operation of technical systems. Increasingly, cooperative interdisciplinary collaboration matters rather than the one brilliant mind that commands thousand hands. The *socio-technical character* of contradictions is thereby intensified and opens up new dimensions of contradiction management.

Today, managers face similar challenges when it comes to placing decision-making processes on a systematic basis, aligning the processes with long term goals, and also achieving the targeted goal corridors. It turns out that many engineering experiences on structured procedures in contradictory requirement situations can be transferred to this area, which has been investigated within the topic *TRIZ and Business* for 20 years.

Nevertheless, experiences and approaches based on systemic concepts are deeper rooted in science and also have much longer historical traditions. *In the seminar*, we want to study different aspects of such concepts more closely, with special emphasis on cooperative approaches in interdisciplinary contexts.

2 What is a System?

Operation and use of technical systems is a central element of today world changing human practices. For this purpose planned and coordinated action along a division of labour is necessary, because exploiting the benefit of a system requires its operation. Conversely, it makes little sense to operate a system that is not being used. Closely related to this distinction between definition and call of a function, well known from computer science, is the distinction between design time and runtime, that is even more important in the real-world use of technical systems – during design time, the principal cooperative interaction is planned, during the runtime the plan is executed. For technical systems one has to distinguish the description, interpersonally communicated as justified expectations, and the results of operation, interpersonally communicated as practical experience.

Most definitions grasp the term *system* as a delimited set of interacting components, whereby the interaction of the components gives rise to a unified whole, which realises an emergent function and is thus more than the sum of its parts.

> A *system* (lat. greek "system", "composed", a whole consisting of parts; connection) is a set of elements that are interconnected and interact with each other, forming a unified whole that possesses properties that are not already contained in the constituent elements considered individually. [4]
>
> A *system* is a set of elements that are in relationship and connection with each other and that constitute a well defined unity, an integrity. The necessity of the use of the term "system" occurs when it is required to emphasize that something is large, complex, immediately not wholly comprehensible, but at the same time a unified whole. Unlike the notions "set" or "aggregate", the concept of a system emphasizes the ordering, the integrity, the regularity of construction, functioning and development. [9]
>
> Systems Engineering "is an interdisciplinary field of engineering and engineering management that focuses on how to design, integrate, and manage complex systems over their life cycles. At its core, systems engineering utilizes systems thinking principles to organize this body of knowledge. The individual outcome of such efforts, an engineered system, can be defined as a combination of components that work in synergy to collectively perform a useful function." (English Wikipedia).

The second definition also points to the purpose of systemic delimitations – it is about making complex relationships accessible to description by reducing them to essentials.

In all these definitions, the *structuredness* and thus *decomposability* of the system in the analytic dimension is emphasised on the one hand, and the *interdependence* and thus *indecomposability* in the execution dimension on the other. This corresponds to the practical experience of the engineer when she assembles a system from individual components – the system is only viable when it is assembled. In the assembled system in addition to the components, the *connecting elements* also play an important role. They mediate the *flow of energy, material and information* that is required for the operation of each component. In component software [7], with *deployment*, *installation* and *configuration* three stages of preparing components for their operation in a systemic context are distinguished, and this preparation for operation is often considered as a separate state – for example, as *maintenance mode* different from the *operation mode.*

The aspect of operating a system did not play a role in the first two definitions. Only here, however, the dialectical interrelationship between decomposability and indecomposability comes to light: Viable components deliver processual services in *guaranteed* quantity and quality during operation, if the *external operational conditions* are guaranteed. These processual services of the components in combination form the emergent function of the overall system. The self-similarity of the concept is obvious: components themselves have an inner life that can be described systemically, but which is largely abstracted from at the level of the overall system. The component enters the description of the dynamics of the overall system only as Black Box with a precise specification. This specification is divided into input and output interfaces. The former describe the necessary operating conditions, the latter the performance parameters of the respective component.

In [2] the system concept is identified as descriptional focusing to make real-world phenomena accessible for a description by reduction to the essentials. Such a reduction focuses on the following three dimensions:

(1) Outer demarcation of the system against an *environment*, reduction of these relationships to input/output relationships and guaranteed throughput.
(2) Inner demarcation of the system by combining subareas to *components*, whose functioning is reduced to "behavioural control" via input/output relations.
(3) Reduction of the relations in the system itself to "causally essential" relationships.

Further, it is stated that such a reductive description (explicitly or implicitly) exploits output from prior life:

(1) An at least vague idea about the (working) input/output services of the environment.
(2) A clear idea of the inner workings of the components (beyond the pure specification).
(3) An at least vague idea about causalities in the system itself, that precedes the detailed modelling.

3 Systems, Components and Reuse

One important aspect, especially of technical systems, has not yet been taken into account in the considerations so far: the aspect of reuse. Reuse plays a central role in computer science – copy/paste of code, outsourcing of repetitive pieces of code in function definitions, grouping of related function definitions in pre-compiled libraries, etc. This in no way exhausts possible forms of reuse, not to mention higher forms of reuse such as design, patterns or frameworks. Szyperski discusses in [7, ch. 8] aspects of the relationship between goals and forms of reuse.

Hence in addition to the description and operation, for technical systems the aspect of reuse plays an important role. However, this does not apply, at least on the artifact level, to larger technical systems – these are unique specimen, even though assembled using standardised components. Also the majority of computer scientists is concerned with the creation of such unique specimens, because the IT systems that control such plants are also unique.

Computer science has long struggled with a form of reuse that is widespread in developed engineering sciences and ultimately turned the manufacturing of tools and products from an art first to a craft and later to an industrial process – the *use of components produced by third parties* (components off the shelf).

Thus, after the analytical and operational dimension of systems and components, the *production by independent third parties* and hence the technical-economic interrelationships of an industrial mode of production based on the division of labour move into the focus of attention.

In such a context, the concept of a technical system is fourfold overloaded. A technical systems can be considered

1. as a real-world unique specimen (e.g. as a product or a service),
2. as a description of this real-world unique specimen (e.g. in the form of a special product configuration)

and for components produced in larger quantities also

3. as description of the design of the system template (product design) and
4. as description and operation of the delivery and operating structures of the real-world unique specimens of this system produced according to this template (as production, quality assurance, delivery, operational and maintenance plans).

The concept of a technical system thus has also in this context a clearly epistemic function of (functional) “reduction to the essential”. To Einstein the recommendation is attributed “to make things as simple as possible but not simpler”. The TRIZ development law of *completeness of a system* expresses exactly this thought, however, not as a *law*, but as an engineering *modeling directive*. The apparent “law” of the observed dynamics therefore essentially addresses *reasonable human action*.

In an approach of “reduction to the essential” and “guaranteed specification-compliant operation” human practices are inherently built in, since only in such a context the terms “essential”, “guarantee” and “operation” can be filled with sense in a meaningful way. These essential terms from the socially determined practical relationship of people are deeply rooted in the concept generation processes of descriptions of special technical systems and find their “natural” continuation in the special social settings of a legally constituted societal system.

4 Socio-technical Systems

The last considerations already embed the concept of system in social practices of cooperatively acting people. This embedding is also present in TRIZ system definitions, when the emergent function realised by the system is considered as *main useful function* MUF and linked to a *purpose*, why this (technical) system exists or was designed or redesigned in this way. This *aspect of purposefulness* (Zweckmäßigkeit) plays only a subordinate role for ”natural” systems, namely for socio-ecological systems, since in this context in most cases the ”purposefulness” comes up against hard limits or causes massive problems or has even already caused them. Nevertheless, this *orientation on purposes* is another throughput parameter (e.g. as monetary throughput) from a social environment relevant for the inner dynamics of a system. It can ultimately be subsumed under the *throughput of information* if a sufficiently viable concept of information is taken as a basis.

This purposefulness transforms the totality of technical systems into an interconnected *world of techical systems* full of preconditions and conditionalities, which opens up a fourth dimension of the concept of system, to secure stable operating conditions of the systems themselves.

The self-similarity of the systems concept provides a solution for this challenge – consider systems as components and the relations of purposefulness as interdependencies, delineate larger socio-technical systemic units, develop appropriate forms of description and operation. The transformation towards a sustainable mode of production and living that is on the agenda just requires a big step forward in this direction. This is one of the objectives of management and hence in the primary focus of our seminar. However, socio-technical systems are, in addition to technical restrictions, charged with the contradictory expectations and interests of concrete people and groups of people.

Ian Sommerville [6] elaborates a number of challenges in this regard. He also starts with the concept of a goal-centered system.

> A *system* is a meaningful set of interconnected components that work together to achieve a specific goal. [6]

Right after he develops a distinction between technical and socio-technical systems:

Technical computer-based systems are systems that contain hardware and software components, but not procedures and processes. ... Individuals and organisations use technical systems for specific purposes, but knowledge of that purpose is not part of the system. For example, the word processor I use does not know that I am using it to write a book.

Socio-technical systems contain one or more technical systems, but beyond that – and this is crucial – the knowledge of how the system should be used to achieve a broader purpose. This means that these systems have *defined work processes*, *human operators* as integral part of the system, are *governed by organisational policies* and are *affected by external constraints* such as national laws and regulations.

Essential characteristics of socio-technical systems:

1. They have special properties that affect the system as a whole, and are not related to individual parts of the system. These special properties depend on the system components and the relationships between them. Because of this complexity, the system-specific properties can only be evaluated when the system is composed.
2. They are often not deterministic. The behaviour of the system depends on the human operators and on other people who do not always react in the same way. Also, the operation of the system can change the system itself.
3. The extent to which the system supports organisational goals depends not only on the system itself. It also depends on the *stability of the goals*, the relationships and *conflicts between organisational goals*, and how people in the organisation *interpret those goals.*

In this context, there is a clear shift on the scale of controllability from direct control by external human operators to indirect control and movement according to intrinsic laws, which is even more prevalent in **socio-economic systems** with a large number of stakeholders or even **socio-ecological systems**.

5 Shchedrovitsky on Systems Analysis

The system concept thus serves to delimit a part of the complex, all-connected world (hereafter *reality*) in order to make this part accessible for description. However, this human activity, which Georgi Shchedrovitsky (a Russian Philosopher and the head of the *Methodological School of Management*) refers to as *mental activity* [5, p. 47], is itself part of that reality and thus also of practical relevance. Real-world processes are thereby charged with description forms. Thus in systems these two dimensions – description and operation – must therefore be distinguished. Charging a system with a description form is what Engels' calls, in reference to Kant's *thing in itself*, the transformation of the *thing in itself* into a *thing for us.*

Shchedrovitsky [5, p. 80 ff.] conceptualises this process in two different concepts of system [5, pp. 89 and 98] as process of breaking down the system into parts (components), charging the components with description forms and then reassembling the components thus charged into a whole. The result is a *new* system in the sense that it is the old one but charged with a description form. In this way, the *structural organisation* of a system can be grasped in a *system concept of the first kind*.

The real world and thus also systems develop and change over time. In order to understand the *development of a system*, its *processual organisation* must be examined. Shchedrovitsky emphasises that the development of a "living system" can *never* be described in its disassembled form, since disassembly destroys the systemic coherence and hence the parts are parts of a "dead system". An aeroplane disassembled into its individual parts cannot fly, only an assembled one. We are dealing here with a fundamental epistemic contradiction.

For details see [5].

6 Theory of Dynamical Systems

6.1 The Approach

The processual dimension of systems can be investigated with the mathematical tools of the Theory of Dynamical Systems if the processes can be modelled as equations of motion in phase space.

The Theory of Dynamical Systems as a branch of mathematics investigates the dynamics of structurally defined and modelled systems. Attributes which are essential for the description of the system are combined into a *phase space* and the changes in the attribute values are described as *equations of motion* by differential equations. If only temporal changes are considered, this leads to systems of *Ordinary Differential Equations* (ODE), complex spatio-temporal changes lead to Partial Differential Equations. We restrict ourselves to the first case, i.e. purely temporal structural changes.

In the simplest case, such as the pendulum or the movement of two bodies in a homogeneous gravitaional field, a *trajectory* can be calculated from the equations of motion.

Examples:

- Pendulum: `https://en.wikipedia.org/wiki/Pendulum_(mechanics)`
- Two body problem: `https://en.wikipedia.org/wiki/Two-body_problem`

6.2 Model and Reality

However, the solution of this equations only describes the motion $m(t)$ in the model. Good modelling is characterised by the fact that the real movement $f(t)$ and the movement $m(t)$ according to the model differ only insignificantly $r(t) = f(t) - m(t)$ in practically relevant parameter ranges (the *context of observation*). This can only be verified empirically through experiments that are to be planned more or less precisely, since reality is only accessible empirically.

Particularly interesting are modellings in which the residual $r(t)$ decreases "by itself". Such systems strive towards an equilibrium, which structure can be derived from the model.

6.3 How Chaotic can Trajectories be?

Examples:

- Double Pendulum, https://en.wikipedia.org/wiki/Double_pendulum
- Magnetic pendulum with three attracting magnets,
- 3-body model: https://en.wikipedia.org/wiki/Three-body_problem

We see that there is apparent stability for a long time, but in phase space there are certain *areas of instability* in which (exactly calculable!) trajectories passing through points in phase space that are close to each other strongly diverge. Such locations are called *bifurcations*. Often there is a single phase parameter that makes this bifurcation particularly clear. Such a bifurcation on a one-dimensional scale is also called a *tipping point*.

Not everything that looks like chaos has to be chaotic:
https://i.redd.it/zr7tet9mdfl01.gif

6.4 Attractors

How complicated can an equilibrium position be?

Examples:

- Pendulum,
- pendulum with three attracting magnets,
- pendulum with one repelling magnet.

Limit cycles: https://en.wikipedia.org/wiki/Limit_cycle

When the body is on the limit cycle, it remains there, i.e. the limit cycle is a *stable solution* of the equations of motion of the system, called **steady-state equilibrium**.

In many cases the real movement $f(t)$ in time is *attracted* by that limit cycle, i.e. $f(t)$ can be decomposed into $f(t) = l(t) + r(t)$ with $l(t)$ the projection on the limit cycle and $r(t)$ a (small) orthogonal deviation. In this way, it is often possible to simplify complicated models.

An attractor is a specific steady-state equilibrium with just this attracting property.

More precisely: Let $f(t, a)$ be a function which specifies the dynamics of the system with starting point $f(0, a) = a$. An **attractor** is a subset A of the phase space characterized by the following three conditions:

- A is forward invariant under f: if a is an element of A then so is $f(t, a)$, for all $t > 0$.
- There exists a neighborhood of A, called the basin of attraction for A and denoted $B(A)$, which consists of all points b that "enter A in the limit $t \to \infty$".
- There is no proper (non-empty) subset of A having the first two properties.

Attractor as stable solution of the corresponding system of ODE
https://en.wikipedia.org/wiki/Attractor

On the importance of "stable" cyclical processes in nature. We are able to perceive such *approximately* repeating patterns in natural processes (i.e. attractors), i.e. perform such a reduction also independently of mathematical abilities.

For given (deterministic) equations of motion one can compute the geometry of such an attractor as *global deterministic* invariant of the equations of motion.

How Complicated can an Attractor be?

- `https://en.wikipedia.org/wiki/Attractor`
- `https://en.wikipedia.org/wiki/Lorenz_system`
- `https://de.wikipedia.org/wiki/Lorenz-Attraktor`
- Attention, with the numerical methods used there for visualisation it is difficult to distinguish whether they are calculating a chaotic trajectory or really the attractor, which is a *global* artefact.
- "Almost all initial points will tend to an invariant set – the Lorenz attractor – a strange attractor, a fractal, and a self-excited attractor" (Wikipedia)

6.5 Dissipative Systems

Closed and Open Systems. Previous investigations were directed towards the inner dynamics of an autonomous, i.e. closed system.

Importance of a (stable) throughput of energy, matter and information for the inner structure formation in systems.

- Self-organisation in dissipative structures
  - `https://en.wikipedia.org/wiki/Rayleigh-Bnard_convection`
  - `https://en.wikipedia.org/wiki/Belousov-Zhabotinsky_reaction`
- Dissipative systems `https://en.wikipedia.org/wiki/Dissipative_system`
- Life on Earth as a dissipative system.

7 Organisations as Systems

A special kind of socio-technical systems (see the definition above) are systems that produce or use technical systems, see the definition of technology in the VDI norm 3780 [8]. To manage such systems it is particularly important to apply systematic innovation methodologies such as TRIZ better to understand their development. The theoretical corpus that emerges in such studies is rooted in engineering and managerial experience from structured processes of planning, implementation and operation of such systems. Increasingly, cooperative interdisciplinary collaboration matters rather than the one brilliant mind that commands thousand hands. The *socio-technical character* of contradictions is thereby intensified and opens up new dimensions of contradiction management.

In the seminar we are particularly interested to shed more light on the connection between the concepts of system and such (social) organisations. **Social organisations** such as companies, associations, projects, unions, parties, governments, states ... are undoubtedly theoretically delimitable and practically delimited parts of reality with outwardly (and inwardly) directed goals and purposes whose internal structure and dynamics are driven by an external throughput of energy, material and information, and which can therefore be studied from a systemic perspective.

The external throughput of energy, material and information is usually not in the focus of consideration, as these throughputs are already mentally charged in language form in a **more complex social context** and in the form of interests, needs, monetary flows and power relations. Nevertheless, a systemic structure is clearly recognisable, which is to be worked out in various theoretical approaches that we will look at in more detail. In particular, the concepts of *action space* and *cooperative action* in such spaces will be conceptualised in more detail.

8 Leadership and Management

Management is an essential form of influencing the dynamics and development of organisations. Shchedrovitsky emphasises that one can only manage something that is in motion[1] and that there is no need for management if there are no problems.

In the previous semester, we had already considered the topic by studying different theoretical approaches to management. Most of them assumed a manager as a single leader and developed approaches and patterns of how persons in such a *role* can develop leadership in achieving given goals. If we project such approaches onto a systemic concept of development in contradictions, there seems to be a recurring central contradiction between the goals of the organisation and the goals and interests of the people involved in realising them.

However, such leadership principles have been under massive pressure for at least 20 years, as they have only limited effect in modern contexts of action in interdisciplinary teams. Even more, they presuppose the authorised individual leader who combines management and leadership in one person. In multi-stakeholder contexts such as socio-cultural or socio-ecological systems, even this prerequisite is not given.

In this context, Shchedrovitsky clearly distinguishes between the notions of *management* and *leadership* [5, p. 27-30] and shows to what extent a new principal is confronted with contradictory challenges of both concepts.

9 Systemic Management Basics

In the further course of the seminar we want to discuss the systemic development of social organisations in the unity and difference of *planned action* and *experienced results* in the light of different theoretical approaches.

This requires a concept of *action planning*, based on a *conceptual understanding* of the process landscape within and around the organisation in an appropriate explicit form of description and *intelligible operational actions.*

The formulated intelligible actions – the *plan* – is in *contradictory tension* with the processes

[1]"Management is only possible if the object we manage is in motion, self-propulsion. Management is the use of this self-propulsion by managers for their own purposes." [5, p. 28]

actually taking place: On the one hand, it has a controlling effect on these practices, on the other hand, those practices partially resist this control.

This difference must be fed back to the planning process as an *evaluation of experienced results* in order to keep also the divergence between plan and reality under control.

Relating planning and experience dimension is only possible on a language level and requires a *system of notions* to accompany the practical real-world development by a discursive process (as *practice of thinking* in the unity and difference of *pure thought* and *mental activity* as explained in [5, p. 33-51]).

This system of concepts is more stable than the real-world practices, but it is not static – it develops together with the practices. ***World* is *reality for us* and thus reality in the process of conceptual grasping.**

These basic considerations are about *processes* and *procedures* within an *organisation.*

10 Organisations

What is an organisation? Wikipedia distinguises between formal aud informal organisations.

Formal organisations.

> An organisation that is established as a *means for achieving defined objectives* has been referred to as a formal organisation. Its design specifies how *goals are subdivided and reflected* in subdivisions of the organisation. Divisions, departments, sections, positions, jobs, and tasks make up this work structure. Thus, the formal organisation is expected to *behave impersonally* in regard to relationships with clients or with its members. [...] A *bureaucratic structure* forms the basis for the appointment of heads or chiefs of administrative subdivisions in the organisation and endows them with the authority attached to their position. (Wikipedia, my emphasis)

See about the "impersonality" and also the "automaton" in the quote by Marx in my first lecture.

Informal organisations.

> [...] The informal organisation expresses the personal objectives and goals of the individual membership. Their objectives and goals may or may not coincide with those of the formal organisation. [...] (Wikipedia)

The further explanations in Wikipedia remain weak and contradictory. Structure-building processes and especially shared conceptual systems also develop in informal organisations, with exciting new structuring processes of co-operative action taking place that are of particular interest to us in the seminar. Wikipedia is a reflection of the weakness of the conceptual basis in this field.

Also ORG – the *organisation ontology of the W3C* [3] – considers `org:OrganisationalUnit`, `org:FormalOrganization` and `org:OrganizationalCollaboration` as subconcepts of the concept `org:Organization` but does not mention informal organisations. In their definition an organisation

> represents a collection of people organized together into a community or other social, commercial or political structure. The group has some common purpose or reason for existence which goes beyond the set of people belonging to it and can act as an Agent. Organisations are often decomposable into hierarchical structures. [3]

`org:Organization` is related to `foaf:Agent`,

> ... the class of agents; things that do stuff. A well known sub-class is
> `foaf:Person`, representing people. Other kinds of agents include
> `foaf:Organization` and `foaf:Group`. [1]

A `foaf:Group`

> ... represents a collection of individual agents (and may itself play the role of a Agent, i.e. something that can perform actions).
>
> This concept is intentionally quite broad, covering informal and ad-hoc groups, long-lived communities, organisational groups within a workplace, etc. ...
>
> While a Group has the characteristics of a Agent, it is also associated with a number of other Agents (typically people) who constitute the Group, its members. ... The basic mechanism for saying that someone is to use the member property of the Group to indicate the agents that are members of the group.

The terms Agent and Group thus introduce self-similar concepts of structures that are *capable of action*. This corresponds to the legal construction of a *juridical subject* (juristisches Subjekt) in the sense of the Civil Code (BGB) if *responsibility for the consequences of action* is added.

11 Organisations as Socio-Technical Systems

While in the Wikipedia definition positions, jobs and tasks are mentioned, but beyond bureaucracy no people, in this definition an organisation is a "community of people". However, it has a goal that does not result from the set of goals of the people involved, but is an emergent function of the organisation – the whole is more than the sum of its parts in the sense that relational synergy effects are of special importance in such an organisation.

This corresponds closely with the *system concept* developed so far:

> A *system* is a *delimited set of elements* (components, objects, resources) that are interconnected and interact with each other. Their interaction realises a *qualitatively new function* (emergent function) and thus constitutes a *new unified whole.*
>
> A system has a *structural* and an *operational* dimension which are in contradictory dialectical relation of decomposability and indecomposability.

> The *operation of a system* requires a qualitatively and quantitatively defined throughput of energy, material and information.

Ian Sommerville [6] also starts with the concept of a system and moves from there to the concept of *organisation.*

> A system is a meaningful set of interconnected components that work together to achieve a specific goal. [6]

Right after that comes a distinction between technical and socio-technical systems:

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In this context, there is a clear shift on the scale of controllability from direct control (technical systems) to indirect control (socio-technical systems), which in **socio-economic systems** with a large number of stakeholders or even **socio-ecological systems** shifts further in the direction of movement according to intrinsic laws ("natural processes").

This relates to TRIZ principle 25 *Exploit Self-Service Processes*, which counts as the mastery of engineering. It claims that the best solution of a task is reached if the aspired goals are realised "by themselves".

Ultimately, this means to resolve the contradiction between plan and realisation and to develop a form of description that brings the "natural" movement in a system according to its own laws in coherence with the human goals and needs.

12 Shchedrovitsky on Organisations

What is an organisation for Shchedrovitsky? In [5, p. 30 ff] he distinguishes three dimensions of that notion

- Organisational work
- Organisation as the result and means of organisational work
- Organisation as a form of life of the collective

Organisational work. [5, p. 26] When we organise we collect something. Let us take a look at design. We need some structural elements, so there is a designer with a set of elements. We must collect these elements in a particular way, and we must establish some kind of connection and relations between them. When we are doing this sort of work we must impose some organisational form on these elements. [. . .]

And when we have done such work on the integration of the elements and the establishment between them of certain relations and connections, we stop this work, and then the whole, which we have organised, can begin to operate according to its laws. But its action according to its laws no longer belongs to organisational work.

Organisers deal with a particular set of elements, collect elements of a certain type and form in particular quantities, combine them and set certain relations and connections between them. When they have done this and have thus created the structure of the organisation – and the structure is defined by the location of the elements and the type of connections and relations – they recede into the background, and this thing either remains dead or begins to operate according to its laws.

Organisation as the result and means of organisational work. [5, p. 29] Organisation as the result of organisational work can be regarded as both an **artificial entity** and as **naturally living thing**.

Who takes an artificial view of organisations? Organisers themselves. And those who design and create organisations always look at them as their own creations. The organiser makes it, and in this sense organisations can be of any kind depending on the goals and objectives of the organiser. The main question is: why does the organiser create a particular organisation? [. . .]

The organisation acts here as an **artificial entity**. It has a purpose (Zweck) and can be considered, as can any structure, in terms of the functions that it, the organisation, must provide. So we are talking about the functions of the organisation, about the purpose of the organisation. These are all characteristics that are seen from an artificial point of view.

As a tool, as a means, **as an artificial entity, the organisation does not and cannot have goals** (Ziele). Organisers can have goals. But for their goals, in relation to their goals, the organisations they create are a means, a means for them to achieve their goals.

Organisation as a form of life of the collective. [5, p. 30] The organisation has been created. And the organiser – a pure organiser, not a manager – has gone. The organisation has been created, and it has begun to live its own life. And then it turns out that, from a natural point of view, other goals may appear in this organisation – the goals of the collective, which was organised. Generally, something quite different begins, this **organisation begins to live its own life**. Then we [...] must seek forms, methods, laws of the life of the groups and the collectives within organisations.

When the organisation is seen from a natural viewpoint, it is not yet the means, but the **form**, the **condition** of the life of the collective (the people) who work in it.

And it is even possible to see the organisation in the same way as we see the sunrise and sunset: the people working in it completely forget that the organisation was created by some other person to resolve particular objectives, achieve particular goals, for a particular purpose. It, this organisation, will be perceived by them like the movement of the heavenly bodies, as a natural condition of life.

13 Systematic Management in Organisations

The subject of *systematic management* are socio-technical and especially socio-economic systems. The latter consist of economic units (companies, government, state, ...) that are interconnected in a market-like manner. The *world of economic units* has a systemic structure similar to the world of technical systems.

In the understanding developed above, **management** therefore means to *control* the processes taking place in the (living) organisation with the *goal* to implement the *purposes* of the organisation in an efficient way.

This is necessary to be operated on several spatio-temporal levels (micro and macro processes), whereby short term goals and long term goals are in contradictory tension. Therefore, management is usually divided into several relatively autonomous levels

- Strategic management
- Middle management
- Operational management
- Infrastructure management and support

which are themselves in systemic system-subsystem interrelations and thus in a co-evolutionary relationship which is best processed via a control loop designed as a feedback loop.

13.1 Systematic Management and ISO 9000

Systematic management requires a descriptive approach to this control loop as part of the organisation's process model, such as given in the modified process model of ISO 9000:2008.

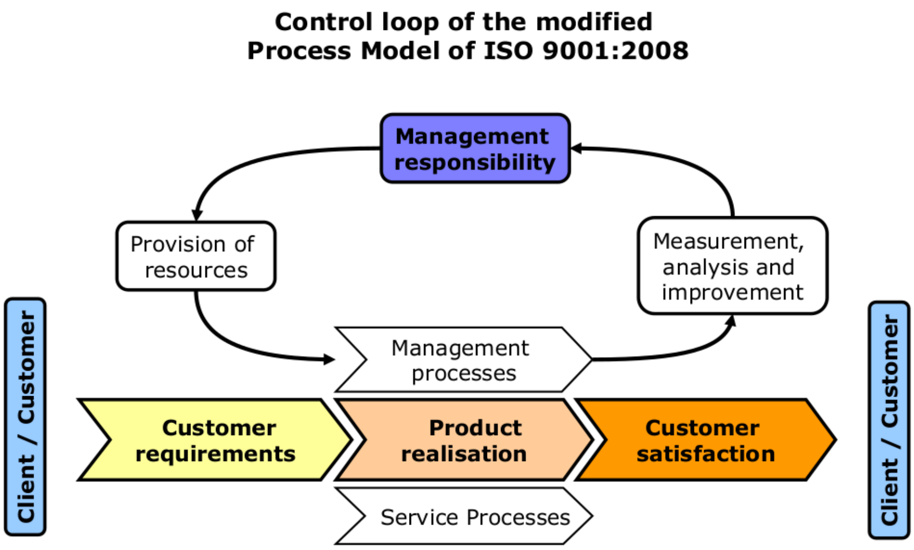

Fig. 1: Control Loop in the Modified Process Model of ISO 9000

ISO 9000 is a set of general quality assurance standards to **assess** the process quality of enterprises. It is a descriptive standard and not directed towards improvement of process quality (although can be used for such an improvement in combination with other tools).

- It is mainly a European standard.
- It is used mainly to assess the process quality of suppliers that demonstrate with a ISO 9000 certificate their ability to produce in a negotiated frame of time, costs and performance.
- Set of standards for the proof of process quality for the creation as of material so also of intangible products and services.
- Framework with a lot of leeway for corporate strategy and concrete management goals. Minimum requirements for a QM system according to ISO 9000: complete, documented, known, verifiable, evolutionary

ISO 9000 contains minimum requirements for the structural and procedural organization, so that quality is not a coincidence, but the result of a controlled process.

Note that the process model shown in fig. 1 is a *standard model* at a higher language level (**meta-model**) than the respective process models of the individual organisations, but unlike the process model of a real-world organisation, it has no real-world instantiation. Such a phenomenon is well known in computer science in connection with abstract classes.

Fig. 2 shows the relation between the ISO norm, quality management documents and real-world process quality at three different levels within a company.

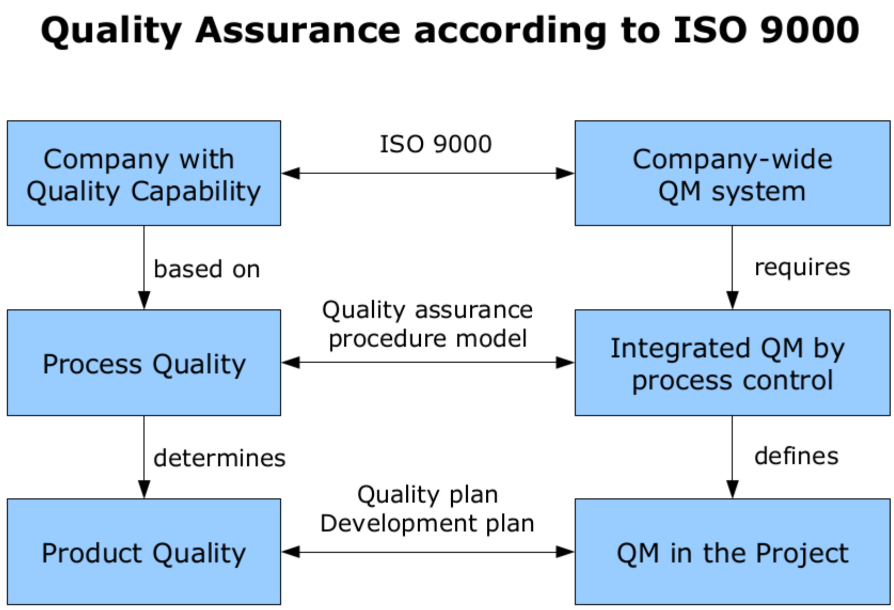

Fig. 2: The relation between model, meta-model and meta-meta-model in quality assurance

13.2 Managing Organisational Development and Capability-Maturity Models

Management is only possible in the context of a clear understanding of the structural and procedural organisation of the organisation. In order to capture this in descriptive terms, a **separation of functions and resources** is necessary. In particular, "human resources" are removed from the description and replaced by the term **role**.

In this way, a *functional decoupling from the resources* is achieved at design time – only at runtime this position must be connected "just in time" with a qualified resource that was produced beyond the horizon of the concrete planning processes.

Only with such a decoupling (and only at the level of such a decoupling) it is possible as management to take an external standpoint on its own activities. Only in this way is **structurally driven organisational development** possible. There are other culturally driven approaches such as TQM, which will be discussed separately (the Toyota model).

Systematic management through structurally driven organisational development means above all the creation and improvement of conditions for the management of well-structured processes.

CMMI (Capability Maturity Model and its predecessor CMM) is such a process model for organisations such as software companies that are project-driven and do not have a continuous production process. The model is a **maturity model** and supports such companies to introduce and improve a company-wide, uniformly structured project management

- from the structuring of individual projects into *process activities and milestones*
- through the definition of *company-wide uniform or specifically adaptable process modules*
- and the *uniform quantitative measurement* of such building blocks
- to the introduction of *qualified error and change management.*

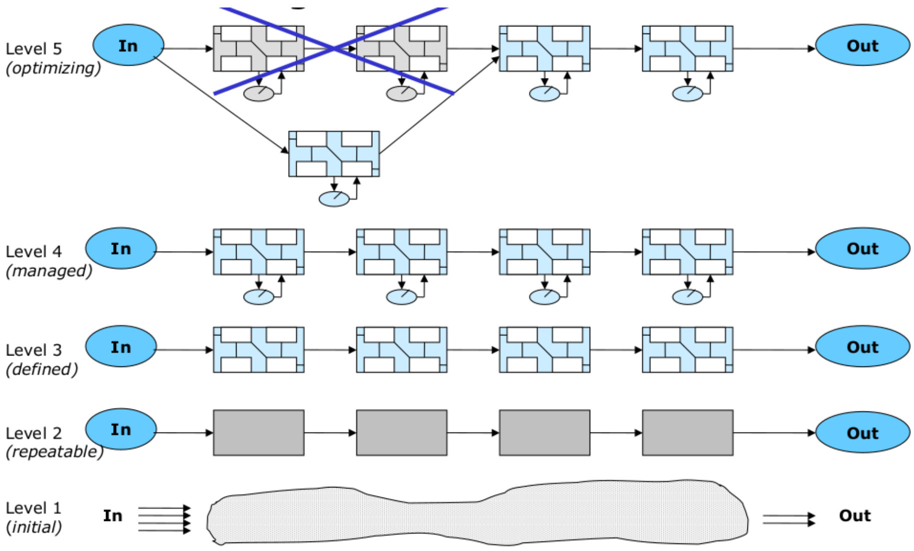

Fig. 3: Increasing maturity of structured project management within CMM(I)

These four transitions are assigned five maturity levels. The transitions are supported by concentrating on predefined *key process areas* and *key practices*.

13.3 Additional Reading: CMMI in More Detail

13.3.1 The Maturity Levels

The five maturity levels according to which processes of an organization are evaluated.

Initial Process

- Process exists only informally
- Low adherence to deadlines and costs, high risk
- Chaos, "heroism", fire-fighting operations

Repeatable Process (CMMI: Managed)

- There are defined and structured requirements for the process
- "Learn from similar projects" (requirements management, project management and quality management)

Defined Process

- Procedures and individual process activities are clearly defined
- The organization is in the learning focus
- Process definition, training programs, team coordination

Managed Process (CMMI: Quantitatively Managed)

- Central control that systematically collects process measures
- Process and product development are quantitatively analyzed and rated
- Information is used as support for decision-making

Optimizing Process

- "Self-dynamically optimizing process"
- Process measures are systematically used for dynamic process control and monitoring
- Process change management
- Technology change management

13.3.2 Expectations

The higher the level of maturity,

- the more precisely goals are achieved.
- the less is the difference between the target and actual results.
  - Level 1 companies miss their deadlines at large.
- The fluctuation range of the actual values around the target specifications is lower.
  - Similar projects are completed within a narrower time frame.
- Costs and development time decrease, productivity and quality increase.
  - Higher process efficiency, low rework rate.
- Expectations are more likely fulfilled in standard projects.
- But: New techniques and applications are reducing the process capability due to higher variability.

13.3.3 Determination of the Maturity Level according to CMM

For each stage a number of **Key Process Areas** are defined in which an organization of this level has to reposition itself implementing appropriate given **Key Practices**.

Level 1: Initial Process

- No criteria and specifications
- Project and quality management may or may not exist but are not consistently applied.
- Projects are managed at short notice, adaptively and reactively.

Level 2: Repeatable (CMMI: managed) Process

Goal: Introduction of a basic project monitoring and management, planning and control.

Focus: Leadership principles, structure and management of projects.

Key Process Areas and Key Practices:

- **Requirements management**
  - Establish a common understanding between customer and project team about the requirements.
- **Project planning, tracking and monitoring**
  - Transparent presentation of the development progress in order to be able to initiate correction measures at early stage.
- **Sub-order management**
  - Select, control and monitor qualified sub-suppliers.
- **Quality management** on process and product level, configuration management
  - Ensure integrity of the products throughout their entire life cycle.

Result:

- Processes as a sequence of "black boxes" with milestones as checkpoints.
- Stable project management.
- Processes can be predicted within limits through constant monitoring.
- Cross-project experience can be quantified.

Level 3: Defined Process

Goal: Definition and introduction of an organization-wide valid unified software process; internal structure of the phases is defined and understanding of roles is visible.

Prerequisite: Projects are planned, managed and monitored (level 2) as a sequence of processes according to uniform principles.

Focus: Process descriptions.

Key Process Areas and Key Practices: Focus on process organization

- **Definition** of processes
  - Development and maintenance of a useful set of process values.
- **Training program**
  - An independent unit is responsible for employees' training.
- **Coordination** between project teams (exchange of experience)
- **Integrated SW Management**
  - Development and management are integrated into one over the entire life cycle defined process.
  - Standard processes can be tailored to projects.
- **SW Product engineering**
  - Process integrates all technical activities to ensure to produce correct, consistent products effectively and efficiently.

CMMI further subdivides some of the main process areas

- **Coordination**
  - Integrated team building
  - Integrated sub-order management
  - Decision analysis
  - Integration organization infrastructure
- **Integrated SW Management**
  - Integrated project management
  - Risk management
- **SW Product Engineering**
  - Requirements analysis
  - Technical solution
  - Product integration
  - Verification
  - Validation

Result: Improved, describable quality; institutionalised process prototypes that are maintained and further developed.

Level 4: Managed (CMMI: Quantitatively Managed) Process

Objective: Quantitative measurement of the quality of products and the productivity of processes through an organisation-wide metrics programme as an objective basis for decision making.

Prerequisite: Uniform understanding across the organisation about projects and process models (level 3) and active project management (level 2).

Focus: Process measurement.

Key Process Areas and Key Practices:

- **Quantitative process management**
  - Quantitatively control and monitor process performance.
- **Quantitative quality managament**
  - Develop quantitative understanding of product quality.

CMMI clarifies as follows:

- Quantitative project management
- Performance of organisational processes

Result: Time, cost and quality become fairly predictable.

Level 5: Optimising Process

Objective: Introduction of a continuous and measurable process for improvement of software development.

Prerequisite: Quantitative monitoring information (level 4) and application of innovative ideas and technologies.

Focus: Process alignment.

Key Process Areas and Key Practices:

- **Error avoidance**
  - Identify and eliminate causes of errors.

  Product innovation management
  - Integration of new technological developments at product level.

  Process innovation management
  - Identification of new, useful ideas and their orderly introduction.

CMMI specified:

- Organisation-wide introduction of innovations
- Analysis of causes and elimination of errors

References

[1] FOAF Vocabulary Specification (2014).
W3C Recommendation. `http://xmlns.com/foaf/spec/`.

[2] Hans-Gert Gräbe (2020). Men and their technical systems (in German).
LIFIS Online, 19 May 2020. `https://doi.org/10.14625/graebe_20200519`.

A shorter English version is available at
`https://hg-graebe.de/EigeneTexte/sys-20-en.pdf`

[3] The Organization Ontology (2014).
W3C Recommendation. `https://www.w3.org/TR/vocab-org`.

[4] Vladimir Petrov (2020). Laws and patterns of systems development (in Russian). ISBN 978-5-0051-5728-7.

[5] Georgy P. Shchedrovitsky. Selected Works. In: Viktor B. Khristenko, Andrei G. Reus, Alexander P. Zinchenko et al. (2014). Methodological School of Management. Bloomsbury Publishing. ISBN 978-1-4729-1029-5.

[6] Ian Sommerville (2015). Software Engineering.

[7] Clemens Szyperski (2002). Component Software. Pearson Education. 2nd edition ISBN 0201745720.

[8] VDI Norm 3780. Technology Assessment. Concepts and Foundations. Sept. 2009.

[9] The TRIZ Ontology Project. `https://wumm-project.github.io/Ontology.html`.