ProHEAL Basics – Extended Version

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1 ProHEAL – the Background

In order to understand the theoretical approaches of the *Programme for Working out Invention Tasks and Solution Approaches* (ProHEAL)[1] as a GDR-specific TRIZ version, the specific economic conditions of the GDR in the 1980s must be taken into account. After an upswing of innovation-theoretical as well as innovation-practical approaches, especially in the context of the boom in cybernetics and measurement and control technology in the 1960s and early 1970s, innovation-technical aspects moved to the background after 1974 in favour of a "unity of economic and social policy".

This undermining of industrial innovative strength showed its effects in the 1980s with a marked decline in the international competitiveness of GDR products, especially in the high-tech sector, and resulted in massive import-export imbalances. Such initially economic contradictions could only be solved through more far-reaching technological changes, whereby the focus was not so much on the classic TRIZ issue of patent circumvention, but rather on import replacements, which became necessary both for reasons of valuta balances and as a result of increased embargoes.

Such replacement processes do not only intervene deeply in technological processes, but also require precise knowledge about the existence and concrete access conditions to required resources, which could hardly be maintained in a centralised and centrally managed planning process. This need for agile management significantly upgraded the position of power of local "captains of industry" (the directors of the combinates) compared to the previously dominant party-controlled central planning bureaucracy and ultimately led to a shift in the power balance in GDR society, as explained in more detail in [4].

In the combinates, it was mainly the R&D directors with an engineering background, who supported and promoted the use of such approaches. Many of them became already familiar with systematic innovation methodologies during their own graduation [13]. The need for *practical* training in innovation methodology led to the boom of the GDR inventor schools in the 1980s as places for in-house and inter-company innovation-methodological training. During these trainings special problems from within the companies formed the backbone of the trainings, see [20, part 1, ch. 3], and the power of Altshuller's TRIZ methodology had to prove themselves again and again in such practical contexts.

There were only loose connections between the inventor schools of the individual combinates, and the interest of most participants was limited to the experienced methodological support

[1] In German: Programm zum Herausarbeiten von Erfindungsaufgaben und Lösungsansätzen.

in solving their own intra-company problems. An overarching connection existed at the level of the lead trainers, among whom Michael Herrlich, Hans-Jochen Rindfleisch, Hansjürgen Linde, Rainer Thiel and Dietmar Zobel (in alphabetical order) are particularly worthy of mention. This group has also been instrumental in generalising, systematising and publishing the experience gained. Two dissertations [14, 11] and various training and other materials [8, 9, 10, 12, 18, 21, 22, 23, 24] were produced in this context.

After the fall of the Berlin Wall, only Hansjürgen Linde and Dietmar Zobel were able to continue working on invention methods in practice. Linde first worked at BMW in Munich and later as a professor at the Coburg University of Applied Sciences. The *Contradiction-Oriented Innovation Strategy* (WOIS)[2] developed in his dissertation [14] is an alternative generalisation of the experiences of the GDR inventor schools, which was published in book form in [15] and is now being further developed by the WOIS Institute in Coburg. Since the methodology and algorithmic approaches are protected by trademark and copyright, we will not go into further detail here, especially since WOIS and ProHEAL come to similar conclusions. We therefore limit ourselves to a more detailed description of ProHEAL. Within the framework of the WUMM project, various materials from that heritage have been compiled in digital form and are publicly available[3] under an Open Source Licence.

Dietmar Zobel plays a special role in this context as a chemical technologist. TRIZ as a whole and also the ProHEAL approaches mainly generalise experiences from mechanical engineering with its emphasis on *artefactual*, *structural* and *functional* moments. In contrast, in chemical technology (and a number of other technology areas little studied by TRIZ), *processual* moments with flows, flow characteristics and dynamic flow equilibria play a more important role, for which only a few elaborated TRIZ tools are available. Zobel – author of more than 30 patents really applied in industry – worked during GDR times as production director at the Piesteritz nitrogen company. After 1990, he founded an engineering office for systems technology and worked as an independent expert, consultant, TRIZ trainer and lecturer for systematic invention. His experience is available in a series of publications [27, 28, 29, 30, 31, 32], with many subsequent editions, which, however, have hardly found any attention beyond a German-speaking community. This, too, cannot be discussed in detail here, see [5, 6, 25].

2 ProHEAL Basics – a Short Overview

This paper elaborates on a number of ProHEAL aspects that could only be touched upon cursorily in [7]. In this section, a brief summary of the interrelationships presented in [7] is given.

2.1 The ProHEAL Path Model

ProHEAL, like TRIZ in general, is based on a *three-level model* of resolution of conflicting requirement situations, which provides for an increased focusing and deepening of the analysis, see the diagram [7, Appendix 1]. The procedure is schematically described in a *decision tree* [7, Appendix 3], which leads in each case to a *Draft Specification*, which in the context of

[2] In German: Widerspruchs-orientierte Innovations-Strategien.

[3] See `GDR-InventorSchools`.

further processing is either to be developed into a solution suitable for production or into a "thought product" as the result of a more comprehensive thinking activity (in the sense of Shchedrovitsky), which further qualifies the planning process.

On the *first level*, the technical-economic problem situation stands as a technical-economic operational field between societal needs as potential requirements and the technical state of the art as the field of possible ways to implement these requirements. The result is a *basic variant* that roughly outlines such a possible realisation. If a problem solution is *feasible* at the state of the art it only has to be detailed and realised.

If this fails due to technical-economic (external) contradictions, this basic variant must be analysed in more detail on the *second level*. The critical functional area within the basic variant is identified as the *core variant* and there the functional IDEAL is contrasted with the harmful technical effects. If a problem solution is *conceivable*, it must be worked out in more detail and then returned to the first level with the correspondingly transformed basic variant.

If this fails due to technical-technological (internal) contradictions, the process-critical operational principle in the core variant must be identified on the *third level* and there the operational IDEAL of the natural law must be contrasted with its harmful effects. If a problem solution is *imaginable*, it must be worked out in more detail and then returned to the second level with a correspondingly transformed core variant.

If this fails due to profound technical-scientific (internal) contradictions, the entire principle of the basic variant is called into question and a fundamental, disruptive innovation is required, which cannot be realised within a delimitable innovation project, but requires fundamental research, which is not further addressed by ProHEAL. If such new research results are available, this *new operational principle* can be used to return to the third level.

2.2 The ABER Matrices

One of the most proven TRIZ approaches for identifying conflicting demand situations in given models and partial models is parameter variation. Contradictions arise where the variation of one parameter in a desired way is associated with the variation of another parameter in an undesired direction. Such contradictions become particularly apparent when parameters are varied far beyond ranges of normal operation.

In this context parameters are usually divided into independent and dependent ones, whereby in TRIZ and also in ProHEAL a *single* independent leading parameter, the *guiding variable* (ProHEAL) or the *main parameter of value* MPV (TRIZ), is assumed to control the behaviour of the system in a particular way with respect to its (externally conditioned) purpose. Parameter groups and generalised contradictions are examined more systematically only in the TRIZ variant where action parameters and evaluation parameters are distinguished.

The probably most interesting ProHEAL-specific TRIZ tool are the ABER matrices for the detection and analysis of such contradictory situations. With the same (or comparable, see below) row labels, the ABER matrices on the three levels of the path model differ in the column headings. Originally, the approach had three rows – Requirements (German: **A**nforderungen), Conditions (German: **B**edingungen) and Restrictions (German: **R**estriktionen) – covering the "hard" part of the external conditions. The fourth row label **E** stands for rather soft external factors and differs slightly on the three levels (expectations (German: **E**rwartungen) on the technical-economic level, experiences (German: **E**rfahrungen) on the technical-technological level, and findings (German: **E**rkenntnisse) on the technical-scientific level). The column headings reflect the most important analytical dimensions on the respective level, the matrix entries are filled according to a level-specific process model, as discussed in more detail in [7].

Each field of the matrix filled in this way contains one or more target variables with expected variation behaviour. Variation of the guiding variable leads to variations of the target variables and thus allows to identify contradictory tendencies between the different parts and analytical dimensions in this multi-dimensional field of the evaluation figure. Here, too, the target conflicts become particularly clear through powerful parameter variations.

Below we reproduce an English translation of an example from [26, p. 62] of an ABER matrix on the technical-economic level concerning the development of transport means.

	Functionality	Profitablity	Controllability	Usefulness
A: Requirements	(A.1)	(A.2)	(A.3)	(A.4)
B: Conditions	(B.1)	(B.2)	(B.3)	(B.4)
E: Expectations	(E.1)	(E.2)	(E.3)	(E.4)
R: Restrictions	(R.1)	(R.2)	(R.3)	(R.4)

(A.1) Performance and fitness to drive up to a driving speed of x km/h
(A.2) 1. Fuel saving
2. Utilises heat of exhaust gas
(A.3) 1. Easy to operate, wearing parts easily accessible
2. Replacement parts available on board (or can be carried)
(A.4) 1. Adaptable to local traffic conditions
2. Can be used as truck unit, delivery van and touring van
(B.1) 1. Approved for road transport
2. Can be used as traction unit
(B.2) 1. Service-friendly
2. Well suited fo load transport
(B.3) 1. Temporarily overloadable to x times of the normal load
2. Good driving behaviour (undelayed), follows steering immediately
(B.4) 1. Insensitive to stone impact
2. Heat repellent
3. Temperature regulating
4. Humidity balancing
(E.1) 1. High acceleration capacity
2. Delay-free acceleration
(E.2) 1. High transport yield
2. Low cost
(E.3) 1. Automatically compensates skidding movements
2. Self-adjusting to changing road conditions
3. Self-monitoring
(E.4) 1. Independent of service stations
2. Insensitive to low temperatures (e.g. when starting)

(R.1) 1. Traction and braking system keep the track
2. Lighting and signalling system in conformity with traffic regulations

(R.2) 1. Robust and low demand in terms of maintenance
2. Frugal in terms of fuel quality

(R.3) 1. Traffic-safe
2. Vibration resistant
3. Shock and impact resistant
4. Theft-proof

(R.4) 1. Compatible with emission standards
2. Corrosion resistant to de-icing salt
3. Suited for inner-city traffic

2.3 The Refinement of the Problem Field Levels

In contrast to other TRIZ versions, in its first phase – the modelling of the technical-economic requirements – ProHEAL discusses also in more detail methodical aspects for the 80% of solutions that can be obtained on the current state of the art solely by tayloring or optimising known approaches. The ProHEAL methodology can thus be applied more broadly, because at the beginning and in an early phase of the analysis of the technical-economic requirements, it is not yet clear whether we will encounter obstacles in the solution process that require strong inventive thinking.

On the other hand, even in solutions that are ultimately obtained through adaptation or optimisation, certain inventive moments arise, especially concerning processual aspects, whose systematic treatment is advantageous.

Finally, the solution of a "hard" inventive problem does not start from scratch, but draws on the experience of the (finally unsuccessful) modelling of the concrete problem that precedes the insight that it is a "hard" inventive problem.

It is therefore only logical to detail this first phase in more systematic-methodological parts as well. In [19, Part A], see also [26, Part 3], ten complexes of a advancing analysis are distinguished for this purpose:

A.1. The social need. Preliminary system designation.
A.2. State of the art. Preliminary selection and system analysis of a starting variant. The variation of the system parameters according to the needs.
A.3. The operational field of the inventor.
A.4. The technical-economic contradiction.
A.5. The harmful technical effect.
A.6. The IDEAL. Starting point and orientation for a deeper system analysis.
A.7. The technical-technological contradiction.
A.8. The technical-scientific contradiction.
A.9. The strategy for the solution of a contradiction.
A.10. Own invention as a pacemaker in the international development of the state of the art.

The first four complexes belong to this first phase. The role of a reference and basic variant of a possible solution in this part is outlined below.

3 ProHEAL – Some Explanatory Notes

3.1 ProHEAL – a Tool for the Engineer and Inventor

The ABER matrix provides the open-minded observer with many suggestions. Varying parameters in one or several matrix fields he probably searched for and perhaps found inventive solutions. The open-minded observer based his considerations on the so-called *basic variant*. But soon the open-minded observer can also encounter obstacles and reach limits that prevent him from advancing. Then the situation gets difficult.

The attempts to improve (increase) common parameter values of technical objects lead mostly to a situation in which the engineer has to pause and ask: "Yes, but what shouldn't happen?" That is a question of undesirable consequences. One objective of inventions is to discover the most accurate knowledge of all possible "Yes, but ...". The goal is to find for every "Yes, but ..." not an "Either ... or", but an "As well ... as". The observing engineer feels now caught in a vicious circle. The "Yes, but ..." signals that there is a dialectical contradiction: Two tendencies are opposed to each other – battle of opposites – each tendency inevitably produces the other, often several others as well. The ABER matrix helps to perceive and understand what is happening. This is the starting point to determine the entries in the ABER matrix. What the observer refers to from the very beginning are the societal needs, the manufacturer needs, the user needs. A concrete objective must be derived from this. If no solution has been found for the contradiction after the first attempts, further questions about the basic variant must be asked and answered. ProHEAL shows the way to a solution.

The *mandatory evaluation figure*[4] (either completely specified or completed by the responsible engineer) is characterised in [26, (1.3)] (of ProHEAL) as expression of the identified system of ABER entries. The technical-economic parameters are to be derived from it. That some or many of them should be improving a lot (but none should deteriorate) is initially just a request or wish. They are rooted in the network of technical-technological or technical-scientific properties of the basic variant and are interlinked by these properties. From these connections in the system of the ABER entries inevitably result the "Yes, but ...", which are to be inventively transformed – through changes in the basic variant – in "as well as". This inevitability is the core difficulty of a purposeful, effective invention.

The "Yes, but ..." become all the more delicate and acute,

- the more the effectiveness E is to be increased, because then limits of improvements based only on optimisation of the technical object are reached or have to be crossed;
- the more consistently the evaluation figure – the ABER system – is respected in its complexity so that improvements regarding some parameters no longer can be achieved by "cheap" approaches at the expense of deterioration in other parameters that can improperly be ignored.

In the technical-economic development, such contradictions can be ignored for a while. This is possible,

- if they are not serious in terms of their importance, because the contradictory parameters are not so important in the overall system; in other words, if the complex target

[4] German: "Zielgröße".

(the system of ABER entries) allows for a distinction between fundamental and less important parameters;
- if the contradiction is in the initial stage of development, where improvements of the parameters affect each other in a not yet excluding way. In this initial stage, a compromise solution can be found by optimisation based on the state of the art which leads to a sufficient increase of value for each of the two parameters.

The invention method must now evoke awareness,

- how the technical-economic contradiction to be resolved is determined by analyzing the technical object – more precisely: the basic variant. Which relationships in the technical object are "responsible" for the conflict situation in the system of ABER entries? These primary, often complex relationships are usually not easily to be disentangled. More about the analysis up to the determination of the technical-economic contradiction see [26, A.1–A.4].
- how to find the point or secondary context hidden deeper in the technical object, in its structure where parameters can be changed in such a way that the primary context, on which the technical-economic contradiction is based, can be rendered harmless. This leads to the question about the technical-technological and possibly technical-scientific contradiction that must be uncovered when the technical-economic contradiction should be dissolved. See [26, A.5–A.9].

3.2 The Basic Structure of ProHEAL

At the beginning the *guiding variable* has to be defined. It is a system-specific parameter of central importance, the variation of which influences the development of the performance and/or the effectiveness of a technical system. In different words: Such influence is – mostly based on many years of experience – expected as a result of the variation of the guiding variable. The guiding variable can be, for example: the unit of performance of a large transformer or a large generator, the number of integrated circuits of a microprocessor, the load level of a transport system, the starting torque of an electrical motor (based on its nominal torque), the clock speed of a machine tool, the equilibrium concentration of a chemical process, the specific number of separation stages of an extraction process. More on the notion of huiding variable in [26, (2.3.4)].

A *technical-economic contradiction* (TEC) arises if in the variation of a technical parameter that is decisive for the achievement of this higher economic effect – the guiding variable (GV) – at least two important technical-economic parameters E_1 and E_2 of the technical object behave mutually opposite.

For example, consider the development of a container. As GV we choose the thickness of the wall of the container in relation to its edge length. Reducing the thickness of the wall two essential technical-economic action parameters of the container are favourably influenced: the specific use of material, related to the container volume, and the payload ratio, i.e. the ratio of loadable mass to the self mass of the container. We can therefore combine both parameters to the technical-economic action parameter E_1. The opposing technical-economic action parameter E_2 is the specific load capacity of the container, i.e. the loadable load in relation to the load level of the transport system in question. The latter becomes to low when the container wall thickness falls below a certain limit thus outweighing by far the economic advantages of material savings and the low weight of the container. In addition, slimming the wall thickness makes the container more susceptible to corrosion and mechanical damage. A further reduction in the specific wall thickness under a characteristic statistical limit value thus gives rise to a critical technical-economic contradiction.

A *technical-technological contradiction* (TTC) is given when during variation of the technical parameter that primarily determines the expression of the functional technical effect – the *structural value* (SV) – at least two decisive technical-technological action parameters T_1 and T_2 of the technical object become opposite to each other in their behavior.

In the example of the container with regard to overcoming the technical-economic contradiction we initially consider the container function as SV. A functional technical effect is decisively influenced by it, namely the distribution of the load forces and the type of their effect (in the form of compression, tension, shear and/or bending stresses) in relation to the local strength distribution in the wall of the container. One of the essential effectiveness parameters of the container is based on this technical effect, its specific, i.e. related to its volume load capacity T_1. By suitably shaping the container wall the technical effect can be brought into effect in such a way that material savings and higher payload ratio no longer are in a technical-economic contradiction with the specific load capacity of the container.

If this does not succeed, we are faced with a TTC. It arises due to the fact that with the container shape as SV not only the load-bearing capacity is significantly determined, but also the specific usable volume, i.e. the portion of the volume of the cargo container that can be filled and its accessibility, i.e. the way of loading and unloading the container. We can combine these properties to a technical-technological effectiveness parameter T_2. The technical-technological contradiction can consist in the fact that a container shape is required to achieve a higher load-bearing capacity, that leads to a lower specific usable volume and/or less favorable way of loading or unloading the container. This is the case, for example, when the container bottom should be given a curved shape to increase the load-bearing capacity and thereby the usable container height (when transporting bulky goods) or its unloadability (when transporting loose material) is inadmissibly impaired.

A *technical-scientific contradiction* (TSC) exists if, in the variation of a technical-scientific parameter that is decisive for the occurrence of a scientific effect, i.e. the *impact value* (IV), at least two technical-scientific effectiveness parameters S_1 and S_2 of the technical object take values in opposite directions.

Concerning the solution of the TTC in the case of the container we can, at least locally, consider the elasticity of the material of the container wall as IV. The impact of the natural law bound to this quantity is the elastic deformation of the container wall. This impact causes two essential technical-scientific effectiveness parameters to go in opposite directions:

- on the one hand, the adaptability of the shape of the container to the shape of the cargo and the adaptability of its strength distribution to the distribution of the specific load (S_1), but also
- on the other hand, the stability of the form of the container (S_2).

Both effectiveness parameters will not contradict each other if the elasticity is appropriately distributed in the container wall or if the shape durability does not play a decisive role or is even undesirable. The latter is for example the case with the waste container. That's why the garbage bag is made of extremely thin, highly elastic and biodegradable plastic film. Choosing the IV "elasticity" not only the TSC is solved, but also the TTC. At the same time the susceptibility to corrosion due to the extremely thin container wall is here even desirable because it results in rapid biodegradation of the container.

A TSC can be given, for example, if the negative influence of the selected impact value "elasticity" on the stability of the shape is evoked by vibrations of the container wall under dynamic loading, which lead to resonance phenomena and as a result to an impairment of the load and/or to premature destruction of the container wall.

3.3 Surprisingly Simple Solutions (SSS)

The SSS are solutions with a particularly favorable ratio of effort and benefit. In [26, (6.4),(9.3)] we pay particular attention to solutions whose verbal description contains word like "by itself", "self-movement", "self-fixation" etc. Already [26, (2.14)] contains a question aimed at such solutions: "Which secondary functions in the system are suitable, to make other side effects usable or to avoid harmful side effects or to transform them into useful ones?" Very often such a suitability is given. Then a solution or partial solution of the type "by itself" can already be formulated during the very beginng of the system analysis, in this case as self-compensation. Experience show that such simple and ideal solutions are ofteb out of the field of imagination. Therefore inventors rarely search for them.

Such solutions are characterised by the fact that their material realisation can be reached predominantly with already existing functional units and energy potentials, with little equipment effort and/or little operating energy. In that sense they are simple, elegant, ideal. The technical world is full of such solutions from ancient times on, which unfortunately we are carelessly passing because we are using them from very childhood on. A typical example is the ship's anchor, an extremely simple device with pointed shovels that "by itself" all the more dig deeper into the ocean floor the stronger the wind or the waves attack the ship. The fishhook behaves analogously in the fish's mouth.

A similar example is provided by Duncker's pendulum, which addresses the problem of accuracy of a pendulum clock under temperature changes. But even in physics classes in schools such SSS that can be found en masse throughout the centuries of history of technology are totally ignored. As a curious child I (R.T.) was surprised that the simple toilet cistern regulates the water supply automatically. So I asked my father, and because he was a craftsman, he explained it to me. Even G.S. Altshuller does not pay enough attention in his books to such surprisingly simple solutions. If you have never seen the opportunities, it becomes difficult.

4 The General Heuristic of the ProHEAL Path Model

The following section is essentially a translation of [26, ch. 5].

W.1. The Structure of the Path Model

The path model, see [7, Appendix 1], is displayed as a heuristic scheme. It shows how from the technical-economic requirements based on the necessary effectiveness and usage properties of technical objects, their structural and functional properties are derived and finally, they are abstracted to operational effects of technical-technological principles and how to advance – progressing from abstraction level to abstraction level – on the search for solution ideas further and further away from the own special domain to distant analogy areas. Already here inventions with a high economic benefit can arise.

W.2. The Social Need and the ABER

From the more or less vaguely formulated technical-economic problem situation as starting point – according to the heuristic path model – the social needs and the associated ABER are to be determined. It is indispensable to derive the causes for the emergence of the social need and the ABER contrasting it with the current available state of technology and its past development. In this course it is always necessary also to check whether the given task is oriented to overcome the causes or only to eliminate undesirable economic, social, technical or ecological effects. During such an analysis the main technical-technological problem to be solved can be delimited and a *reference variant* of the technical system can be determined that most closely matches the ABER.

Now in order to identify and weight the defects and shortcomings of the reference variant, to find the causes and to create an independent, "tailored" definition and solution of the specific problem, first the *evaluation figure* is determined within a conceptual process of product planning. Along that target, from the ideal state of the art a representative *basic variant* of the technical system is created, identifying through patent research and analysis of world-class solutions suitable technical means and combining them to form the overall system. As part of a system analysis the basic variant is compared to the reference variant to find weak points and defects that lead to TEC in their behavior which are inventively to be fixed. From the basic variant a solution is to be developed that has clear technological and economic advantages compared to the reference variant.

W.3. The Evaluation Figure and the State of the Art

The ABER are initially available in a verbal-descriptive form and express social, economic and technological issues that affect a certain social situation of needs and interests (see [26, A.1]). From this an evaluation figure is to be derived, which essentially expresses the usage properties of the technical system to be created and how its production and application does meet the social need in the best way. This is done assigning to the components of the evaluation figure the relevant ABER entries. This defines and evaluates concrete characteristics of suitability and effectiveness. On the one hand, these include the respective social, economic and/or technological specifics of the social need and on the other hand the objective specificity of the technical object or object area (see [26, (1.3)]).

These suitability and effectiveness characteristics must first be described qualitatively, before parameter values can be specified. A premature and uncritical commitment to functional or economic parameters that are familiar or mentioned in the problem description or even limiting oneself to them must be avoided.

In order to be able to define these parameters correctly, it is necessary to derive from the state of technology the most suitable *technical-technological principle* (TTP) for the technical object to be developed. That is a characteristic principle of manufacturing and/or applying technical objects in a specific technology domain. With this principle, a class of methods and means is delimited in the state of the art which represents the context for further processing of the problem. Thus the choice of the TTP has decisive importance for the further solution. It should be done in such a way that a TTP is preferred that fits the purpose of the technical object to be created (target component Z_1) in the best way and that does not conflict with the ABER or – in comparison to other principles – violates as less as possible A and E from the ABER system. For this, it should be considered first all procedures and means (see [7, Appendix 1])

- that are *available* on the material state of technology,
- that *appear feasible* based on the ideal state-of-the-art, and finally
- that *seem conceivable* on the given state of technological and that *seem imaginable* on the given state of scientific development.

If a TTP is prescribed with the problem setting, it has to be checked if it is feasible for the evaluation figure and should be compared with other known principles. If necessary, this must be discussed with the client.

On the basis of the TTP, basic variants of the technical system are designed using the *methods and means available from the state of the art.* This is done transforming the evaluation figure determined by the ABER in two stages:

In the *first transformation stage*, the types of technical objects are determined, which are *necessary* according to the TTP to ensure the suitability of the technical system with respect to the evaluation figure. To every object type now such utility properties are attributed, which on the one hand are typical for the respective object type and on the other hand correspond to special suitability characteristics of the evaluation figure. In doing so, it is appropriate first to determine the necessary contributions specific for that object type to the expediency of the system (component Z_1 of the evaluation figure). Then those functional properties are defined that are characteristic for the respective object type and that guarantee the suitability of the technical system with regard to its controllability and its usability. For a sufficient suitability of the technical system – especially with regard to its controllability – it can be necessary to take into account additional object types, that match specific suitability characteristics with their functional or operational properties.

In this way, the evaluation figure is transformed from a system of socially determined *suitability characteristics* into a system of object-related *usage properties.* This evaluation figure is the basis for a systematic patent research and world status analysis for the pre-selection of suitable technical objects, which in their combination according to the TTP are sufficiently suitable to form a technical system that meets the ABER.

In a *second transformation stage*, the *main function* of the technical system according to the TTP is defined. It can be assumed that the main function activates the usage properties of the individual objects and links them in the process of their use in such a way that the characteristics of the technical system responsible for its suitability according to the ABER are produced. This main function has to be broken down, related to the usage process, in its *necessary and sufficient subfunctions.* Here, a hierarchy level of the technical system is selected that on the one hand is as high as possible, on the other hand takes into account the formation of object types from the evaluation figure that was already completed.

To the individual sub-functions such objects are assigned, that are activated by the respective sub-function in the sense of the main function of the technical system. For each sub-function, those functional properties are defined that are caused by these technical objects, which means that they obtain the *character of specific technical means.* The sub-functions through which object-related usage properties are activated to support the suitability of the technical system concerning manageability and usability, are established in the same way, however as *necessary support functions.*

In this way, the evaluation figure is transformed from a *system of object-related usage properties* into a *system of process-related functional properties of technical means.* This evaluation figure is used for the appropriate selection of technical means from the set of relevant technical objects and their functional couplings to build up the basic variant of the technical system. Additionally, in this transformation stage the evaluation figure forms together with the non-transformed component Z_2 (profitability) the basis for the definition of the main technical-economic performance data of the technical system and for their quantitative determination in terms of a nominal figure.

The *system analysis* is based on this nominal figure. It is aimed at determining the effectiveness properties of the technical system in their combination, especially to uncover contradictory tendencies in their developmental behavior and to reveal the relevant technical causes in the context of a developmental weakness analysis. The function-related evaluation figure can already provide an initial indication of the critical functional area (critical system area). This is usually the area where the greatest number of sub-functions meet in a technical object.

W.4. The Basic Variant

The technical means selected from the available state of the art according to the evaluation figure are divided into *sub-systems in the form of separable structural units* based on their function. Each structural unit embodies one of the process-related sub-functions as part of the main function or a necessary support function that is responsible for control, protection and/or environmental compatibility of the system. With the functional combination of the technical means to sub-systems and the sub-systems to the overall system of the basic variant the ABER – the functional requirements (**A**nforderungen) and structural conditions (**B**edingungen) as well as the external influences (**E**inflüsse) and restrictions (**R**estriktionen) – have to be taken into account which describe influence of the individual technical means or subsystems on each other when combined to form the basic variant. To do this, for their coupling (by means of a morphological scheme) a *ranking* has to be defined according to the technical-technological importance of the subsystems in such a way that a subsystem or technical means of higher rank defines the ABER for the subsystems or technical means on the respective lower levels of hierarchy.

W.5. The Decisive Defect and the Core Variant

The basic variant developed according to the state of the art or the technical sciences usually still has decisive deficiencies. These deficiencies can be of technical-economic nature, arising from the fact that the utility and profitability properties could not be aligned with the evaluation figure, i.e. requirements and/or restrictions had to be neglected. The defects can also be of "heuristic" nature, e.g. if means are neither available nor feasible, but at most conceivable or even only imaginable.

A *technical-economic deficiency* is present if the technical means required according to the evaluation figure are principally available or known, but at least in a crucial usage property the required performance and/or effectiveness parameters are not achievable or only at the expense of other parameters relevant for usability.

A *heuristic deficiency* is present if for at least one of the usage properties required by the ABER no technical means are known which would be suitable according to their functional properties to produce the required means-effect relationships. To become aware of a heuristic deficiency requires inventive instinct and courage to question conventional and proven technology.

For further problem processing, that basic variant is selected which has the smallest deficiencies. An inventive approach is characterised by the property that it does not allow any serious technical-economic deficiencies, but deliberately accepts serious heuristic deficiencies if they challenge for inventive solutions. If there is a serious heuristic deficiency the subsystem or system area where the deficiency appears is declared as the decisive subsystem or the *core variant* of the technical system. For the problematic core of the basic variant in this subsystem or system area new, conceivable solutions are generated by new modifications or previously unusual combinations of known technical objects. From these core variants, the one is chosen that does best fit into the overall context of the technical system of the basic variant. This may already be an inventive solution as the result of a heuristic approach, which can be denoted as *projecting invention.*

If the basic variant consists of an inventive core variant with only small technological scope and in the remainder of verified and tested system components according to the available state of the art, and does not show significant deficiencies in relation to the evaluation figure, it can be optimised, transferred into an overall operational project and tested in a pilot series or trial production.

However, if there are still considerable deviations between the usability and effectiveness of the basic variant on the one hand and the evaluation figure on the other, and in particular the functional characteristics of the core variant in the overall context of the technical system are still in question, then the further processing is aimed at identifying the causes of these deficiencies more precisely and to investigate and fix them. For this purpose, first of all, a *technical-economic objective* is derived from the evaluation figure as a more precise specification, which is aimed at the increase of those performance and/or profitability parameters (main performance data), that are still in question.

W.6. The Structurally Prepared Basic Variant

The cause of the deficiencies is initially searched for in the structure of the technical system. For this purpose, the basic variant is prepared according to the aspect of its structure abstracting from usage properties of individual objects or groups of objects to structural properties of the technical system. This is done in such a way that the technical objects combined and functionally linked within the basic variant are considered with regard to their required structural usage properties (mainly contained in the components *controllability* and *usability* of the evaluation figure) and are coordinated in such a way that they can be spatially and/or temporally combined to form the structural units and the overall system of the basic variant.

This creates to some extend the system-specific structural properties of the technical means. Here, above all, the structural properties in the system area of the core variant are emphasised that primarily influence the specific performance and/or profitability parameters of the technical-economic objective. A variation of the structural properties of the technical system in the sense of the technical-economic objectives often results in a deterioration in specific functional properties that already indicates a technical-economic contradiction.

In many cases this is a conflict between the requirements of manufacturability, mountability and/or maintainability (or the continuous process management, the monitorability and controllability of procedures) and the requirements of functionality, insensitivity to external disturbances and internal functional security.

Here the inventive processing is initially aimed to find the critical structural unit or functional weak point that primarily prohibits an optimal design and dimensioning of the basic variant. By a clever transformation or redesign of one or more objects within this critical system area the functional performance can be increased without changing the function itself. If this succeeds, then an inventive solution of the contradiction between structural and functional properties of the basic variant has been found in the sense of the technical-economic objective. Such an approach is called *constructive invention.* The inventive solution has to be realised in a functional sample and to be tested for its functionality.

If it turns out that the technical-economic objective cannot be met without changing functions, the basic variant has to be prepared concerning its functional properties and a corresponding system analysis is required.

W.7. The Preparation of the Basic Variant Concerning its Functional Properties

In the functional preparation of the basic variant, the structural properties of the technical objects are abstracted to their functional properties. The aim is to *identify the essential functional relationships* of the basic variant as technical system with its environment, and the internal functional relationships (means-effect relationships) between its components which are decisive for that.

First of all, on has to determine the overall function of the basic variant and its known or foreseeable side effects as well as the interface conditions to its technical-technological environment. This is done by a *black box analysis.* The interface conditions (boundary conditions) of the black box define the input variables of the technical system from the specified output variables of a preceding system within a higher-level process, and its output variables from the specified input variables of a following system at the same higher level. Depending on the type of input and output variables the transfer or support function is given from this results which has primarly to be implemented by the basic variant as a technical system. This is therefore defined as the *main function.*

However, this is *not* process-related – as with the transformation of the evaluation figure – but object-related. That is, the function is not considered as necessary, process-related activation of certain usage properties of technical objects, but as *structurally constrained effect of certain functional properties of technical means.* On this basis the necessary technical prerequisites for the creation and maintenance of the main function – i.e. for the viability of the technical system – are determined. From this the required auxiliary functions are defined, starting from the types *interference suppression function* and *protection function*.

Defining the *interference suppression function*, one can first refer to the usage properties that are contained in the component Z_3 (controllability) of the evaluation figure. In addition, it is necessary to determine what side effects are triggered from the specific objects of the basic variant during operation or use. These side effects must be recorded as completely as possible. There are harmful as well as useful or usable side effects. Necessary measures to suppress the harmful side effects caused by the overall function to acceptable levels lead to the definition of the interference suppression function.

Necessary measures to suppress harmful effects caused on the main function and the interference suppression function of the technical system by the environment, lead to the definition of the *protection function* of the system. Defining the protection function we can initially be conducted by the usage properties and usage conditions, which are combined in the component Z_4 (usability) of the evaluation figure. Concerning the harmful effects from the environment not only technical, technological and natural effects are to be considered, but possibly also social (qualification, discipline) and organisational (supply of means of transport, material, energy and/or information) are to be taken into account.

An important for the inventor functional class are the *auxiliary functions*. This are functions, which are generated or can be generated "for free" by the objects of the basic variant in addition to their main functional destination. They have to be investigated whether and to what extent they can used to support or even to replace functions of one or more other objects of the basic variant. This can lead to a *trimming of functions*, the effect of which goes beyond the sum of the individual effects of the objects in question. This is an important indicator for an inventive achievement.

Auxiliary functions that cannot be used are considered as *unnecessary functions*. They should be eliminated as completely as possible by a more suitable choice or design of the objects of the basic variant, at least when they provoke a disruption of the functional value flow or cause unnecessary costs.

For a complete recording and advantageous design of all interrelationships between the system and its environment, it is necessary to delimit an *operational field* for the inventor in relation to the technical system. It includes all objects – technical and natural – as well as all factors – social, organisational and technological – with their harmful and beneficial effects that the technical system with its function has to take into account or that can be effectively included in its function. It depends on the correct delimitation of the operational field and the technical system whether the protection function is correctly determined and whether objectively available options to simplify functions or to increase the value of functions are recognised and used for improvements. (See [26, A.3]).

Depending on the situation, this can be done in such a way that suitable objects from the operational field are used to support or simplify functions including them in the basic variant by structural as well as functional integration by an adaptation function. Conversely, it can also be advantageous, and in some cases even necessary to relocate certain objects from the basic variant to the outer part of the operational field. A close functional and structural link across the system boundary as a mediation function can generate a positive influencing factor in the outer operating field or reinforce an existing one. In certain cases one gets thus at the same time a simplification of the function of the basic variant or an increase in their functional value.

With the black box analysis of the basic variant, its function-related preparation is essentially completed. The knowledge gained about the functional characteristics of the basic variant, their mutual dependencies and the possibilities to optimally coordinate them with each other and with the system environment are now used to attempt to resolve the contradiction between structural and functional properties that occurred during the structure-related preparation of the basic variant. Here you can in an inventive way, through an original distribution of the required functions to the individual objects of the basic variant and the skillful use of so far neglected structural and functional properties create the prerequisites for an optimal overall solution.

W.8. The Optimisation of the Basic Variant Compared to the Reference Variant and the TEC

In order to be able to optimise the basic variant, a technical performance parameters has to be determined as a *guiding variable*, the variation of which affects to a decisive extent on the one hand the effectivity parameters of the technical-economic objective and, on the other hand, the necessary structural and functional properties of the technical system. Choosing the guiding variable, we decide the direction of the further development of the technical system and the development trend of its utility and profitability properties.

The guiding variable must therefore be in agreement with the evaluation figure, even if it turns out that its variation – although professonally thought ahead – leads to changes in the structural and functional properties of the technical system, which (at least partially) are still in contradiction to the technical-economic objectives. As orientation for the correct determination of the guiding variable can serve the reference variant which was derived from the worldwide material state of the art.

As guiding variable serves such a technical performance parameter in which the reference variant still deviates at most from the evaluation figure. That is, the requested performance (in the component Z_1 of the evaluation figure) is achieved either not at all or under the given implementation conditions only with impermissibly high technical (Z_3), technological (Z_4) and/or economic effort (Z_2). This way, a follow-up strategy is avoided from the beginning and a progressive solution strategy is designed that meets the real social needs.

In addition, the reference variant can be included in the black box analysis as a suggestion for the functional and structural conceptualisation of the basic variant. Did we already succeed – possibly in an inventive way – to develop a basic concept that can be optimised then we will find an optimal overall solution for the basic variant that meets the technical-economic objective through well-coordinated design and dimensioning of the individual objects. If it is found, then the functionality and the functional value of the basic variant has to be tested on a test sample. For this, it is sufficient to reconstruct that part of the functional area of the basic variant, in which the decisive structural and functional changes are located that were carried out compared to the tried and tested state of the art. As a rule, it is the core variant and its closer system environment.

If an optimal overall solution has not yet been found or if the design of the basic variant proves to be not functional, the decisive *TEC* is to be determined. In other words, the decisive technical-economic effectiveness parameters have to be determined that relate to one another in such a way that the increase in one parameter leads to an impermissible reduction of the other parameter, if the guiding variable is varied according to the technical-economic objective (see [26, A.4]).

The further processing is now no longer possible through *accompanying* or tactical inventing, but characterised by *forward-looking*, strategic invention. It is actually inventing in the true meaning of the method, the *invention itself*. This brings us to stage 2 of the organisational model, at the beginning of which a *renewal pass* and a *draft specification* with a clear inventive task have to be negotiated. The subject of the invention is now a technical-economic contradiction, the goal is to overcome it.

W.9. The Inventive Core Variant (Key Variant)

To overcome the TEC, it is assumed that its cause is not distributed around the whole technical system, but essentially focused in a specific system area – the area that is critical for the functioning of the technical system, the *critical functional area*. The inventive goal now is to *discover* this system area and to produce an inventive solution, that creates in this critical area new technical conditions, new means-effect relationships, opening new possibilities for the development of the basic variant and the corresponding variation of the guiding variable in terms of the technical-economic objective.

W.10. The Critical Functional Area of the Basic Variant and the ABER

Based on the result of the black box analysis, the findings during the unsuccessful optimisation of the basic variant and possibly from a functional trial that was completed with negative test results, the causes of the technical-economic contradiction are to be explored. (See [26, A.5]).

For this purpose, continuing the black box analysis the basic variant is first divided into the object-related sub-functions, which are essential for a viable chain of intended and/or prevented *state changes of one or more objects* that produces in the end a stable and effective main function. For the specification of the necessary functional features one can exploit the usage properties that are summarised in the component Z_1 (functionality) of the evaluation figure in terms of effects of their activation. Thus one can assign system components contained in the basic variant as objects to individual sub-functions and assess them with regard to their functional value.

It will always be possible to delimit an area of the technical system in which one or several sub-functions are present, which in comparison to the neighboring system areas have a significantly lower functional value. This system area acts like a bottleneck in the function value flow of the main function, which does not take full effect of this and other sub-functions and thus decisively limits the overall functionality of the technical system. It is therefore called *critical functional area* of the technical system.

For the inventor, it is not only the question of the technical-technological causes for the emergence of the functional bottleneck, but also the question of the *technical-constructive or technical-operational reasons* that prevent the elimination of these causes on the way to an optimal dimension. These reasons are to be reduced to a *harmful technical effect* (HTE), which prevents the development of the technical system according to the evaluation figure.

The answer to this question about the HTE, which is crucial for the inventional task, can only be derived gradually. For this purpose, the sub-functions created in the critical functional area are divided according to their operating principle into *elementary functions* and their corresponding *functional units*. The individual functional units are resolved into their operational parts – *operation*, *operand*, *operator* and *counter-operator* – and these parts technically defined as functional parameter according to the operating principle of the respective functional unit. In this way the critical functional area can be clearly and transparently displayed in a morphological scheme.

The *function value flow* is now examined from elementary function to elementary function. In doing so, following a suitably selected guiding variable (structural variable), an optimisation of the functional units is attempted varying the functional parameters while keeping the operating principle.

Depending on the result of these optimisation attempts, the core of the harmful technical effect may be restricted to certain functional units and their structural and functional properties. This means that the critical functional area is increasingly narrowed and more precisely defined. At the same time, the technical-technological requirements, constraints, influences and restrictions (the ABER) are determined in their specific for the technical system form of interrelations that determine the technical-technological core of the problem.

That is, this set of ABER becomes a *system* which links sub-objects of the basic variant. This ABER on the technical-technological level is the analogue of the ABER on the technical-economic level. Note that at this level, we work with *influences* (German: **E**inflüsse) rather than *expectations* (German: **E**rwartungen) as **E**.

These new ABER prevent to overcome the TEC. They are to be changed in a following stage of the inventive process in the sense of a technical ideal (IDEAL) in such a way that the HTE disappears. In that process it is initially not allowed to vary technical functional requirements or restrictions by natural laws.

W.11. The Harmful Technical Effect and the IDEAL

The (technical) IDEAL primarily refers to the behavior of the technical system in its critical functional area. Initially, the rest of the technical system is essentially set immutable. With the IDEAL, such ideal constructive conditions and/or such ideal operational arrangements are thought ahead the recognised optimisation limits, that all undesired technical-technological factors of influence disappear or are at least reduced to such an extend in their effect that the functional value in the critical functional area decisive increases. The functional principle or the operational principle are initially not changed. (See [26, A.6]).

In contrast to the technical-economic ABER the technical-technological ABER are not directly derived from the social supersystem and the technological environment of the technical system, but rather from its constructive or operational structure and the functional principle implemented there. With these ABER next to *requirements*, *conditions* and *restrictions* also *influences* (in the sense of side effects) of technical-constructive and technical-scientific type are recorded, which the components of the technical system exert on each other, or which affect them from the system environment.

Opposing new conditions and pushing back the influencing factors has to respect the technical requirements for structural and functional basic properties of the basic variant and must not violate restrictions by natural laws, which are set by the overall function of the basic variant in a principal way. Otherwise the IDEAL will cause another harmful technical effect in another system area, which usually also leads to a specific TEC.

If it turn out that the elimination of a harmful technical effect is only possible with the emergence of another one, so in any case it is to "scout" whether there is one of these harmful consequential effects, against which a supplementary IDEAL may be thought that meets all the requirements and restrictions of the technical system. As a rule, however, this requires a detailed examination of the structural and functional interrelationships of the technical system – at least in the environment of the critical functional area.

In order to avoid an odyssey through the technical system in such a situation, this exploratory procedure therefore only makes sense as long as it does not go too far beyond the originally delimited system. If such an IDEAL approach is found that can be developed further, a stable *technical effect* and a mediating *functional principle* have to be searched which correspond to the new conditions and influencing factors in the system of technical-technological ABER. This is the starting point to develop the *sub-function principles* and the *technical principle* of the inventive solution for the core variant (key variant) that can be tested in a test sample.

However, if no viable IDEAL has been found, so the further processing starts with the approach that is in greatest compliance with the requirements and restrictions in the system of technical-technological ABER. The findings from the exploration of the technical system are now summarised as the technical-technological contradiction (TTC). (See [26, A.7]).

W.12. The TTC and the New Functional Principle for the Key Variant

The TTC substantiates the specific technical issue that removing the initially found harmful technical effect *necessarily* yields another, just as difficult to remove harmful effect. To resolve this contradiction now the *general problem-solving principles* are brought into consideration. (See [26, A.9]).

If a solution approach has been found to overcome the TTC, it is first to be checked its *technical effect* at the IDEAL for its principal usability. Then the technical-technological ABER are to be modified accordingly, and it is important to ensure that this does not violate the technical requirements or restrictions by natural laws. Finally, it must be checked whether the *harmful technical effect* has actually been eliminated and no new TTC did appear. Only then it is time to define – with reference to the IDEAL – a more detailed specification of the *new technical effect* and the system-compatible expression of the *new functional principle* for the key variant.

If a useful approach to solve the TTC is not found, the technical-scientific fact is to be determined, which decisively opposes this solution. For this purpose, the system analysis is directed to the critical operational point of the key variant, where those technical-scientific restrictions start that are decisively involved in the creation of the TTC. This technical-scientific restriction emanating from the critical operational point is called a *harmful scientific effect* (HSE). It essentially consists in the fact that the operational principle of a partial technical effect which should be evoked at the critical point to provide an effect of functional importance or an utility value prohibits certain functional and/or structural changes in the vicinity of this operational point. (See also [26, A.7]).

W.13. The Technical-Scientific Contradiction (TSC) and the New Operational Principle for the Key Variant

In a *database of scientific effects and principles*, such approaches are searched for that produce the necessary technical partial effect at the critical operational point in at least the same strength but the original restriction by natural law is no more relevant.

Of course, it must always be checked whether only a problematic restriction has been exchanged against another. This examination can initially be done on a theoretical basis of a technical-scientific model at the operational point and its immediate surrounding. In this process the elementary (functional and structural) conditions and relationships have to be investigated that are required to create the necessary conditions for the appearance of the new technical partial effect at the operational point. It always turns out that at least one of these conditions must be met without restriction due to the selected operating principle. That is, it is to be regarded as the *new restriction by natural law.*

To determine whether or not this new restriction prevents solving the problem it can be compared with the IDEAL within the system context of the technical-technological ABER and examined whether the harmful technical effect is now eliminated or the TTC can be solved. If this is the case, starting from the IDEAL a *specification of the new technical effect* and the system-compatible *expression of the new functional principle* for the key variant are to be developed.

However, before the partial function principles and the technical principle are developed from this, the simplifying assumptions and the neglected possible secondary effects and subordinate influencing factors of the *technical-scientific model* have experimentally to be checked for validity and reliability. A *laboratory sample* has to be used for this, i.e. a reproduction of the structure of the technical system in the area of the critical operational point.

If, even after several approaches, a suitable technical-scientific operational principle for the solution of the TTC is *not* found, the knowledge gained is expressed as *technical-scientific contradiction* (TSC). This substantiates the problem-specific scientific fact that for the technical system of the basic variant *there is no operational principle*, that removes a technical-scientific restriction without causing other equally serious ones. The reason for this are *restrictive functional and/or structural conditions and requirements* of the technical system that do not allow new operating principles to be developed either.

With the help of the *general problem-solving principles* an attempt is now made to "weaken" these conditions and requirements in such a way that one of the considered operational principles no longer leads to a TSC. This means that also the TTC and the TEC can be solved in principle. (See [26, A.9]).

5 German-English Translations of Terms

English	German
adaptation function	Anpassfunktion
auxiliary function	Nebenfunktion
available	verfügbar
basic variant	Basisvariante
conceivable	denkbar
constructive invention	konstruierendes Erfinden
controllability	Beherrschbarkeit
core variant	Kernvariante
critical functional area	kritischer Funktionsbereich
critical funtion matrix	kritische Funktionsmatrix
critical operational area	kritischer Wirkbereich
deficiency	Mangel
developmental weakness analysis	Entwicklungs-Schwachstellen-Analyse
draft specification	Pflichtenheft
evaluation figure	Zielgröße
evaluation matrix	Zielgrößenmatrix
evaluation parameter	Zielparameter
feasible	machbar
follow-up strategy	Nachlaufstrategie
functional area	Funktionsbereich
functionality	Zweckmäßigkeit
functional structure	Funktionsstruktur
functional unit	Funktionseinheit
function value flow	Funktionswertfluss
guiding variable	Führungsgröße
harmful natural laws	schädliche Naturgesetzmäßigkeit
heuristic deficiency	heuristischer Mangel
honorable inventors	Verdiente Erfinder
imaginable	vorstellbar
impact value	Wirkgröße
interference suppression function	Entstörfunktion
main function	Hauptfunktion
main performance data	Hauptleistungsdaten
means-effect relationship	Mittel-Wirkungs-Beziehung
mediation function	Vermittlungsfunktion
nominal figure	Sollgröße

English	German
objectives	Zielstellung
operational area	Wirkbereich
operational effects	funktionstragende Effekte
operational field	Operationsfeld
operating principle	Wirkprinzip
operational field matrix	Wirkfeldmatrix
path model	Wegemodell
problem field level	Problemfeldebene
procedure	Verfahren
profitability	Wirtschaftlichkeit
protection function	Schutzfunktion
reference variant	Referenzvariante
renewal pass	Erneuerungspass
social need	gesellschaftliches Bedürfnis
structural value	Strukturgröße
subfunction	Teilfunktion
suitability	Zweckmäßigkeit
suitability characteristics	Eignungsmerkmale
support function	Hilfsfunktion, Tragfunktion
surprising impact (SI)	überraschende Wirkung
surprisingly simple solution (SSS)	raffiniert einfache Lösung (REL)
target component	Zielkomponente
technical-constructive boundary conditions	technisch-konstruktive Randbedingungen
technical-economic deficiency	technisch-ökonomischer Mangel
technical-economic objectives	technisch-ökonomische Zielstellung
technical-operational reason	verfahrenstechnischer Grund
technical-technological principle	technisch-technologisches Prinzip
usability	Brauchbarkeit
usage properties	Gebrauchseigenschaften
viability	Funktionsfähigkeit

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