Biases in the Process of Designing a System

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Chapter 1

BIASES IN THE PROCESS OF DESIGNING A SYSTEM

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ABSTRACT

System design is mostly considered as a rational process running from a set goal to a final design. Yet this paper analysis system design in a wider context and identifies 7 biases which influence it: (1) The educational/environmental/cultural base of the goal-setter and the system designer; (2) material constraints; (3) the explicit goal-setting for the design, coming with implicit material, ethical, moral and political valuations; (4) the specific knowledge, creativity and intuition of the system designer and (5) actual decisions based on that, determining investigated solutions; (6) the acceptance criteria, determining when a design is 'good enough'; (7) the dominating educational/environmental/cultural context-specific paradigms, which determine how a design is received in a larger context. So the paper concludes that systems design is not purely rational and value-free, as mostly assumed. Instead, it is a highly biased process depending primarily on a material base, related interests, and power in the relevant context.

Keywords: system design, system design methodologies, system context, context dependence, bias, truth

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1. Introduction

> "One option is to maintain the spirit of the classical laboratory by collecting just those data that appear relevant and can be obtained objectively [...]. The other option, the harder one, is to recognize that the unpredictable human is an essential aspect, and to begin to invent a methodology in which human bias is a central aspect. Will this methodology be 'scientific'? No, if we doggedly stick to the assumption that the classical laboratory is the basis of science. Yes, if 'science' means the creation of relevant knowledge about the human condition." C. West Churchman (1979, 62)

System design is mostly considered as a purely rational process running from a set goal to a final design.

Yet in this chapter, our objective is to follow Churchman's consideration quoted above and to investigate system design in a larger context than usual. We will analyze how this context influences the design process and particularly how biases resulting from individual actors, societal settings and stakeholder interests shape its outcome.

Before, we start reviewing a few selected approaches to system design. This selection is far from complete, and cannot do justice to the many thinkers in the field. But we think it provides a sufficient overview on the field by presenting widely complementary views.

In the following summaries we will primarily focus on the highly original core contributions of the various authors. But secondarily we will discuss important aspects, which are not clarified in these selected approaches. This is an unjust procedure, because it tends to neglect what is clarified. But we think that is necessary to develop the starting point for our investigation below. There we will try to integrate important aspects of the presented approaches, as well as to address some important aspects of system design, which were often left out so far.

1.1. Mesarovic and Takahara's General Systems Theory

We start the discussion of approaches to systems design with the work of Mesarovic and Takahara (1975, 4), a classical text on mathematical systems science. According to these authors, just four steps are necessary to design a system:

1. A verbal description;
2. A block diagram;
3. A set theoretical "general systems model";
4. Preferably a detailed mathematical model consisting of (differential) equations, or otherwise a computer simulation.

Mesarovic und Takahara (1975) consider the verbal description and the block diagram as imprecise preliminary steps, and consider even their own set theoretical “general systems model” as mathematically trivial, while they see only a mathematical model as an “exact” method.

We think this approach reflects widespread current thinking in science. Here the whole process seems quite simple, short and straightforward. What is sought is a fast track to mathematical formulae. Once these are formulated, then “exact” science must have occurred. What seemingly does not occur on this route are any epistemological questions, e.g., how a certain design is influenced by the goals pursued, or by decisions to include or exclude variables, etc.

1.2. Systems Engineering

Systems engineering uses much more detailed schemes for system design (see, e.g., Patzak, 1982, Winzer, 2013). Here the main steps are:

1. A prime step of goal-setting specifies what should be achieved.
2. Then follow some steps of sketching and then increasingly detailing the system design. After each step, some tests are carried out to evaluate, if the current detailing of the design might be appropriate to realize the goals.

   Should some of these tests fail, then the design is reworked and changed, till one is found that passes the tests.
3. Finally, if a sufficiently detailed design passed all theoretical tests, the system is realized.
4. Then all parts of the design are realized, and are again tested and evaluated.
5. When all the parts passed the tests, the whole structural design is realized, and a planned start up procedure is carried out to test the function of the whole system; if all tests are passed the system is released to normal use.
6. Finally the planners evaluate the whole design process and consider ‘lessons learnt’, i.e., which of the recent experiences can be generalized and can contribute to the design process, so that it will be improved, if a comparable systems has to be designed again in the future.

Here we find a much more detailed and considerate view of the very system design process, than in Mesarovic and Takahara (1975).

We find the prime act of goal-setting, a step-by-step detailing of the design, the evaluation of each step, and a variety of conceptual tools, which need not be mathematical formulae, but my be technical drawings, flow-sheets, organograms, etc.; and, finally, we find a rail to generalize any insights, which might be useful for future projects.

We do not find here any considerations of the goal-setting process itself and of the evaluative steps; nor do any persons, like clients, system designers, or users play an explicit role.

1.3. Klir's Architecture of Systems Problem Solving

A different and quite complex general approach was elaborated by Klir (1985; for a useful short summary see Flood, 1989). He developed a multi-level bottom-up approach to system design, and he even found a place for the role of the investigator or investigating team in the design process.

Let us try to briefly summarize Klir's scheme:

Klir starts with the "formulation of a source system". Here an investigator or an investigating team observe an "object" within the "environment" of the investigator(s). Their consideration of the object is guided by the "purpose" and by "constraints" of the investigation. From these considerations the investigator(s) derive(s) a "hierarchy of epistemological types of systems", which consists of at least five basic levels, but may have more, when complex issues are investigated. The five basic levels are:

Level 1: The lowest level is the "source system". It consists of a set of the variables, which are considered, a set of ranges of validity of these variables, and operations to characterize these variables when observing their occurrence in reality.

Level 2: Then follows the "data system"; it provides the actually observed data for the variables defined a level 1.

Level 3: This is the "generative system" containing the models, which are applied to generate the data of level 2.

Level 4: This is the "structure system" defining the relations between the models of level 3.

Level 5: This is the "metasystem" describing the relations between the relations on level 4.

There may be more levels starting with a "meta-metasystem", and so on, to characterize more levels of relations between complex systems.

So, Klir (1985) addresses the role of the system designer(s) and the goal-setting in the design process, and acknowledges that constraints may decisively limit it.

Klir reflects the important fact that any integration of two (or more) elements or subsystems into a larger system always requires a higher meta-level containing meta -

decision rules how to combine them. And Klir's system designers create, fill and modify these epistemological levels moving up and down within their system design.

What remains open in Klir's bottom-up approach is how the system designers can create any additional level of their design, without having already an even higher level how to combine the elements making up the additional level.

1.4. Van Gigch's Metamodeling

Van Gigch (1993) developed a more-level approach, too, less detailed than Klir's (1985) approach, but with some resemblances and additions.

Let us briefly describe van Gigch's levels bottom up:

Level 1: This is the "lower level" of "practice", where "evidence" of "organizational problems" forms the input. To these problems "scientific theories and models" are applied, which lead to planned actions. These actions lead finally to the output of "solutions" to the problems.

Level 2: This is the higher "object level" of "science", where "evidence" of "scientific problems" is the input. To these problems "paradigms" are applied, and theoretical considerations and research activities are derived from them. These lead to the output of "scientific theories and models", which are applied later on level 1 to solve practical problems.

Level 3: This is the "meta level" of "epistemology", where "evidence" of "epistemological questions" forms the input. To these questions some "philosophy of science" is applied and thought processes are derived from it. These, in turn, lead to the output of epistemological and scientific "paradigms", which are applied on level 2 to resolve scientific problems.

What van Gigch (1993) emphasized more clearly than Klir (1985) is that there are continuous cyclic processes; these consist, first, of normative top-down processes, followed later by corrective and innovative bottom-up processes:

System designers implicitly apply paradigms (van Gigch's level 3) which determine scientific theories (level 2), which they use to solve practical problems (level 1). Whenever that does not work and there remain unsolved practical problems (level 1), they move to a higher level, trying to develop new scientific theories (level 2), while applying given paradigms (level 3). Then they move down again, and test the new scientific theories (level 2) applying them again to practical problems (level 1). Whenever that does not work (level 1), too, and there remain unsolved scientific problems (level 2), they move to an even higher level, trying to develop new paradigms (level 3), while applying a "philosophy of science" (an even higher level not numbered by von Gigch). Then they move again down one level and apply these new paradigms (level 3) to develop new scientific theories (level 2), which are tested again on the lower level when applied to practical problems (level 1).

According to van Gigch (1993) the "metalevel" of "paradigms" (his level 3) is decisive for system design, because it contains the "design foundations of modeling", which "consist of reasoning processes, guarantees of truth, proofs, axioms of validity, or any other logic which underlies a methodology."

So, we find in van Gigch what we missed in Klir's bottom-up approach (1985), namely that the design process starts top-down by applying some given (levels of) theories (like "paradigms" and a "philosophy of science") to problem solving.

Yet surprisingly van Gigch fails to explain why his unnumbered highest level, the "philosophy of science", which directly or indirectly *determines* the content of *all* his lower levels including his "metalevel", is not the most important one. And he does not explain, too, where this determining "philosophy of science" might come from and how it is formulated.

1.5. Churchman's Design of Inquiring Systems

Churchman (1971; for a very good summary see Linden et al., 2007) started with the interesting observation that system design always has to begin with limited, *preliminary knowledge*, for it is exactly this limitation that makes the investigative process necessary (p. 4).

Then he continues with a preliminary description of the design process (without ever giving a final one) suggesting that it has at least five characteristics (Churchman, 1971, 5 - 8):

1. The design process has to distinguish between different possible behaviors (distinguishing *what* can be done).
2. The design process has to try to evaluate which behavior will best serve previously defined goals (answering *when* something should be done).
3. The aim of the process is to provide a design in a form that can be communicated to others, so that these can realize it, and actually serve the previously defined goals (telling *how* something should be done).
4. Furthermore, the design process aims at generality, too, to provide guidelines for other system designers facing similar problems (answering *why* something should be done).

5. The system designer defines the elements considered in the design process and the interrelations between them; and with that he or she determines the limits of the design, too.

Now this design process can be applied to design five types of "inquiring systems", which start from different presuppositions, and are designed to serve different notions of "truth" (van Gigch, 1988). We follow here widely the crisp summary of Linden et al. (2007):

- Leibnizian inquiring systems:

  Here "Knowledge of *a priori* law predominates knowledge of *a posteriori* fact";

  And "Knowledge of *a posteriori* fact does not predominate knowledge of *a priori* law" (Linden et al., 2007, 839).

  Leibnizian or "rationalist" inquiring systems "begin with some given propositions, postulates, or axioms and use deductive logic to drive the process. Empirical facts are meaningful only in so far as they fit into or inform the logical scheme" (Linden et al., 2007, 839).

  Here "Truth is analytical, that is, the truth content of a system is associated entirely with its formal content"; and: "Systems can be represented by formal models whose validation rests with their ability to offer theoretical explanations of a wide scope of phenomena" (Churchman, 1971, 9).

- Lockean inquiring systems:

  Here "Knowledge of *a priori* law does not predominate knowledge of *a posteriori* fact";

  And "Knowledge of *a posteriori* fact predominates knowledge of *a priori* law" (Linden et al., 2007, 839).

  Lockean inquiring systems or "empiricism" "begin with elementary observations or facts which drive the process by becoming the raw material input for inductive generalizations. Laws are meaningful only in so far as they help explain the data" (Linden et al., 2007, 839).

  Here 'truth' is only obtained from observations, facts and data.

- Kantian inquiring systems:

  Here "Knowledge of *a priori* law predominates knowledge of *a posteriori* fact";

  And "Knowledge of *a posteriori* fact predominates knowledge of *a priori* law" (Linden et al., 2007, 839).

  Kantian inquiring systems place "laws and facts on equal footing" and seek "to find the best model to fit the data often moving back and forth until an adequate synthesis is found" (Linden et al., 2007, 839).

Here ‘truth’ is approached in an approximating process where *a priori* knowledge is applied to make empirical investigations, which in turn are applied to improve the previous knowledge, and so on, to achieve an increasing fit between the two. So, Kantian inquiry systems combine aspects of Liebnizian and Lockean ones.

- Hegelian inquiring systems:

  Here “Knowledge of *a priori* law does not predominate knowledge of *a posteriori* fact”;

  And “Knowledge of *a posteriori* fact does not predominate knowledge of *a priori* law” (Linden et al., 2007, 839).

  Hegelian or “dialectic” inquiring systems relegate “both laws and facts to a secondary role” and stress “the dialectical arguments that drive the process toward a synthesis” (Linden et al., 2007, 839).

  Here ‘truth’ is sought by confronting opposing views, a thesis and an antithesis, attempting to find a more encompassing synthesis; this may get confronted again with an antithesis to drive the process further on towards an all-encompassing *Weltanschauung*.

- Singerian inquiring systems (named after the American philosopher E. A. Singer):

  Churchman finally developed a fifth type of Singerian inquiry systems trying to unite the advantages of the other four, while overcoming their weaknesses, particularly when dealing with complex systems.

  Here again “Knowledge of *a priori* law does not predominate knowledge of *a posteriori* fact”;

  And “Knowledge of *a posteriori* fact does not predominate knowledge of *a priori* law” (Linden et al., 2007, 839); so, in a way Singerian inquiry systems are Hegelian.

  But Singerian or “pragmatic” (Linden et al., 2007, 840) inquiry systems do not consider observations as unequivocal facts (like X = P), but as attributions (like $X \rightarrow P \pm p$), because P always depends on measurement (Churchman, 1971, 202); and it may depend on the context of a changing larger system. Furthermore Singerian inquiry systems start to question any laws and any given knowledge, whenever correspondence between laws or knowledge and observations is observed too often. Therefore, they ask when it is time to refine knowledge and/or even to reconsider previous goals for system design, to get to an ever more differentiated picture of the world and to be able to serve ever more individual interests of different “users”.

  So, whenever the other inquiry system approaches might have led closer towards a final ‘truth’, Singerian inquiry systems move in the opposite direction, start to question their knowledge and to differentiate it, developing ever more measurement-, context-, goal- and user-specific system designs.

Churchman (1971) is not very specific on the process of designing a system, but he adds the decisive insight, that designs may strive towards different notions of 'truth', which may be sought in the following alternative options:

- Leibnizian 'truth': The correspondence with a given body of thought;
- Lockean 'truth': The correspondence with observed facts;
- Kantian 'truth': The approximative development of an increasing correspondence of a continuously improved body of thought with increasing numbers of observed facts;
- Hegelian 'truth': The integration of opposing views into an encompassing agreement;
- Singerian 'truth': The development of ever more problem- and user-specific solutions.

So, put very shortly and in more profane language, we can say that Churchman (1971) addresses the important question: When is a system design 'good'?

Only when we agree that a system design is 'good', we know we are on the right track, and can proceed on the chosen way. Churchman tells us that a system design might be 'good', when it fits a holy text or scientific paradigm, or fits some facts, or fits facts better than a previous system design, or enables agreement, or enables individual solutions.

1.6. Jackson's Systems Paradigms

Jackson (2003) reviews approaches to system design for management applications and orders these approaches in a "system of systems methodologies".

From Jackson's numerous insights we take here only the point that system design can happen in different contexts, where parties can pursue different systems of goal-values, and therefore can get in different relations with which each other:

(1) Parties can pursue diverging goal-values. In such contexts we usually find some powerful and coercive actors, which can establish hierarchical relations and can enforce the realization of their goals, against the interests of others.

(2) In these contexts, where parties pursue diverging goal-values, we find, accordingly, victims of coercion, too, which are subordinated to coercive actors, who ignore or suppress their interests.

(3) Parties can pursue pluralistic goal-values, i.e., they have different, but somehow compatible views. This allows peaceful coexistence, and searching for possible mutual endeavors, which can be realized with means all parties can agree on.
(4) Parties can pursue unitary goal-values, i.e., they widely agree on what they want to achieve. This is the base for cooperative relations and mutual optimization of outcomes.

So, Jackson (2003) shows that system design can happen in different contexts coming with different relations, or we would say different modes of coexistence (Nechansky, 2016a, 2016b, 2017), between the parties concerned. And Jackson's analysis adds to the system design literature that the context can decisively influence the design process, and particularly the goal-setting process. Additionally he suggests that the system design process should be modified in accordance with the context to enable the involvement of many and ideally all parties concerned; if that does not prove possible, system design will only lead to the satisfaction of few.

1.7. Summary of the Selected Approaches to System Design

After this review of some selected approaches to system design let us try to bring order into the variety we found. We start trying to show some *common* elements:

- Mostly there is agreement that the whole process of system designs starts with setting goal-values, describing what should be achieved.
- Then there is wide agreement that system design proceeds in steps:
  - Here first parts of the system are conceptualized.
  - Then the parts are evaluated.

    When the parts passed the evaluation the design process can proceed: First to the next parts, then to the integration of the parts into subsystems, the evaluation of the subsystems, and so on, till finally the whole system is conceptualized and evaluated.
- There may be alternative solutions for the design of the whole system, which may be evaluated to finally choose the best system design.
- There may be a realization phase of the system (if the system is not a purely conceptual one), using similar steps of making and testing parts, putting these together, testing, etc.

Let us remark at that point, that even if most approaches acknowledge the necessity of goal-setting and evaluative processes, surprisingly little is said about how these processes actually work.

Then there are some aspects of the design process, which seem to apply generally, but are highlighted only in *some* approaches:

- Usually there are material constraints limiting system designs (Klir, 1985).
- Some preliminary (Churchman, 1971) or higher level knowledge (van Gigch, 1993, Klir, 1985) is needed, which determines the decisions, which parts and subsystems should enter into and make up the final system design.
- Different notions of 'truth' (Churchman, 1971) can be applied, each giving a system design process a different direction, to satisfy different criteria evaluating when a design might be considered as 'good'.

Finally there may be different contexts in which system design can take place:

- Jackson (2003) points out that system design can take place in contexts with different modes of coexistence (Nechansky, 2007, 2016), with coercive, suppressed, indifferent, or agreeing parties, showing different degrees of correspondence about the goal-values, which should be pursued.
- Churchman (1971) implicitly adds that parties might not only differ in their views about goal-values, but additionally in their notions of 'truth', too, i.e., how to evaluate if a goal or system design is 'good'.

So, from the approaches we reviewed here, we get a quite unclear and complex picture of the many aspects of system design. As far as we know, it was never tried to unite all these aspects to develop a unified theory. In the following we will investigate the interrelations between these aspects, to move towards such a unified description of system design.

Before we start with that investigation, we have to clarify some notions.

2. Some Basic Notions and Some Immediate Consequences

2.1. Definition of Core Notions

We will use the following notions in our analysis of system design:

- We take our notion of a system from Klir's (1991) simple and pragmatic definition:

  A system is defined by a set of elements and relations between these elements.

  We will try to remain as general as possible, so we will not give any more detailed description of either elements or relations, leaving open if they are just abstract concepts, or certain physical or social entities. We will occasionally give examples to illustrate our general considerations.
- We understands *states* as patterns or sequences of patterns, which an individual can observe in the external world around him or her, or which may be the result of thought processes modifying previous observed patterns or sequences of patterns.
- We name a *goal-value* (or sometimes shortly a goal) a certain state which should be achieved with a system design.

  That means the goal-value describes these pattern or sequences of patterns, which should be observable once the system is finished. So, a goal-value may describe a scientific conceptual understanding of a chain of causes and effects, or a technical function fulfilled, or a social interaction enabled, etc.
- We understand as *knowledge* any representation of states available to a human individual, i.e., patterns and/or sequences, which have been either observed, or created in thought processes.

  Particularly we distinguish between the following:

  - *Passive knowledge* consists only of observed or created patterns and sequences.
  - *Active knowledge* contains decision rules, which combine patterns or sequences with particular actions effecting and changing these patterns or sequences.
- We understand as *system designer* the human individual carrying out the design process, i.e., the person in charge of the decisions, which states should become elements and relations making up the system.

  (That means we rule out here some automatized system design with computers; we consider this as a second rated problem, because any computer was initially programmed by a system designer according to our definition.)

  We will consider only single system designers, leaving out any conflicts or coordination problems, which might occur when more are involved.
- We understand as the *design process* that sequence of activities of the system designer, which leads from a given state towards the state described by the goal-value.

- Finally we understand as *bias* any decision criteria of persons concerned with the design process, which are applied during the design process and give a systems design a more personal form rather than a universal character.

  Such decision criteria may result, e.g., from personal views, personal interests, group interests, or group- or culture-specific accepted models of thought, etc.

2.2. Some Consequences Derived from the Definition of Core Notions

Already from that very general definition of a system taken from Klir (1991) we can derive some basic aspects of the process of system design:

1. If the selection of the elements and relations, which shall make up a system, is not an arbitrary choice from the sets of all possible elements and relations, then a system has to be the result of a *goal-orientated* design process. Here the goal-value delivers the criterion to investigate, understand, model and/or realize some states.
2. The goal-value serves primarily as the criterion to select appropriate elements (while leaving out others), which are the smallest units of investigation and are characterized by having certain properties.

   These elements are not further analyzed within a certain systems approach. The properties, which they are supposed to have, are not explained within that systems approach. But these properties have to explain at least the kind of relations, which can be established between the elements.
3. A system has certain *limits*, constituted by the fact that only selected elements belong to it. With these limits comes the definition of an *environment* or *context*, containing everything not considered as part of the system.
4. The goal-value serves secondarily as the criterion to select certain relations (while leaving others out), which connect the elements of the system. Relations can be any kind of connections, static or dynamic, uni- or bidirectional, able to transport matter, energy and/or data, etc.

   Inputs are ingoing relations leading from the environment to elements of the system.

   Outputs are outgoing relations leading from elements of the system into the environment.
5. The sum of all elements and the considered relations, inputs and outputs constitute the *structure* of the system. It determines the actual complexity of the system.

After these definitions of key terms, we can now turn to our analysis of system design.

3. Outline of the Developed Approach to System design

Above we reviewed various approaches to system design and the different aspects, which they highlight. Now, let us outline what we take from these approaches, what we add to them and how we additionally investigate interrelations between all aspects considered. We will proceed as follows:

- System design happens in a *context*. We take that view from Jackson, but differentiate it:

  We start with the investigation of the core actor(s): There is at least one system designer; but additionally there may be a client, ordering a design, and an employer employing a system designer.
- System design has a necessary *material base*. Surprisingly this is only mentioned by Klir.

  System design requires material resources, at least to support one system designer and to document the final design. But, of course, requirements can be enormous. Anyway, the available resources always limit what can be done.
- A *process of goal-setting* initiates a system design. Practically all approaches agree on that.

  But usually goal-setting is simply taken for granted as starting point, but never investigated. Yet we think it is decisive to understand where goal-values actually can come from, how they are related to actors, are restricted by the material base, and determine the whole design process.
- Goal-setting is necessary, but not sufficient to evaluate the design process. We need additionally *goal-orientated evaluation criteria*, to decide, first, if the design process is '*good*' and leads towards the goal (this was the focus of Churchman, 1971), and, secondarily, to decide when it is '*good enough*', to know when the mission is accomplished; this latter point is practically never considered.
- Once the previous points are clear, at least one system designer can carry out the core design process.

  Most approaches focus on the *steps* of this process (and particularly systems engineering). But we will emphasize the related activities and particularly the *decisions* of the system designer(s), and how his or her knowledge and assumptions, as well as the goal-setting process influence the design process.
- Finally we will consider the *wider context* of the system design.

  Here we investigate how the design of the core actors may be received in a wider context, where various parties may be concerned, which may be coercive, suppressed, indifferent or cooperative, according to Jackson's (2003) approach (discussed in section 1.6.).

So, we will take a wider look on the process of system design: We will ask where goals may come from, and how they determine the whole design process; we will consider the influence of the designer and of a wider context. And particularly we will investigate how these factors can amount to *biases,* which can crucially determine the final design and can make it something quite different than the result of purely rational process to optimally realize a certain goal. So, let us analyze these factors in turn.

4. The Core Context for System Design

Following Jackson (2003), we have to consider the context of system design. However, we will differentiate and supplement his approach:

We will focus here on a *core context*, where core actors a directly involved in a design process. We will consider only later a *wider context* (see section 9), where more parties with different power may be concerned, which may be coercive, suppressed, indifferent or united (Jackson, 2003).

In the core context *core actors* have to accept clear goal-values so that a design process can start:

1. In the simplest case, there is just a single actor, a *system designer* making a system for himself or herself.
2. More often, we will find additionally a second core actor, namely at least one *client* ordering a system designer to make a design.
3. Additionally we find often that a client addresses an *employer,* who employs the system designer.

So there may be one or up to three different types of core actors.

How these core actors can work and realize their system design in the *core context* depends on their positions according to Jackson the *wider context*. If they are part of coercive parties, they will have a more easy play. But if they belong to suppressed ones, they will have to consider the coercive parties throughout the process, from goal-setting, via the design process to some final realization. Furthermore, the whole process can be complicated, if the parties forming the context apply different criteria for 'truth' according to Churchman. We will consider the effects of such settings in section 9 below.

5. The Material Base for System Design

Next we have to consider the material base for the system design. Surprisingly only Klir (1985) acknowledges that this may be a major constraint.

5.1. The Material Needs for System Design

There are two material demands for designing a system:

The first concerns the material needs of the system designer. Obviously, like every human, the system designer needs an income securing at least his or her existential needs (i.e., at least food, shelter and health care). Here the available material means determine the amount of time and effort the designer can spend on the project.

The second material needs concern the design process itself. Here the available material means determine the support that can be offered to the designer (like technical equipment, information, personal services, etc.).

The overall availability of material means for both, designer and design process, limit the scope and the sophistication of any design. This *material constraint* is one *bias* limiting the system design.

5.2. The Sources of the Material Base for the System Design

Now there are different possibilities to provide for the material need of design and designer, which depend on the core context (as discussed in section 4 above):

- The system designer may cover all material needs from personal wealth;
- The system designer may get a personal income and a budget for the design process directly from some client, who entrusts him or her with the systems development.
- The system designer may get a personal income from an employer, who gets a budget for the designer and the design process from some client.

Again, the activities of the core actors as well as their use of their means, may be influenced by the larger context, e.g., if they have to act against coercive parties, or may work freely (see section 9).

Let us consider next how the source of the material base that can influence goal-setting and can introduce further biases in the design process.

6. THE GOAL-SETTING PROCESS

So far, we have clarified possible core contexts for system design. And we have addressed material needs, which may be served by different sources, which can vary again with the core context. These are major determinants, which influence the decisive goal-setting process specifying what a system design should be all about. We turn now to this process.

We start considering the options for goal-setting, i.e., which of the core actors may actually set the goals, and which interests come with that. Next, we highlight the interrelations between goal-setting, interests and material constrains, before we turn to the goal-setting process itself.

6.1. The Options for Goal-Setting

In our scheme with three possible core actors, which may be involved in the system design, there are only two sources where goal-values may come from:

- First, the system designer can set the goal-values, if, and only if, he or she has a secure material base (ideally from own personal wealth, or from some guaranteed personal income) to provide for himself or herself as well as for the design process.

  Only in that case there are no external goal-conflicts or conflicts of interest during the design process.

  Here remains just the question, if the system designer is driven by impersonal professional interests (like scientific rigor) or by prevailing personal interests (like fame).
- Secondly, a client can set the goal-values for the system and provides the material resources for the design process.
  - Here the client may enter in a direct relation with the system designer.

    Then we have an implicit conflict of interests between client and designer.
  - Or, the client enters in a relation with an employer, who cares for the design process and provides for the system designer.

    Here we have an implicit conflict of interests between client, employer and designer.

These are the basic settings for system design. And here we have to emphasize one decisive point, which most approaches to system design, which neither consider the material base nor where goals may come from, do not even touch:

The right of goal-setting for a system design is mostly linked to the ability to provide the necessary material resources.

The ideal case seems to be the first case, the single, wealthy researcher driven by impersonal professional interests and pursuing own goal-values. Yet with scientific, technical and organizational systems getting ever more complex, the reach of a single individual seems too limited to achieve very much alone. So other settings become increasingly important, particularly the third one, which may include many system designers working under one head. Yet with these settings come conflicts of interests, at which we have a closer look next.

Anyway, to think that system design may be just a linear, rational, value free process leading from a goal-value to an optimal solution, without any intervening diverging interests, is at best possible for the single wealthy system designer. Yet much of the literature on system design leaves out the context of goal-setting, the source of the material base, as well we the resulting interrelations of interests and the related biases creeping in.

6.2. Contexts of Goal-setting and Resulting Biases Influencing the Design Process

Depending on the number of core actors, as well as on the source of the material base and of the goal-values for the design project, we get ever more complex interrelations of different interests playing into a design process.

When we consider the core actors alone, without considering a wider context yet (to which we turn in section 9 below), we find the following constellations for system design:

- There are always the interests of the system designer.

  These consist of continuously securing an income (at least for existential needs like food, shelter and health), and maybe a prevailing impersonal professional interest in the quality of the system design, or maybe prevailing personal interests in fame, quick income, etc.

  Additionally there are probably long-term interests in stable social relationships with a community (probably including family and friends), i.e., a wider context (see section 9).
- There may be additionally interests of a client.

  Of course, the interests of the client have to include, too, continuously securing an own income (at least for existential needs like food, shelter and health).

  The client's goal-values for the system design may directly serve his or her material interests (maintaining or increasing income); or, provided these are served, the client may want to pursue any other personal goals. Anyway, independent of the content of the selected goals, he or she will probably demand a material optimality, i.e., he or she will wish to get a maximum of value with minimal effort.

The interests of the client will probably include, too, long-term interests in stable social relationships with a community (probably including family and friends), i.e., a wider context (see section 9), and/or eventually with the system designer.

And here, when working for a client, the system designer's interests may include the wish to provide a system design that is a good compromise between value for the client and value for him- or herself. This may include the trial to use or to fit in available information, know-how from previous approaches, or to reuse other designs for the design for the actual client, etc. Additionally the system designer's own professional and personal interests, as well as his or her social interests may be moderated by long-term interests in stable social relationships with the client, to secure long-term income.

- And there may be additionally interests of the employer of the system designer.

  Of course, the interests of the employer have to include, too, continuously securing an own income (at least for existential needs like food, shelter and health).

  Additionally the interests of the employer may include the wish for a system design that is a good compromise between value for the client and value for the employer. This may include the trial to use or to fit in available information, know-how from previous approaches, or to reuse other designs for the design for the actual client, etc.

  The interests of the employer will probably include long-term interests in stable social relationships with a community (probably including family and friends), i.e., a wider context (see section 9), too, and/or eventually with the client to secure long-term income and/or additionally the system designer to secure long-term services to clients.

  And here the client's interests may be moderated by long-term interests in stable social relationships with the employer.

  And here the system designer's interests may be moderated by long-term interests in stable social relationships with the employer.

We think it is important to make explicit all these possible and likely interests that may be involved in the core design process alone. And we think it is particularly important, to emphasize the obvious, i.e., that humans continuously have material existential needs. Only if they have an income to serve these needs, then they can engage in anything else. So system design either directly aims at securing someone's income; or otherwise we will find behind it a solution securing the income of the core actors, that allows them to pursue the design. Ignoring these existential dependencies means turning away from the divergent material interests, which may influence or even shape a system design process.

In sum these interests of the core actors can amount to the following *goal-setter biases*:

There are always *explicit objectives for the design* (a necessary bias), usually determined by the provider of the material base for the systems design. The pursuance of these objectives may be influenced by the *interests of a system designer* (a first occasional bias) and additionally by the *interests of an employer* (a second occasional bias).

So, considering system design as a rational, scientific, value-free process may apply at best to the single and wealthy researcher, but seems to be fairy tale in the most usual settings today.

6.3. Goal-Setting

So, there may be two sources for setting the goal-values what to achieve with the system design: The system designer, or a client.

And there may be three different contexts for the system design: With a system designer alone, or one hired by a client, or one hired by an employer working for a client.

Most approaches to system design do not even distinguish these different settings. They just agree that the whole process starts with some goal-values, and simply take them for granted, without asking where they might come from. And they only ask how to realize the set goals.

We consider that as a technically valid move, if one just wants to get an overview on the steps of the design process. But that means leaving out the decisive questions of systems design, which are:

- What is a goal-value at all?
- What is a goal-value for?
- And how does a goal-value come about?

We suggest the following answers to these questions:

- A goal-value is a *description of some future states*, which currently do not occur, or at least do not always occur (i.e., it is "teleological" as Churchman, 1971, has put it.)
- A goal-value includes the assumption that *the described states are 'better' for somebody in some way* than the currently given states.

We strongly suggest that we can widely ignore cases where something should not be ‘better’; we will shortly come back to that below.

Now, from our analysis of the role of the core actors above we can say that the crucial guiding assumptions ‘*better for whom*’ and ‘*better in which way*’ depend on the person setting the goal-values; and that is normally, too, the person providing the material resources, i.e., paying for the system design.

That means that system design usually aims at something, which is ‘better’ either for the wealthy system designer, or for the wealthy client.

- Finally, as an assumption of some future ‘better’ states, a goal-value is itself sort of a system design:

  But such a goal-value is only *an intuitive and vague system concept*, a quick and brief sketch, delivering a simple outline of some ‘better’ goal-states, which seem possible and feasible.

So, we suggest that actually an *intuitive* system concept delivering goal-values precedes the systematic, rational and technical system design process trying to realize these goal-values. This intuitive concept includes the assumption that something might be better for somebody, usually the system designer or the client. And the role of system design is to investigate and, if possible, to validate, if the intuitive assumptions of possibility, feasibility and betterment actually do hold.

We cannot overemphasize that point:

There are no problems in the world per se, *there are only problems because of goal-values, i.e., because of intuitive, imaginative concepts and assumptions that something might be ‘better’*.

If you are always satisfied with the world as you find it, there are no problems. You might happily walk to the next spring to drink water, pluck fruits wherever you find them, and sleep under trees. Perhaps you traveled that way sometime, when you were young, or still occasionally do it when you take holidays. You might even experience a welcome relaxation in such times. Why that: Because problems occur only if you start to imagine that something could be any different, e.g., that water should be available out of a pipe near you, fruits should be delivered on order via mobile phone, sleep should be protected by an air-conditioned house, etc., etc. Whenever you select such an imagination and try to realize it, you have set a goal-value, you have declared some current state as unsatisfactory and you have *created* a problem. And only after that you can enter the realm of system design as it is understood by most thinkers - as starting once a goal is *set*. But actually, once the goal is set the decisive decisions determining the whole design process have already been made.

So, we strongly suggest that setting goal-values for system design unites two features, which are usually not associated with systematic developments and even less with science:

- *Setting goal-values is an intuitive act*. (And actually it is only the first important place of intuition in system design; we will identify a second one in section 8.1.1. below).

  We follow here Bergson (1912, 89), whose work dealing with intuition was acclaimed in philosophy, but was never closely observed in science:

  > "But the simple act, which started the analysis, and which conceals itself behind the analysis proceeds from a faculty quite different from the analytical. This is by its very definition intuition."

  In the goal-setting act *one somehow promising option* is selected from available knowledge. If this option actually will be promising is an open question, but that is evaluated as worth investigating.

  So the goal-setting act, consisting of the selection of one option as well as the evaluation of the worth to investigate it, is not and cannot be 'rational' in the sense, that it could be explained completely with available clear and unequivocal arguments. Since it is not known that the option will really turn out promising, there cannot be such arguments; so both, the selection and the evaluation derive from intuition.

  And the lack of unequivocal arguments for the goal-values is exactly what makes the investigative system design process necessary.

- And setting goal-values comes with a notion of 'better'.

  Again we can follow Bergson (1912, 41):

  > "We do not aim generally at knowledge for the sake of knowledge, but in order to take sides, to draw profit – in short to satisfy an interest."

  There seems to be no reason, why the states described in the goal-value should have been selected, if not because they are promising, i.e., 'better' in some regard, than the given states. (Even masochists, sadists and suicide bombers, which tend to select states, which most people consider as objectively 'bad', do that because they consider them as subjectively 'better' in some, fortunately, only unusual and personal way.)

  But where does this notion of being 'better' come from:

  First, it is the privilege of the person setting the goal-value, i.e., the system designer or the client, not only to determine what shall be tried to achieve, but additionally, *implicitly, but inseparable included,* to decide what is considered as 'better' in some way, for somebody, what is worth trying, worth working for, important to realize.

Second, let us emphasize that this notion of ‘better’ can have only one ultimate source:

Any *ongoing* activities of humans (leaving aside activities like personal sacrifice, suicide, suicide bombing, etc.) require that persons continuously secure their existential needs. (These include primarily existential goal-values, like physiological necessities of maintaining a certain body temperature and levels of nutrients; humans can survive deviations from these existential goal-values only for short periods of time. So they need secondarily the material supply of air, water and food to maintain that; and tertiary usually an monetary income is needed to provide for that. And they can decide just once to ignore that, as in an act of personal sacrifice or in a suicide.)

So any notion of ‘better’ usually will at least *include* the provision not to endanger the existential goal-values of the person defining it. Only if that is secured, then ‘better’ may concern anyone or anything else.

So, the act of goal-setting relevant for system design is ultimately derived from the existential interests of the goal-setter, who has an intuitive, sketchy idea of something ‘better’. Or put the other way round: ‘Better’ is something normally only then, when it does not endanger existential material requirements of the goal-setter.

That means that the act of goal-setting does not provide just a technical, rational and unbiased answer to the question of what shall be done. The act of goal-setting allows the person, which has the privilege and the discretion to carry it out, to implicitly make the following decisions going beyond the mere content of the goal:

- Goal-setting comes with an implicit *material* decision for something, which at least does not endanger (if not improve) the existential conditions the decider (but may have other, positive or negative, effects on the material conditions of others).
- Goal-setting comes with an implicit *ethical* decision, what the decider considers as ‘better’ than the status quo, as worth spending his or her material resources for, and as worth investigating.
- Goal-setting comes with an implicit *moral* decision that pursuing a selected goal-value can be justified in relation to others (which might have other views of what might be ‘better’, or other material interests), which do not profit or even might suffer from the ‘better’ states aimed at.
- Goal-setting comes with an implicit *political* decision, that there are no more important goal-values within a community, than the particular goal-values selected for a certain system design.

The relation between goal-values and ethics was already observed by Aristotle (1984) at the very beginning of the Nicomachean Ethics, where he writes that goals always point towards some "good", behind which we finally find some "ultimate good". Churchman stated practically the same the other way round, when he claimed that ethics is "the theory of the appropriate goals of a system" (Churchman, 1979, 21).

Yet surprisingly this knowledge of the interrelation of goal-setting and ethics never really became a main concern in the consideration of system design:

The process of system design, understood solely as a process running from a set goal to the desired end product, may seem to be a widely straightforward, rational, un-biased, value-free process. (We will look more closely at this process shortly.) But the goal-setting, from which it all started, is definitely neither un-biased nor value-free, and with that the very end product, the realization of the goal-value towards which that whole process runs, is, of course, neither un-biased nor value-free, too. So, focusing narrowly on the process in between leaves out the decisive biases and values, which drive the whole development.

The value judgment that goes parallel with goal-setting comes implicitly with the exclusion of other projects. Deciding for certain goal-values is a material decision excluding to fund other projects, is an ethical decision personally excluding alternative activities, is a moral decision to confront others with certain developments and results, and a political decision to withhold alternative ends from a larger community.

A simple example may illustrate the point:

The steps of system design may be quite similar, if a system designer gets the order to make a tank or an ambulance car. But the questions of ethics, morals and politics are concentrated in the act of goal-setting, in ordering the one or the other. The system designer with the order to construct a tank may have some freedom to apply own biases and to make it a more defensive, and less threatening and deadly weapon. But he or she has not the freedom to leave out any means for killing and even less to turn out an ambulance car. So, can we say that the process leading from the goal-setting to make a tank to the final weapon would be 'value-free' anyway?

Western philosophy and science seemingly ever lived happily with a focus on the 'value-free' and 'rational' process between goal-setting and goal-realization, neglecting that neither the first nor the second are.

Let us mention here in passing that Graham (1989) sees a main difference between Western and Chinese philosophy in their different focus on goal-realization versus on goal-setting:

> "[…] and the crucial question for all of them [the Chinese philosophers] is not the Western philosopher's 'What is the truth' but 'Where is the way?', the way to order the state and conduct personal life." (Graham, 1989, 3)

> "We might sum up the Chinese attitude to reason in these terms: reason is for questions of means, for your ends in life listen to aphorism, example, parable and poetry." (Graham, 1989, 7)

So, in Chinese philosophy, there is a focus on the prime question of how to determine "ends", i.e., on setting goal-values, and how to justify them in relation to a larger whole, i.e., in relation to the material, ethical, moral and political questions, which implicitly come with goal-setting. Therefor the core of Chinese philosophy is not, cannot and does not want to be 'rational' in the Western sense (see Ames and Hall, 1987, 1995, 1998), because it tries to stimulate the *intuition*, which we identified above as a part of goal-setting; and this can be achieved, e.g., by listening to "aphorism, example, parable and poetry". With that comes a vague, but wide-ranging knowledge what really might be worth to be done, worth to serve whom in particular, and, with that, worth to be considered as really 'better' within a larger whole.

Bergson (1912, 92) tried to approach this question of the vague knowledge of a larger whole, which he called the "integral experience", which "has nothing in common with a generalization of facts". We think that nicely and shortly grasps the core issue. What science transmits is the "generalization of facts". Yet what cannot be transmitted completely from individual to individual is the "integral experience", which contains those particulars, which may decisively deviate from the generalizations in certain contexts. Individual intuition can consider such particulars and in that way may be superior to scientific prognoses.

Only more recently Western systems theory turned to this vague knowledge, addressing questions of holism, and trying to overcome the increasing separation of the ever more specialized fields of science. But perhaps its most important insight is to make aware that an all-encompassing holism cannot be achieved, because, due to the limited capacities of humans, we have always to work with restricted models trying to somehow represent the whole. Ulrich (1994, 35) summarized that crisply:

> "The implication of the systems idea is not that we must understand the whole system but rather that we need to deal critically with the fact that we never do."

So, questions of holism, of the vague knowledge of a larger whole, have at least arrived in Western thought, too. But the relation between the currently available vague knowledge (i.e., Bergson's "integral experience") and goal-setting was, to the best of our knowledge, never systematically addressed.

And while the relation between goal-setting and ethics was early acknowledged in Western thought, it is still hardly considered. Instead it concentrates on "means" (as Graham put it, see above), on the alleged 'value-free' process of a science, of system design, which excluded the consideration of goal-values from its agenda, and with that their personal and material sources, and their implicit ethical, moral and political justifications. Western science and following it, Western technology, simply accept goal-values and their definitions of something 'better', and focus on a 'rational' way running towards them, whoever may have formulated them, to whatever end they may lead and whomever they may finally serve.

So, we have to conclude here, that the goal-setting process not only sets an explicit objective (the bias discussed in section 6.2. above), but with that provides an implicit notion that this objective is 'better' in some way than other options, and therefor comes with an *implicit bias containing material, ethical, moral and political valuations*.

6.4. Summary: The Goal-setting Process

In consideration of the described philosophical and scientific background our previous analysis tried to shed more light on the relation between knowledge, goal-setting, ethics, morals, politics - and the material requirements to pursue a system design project.

We suggest that the setting of far-reaching goal-values (i.e., which go beyond immediate existential needs) depends on:

- A person in control of secured material means to pursue such a far-reaching endeavor (which may be the system designer, but is mostly a client).
- The entire knowledge that is currently available to that person, which constitutes the current state of 'holism' (i.e., Bergson's, 1912, "integral experience"), from which goal-values can be derived.
- An act of intuition, in which that persons singles out a subset of states contained within this personal knowledge; these states are assumed to be 'better' in some way than some currently given states, in a way that is important to that person.
- An evaluation by that person, that these singled out states are worth to be pursued as the goal-values for a system design project.

  With that evaluation implicitly material, ethic, moral and political decisions are made, too. These implicit decisions come about by excluding to fund other projects, excluding alternative personal activities, and excluding alternative results for concerned others and alternative priorities for a larger community.

We want to emphasize explicitly that we link at that point material personal well-being with what can become a goal-value for system design. So, we suggest a relation how economic facts determine what can become scientific, conceptual, technical and social facts.

In sum all the discussed interests can amount to the following *biases related to goal-setting*:

There is always *a first goal-setter bias in the form of explicit goal-values*; with that comes *a second goal-setter bias in the form of an underlying implicit value system, containing material, ethical, moral and political valuation*, which justifies the explicit goal-values. The pursuance of these explicit goal-values may be moderated if a system designer and an employer are involved; that can introduce a *bias of designer interests* and a *bias of employer interests*.

As practical implications of this section we suggest that considering a system design should always start with the following questions:

- What exactly is the goal-value, at which the system design aims?
- For whom should that be 'better', and in which way?
- And: Who paid for it?

7. THE PREREQUISITES OF SYSTEM DESIGN

So far we addressed the context, the material base and the goal-setting for system design. But before we can proceed to the very design process we have to clarify a problem, which we introduced when we discussed goal-setting.

Above we said that goal-setting is a form of system design, even if only an intuitive, sketchy and conceptual one. Now we cannot investigate the process of system design and say it starts with some process of system design, without clarifying where that beginning comes from.

Therefore we will suggest in the following the way of the development of knowledge, from *a priori* given human abilities towards that preliminary knowledge that enables intuitive goal-setting and which is the base of system design, too.

7.1. *A Priori* Knowledge

We suggest that humans are born with quite a lot of '*a priori*' knowledge. This is based on internal controller structures, which provide knowledge in the form of decision-rules to control the fulfilling of existential needs; and it is based on externally orientated controller structures, which provide knowledge in the form of basic decision-rules how to interact with the environment.

The internal controller structures provide the following main functions:

- They provide the highest existential goal-values of the individuals (concerning basically body temperature, and necessary level of air, water and food supply).
- They provide sensors to measure the current internal states in relation to these existential goal-values.
- They provide a basic inbuilt notion of what is ‘better’ for the individual, and that is basically anything that is closer to the goal-value for temperature, and above the necessary level of air, water and food supply.
- They start externally orientated controller structures for protection and for search mechanisms, whenever the individual tends to leave one or the other range of what is defined as ‘better’, in the way stated in the previous point.

Now these externally orientated controller structures consist of the following main elements (for the basic principles of the processes involved here see the ongoing series of Nechansky, 2012a, 2012b, 2013a, 2013b):

- They provide sensors (eyes, ears, sensors for touch, smell, taste) directed towards the environment.
- They provide structures, which enable a constant spatial and temporal mapping and storing of sensor data (in terms of left - right, up - down, and before - after).
- They provide effectors to act on the environment (hands and arms, feet and legs, and a mouth).
- They enable pattern and sequence recognition in observed data.
- They enable the formation of decision-rules, how to combine sensor data, patterns and/or sequences to steer particular actions of the effectors.
- They enable immense abilities to deal with stored sensor data, patterns and sequences to recombine them, to derive generalizations and particularizations from them, to find similarities in them, etc., to arrive at conceptions of sensor data, patterns and sequences, which have never been observed in the environment.

The last three points are usually summarized under the heading of ‘learning’, consisting of (1) observing and storing of patterns and sequences, as well as of (2) combining these with actions to form decision-rules how to change observed patterns and sequences and (3) reusing and recombining patterns, sequences and decision-rules for future applications.

This is a very short sketch, how the ‘*a priori*’ knowledge coming with the inborn human controller structures enables the acquisition of that preliminary knowledge, which is needed for both, goal-setting and system design.

7.2. From *A Priori* Knowledge to Preliminary Knowledge

Now humans apply the ‘*a priori*’ knowledge, as sketched above, to their environment, primarily to find out what serves their existential needs (i.e., what keeps them warm, what they can drink and eat). But the better these interests are served, the more individuals are free to learn anything else by observing, playing with and acting on anything that may come to their attention.

From observing the basic objects of their experience (like stones, sticks, flow of waters, and plants, animals, and other humans) they will store patterns and sequences. Then they will try to interact with some of them. And they will evaluate, if the results of these interactions are ‘better’ for them, primarily in relation to their existential goal-values, and secondarily in relation to any other personal interests. And so they will develop decision-rules combining observed patterns, tried actions, and achieved results, i.e., the resulting changed patterns; and they will remember that for future application, particularly if the achieved results are ‘better’ in some existential or other way.

All that leads primarily to a passive knowledge of observed patterns and sequences, and secondarily to an active knowledge containing decision rules, how particular observed patterns or sequences can be changed with particular actions.

And finally, the third ability of learning, which we identified above, is applied to all that. Generalizations, particularizations, and similarities are derived from observations, using the processes of induction, deduction and abduction. From known decision-rules possible future decision rules are conceptualized.

So, from the observation of and the interaction with basic objects, individuals can derive assumptions about what can be done with somehow similar objects (e.g., from stones, sticks, flows of water to other solid elements, connections, flows of other media). And they will notice that other objects, which seem quite similar on the surface (e.g., plants, animals and other humans) do not allow the same degree of coherence and consistence, when making assumptions and conceptions about seemingly similar ones.

So humans can develop an increasing body of preliminary knowledge consisting of observations, of decision rules and of derived likely assumptions and conceptions about two different kinds of objects, which we can classify as follows:

- A first body of knowledge deals with material, strictly *law-bound systems*.

  This consists of quite precise observations and decision-rules, which allow a high degree of predictability when dealing with comparable patterns (like stones, sticks, flow of waters, etc.) in comparable contexts.

  This knowledge is additive: New experiences add to the existing knowledge.
- A second body of knowledge concerns living, only *constraint-bound systems*.

> This consists of vague observations and decision-rules, which allow only an occasional and approximate predictability when dealing with seemingly comparable patterns (like plants, animals and other humans) in seemingly comparable contexts.
>
> This knowledge is cumulative, but not additive: New experiences enter into a collection of case-specific knowledge, with imprecise differentiation and overlap.

These bodies of knowledge contain the base on which any system design has to be built.

And combining any element of these bodies of knowledge with some notion of something ‘better’ is all we need for the intuitive and sketchy process of goal-setting:

We can start with one pattern or sequence that occurred in one context. Then we may apply a thought process of induction, deduction or abduction. Based on that, we may conclude that a somehow similar pattern or sequence may work in another context to make something ‘better’. Then we have created a possible goal-value. And when we decide to pursue such a goal, decide to strive for that idea of ‘better’, then we enter into the core process of system design. Then we have to apply again such preliminary knowledge - either our own or that of a hired system designer - to systematically approach that goal.

Now, even if all this knowledge is difficult to describe in general terms and we had to remain vague here, we think we provided a valid outline of the way leading from inborn human ‘*a priori*’ knowledge to that ‘preliminary’ knowledge, which is the base for the intuitive goal-setting for a system design (as discussed in section 6.3. above).

Since this ‘preliminary’ knowledge is the product of all the previous experiences of the goal-setter, it reflects the education, the environment and the cultural setting, which he or she got to know. Therefor we call it the *educational/environmental/cultural bias* influencing the system design.

7.3. The Preliminary Knowledge of the System Designer and Its Necessary Scope

So, we have clarified above the way leading to the kind of intuitive knowledge needed for goal-setting.

Now we suggest that the system designer, of course, starts with some preliminary knowledge, too, reflecting his or her educational/environmental/cultural background. We call it ‘preliminary knowledge’, because it is not sure at the outset of system design, that this knowledge will be sufficient to realize a set goal-value; in many cases it turns out to be not sufficient.

And even if we cannot say at the outset if that preliminary knowledge will be sufficient, we can specify, what minimum knowledge a system designer does need, in case he or she is hired by a client who set the goal-values. Or, put the other way round, we can specify, what kind of minimal knowledge a client must demand, when selecting a system designer. We suggest the system designer has to have the knowledge to understand at least the following:

- The system designer has to understand the goal-values, i.e., the states described by it.
- The system designer has to understand the problem that is constituted by setting the goal-value, i.e., the difference between the goal-states and some given states, and why these problem-states are considered as 'worse' than the 'better' states named with the goal-value.

  This includes the knowledge of an evaluation process, which includes at least a step function (or, better, a continuous function), which can characterize the difference between the given 'worse' problem-states and the 'better' goal-states, and any states in between.

  Notice that as this point the system designer must be able to apply an evaluation function, which is *goal-specific*, because it distinguishes and judges *all* possible states considered during the design process *in relation to the set goal-value*. Here our entire material, ethic, moral and political considerations come in, as discussed in section 6.3. above, and that *permanently during the whole design process*.

  So the system designer must be ready to continuously subordinate his or her activities to such an evaluation function which is derived from the set goal-values. He or she must be ready to act neither unbiased nor value-free, but always focused on the goal-values and the criteria, which determine what the goal-setter considers as 'better'.
- The system designer has to have some understanding of the context of the problem.

  The context concerns all those states with currently or during a realization of a system design might play a role, which might hinder or endanger the realization of a goal-value. This necessary understanding of the context is the most difficult to define.

So the preliminary knowledge of the system designer, acquired within his or her educational, environmental and cultural setting, has to include the goal-states, the derived problem states and a measure for the difference between them, as well as relevant states separating the two.

The degree, how far the preliminary knowledge of the system designer covers that, forms his or her *educational/environmental/cultural bias*.

8. THE CORE PROCESS OF DESIGNING A SYSTEM: FROM THE PREREQUISITES AND GOAL-VALUES VIA PRELIMINARY KNOWLEDGE TO THE FINAL DESIGN

Now we have addressed all the preparatory issues that play a role and have a determining influence already before the very core process of system design can start: The context, the material sources, the goal-setting process with its implicit material, ethical, moral and political assumptions, and the sufficient preliminary knowledge of the system designer.

All these issues are widely neglected in most of the literature on system design., e.g., Mesarovic und Takahara (1975) seem to think that all of them play *no* role on their way to their "general systems model" (as discussed in section 1.1.).

Anyway, assuming that all these issues are sufficiently provided for in some way, we can move now to the core process of system design in the more narrow sense, in which it is usually understood. So, we come now to the construction of a system consisting of certain elements and relations (according to the definition we derived from Klir, 1991, in section 2.1. above).

We suggest that this core design process is usually carried out in some steps, many of which may be repeated. These steps lead from selecting elements and relations, to combining them to parts and subsystems, etc., testing and evaluating all these intermediate components till a final design is available; this has again to be tested, and eventually modified, till it can be accepted.

We look now closer on these steps, without going into too much detail. We think the technical aspects of this core design process are completely covered in systems engineering (see, e.g., Patzak, 1982, Winzer, 2013).

8.1. The Core Process of System Design: From Elements and Relations via Subsystems to a Complete System Design

Faced with the task to find a way from a given problem-state to the wanted goal-state the system designer has to make decisions what might be relevant and what not. We suggest that these decisions usually amount to a process carried out in steps of increasing detailing, with each step consisting of the following parts:

1. The system designer derives assumptions from his or her preliminary knowledge, about what might be relevant.
2. Based on these assumptions he or she selects particular elements and relations to make up parts or subsystems of the system.
3. Then he or she applies some test and evaluates the result, to decide if the elements, relations, parts and/or subsystems seem sufficient for reaching the goal.

These steps are repeated until a complete system design is finished.

Whenever the test (point 3) is not passed, other elements and/or relations will be selected (moving up to point 2), whenever that does not work either, other assumptions have to be made (moving up to point 1).

We find here principally the leveled process described by van Gigch (1993, see section 1.4. above) or in a more detailed way by Klir (1985; see section 1.3.). Yet we suggest the highest level of this order is not a “Philosophy of Science”, as van Gigch (1993) assumes. We strongly suggest:

At the top of this order stands the preliminary knowledge of the system designer.

This preliminary knowledge will *probably contain* a “Philosophy of Science”, understood as knowledge that is derived from the context in which the system designer learned, and that is shared with others in that context. Yet we cannot say for sure that it is only or just primarily such knowledge that will be applied in a certain design process. Quantum leaps in human development often occurred exactly when such shared knowledge of a certain “Philosophy of Science” was *not* applied.

What we can say is that if this preliminary knowledge is not sufficient to drive the whole process, then the system designer is not fit for this system design. Then he or she has to move to a playful and experimental way of developing improved preliminary knowledge (as discussed in section 7.2. above) to become able to enter into a straightforward design process later on.

Let us discuss in the following what has to happen generally in each step of the design process, without considering if we discuss a selection of elements, relations, parts or subsystems.

8.1.1. Assumptions

Since system design is a process searching for a way from a given problem state to a goal-state, it has always to start from preliminary knowledge. For if we had complete knowledge, we would not need any investigative design process, but could go immediately to the realization of the goal. This is an important point, mostly overlooked, mentioned only by Churchman (1971, 4). But Churchman did not elaborate his observation. It means that we have to make assumptions when we go into the design process.

And when making such assumptions the personality of the system designer is in three ways crucial for the whole process:

- First, his or her *preliminary knowledge* sets the frame and the limit from which solutions can be derived. (This is the “integral experience” of the systems designer, in the sense of Bergson, 1912, which we mentioned in section 6.3. above).
- And, second, his or her *creativity* to relate parts of the preliminary knowledge to the goal-value determines the number of possible solutions, which the system designer can consider.
- And, third, his or her *intuition* leads to assumptions, which of these possible solutions might work best and should be primarily tried, detailed and tested.

It is important to notice here that a system designer with a lot of preliminary knowledge need be one with much creativity, nor with much intuition, and *vice versa*.

Anyway, we find here intuition for a second time. All we said about intuition in relation to goal-setting applies here, too. When making assumptions about details of the system design, then again *one somehow promising option* is selected from the available ones. If this option actually will be promising is an open question; but that is intuitively evaluated as worth investigating.

So, intuition not only determines the goal-setting process. It determines making assumptions when detailing the system, too, when selecting possible solutions, which have to be elaborated and tested; so it decisively determines the effort, which has to be put into the project, and how fast and accurate it can proceed, as well as its chances for success.

Based on his or her preliminary knowledge, creativity and intuition the system designer has to make *assumptions* concerning at least the following issues:

- Which states within the context do exactly make up the ‘problem’?
- Which details might be important to exactly characterize the goal-states, which might not be provided by the sketchy and intuitive formulation of the prime system concept?
- Which elements, relations, parts and/or subsystems might be important to get to a system that can realize the goal-values?

The results of these assumptions determine what will be elaborated, tested and evaluated in the next steps.

Ashby (1970, 178) nicely summarized this problem of approaching a goal by making assumptions derived from preliminary and incomplete knowledge:

> "The fundamental principle of decision on a finite quantity of information may be expressed thus: Use all that you know to shrink the range of possibilities to their minimum; after that, do as you please."

Hylton (2007, 84) formulated the same problem in more positive words:

> "Creating good hypotheses is an imaginative art, not a science. It is the art of the science."

That said we have to emphasize again, that the searching of the preliminary knowledge to derive assumptions is a goal-orientated process, solely driven by goal-values, which have been set before for the system design.

So, based on our previous analysis, we have to emphasize the following:

The art of science, of making assumptions for hypothesis, follows and is dependent on the art of goal-setting, which in turn depends on the art of providing the material base to pursue all that.

Finally, we want to suggest at that point, that we think it would be important to always make explicit the core determinants of system design: And these are the goal-values, towards which the whole process should run, and the assumptions made and the options considered to realize them. All that is seldom made explicit. But it would be an act of intellectual honesty to let others explicitly and completely know these determinants, to explain and justify the own approach and to open its base for critical and scientific questioning.

Anyway, these implicit assumptions, which determine the next step, the selection of elements and relations, form a *decision bias* of the system designer.

8.1.2. Selecting Elements and Relations

Now, based on his or her intuitive assumptions the system designer has to decide what to include in the system and what to leave out.

These decisions determine directly which elements and relations should make up the system. At the same time they determine the internal structure of the system, and its limits.

In the simplest case these decisions make up a linear process leading directly to a layout, or it might be a parallel process leading to parts and/or subsystems, which are put together later on (as was investigated by Klir, 1985). This adds to the complexity of the sequence, but does add not any new aspects; it is always a repetition of the goal-orientated decision process. Therefore, for our purposes we need not consider these more complex processes.

8.1.3. Intermediate Evaluation

Once certain elements and relations have been selected, sooner or later an evaluation process has to be carried out. Here the question has to be clarified, if the system designer is on the right track, i.e., if his or her design fulfills the specifically demanded criteria of ‘better’, which come with setting the goal-value (as discussed in section 6.3.).

Now, to determine if any current development of the system design fulfills this criterion of being ‘better’, the current state of the design can be compared either to the problem state, or to the goal-value.

It is at that point that the system designer needs the evaluative function we talked about in section 7.3., which has to be at least a step function to evaluate, if different intermediate designs actually move away from the problem state and towards the goal-state. Here that solution will be accepted, which comes in ‘best’ in this evaluation, i.e., leads farthest away from the problem state, or closest to the goal-state.

This evaluation is a widely objective and rational process, particularly if measurements based on empirical data or at least empirical observations can be applied, i.e., if we can use the criteria for ‘truth’ of Leibnitzian or Kantian inquiry systems according to Churchman (1971); for other inquiry systems that evaluation remains vague.

But, we have to emphasize again, even than the objectivity and rationality of these measurements depends on the acceptance of the goal-value for the whole design, as something that is better (as discussed in section 6 above). This applies, of course, too, to the decisive evaluation process, when a final decision is made, if an element, a relation, a part, or subsystem can sufficiently serve that goal and should enter into the design or not.

If these tests fail, we have to move up again (as indicated in the introduction to section 8.1. above), and have to search for other elements and relations (as discussed in 8.1.2.), or, if this repeatedly fails, too, we have to make different assumptions (as discussed in 8.1.1.). If all that repeatedly fails, we have to question the preliminary knowledge of the system designer, and make him or her research for further preliminary knowledge. Or we might fire him or her and engage another one. An interesting and open question is here, how much failures have to occur so that we speak of ‘repeated’ failure. Material constraints may play a role in determining that.

Anyway, to whatever level we have to move up at that point, we have to move down to testing any new trials again.

Let us emphasize that this evaluation of elements, relations, parts or subsystems, or even complete system designs does not define the end of the design project. We address that next.

8.2. From a Complete Design to the Final Design or When Is a System Design 'Good Enough'?

During the evaluation processes applied to the selected elements, relations, parts, and subsystem, we continuously ask, if they promise a system that is 'better' than the problem state. So we get finally to the point when we have a first complete system design fulfilling that criterion.

Now we have to make a *different evaluation*, not only asking if it is really 'better' than the problem state, but if it is '*good enough*'. Here the first question delivers just the information that the system design is on the right track. But the second question, which is less clear but more important, has to deliver the information, if the system design was successful and can be accepted, or if the work must be continued till delivering something really 'good enough'.

And the first question can probably be objectively answered by anyone with sufficient preliminary knowledge. Yet the second question can only be answered by that person, which had set the goal-values for the system design, i.e., in our approach either the system designer, if acting alone, or the client. Only that person can decide, if his or her expectations are fulfilled or not.

Now the decision, if the system design is 'good enough' may be restricted by material constraints, e.g., if further improvement simply cannot be paid; then the person setting the goal-values would have to accept whatever he or she got (we are not interested here in processes like suing to get the material input back).

Otherwise the decision on the acceptance of a system design is the expression of the *satisfaction* of the person setting the goal-values with what has been achieved. This is a freely and individually determinable decision criterion.

Let us explicitly point out that we discuss her two different criteria, and that that even applies to empirical scientific work. Let us detail that:

The criterion to evaluate a scientific theory is the correspondence of theoretically predicted data and empirical data. To determine the correspondence we use statistical methods, mostly regression analysis and calculation of a regression coefficient (which may lie between 0 and 1); here one theory (a form of system design) delivering a higher regression coefficient (closer to 1), means that it is 'better', than another theory delivering a lower value. But this does not touch the question, if we consider any of these theories as 'good enough'. For that we have to deliberately choose a '*level of significance*', which says, which kind of correspondence we want to achieve. In the natural sciences most often a 'level of significance' of 0,95 is demanded, while anything below 0,9 is usually seen as no correspondence. In social sciences even a 'level of significance' of 0,6 may be seen as a good result. Anyway, the point is that, *if a scientific theory is considered as 'good enough' depends on the previous decision for a goal-value for a 'level of significance'*. Let us emphasize that in this context ‘good enough’ is equal to the notion ‘true’. So if we demand a higher ‘level of significance’ we may have to reject some theory and may get a *different* ‘scientific truth’.

So, while the decision what is ‘better’ is rational in regard to the goal-value for the system design, the decision of what is ‘good enough’ results from the individual view of the person setting the goals. In terms of Churchman’s inquiry systems the question what is ‘better’ is mostly part of a Lockean or Kantian system, dealing with facts, while the second one, what is ‘good enough’ is part of a Leibnizian system: here a necessary, but arbitrarily determined, *a priori* set individual demand determines what will be accepted.

We cannot overemphasize that point:

1. First a widely *objective* criterion is determined, how far a system design is ‘better’ than a problem state, i.e., in which properties it is closer to the goal-state; this is objectively ‘rational’ in relation to the goal-values set for the whole design.
2. And then a purely *subjective* decision criterion is applied, reflecting if that system design can be considered as ‘good enough’, i.e., if its properties are that close to the goal-state that it is acceptable for the person setting the goal-value. This second criterion depends only on the individual desires and preferences of the goal-setter; it is only subjectively justifiable in relation to these individual desires and preferences.

Based on that, we want to express again our doubts, that *any* system design could be considered as value-free. We found that already goal-setting is an individual and value-loaded process; now we find that ending and accepting a design is an even more individual evaluation act. This is another goal-setter bias: the *acceptance criteria*.

8.3. A Byproduct: An Increase in the Preliminary Knowledge of the System Designer

No matter, how good the result was, which was achieved with a first complete system design, one thing already increased: And that is the preliminary knowledge of the system designer, with which he or she can start the next time.

Now, at least, he or she does know, what does not work. Given that, he or she has a more accurate base for his or her intuition enabling to make better assumptions next time. The amount of this increase depends on the issue of the project, and if it is in the realm of additive or cumulative knowledge (as distinguished in section 7.2.).

8.4. Redesigning a System

Finally, let us briefly address the case that the system design was not ‘good enough’.

Then, given a sufficient material base to proceed, of course, a redesign has to start. Then the system designer has to move up again, on the scale discussed in sections 8.1. and 8.1.3. So, he or she has to reconsider selected elements, relations, parts and/or subsystems. Here using a design with parts or subsystems can strongly ease a redesign, if changing and improving of one can be done without having to change any other. If that does not work, again, assumptions and eventually the sufficiency of the preliminary knowledge have to be questioned.

Anyway, after moving up, the whole steps discussed in sections 8.1. and 8.2. have to be carried out top - down again.

8.5. Summary of the Core Design Process

In sum the core of system design is an approximating process leading from assumptions towards a final system design. This process is guided by permanent reference to the goal-values for the design. Here the following aspects are particularly important:

- The preliminary knowledge, creativity and intuition of the system designer determine the scope, number and selection of assumptions, which guide the design process.
- These assumptions determine what exactly is considered as the problem and as the characteristics of the goal-state;
- And these assumptions lead to the selection of elements and relations, parts, etc., which are included in the design and elaborated.
- These elements and relations, parts, etc., have to be tested and evaluated, if they contribute to a design that is ‘better’ than the problem state; if not they have to be reworked or exchanged.
- Once a complete system design is available, it has to be tested, if it is ‘good enough’, i.e., if it meets the individual criteria of the person setting the goal-values, and therefore can be accepted.
- During the whole process, the system designer subordinates all activities to the question, if they might lead towards the goal, or not. So the presumed ‘rationality’ of this process depends completely on the acceptance of the goal and the implicitly included ethical, moral and political valuations (see section 6.3. above).

As practical implications of this section we suggest that the first questions when considering a core system design process should always be:

- What assumptions have been made and what options have been considered?
- What were the criteria to consider the system design as 'good enough'?

9. Putting a System Design in a Wider Context

In section 8 we discussed the core process of system design, running from a given goal-value to a final design considered as 'good enough'. There we focused on the work of a system designer, working either for him- or herself, or for a client, or eventually for an employer. So, till now we focused on activities of the core actors, as defined in section 3.

Now we assume that we got a system design that is considered as 'good enough' by these core actors. And we ask, what may happen, if these core actors have to introduce their design into a larger context. This may mean to publish a theoretical concept, to realize a technical system, or to intervene in an organization, etc. Anyway, here the system design enters in one of the contexts, which we identified in section 1.6., following Jackson (2003).

So, we have to consider now what can happen, if the system design has to face a public, while being forwarded from one of the different possible positions, and what that means for the chances to be still considered as 'good enough'. Additionally we will consider Churchman's (1971) different criteria for 'truth' (see section 1.5.), where appropriate:

(1) The core actors may belong to the coercive parties (following Jackson, 2003; see section 1.6.).

Then they dominate other parities in the context and will have an easy play to forward their design, whatever its content.

In case there is disagreement between the coercive parties point (3) below does apply.

(2) The core actors may belong to the suppressed parties and are victims of coercion (following Jackson, 2003, section 1.6. above).

Here their chances to forward their design will depend on which of Churchman's criteria for 'truth' the design does fulfill:

- If it fits in the dominant ideology or paradigmatic position of the coercive parties and meets their criteria (i.e., fits the Lockean criteria of what the suppressors consider as 'truth'), there is a change that they may go ahead with their design.

- If it forwards evidence that might challenge the dominant ideology or paradigmatic position or derived criteria of the coercive parties (i.e., does not fit their Leibnitzian criteria of 'truth'), their chances are usually slim.

This is sort of a Bayesian aspect of system designs coming to the public: Anything coming up in opposition to dominant views is not only surprising, but must contain some remarkable aspect of (Leibnitzian) 'truth', i.e., point to facts that must be difficult to deny.

(3) The core actors and other parties may have different, but somehow compatible goal-values (following Jackson, 2003, section 1.6. above).

Here again Churchman's criteria may play a role:

- There is a good chance that an approximation and some compromise are possible.

  Then the parties arrive at a mutual definition of a Hegelian criterion of 'truth' and the result is probably a modified system design that acknowledges and takes care of the different interests.

- But it may turn out, too, that the differences cannot be overcome.

  This can be the case, e.g., if some (maybe coercive) parties see a challenge to their dominant ideology or paradigmatic position, while others see non; or, e.g., if a scientific community, united by an approximate overall consensus, faces a new theory challenging an established theory or paradigmatic position. Then a conflict may arise, if the new system design can be accepted or not. And at that point no agreed on, mutual decision criteria are available to settle the conflict. This is the case in times of "paradigm changes", as Kuhn (1970) called that.

  In Churchman's (1971) scheme this is a Kantian problem, where the question arises if new facts or previous assumptions should be the standard to evaluate future work. Unless the parties do not reach a new agreement (finding to a Hegelian definition of a new mutual 'truth') this question cannot be solved. Or, as Kuhn (1970, 94) put it:

  > "As in political revolutions, so in paradigm choice - there is no higher standard than the assent of the relevant community."

(4) The core actors and all concerned parties may share mutual goal-values.

Then, finally, a system design will be easily accepted.

These considerations are particularly important for the following reasons:

- There is an interrelation between the context and the kind of system designs, which can come to the surface in a society and can be realized.

Correspondence to the prevailing views, interests, and ideological and paradigmatic positions within a society (i.e., to the Lockean criteria of what is generally accepted as 'truth') will ease the acceptance of a system design.

- The previous point together with the fact that system design can only be carried by those who can afford it (see section 5), suggests that system designs, which are easily accepted within a society, will probably show a correspondence with the interests of the wealthy, as well as with the prevailing views, ideological and paradigmatic positions within the society.
- Realized or published system designs, which were accepted at one point in time, form the pool of exemplary, easily available and accessible solutions in a certain context. These solutions will be used in education and in the development of the preliminary knowledge of future goal-setters and system designers.
- So there may be a reinforcing effect, since the previous acceptance of system designs influences what kind of preliminary knowledge a system designer will develop in that context. And this in turn influences what forms of system designs become possible in future.
- So, the carrying out of system designs mainly depends (1) on a goal-setter providing material wealth, and (2) on the preliminary knowledge of system designers; then (3) the reception and acceptance of system designs depends widely on the correspondence with prevailing interests, views, and ideological and paradigmatic positions; and (4) future knowledge of systems designers depends partly on such accepted system designs.

Together these points mean:

We should rather expect a reinforcement of the correspondence of interests of wealthy persons, existing knowledge, and dominating interest and prevailing views in the society than a questioning of them all.

In sum, in the context, where a system design is applied, the core actors will face parties with own views, interests, and ideological positions. These will introduce another bias, i.e., the *bias of context-specific prevailing paradigms*. If the core actors face suppressors that will take a particularly severe form, namely *bias of the paradigms of the suppressors*. Anyway, the intentions pursued with the system design may be in accordance or in opposition to these biases; and that will influence the chances of acceptance.

As practical implications of this section we suggest to ask the following prime questions, when considering the reception and the evaluation of a system design in a certain context:

- What is the position of the core actors in relation to other parties in the context of the system design (coercive, suppressed, indifferent, or united)?

- What are the prevailing interests, views, and ideological and paradigmatic positions, which are relevant to evaluate a system design?
- Is the system design in accordance with or deviating from prevailing views, interests, and ideological and paradigmatic positions in the context or society?

10. SUMMARY AND CONCLUSION

In this paper we suggested to take a wider look at system design than usual. We did not just consider the core process running from a set goal to a final design.

Instead, we looked at a wider context including core actors, which set the goal-values for a system design, provide the material means and carry it out. And particularly we asked which influence these core actors can have on the design process, and at which point their influence and their decisions become decisive for the final design. Furthermore, we asked which role other parties, which may be concerned about the results, might play in the acceptance or rejection of a design.

From this analysis, we suggest that system design is the result of the interplay of the following factors. And, returning to our quotation of Churchman (1979) at the beginning of this paper, we suggest that these factors introduce different biases influencing system design:

- A given context influences what can easily become the preliminary knowledge of goal-setters (*Bias 1: Educational/environmental/cultural standards of the goal-setter*; see section 7.2.).
- An available material base limits which goal-values for system design can be pursued (*Bias 2: Material constraints*; section 5.1.).
- Usually the provider of the material base has the right to set the goal-values for system design (*Bias 3a: Goal-setter bias I - explicit objectives*; section 6.2.).

  The goal-values for a certain system design come with implicitly contained material, ethical, moral and political valuations (*Bias 3b: Goal-setter bias II - implicit value system*; section 6.3.), which come from the fact that pursuing one goal excludes alternative design projects.

  Only if the system designer can provide the material base, then goal-setting and design process are in the same hands.

  Otherwise a client, providing the material base and setting the goal-values, has to engage a system designer (*Occasional bias 3c: Designer interests*; section 6.2.). Here an employer (*Occasional bias 3d: Employer interests*; section 6.2.) of a system designer may play an intermediate role.

- When goal-values are explicitly accepted, the core design process can start:

  Then the actual preliminary knowledge, the creativity and the intuition of the system designer (*Bias 4: Educational/environmental/cultural knowledge of the designer*; section 7.3.) determine what can be achieved in the design process. Together they lead to assumptions (*Bias 5: Designer decisions*; section 8.1.1.), which possible designs might work best and should be elaborated and tested.
- Tests determine first, if possible designs actually are ‘better’ than the problem states and lead towards the goal-values. These evaluations use rather objective criteria.
- Final tests of a complete design determine, if it is ‘good enough’ to meet the goals, and if the core design process can be finished. These decisions use subjective criteria determined by the person setting the goal-values (*Bias 6: Goal-setter bias III - acceptance criteria*; section 8.2.).
- So, the whole core design process is subordinated to the goal-values and the acceptance criteria of the person setting the goal-values.

  It is ‘rational’ only in relation to the achievement of these goal-values; it does not ask, if it is ‘rational’ to pursue these goals at all, seen from any other point of view.

  And the design process is not value-free because it accepts the implicit material, ethical, moral and political valuations coming with the goal-value, and because the final acceptance criteria, when the design is considered ‘good enough’, are purely subjective.
- The larger context determines how a system design is received.

  Here it is decisive, if the system design is in accordance with prevailing interests, views, and ideological and paradigmatic positions (*Bias 7a: Context-specific prevailing paradigms*; section 9), or is deviating from, or even in opposition to these views.

  In this larger context the position of the core actors (system designer, client and/or employer) has a modifying effect: If they are coercive parties they will meet little resistance; if they belong to suppressed parties and forward opposing views they will face more difficulties (*Occasional bias 7b: Paradigms of suppressors*; section 9); if there are diverging, but somehow compatible views of concerned parties the result is open; and only if there are uniform views there will be no difficulties.

These factors and the related biases 1 to 7 are always at work: Bias 3a (goal-setting for the system) is the most obvious, while the others go widely unnoticed. Only when bias 7b eventually shows (paradigms of suppressors), it is often criticized from persons outside a society holding a different ideological position. Yet these factors and biases seem to influence strongly, which system designs can surface within a society, i.e., will be pursued, elaborated and accepted:

- Prevailing interests, views, and ideological and paradigmatic positions (bias 7a/7b) will not only strongly influence what system designs can be realized in a society, and so can become a model solution available to future systems designers; they determine, too, what is generally taught in education, too (bias 1). So, the final point of the list above leads us back to the first one.
- Furthermore system designs that are in opposition to the interests of wealthy persons as well as to dominating interests and prevailing paradigms seem less likely to emerge, because they lack an educational base (bias 1), will get less material support (bias 2) and will meet more resistance (bias 7a/7b).
- And, turning the previous point upside down seems to suggest the fast track to a 'career': Alignment to educational standards (bias 1), to the interests of the wealthy (bias 2), and to dominating interest and prevailing paradigms (bias 7a/7b) will open material sources and reduce resistance.

In sum, we should rather expect a reinforcement of the correspondence of interests of wealthy persons, existing knowledge, and dominating interests and prevailing views in the society, than a questioning of them all.

We suggested a number of practical questions, which might be useful to get quickly to these core aspects of system design and the related biases. Ideally we should demand that answers should be published with any systems design, clarifying at least the most important questions (The goal-values of the system; For whom and why should that be 'better'; Who paid for it; What are core assumptions, and what alternative options have been considered/rejected; What were the acceptance criteria for 'good enough'). But, anyway, applying these questions personally and trying to get the answers to them may help to get an impression of the biases at work in any system design.

So, in our analysis we tried to consider system design in a very general way and in a wider context than usual, to show factors and biases which strongly influence it, even if they do not directly show in the core design process. Proceeding that way we left out many details, which were a concern of those authors, whose approaches we surveyed in the introduction. Yet we strongly suggest that the biases coming with the larger context we analyzed here may have a greater influence on system design, than many of these details.

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