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INNOVATIVE PROCESS CHAIN OPTIMIZATION - UTILIZING THE TOOLS OF TRIZ AND TOC FOR MANUFACTURING

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Abstract

The enormous potential of process innovation and optimization is often undervalued. In order to stay competitive organizations are forced to adapt quality of products and production to permanently growing requirements. Modern manufacturing processes need to fulfill highest demands on efficiency, flexibility and reliability. Thus, process optimization gains significantly in importance. The increasing complexity and integration of production systems complicate their optimization. Hence, the classical approaches of manufacturing process optimization reach their limits. Depending on the development state of the production system, exponential improvement can only be achieved, using a form of optimization that considers and questions the existing system structure as a whole and enables innovative process design. However, up to now operational practice mostly focuses on the improvement of single process steps and optimizes only within the existing structures. Thus, a large potential for optimization stays unutilized in the manufacturing area.

The objective of the project »Innovative Optimization of Process Chains« which was conducted by the Fraunhofer IPT was to develop a system for the innovative optimization of process chains in manufacturing. The system enables a holistic consideration and optimization of manufacturing processes that results in an innovative process design. To achieve this goal a procedure was developed that integrates classical tools of quality management as well as innovative methods for manufacturing optimization. These are among other things the tools of the so-called »Theory of Inventive Problem Solving (TRIZ/TIPS)« and the »Theory of Constraints (TOC)« which promise a high profit and a relative low effort for qualification. TRIZ and TOC share the assumption that most core problems exist because some underlying conflict or contradiction prevents the straightforward solution of a problem (e.g. improving one characteristic leads to impairment of another). TRIZ especially provides tools to find breakthrough solutions (innovative process design) that overcome these conflicting objectives. TOC is a systems approach to continuous improvement of process chains. It provides a set of five powerful tools, three of them focusing on the safe implementation of solutions found for the problems of optimization, particularly since most great ideas fail in the implementation stage.

The procedure was developed on the basis of the DMAIC (Define-Measure-Analyze-Improve-Control) cycle that originates from the Six Sigma approach. Each stage of the DMAIC process is supported by one or more tools of an interdisciplinary toolset which combines classical QM-methods with TRIZ- and TOC-tools.

The research project was accompanied by a workgroup that consists of representatives from different industries. The suitability of the systematic for industrial practice was validated in the course of two pilot-applications. The presentation will provide an overview of the research project and give an introduction into the developed system and it's tools. The application of the systematic and the DMAIC cycle will be explained on basis of examples from the pilot applications.

Challenges of Process Optimization in Manufacturing

The competitiveness of modern-day companies is more than ever a direct function of their ability to implement process innovations and optimization. Such optimization, however, is becoming increasingly harder to realize, due to the growing complexity of the ways in which the networks of structures and processes in the manufacturing area are interconnected.

In operational practice, process optimization often means trouble-shooting. People in charge of (continuously) improving production processes strive towards "problem solution in a single stroke". The analysis of the problem frequently gets a raw deal. If any, primarily basic tools for problem solving (e.g. brainstorming) and trial-and-error are applied. The quality of the solution is strongly dependent on the experience and intuition of the problem-solver. Furthermore, many great ideas fail in the implementation stage. When the complexity of the problem is high and no obvious solution is known this approach reaches its limits **/Lit 1/**.

Quality management in manufacturing provides several tools to support optimization efforts. FMEA, SPC or test data evaluation can be used to reveal problem areas in a process chain. DoE is a powerful tool that helps to understand an individual process and to simultaneously optimize it for all critical outputs. However, classical QM-tools for manufacturing are mainly focused on the prevention of failures without considering and questioning the existing structures as a whole. The efficiency and the effectiveness of a process chain are not only measures of defects but are multidimensional. This is where classical methods often run into their limits. Technologically mature systems – which serial production facilities invariably are – can only be improved on a profound level by integrated system analyses and holistic optimization efforts that may result in innovative process design. This means that a large part of the optimization potential in the production sector and neighboring fields remains untapped so far. A holistic approach for innovative process chain optimization is required. This approach needs to utilize classical and innovative methods that can cover the integrated analysis of the process chain, the systematical generation of innovative solutions and their safe implementation.

The Project »Innovative Process Chain Optimization (IPO)«

The objective of the research project (duration: Dec. 1st 2000 until Dec. 31st 2002) was the development of a system which allows the holistic optimization of process chains in the manufacturing area with a view to increasing quality and performance **(see slide 4)**. For practical purposes, a pertinent procedure was developed which successfully combines conventional quality management methods with new and integrated approaches. These incorporate the Theory of Inventive Problem Solving (TRIZ/TIPS) and the Theory of Constraints (TOC), both of which provide high-performance tools for process optimization. The palpable results of the project include an advanced tool kit for quality management operations in manufacturing business environments. The contained tools support the individual stages of the optimization process to which they can be clearly and easily assigned.

The internal experts are supported with learning and applying both the procedure and the integrated tools by a guidebook and a corresponding qualification module. The qualification module and the guidebook are now available as a CD-ROM (presently only in German). The CD-ROM also includes the IPO-tools with step-by-step instructions for their application as well as templates and worksheets. The CD-ROM can be found with the final report (DGQ-FQS-Band 86-03) of the IPO-project, that can be ordered from the Federation for Quality Research and Science (FQS).

The project »Innovative Optimization of Process Chains« was sponsored by the German Federation of Industrial Cooperative Research Associations (AiF) and was funded by the Federal Ministry of Economics and Technology (BMWi). It was administrated by the Federation for Quality Research and Science (FQS). To ensure the suitability for industrial practice, the project was supervised by a working group that consisted of companies from various industries. The developed system (procedure and toolset) has been successfully validated in the course of two pilot applications in different companies.

TRIZ - Systematically to Innovative Solutions

In the optimization of a process chain the project team has to face a problem which is usually characterized by many requirements and objectives, some of which are conflicting. The team may have to solve a problem with no known solution. This is called an inventive problem and may contain contradictory requirements. Knowledge and creativity are two essential conditions for a successful solution. However, there is often a lack of both **/Lit 2/**.

Even though the composition of the team is interdisciplinary, it is virtually impossible to integrate universal knowledge of all specialized areas into a team. Independent studies have shown that creativity diminishes steadily throughout the work phase of life **/Lit 3/**. Many people hesitate to be creative, because they fear that they lack the essential skills. In general humans solve problems by analogical thinking. That is, we try to relate the problem we are facing to some standard class of problems (analogs) we are familiar with, and for which a known solution exists. If we can draw the right analogy, we can find the right solution. Our knowledge of such analogous problems, however, is the result of our educational, professional, and life experiences. Ideally, all potential directions for solutions should be equally regarded. In reality however, only solutions within one's own experience are considered while the consideration of alternative technologies to develop new concepts is ignored **/Lit 4/**. This results in what is called psychological inertia which defeats randomness and leads only into those areas of personal experience.

For process optimization it would be a decisive advantage if the team had an extensive knowledge base and was capable of generating innovative concepts purposefully and systematically, rather than more or less at random. The TRIZ method provides some suitable tools. TRIZ expands the knowledge horizon of the developer by using a scientific-engineering knowledge base and supports the user systematically throughout the process of creative problem solving. The method ensures an effective and efficient search for innovative solutions, focusing on the so-called Ideal Final Result. It limits the search field considerably, but fosters creativity within that search field. TRIZ also helps the user to detach himself from the psychological inertia vector, i.e. from his usual thought patterns and structures **/Lit 5/**.

TOC - From Concept to Implementation

With the Theory of Constraints (TOC) another powerful methodology for process chain optimization was identified. TOC offers a lot of promising synergy to TRIZ. Both share the assumption that most core problems exist because some underlying conflict or contradiction prevents straightforward solution of a problem. Each approach is capable to analyze the problem situation and to identify the conflict. TRIZ is especially strong in generating innovative concepts to overcome these conflicts. TOC additionally provides tools to answer the question »How do we implement the change?«.

The Theory of Constraints is a systems approach to continuous improvement that has its basis in the manufacturing environment. TOC was developed by Eliyahu M. Goldratt in 1984 which he presented in his first book 'The Goal'. Goldratt likens (production) systems as chains, or networks of chains. A process chain in manufacturing can be thought of as a chain of dependent events that are linked together. The activities that go on in one "link" are dependent upon the activities that occur in the preceding "link". Since »a chain is only as strong as its weakest link«, optimization efforts should focus on "chain strength" by working to strengthen the weakest link – the constraint. TOC is based on several principles that are very important for successful improvement. The crucial principle is *»Systems as Chains«* that has already been mentioned. Other vital ones are **/Lit 6/**:

»Cause and Effect«: All systems operate in an environment of cause and effect. One particular event acts as a cause for another event, while the particular cause leads to a specific effect. This relationship between cause and effect can be very complex.

»Undesirable Effects and Core Problems«: The indication of the existence of a problem is brought out by undesirable effects (symptoms). Eliminating undesirable effects gives a false

sense of security. The elimination of the core problem, however, not only eliminates the symptoms but prevents them from happening again.

»Solution Deterioration«: The solution to any problem deteriorates with time, because the environment changes. Hence, a process of continuous improvement is required to maintain the same levels of efficiency at all times.

»Ideas are not Solutions«: Mere the idea on how to solve a problem does not result in improvement, rather, the effective implementation of this idea that results in real improvement. However, in many cases ideas fail in their implementation stage.

The TOC thinking process focuses on the answer to three fundamental questions: »What to change?«, »What to change to?« and »How to cause the change?«. This thinking process is supported by specific thinking tools, the five logical trees **(see slide 6)**. *The Current Reality Tree (CRT)* is designed to analyze the current condition of a system and to gain a better understanding for the problem. It identifies the core problem(s) that lead(s) to observed undesired effects which decrease(s) the performance of the system. Solving these core problems becomes the objective. This often requires the elimination of an underlying conflict, that prevents straightforward solution. The *Conflict Resolution Diagram (CRD)*, also referred to as "Evaporating Cloud", helps to resolve these conflicts and strives to create a breakthrough solution to the problem that avoids compromise. Being armed with the tools of TRIZ is here particularly useful. Once a proper improvement measure has been found, the *Future Reality Tree (FRT)* serves to check if it will in fact produce the desired effect without introducing new and unexpected side effects. The FRT can also effectively test alternative solutions before allocating expensive resources to them.

Once the realization of an appropriate solution has become the objective the *Prerequisite Tree (PT)* comes into operation. The PT is designed to find all obstacles and the responses needed to overcome them in realizing the objective. It identifies minimum necessary conditions and requirements without which the objective cannot be achieved. The result of the PT is a sequence of intermediate objectives to be followed to neutralize all obstacles. The TOC thinking process is completed by the *Transition Tree (TT)*. The TT provides a detailed step-by-step instruction for implementing a course of action. It shows all the steps necessary in achieving a specific objective, providing a so called 'road map' to the entire implementation effort. The construction and review of the trees is governed by so-called *Categories of Legitimate Reservation (CLR).* These are eight rules, or tests of logic that are applied for building, scrutinizing and improving the trees. They also serve to communicate effectively disagreements related to the construction of relationships. The CLRs are clarity, entity existence, causality existence, cause sufficiency, additional cause, cause-effect reversal, predicted effect existence and tautology. **/Lit 6/**

Both approaches, TRIZ and TOC, provide tools for analyzing the initial situation and for identifying core problems. TRIZ is extremely powerful in generating innovative solutions that overcome underlying conflicts/contradictions and bring the system closer to ideality. The solutions found with TRIZ can be successfully scrutinized and implemented by applying the last three tools of the TOC thinking process (FRT, PT and TT). The combined use of classical QM-tools, TRIZ and TOC promises a holistic optimization of process chains in manufacturing, without giving in to compromise. However, to achieve this, two steps were essential. On the one hand some of the individual tools had to be redesigned in order to fit them together. On the other hand a procedure was developed that sets the individual tools into context.

DMAIC – Step-by-Step to Success

The system for innovative process chain optimization that was developed in the research project consists of two major elements. A procedure describing the course of an optimization project and an interdisciplinary toolset that supports each stage of the model. The toolset contains TRIZ-, TOC- as well as classical QM-tools **(see slide 5)**. The procedure was developed on the basis of the DMAIC cycle (Define-Measure-Analyze-Improve-Control) that originates from the Six Sigma approach **/Lit 7/**.

In *Define* the team has to identify and define the problem, the objective, customer requirements (internal and external) and important boundary conditions. The process chain to be investigated needs to be understood. To support this stage the Define-Checklist was developed, based on the Innovative Situation Questionnaire of TRIZ. The objective of *Measure* is to determine the current performance of the process and the extent of the problem. The current state of the process is recorded which is essential to rate the achieved success at the end of the optimization project. The Measure phase also prepares the analyze step of the DMAIC cycle by gathering key data that helps to identify the process constraint. Usually a lot of data (test data, MTM, …) is already available in the manufacturing area. The gathered data is scrutinized in the *Analyze* phase. This stage can be classified into data analysis and process analysis. The common objective is to identify the root causes of the problem and the constraint. As a result of Analyze, optimization priorities are set up. Classical QM-tools (Capability studies, 7 tools, …) may serve for data acquisition and evaluation. The process analysis can be effectively supported by the CRT.

The optimization problem is solved in the *Improve* phase. The constraint in the process chain is examined carefully in order to find out how to elevate it. Sub-problems, conflicts and/or contradictions are systematically revealed by applying several powerful TRIZ-based tools (e.g. Function-Effect-Modeling). Innovative concepts for solutions are generated, structured and compared. The solutions to be implemented are selected. This can be done by portfolio analysis (e.g. chance/risk; cost/time) or the application of the Future Reality Tree, for instance. The implementation of these solution is methodical safeguarded by the Prerequisite Tree and Transition Tree. The first 4 steps of DMAIC were dedicated to identifying, measuring and implementing change. However, without sustaining the gain, the initial enthusiasm for improvement can easily be lost. The *Control* phase serves for confirming the fact that the improvement measures selected have achieved the goal set up in Define. Therefore, compiled result data has to be reviewed. A second important objective of Control is to select ongoing measures to monitor performance of the process and continued effectiveness of the implemented solutions.

Conclusion

Classical methods of quality management in manufacturing already do a good job in the prevention of failures and can optimize the output of an individual process. However, improvement efforts normally focus on individual elements of a process chain and do not question the existing structures. When it comes to improving a process chain with a holistic view to increasing efficiency and effectiveness, the conventional QM-methods often reach their limits. Especially, when the complexity of the system is high, support is needed.

Core problems that prevent straightforward solution are often caused by an underlying conflict or contradiction. For example, from the current point of view, improving one characteristic of the process will result in impairing another characteristic. Hence, a trade-off seems to be necessary. TRIZ provides powerful tools for overcoming conflicts and contradictions without the need for compromise. TRIZ expands the knowledge horizon by providing a knowledge basis that represents the combined experience of over 2.5 million patents. It also helps users to detach themselves from their usual thought patterns and structures.

Armed with TRIZ, the optimization team can generate innovative concepts for breakthrough solutions. However, ideas or concepts are not solutions. Not until they have been successfully implemented. The implementation stage needs to be methodically safeguarded as well. This is where TRIZ and TOC can complement one another. TOC provides tools that enable the user to evaluate alternative concepts for solutions and ensure successful realization. TOC also supports the analysis of the process chain in order to identify the "weakest link", the constraint, that needs to be strengthened.

The DMAIC cycle as a proven procedure for process optimization sets the individual tools into context. It emphasizes the measurement of the current performance of the process chain, which is essential to evaluate the achieved improvement. The concerted application of classical QM-tools, TRIZ and TOC in the DMAIC cycle results in a holistic optimization of process chains with innovative design. Even if the maturity of the system is high, improvements in quantum leaps are possible. The system for innovative process chain optimization enables enterprises to tap substantial innovation-based optimization potentials and contributes to improving both their quality standards and their competitiveness.

Literature

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Innovative Process Chain Optimization (IPO) –

Combining the Tools of TRIZ and TOC for Manufacturing

ETRIA World Conference - TRIZ Future 2003
Aachen, November 13th, 2003

Martin Tillmann, Fraunhofer IPT, Aachen

Structure of Presentation

IPO - Motivation and Objectives

IPO - Systematics

IPO - Application and Implementation

Production Process Optimization

Importance

»Future competition is increasingly between processes!«

78% of more than 440 surveyed companies rated the importance of production process optimization as »high« to »very high«.

70% of those companies said, that present methods of process optimization need to be improved.

3% use innovative methods like TRIZ for process optimization.

[*QM-Study Fraunhofer IPT 2002*]

Trend

Complexity and integration of modern production systems increasingly complicate their optimization.
Classical approaches are reaching their limits.

[*D. Steins, Dissertation RWTH Aachen 2000*]

The Project IPO – Motivation and Objectives

Present Proceeding

- Acute problems are still the most frequent trigger
- Focus on single elements of the process chain
- Strive towards „problem solution in a single stroke“
- If any, primarily application of basic QM-tools (e.g. 7 tools)

Present Results

- If maturity is high, only small improvements are possible
- Many good ideas fail during implementation

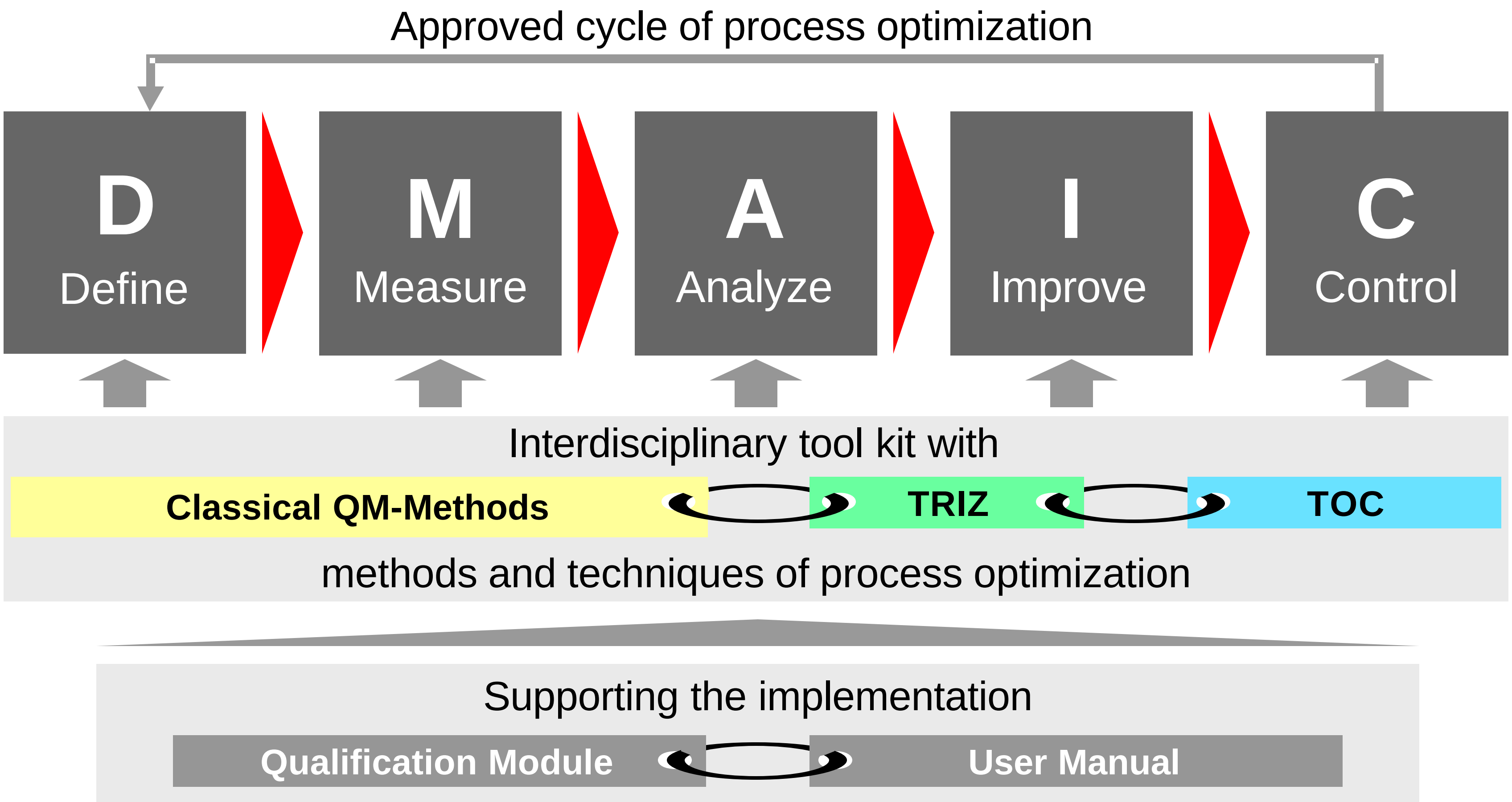
⇒ **Substantial potential for optimization is not utilized yet**

Objectives of IPO

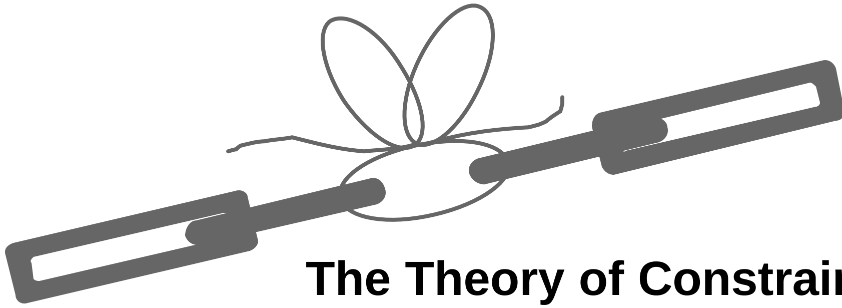
- Holistic optimization of process chains in manufacturing
- Utilizing innovative methods for process optimization
- Concerted application of classical and innovative tools

⇒ **Breakthrough solutions for process optimization**

IPO - Innovative Process Chain Optimization



The Theory of Constraints (TOC)



The Theory of Constraints

Production systems consist of process chains, whose quality depends on the weakest link!

The Principles:

- Systems as Chains
- Local vs. System optima
- Cause and Effect
- Undesired Effects and Core Problems
- Solution Deterioration
- Ideas are NOT solutions!

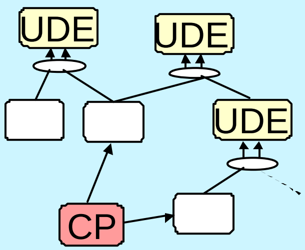
Thinking Process and Tools

What to change?	What to change to?	How to cause the change?
Analysis of the current situation	Analysis of „real causes“	Analysis of obstacles
Current Reality Tree	*Conflict Resolution Diagram*	*Prerequisite Tree*
	Projection of the future	Planning the detailed implementation
	Future Reality Tree	*Transition Tree*

TOC – Five Logic Trees

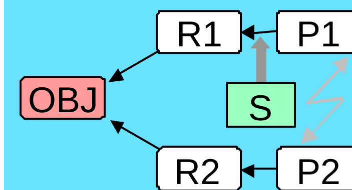
- Information about process chain
- Undesired Effects [UDE]

Current Reality Tree



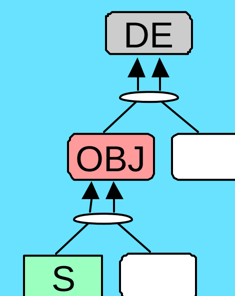
- Cause-and-effect relationships
- Core Problems [CP] or constraint
- Objective [OBJ] of optimization

Conflict Resolution Diagram



- Breakthrough Solutions [S] for resolving conflicts
- Desired Effects [DE]

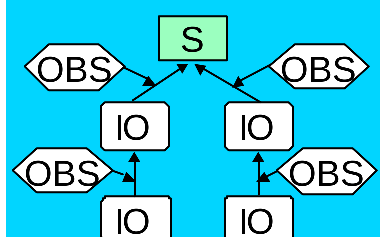
Future Reality Tree



How to cause the change?

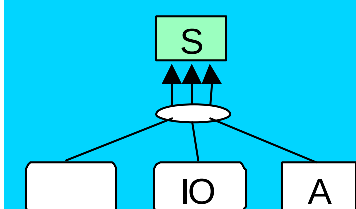
- Simulation model of the future
- Verification of solutions

Prerequisite Tree



- Obstacles [OBS]
- Intermediate Objectives [IO]
- Milestones of implementation

Transition Tree



Step-by-step Actions [A] for successful implementation

Intermediate Conclusion

TRIZ

+ Analysis of initial situation
+ Extensive knowledge-base
+ Powerful tools for generating breakthrough solutions
■ Support by other methods of Systematic Innovation possible

TOC

+ Evaluation and selection of solutions
+ Identification and elimination of implementation-obstacles
+ Step-by-step instructions for implementation

Both

+ Problem analysis and identification of core problems
+ Resolving hidden conflicts/contradictions
+ Highly effective and easy to learn

Combined application of QM-, TRIZ- and TOC-tools results in holistic optimization, without compromise!

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Product and Process Chain

Information of the Product and the Process Chain

Product

Window regulator for a cabriolet.

Key characteristic:

- Operation time
- Force
- Stroke
- ...

Process Chain

Strengths:

- Experienced employees
- U-Shape
- Kanban
- Poka Yoke
- ...

Potential of optimization:

- Handling
- Fault liability
- Clamping system

The Project Team

- Employee of Service Team Assembly
- Employee of Production Scheduling
- Shop Floor Personnel
- Employee of Quality Management
- Employee of Engineering
- Employee of Continuous Improvement Process (CIP)
- Consultant (IPT)

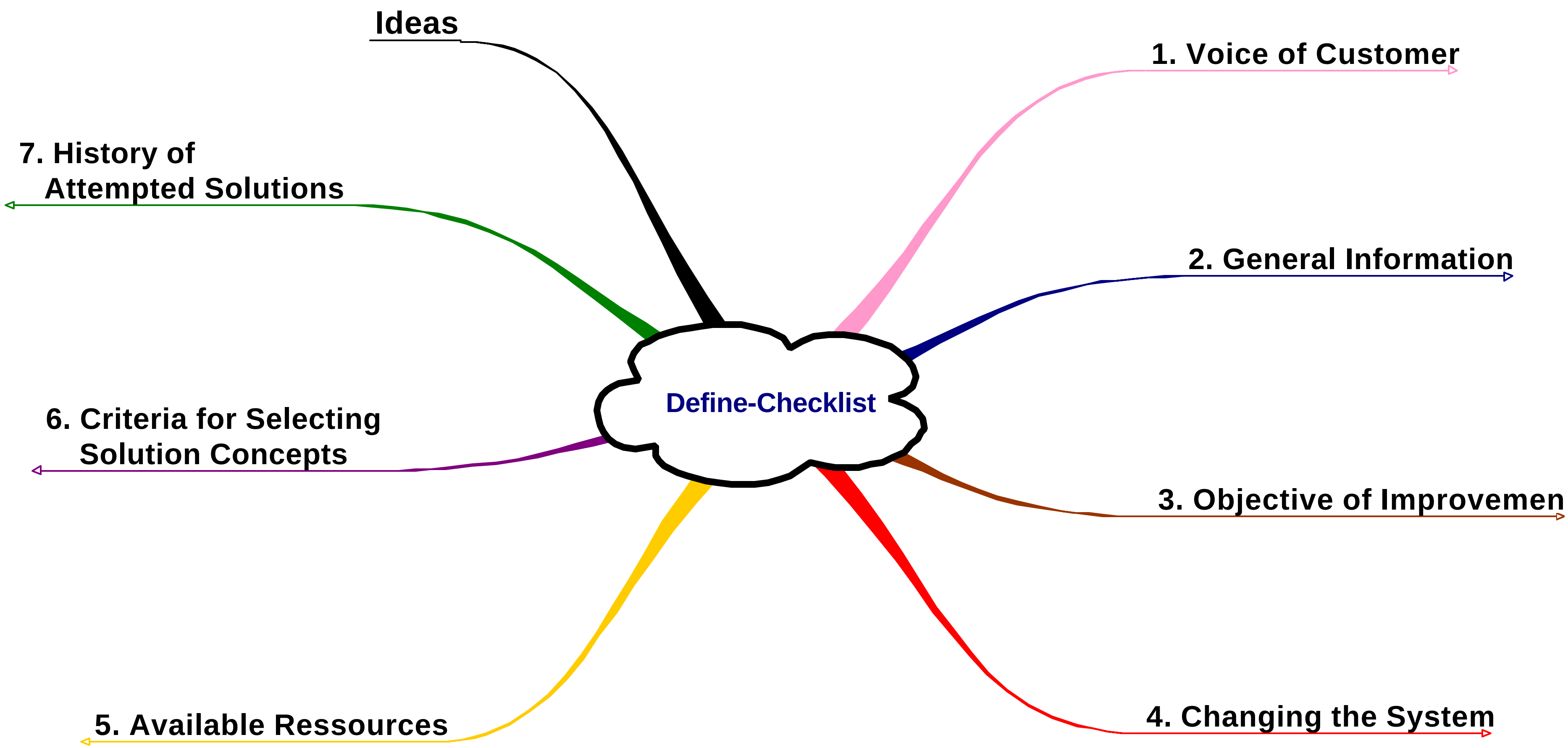
Define-Phase

Purpose and Objectives	■ Definition of the project ■ Relevant boundary conditions ■ Description of the process chain ■ Objective of optimization

D Define → **M** Measure → **A** Analyze → **I** Improve → **C** Control

Proceeding	■ Define-Checklist for the definition of project and objective ■ Process-charts to characterize the process chain ■ Appreciation of existing structures (What should be retained?)

Define-Checklist



Measure-Phase

Purpose and Objectives	
	▪ Acquisition of metrological data of the current situation ▪ Determine the degree of the achievement of objectives ▪ Basis for the identification of main problems ▪ Basis for the measurability of success

D Define → **M** Measure → **A** Analyze → **I** Improve → **C** Control

Proceeding	
	▪ Ensure actuality in case of using already available data ▪ Get clarity about the definition of the measurand ▪ Ensure capability of the measuring equipment (e.g. R&R)

Analyze-Phase

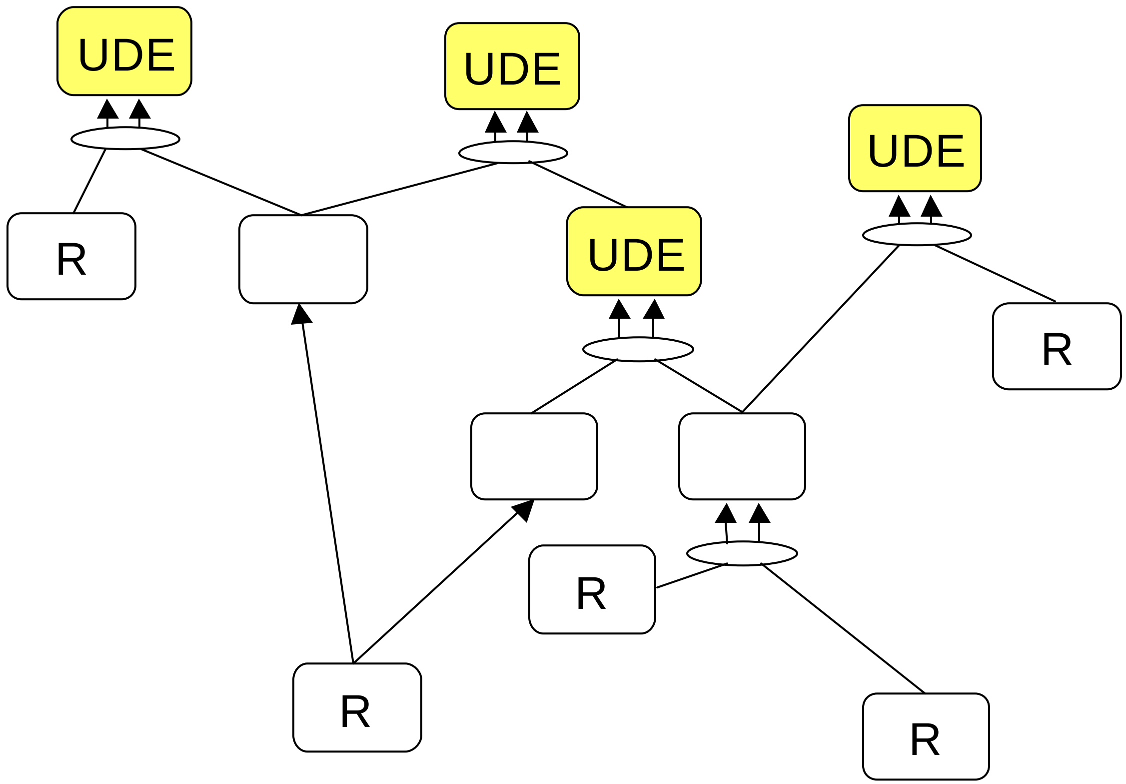
Purpose and Objectives	
	■ Analysis of acquired and available data ■ Identification of cause-effect relationships ■ Identification of the core problem ■ Localize the constraint of the process chain

D Define → **M** Measure → **A** Analyze → **I** Improve → **C** Control

Proceeding	
	■ Current Reality Tree for root cause analysis within the process chain ■ Reliable determination of the constraint only by combined analysis of data **and** analysis of process

TOC - Current Reality Tree (CRT)

- Undesired effects [UDE] are symptoms of the optimization problem
- Roots [R] are the starting point of a cause-effect relationship

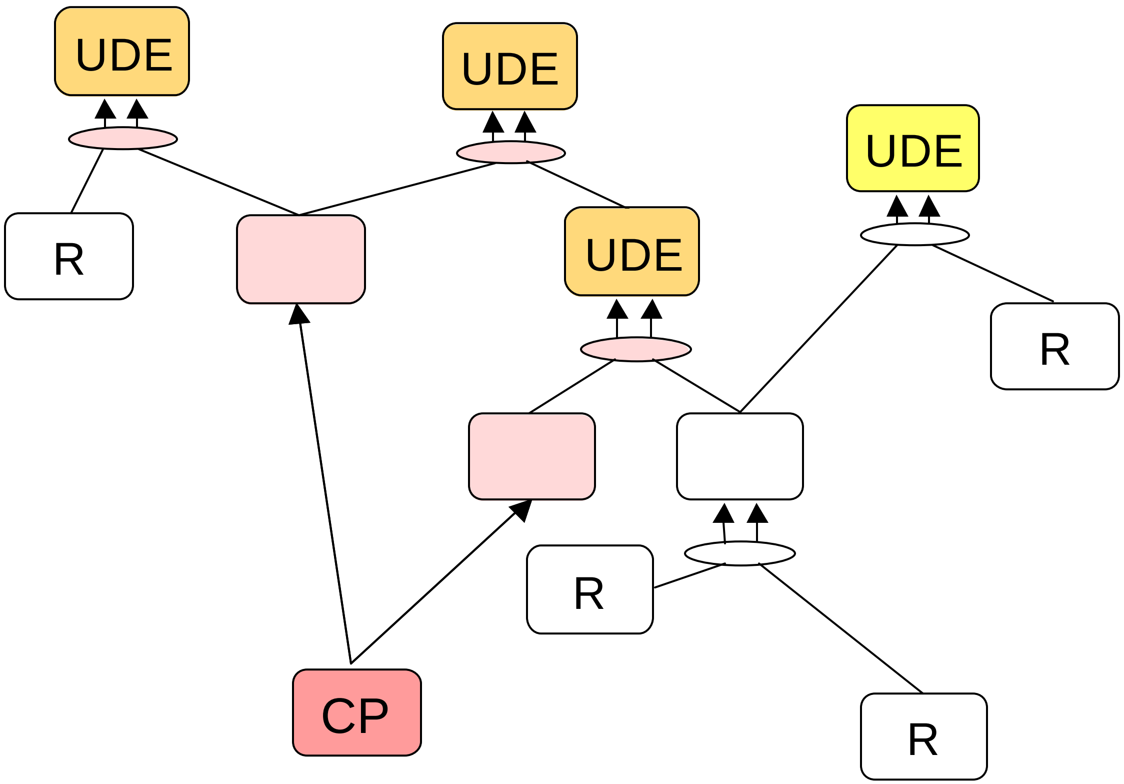


Keep »8 rules of legitimate reservation« in your mind!

Source: H. W. Dettmer

TOC - Current Reality Tree (CRT)

- Undesired effects [UDE] are symptoms of the optimization problem
- Roots [R] are the starting point of a cause-effect relationship
- The core problem [CP] is the origin of a substantial number of UDEs and determines the constraint



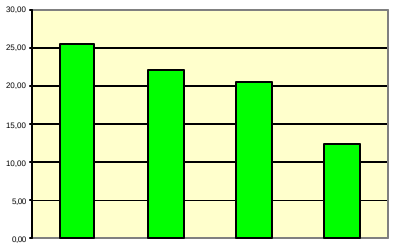
Keep »8 rules of legitimate reservation« in your mind!

Source: H. W. Dettmer

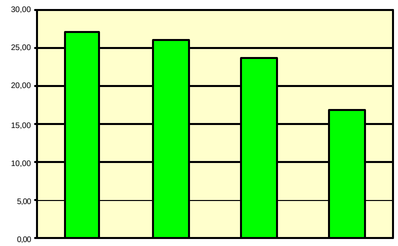
Identification of the Constraint

D M A I C

Pareto-Analysis of Malfunctions

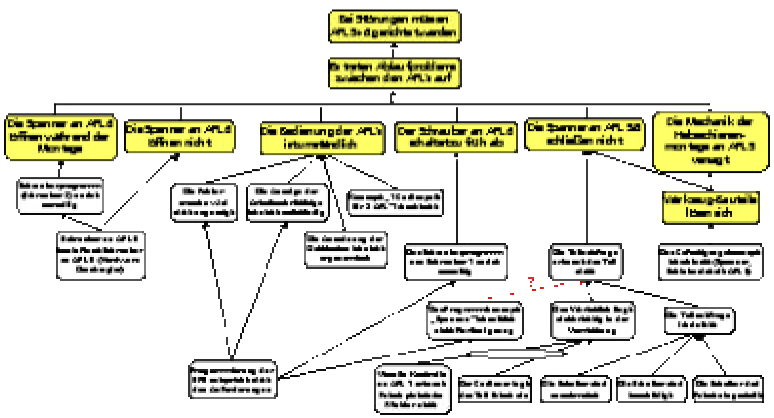


Frequency



Duration

Current Reality Tree



Constraint: Workplace 5

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Improve-Phase

Purpose and Objectives

- Developing innovative solutions
- Evaluation of solutions and selection of best solution(s)
- Identification and overcoming obstacles of implementation
- Implementation plan for the best solution(s)

D Define → **M** Measure → **A** Analyze → **I** Improve → **C** Control

Proceeding

- Improve roadmap guides through the optimization process
- TRIZ tools help to detect and to overcome underlying contradictions and conflicts in objectives
- TOC tools safeguard the successful implementation

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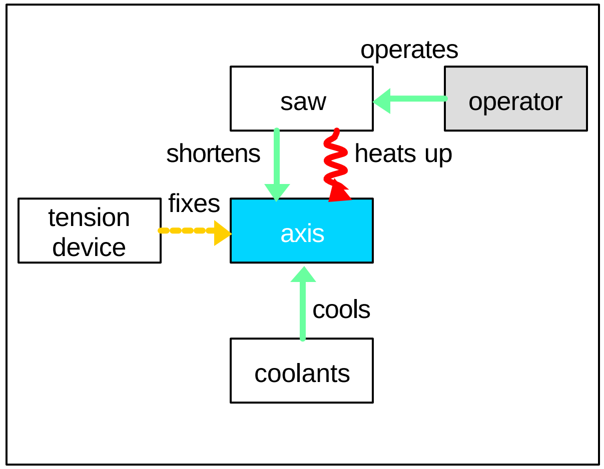
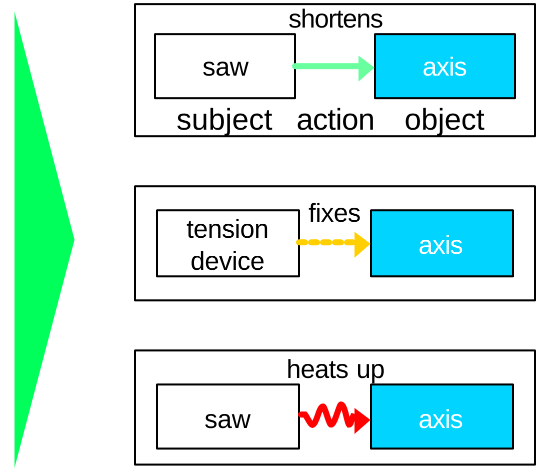
Modeling

- Define objects
  - Components
  - Supersystem
  - Products
- Connect objects through defined interactions
- Identify
  - Productive functions
  - Aiding functions
  - Harmful functions
  - Useful/Harmful effects
  - Conflicts/Contradictions

Modeling



Analysis



product — Object of the main function of the engineering system

component — An object that is a constituent part of an engineering system

super-system — An engineering system, personnel, or an environment that interacts with the system to be analyzed

normal arrow: desired, satisfying interaction

broken arrow: desired interaction which is not satisfying in characteristic, intensity or quality

winding arrow: undesired interaction

Improve-Phase – Modeling

D M A I C

Definition of Sub-Process and Modeling: Workplace 5

Pre-assembly and deposition of distance bolt

Bolt the glider together

Preparation of the regulator’s track for screw connection

Bolt the track together

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Dealing with contradictions and sub-problems

D M A I C

Developing Solutions

Identified Contradictions

Prioritized Sub-Problems

Contradiction Analysis

Conflict:
Improving one characteristic results in impairing another characteristics.

Contradiction:
Two conditions excluding each other.

Trimming

1. Can another object perform the function?
2. Can the object, that is affected by the action perform the function itself?
3. Can the action be dropped out?
4. Can a part be replaced or be eliminated?
5. Can the functional principle be changed?
6. Can further resources be used?

Contradiction Matrix
40 Principles

4 Separation-principles

Substance-Field-Analysis

76
Standard Solutions

Solution concepts/ideas

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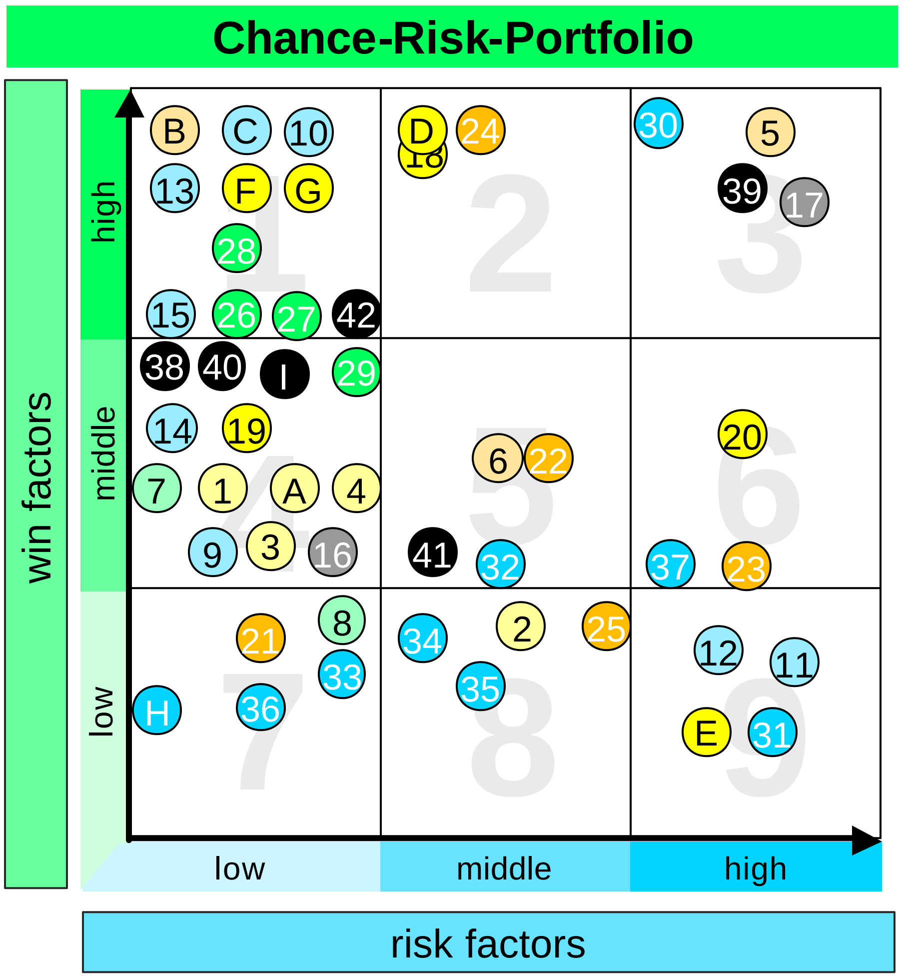
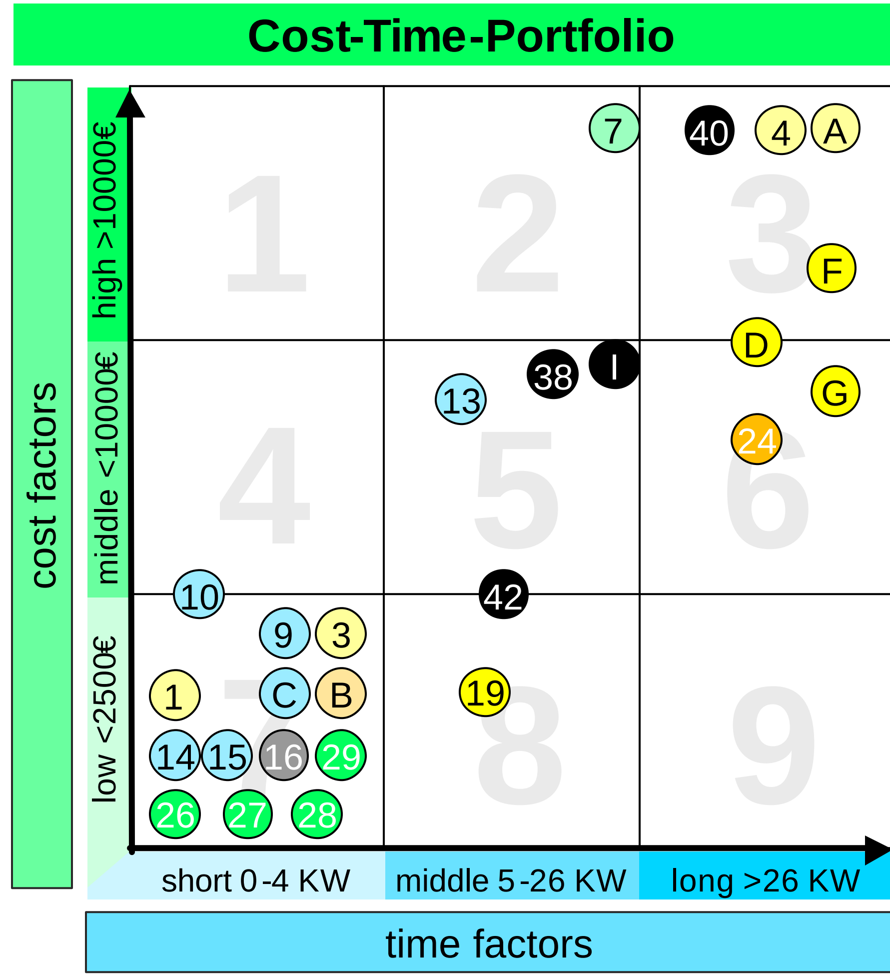
Choosing the right Solution(s)





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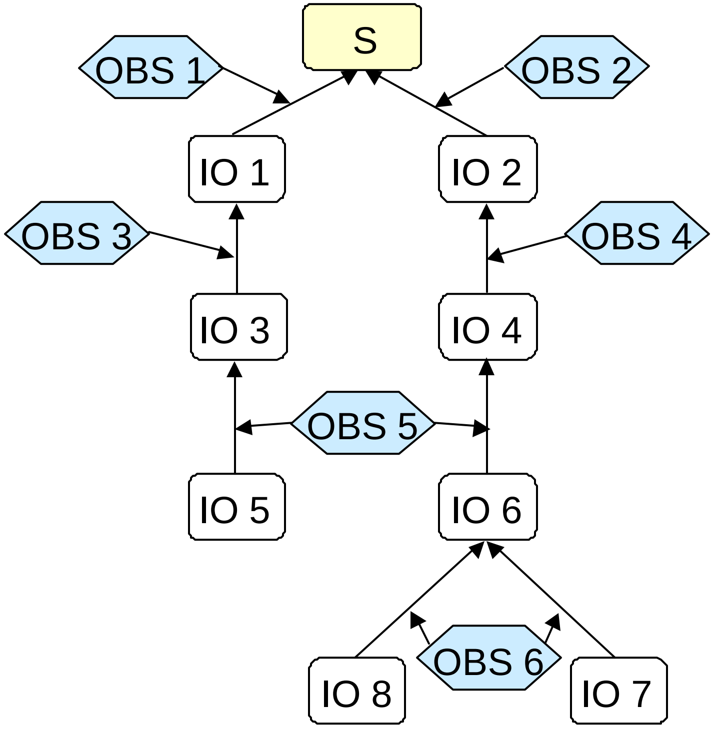
Safeguarding the Implementation

Prerequisite Tree (PT)

Purpose and Objective

- Answers the question:
  How can the solution concept be implemented?
- Starting-point:
  Solution [S]
  (e.g. from TRIZ-Application)
- Identification of obstacles [OBS] to implementation of solutions.
- Deduction of intermediate objectives [IO] in order to overcome these obstacles.

Result



Obstacles are solely to overcome, not to eliminate!

Control-Phase

Purpose and Objectives

- Surveillance of effectiveness
- Observation/measurement of long-time behavior
- Reaction on changes
- Documentation of project and process chain

D Define → **M** Measure → **A** Analyze → **I** Improve → **C** Control

Proceeding

- Consideration of higher level monitoring instruments
- Preservation of solutions as example of success
- Lessons-Learned analysis
- Dignify and celebrate success!

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