Graz, University of Technology
Department of Mechanical Engineering and Business Economics
Institute of General Management and Organization

Diploma Thesis

Taxonomy for the generation of technological knowledge as basis for platform development of cooling compressors

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Preface and Acknowledgement

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Special thanks is due to DI Walter Brabek, head of the product development at ACC Austria, because his incitements have a big stake on the success of this assignment and he exhibits that he is always poised to break new paths, not a common characteristic.

For the excellent supervision on the part of the Technical University Graz I would like to thank DI Christiana Müller and DI Ernst Stelzmann of the department of General Management and Organization, both have always taken time to answer my questions and have bothered themselves to facilitate my action.

I have to take this opportunity to thank those people who enabled my studying and without them I would not have had even the chance to apply myself in that, my parents. They allowed me not only to focus absolutely on my education; they permitted also my studying abroad and kept me grounded in every situation.

*"Visions are
the architects of bridges
into reality"*

Statutory Declaration

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

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Abstract

The corporation ACC, Appliances Components Companies, was founded 2002 as a spin off group of Electrolux, manufacturing compressors for household refrigeration appliances with production facilities in Europe and China. In addition ACC is also a manufacturer of electric engines for oil and gas burners in Germany. The headquarter of the corporation is situated in Pordenone, North-Eastern Italy, close to Venice.

The R&D centre of ACC for cooling compressors is located at ACC Austria in Fürstenfeld, South-Eastern Austria. ACC Austria was founded in 1982, occupies 750 employees and had a turnover of 133 million € in 2009 by 5,2 million manufactured compressors.

In order to maintain the company's success and to be well prepared for the new highly dynamic market situation, ACC Austria focuses on a long term product planning called CC2018, Cooling Compressor 2018, an innovative vision of a new cooling compressor platform.

This thesis intended to define distinguishable technology fields and to derivate technology development projects as foundations of a path making structured knowledge available in the field of technology development. Therefore a comprehensive situational analysis of preparatory exertion was done at the beginning of this work. Furthermore, the creation of a generic approach for the processing of these particular projects was another main focus within the scope of the thesis. Much effort has been dedicated to create "guidelines" how to handle technology development projects at ACC Austria on the way to the cooling compressor of the future. The result was a clear structured and traceable phase approach based on Systems Engineering (SE) as code of practice to generate the required technological knowledge as basis for further product development.

Referring to Systems Engineering means, the main focus of this assignment was predominantly the definition of a procedure for systems design with the objective to realize a preferably direct cross-linking between theory and praxis.

Zusammenfassung

Der Konzern ACC, Appliances Components Companies, wurde im Jahre 2002 als Ausgliederungsgruppe von Electrolux gegründet und stellt Kompressoren für den Einsatz in Haushaltskühlgeräten her. Zudem produziert ACC Elektromotore für Öl- und Gasbrenner in Deutschland. Der Konzernsitz liegt in Pordenone, nordöstliches Italien in der Nähe von Venedig mit Produktionsstätten in Europa und China.

Die Forschungs- und Entwicklungszentrale von ACC für Kältekompressoren ist bei ACC Austria in Fürstenfeld, südöstliches Österreich, ansässig. ACC Austria wurde 1982 gegründet, beschäftigt zurzeit rund 750 Mitarbeiter und erwirtschaftete 2009 einen Umsatz von ca. 133 Millionen € bei 5,2 Millionen produzierter Kompressoren.

Um auch zukünftig den Unternehmenserfolg sicherstellen zu können und entsprechend gerüstet für die neue, hoch dynamische Marktsituation zu sein, konzentriert sich ACC Austria auf eine langfristige Produktplanung mit dem Namen CC2018, Kältekompressor 2018, eine innovative Vision einer neuen Kältekompressor Plattform.

Diese Diplomarbeit behandelt im Bereich Technologieentwicklung die Definition von Technologiefeldern und Ableitung von Technologieentwicklungsprojekten als Grundlage einer Methodik, um strukturiertes Wissen verfügbar zu machen. Aus diesem Grund stand eine umfassende Analyse von bereits getätigtem Aufwand am Beginn der Arbeit. Ein weiteres Hauptaugenmerk lag auf der Erstellung einer generischen Vorgehensweise für die Abwicklung von eben jenen Projekten. Große Bestrebung war es, einen „Roten Faden“, wie solche Technologie Entwicklungsprojekte bei ACC Austria handzuhaben sind, auf dem Weg zum Kältekompressor der Zukunft zu kreieren. Das Ergebnis ist ein klar strukturierter und nachvollziehbarer Phasenplan basierend auf Systems Engineering (SE). Dieser dient als Leitfaden zur Generierung von technologischem Wissen als Basis für die weiterführende Produktentwicklung.

Bezug nehmend auf Systems Engineering bedeutet dies, der Schwerpunkt dieser Arbeit lag überwiegend im Bereich der Definition einer Vorgehensweise zur Systemgestaltung mit dem Ziel, eine möglichst direkte Vernetzung von Theorie und Praxis zu realisieren.

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1 Introduction

"In every sector and every industry, the players that compete best will not be the wealthiest and the most powerful, but rather the most flexible and the most insightful." [Laszlo 1997, p.13].

This citation has more validity than ever before, not only in economic affairs. In times of globalization and exceedingly dynamic processes in industries the capability of change and flexibility is an essential key to success for any business. The fact that our globe becomes smaller and smaller in terms of communication, networks and economic unions leads to new opportunities but also to new challenges which have to be met. In this context the buzzword is innovation. But with the objective to be an innovation leading industry the dealing with new emerging technologies goes hand in hand.

A company with the vision of being a global centre of innovation in the field of cooling compressors for refrigerators in household appliances is ACC Austria. Distinctive networks with scientific institutions, continuous improvement and a long term product planning are just a couple of examples that underline this ambition. One part of the long term product planning at ACC Austria is technology development with the initial goal to make structured knowledge for industrial usage available as basis for further product development. This should be performed in differentiated technology development projects to maintain the usability of the information for the company.

1.1 Objectives of the thesis

Constitutive on former diploma thesis, where the main parameters of the new compressor platform CC2018 and contradictions as barriers of reaching those have been defined and evaluated, the objective of this thesis is to define technology fields as areas of expertise. Based on those fields technology development projects should be derived as operational activities to acquire the essential knowledge to overcome those contradictions. Another point is the creation of a generic approach to handle the mentioned projects according to the requirements of ACC Austria. The applicability should be assured by gearing to Systems Engineering principles. In the end the diploma thesis should allegorize a certain kind of manual for ACC Austria how to handle technology development as predevelopment for a new product design.

In other words, the goal of the thesis is the description of a path to make structured knowledge available on the way to the cooling compressor platform of the future.

1.2 Conceptual formulation

The general projects of the product development department of ACC Austria have spanned not more than three years. The long term product planning CC2018 is the first compressor platform development project whereby a clear and structured technology development phase should antedate. Therefore, based on the input parameters (Chap. 3), a definition and terming of technology fields as expertise clusters prepared with ACC experts is required. Within those fields technology development projects have to be executed what presupposes the creation of a generic approach, according to the Systems Engineering methodology, as guideline for the project handling. Remarks where to pay particular attention are essential and imperative for the practical adaptability.

1.3 Course of action and structure of the thesis

The proceedings along the thesis have been arranged according to the Systems Engineering concept pursuant to Haberfellner et al. [2002, p.29ff], also implemented and used at ACC Austria, to ensure a structured procedure, manage clearness, build variants and make sure that unqualified variants will be identified early (Ill. 1.1).

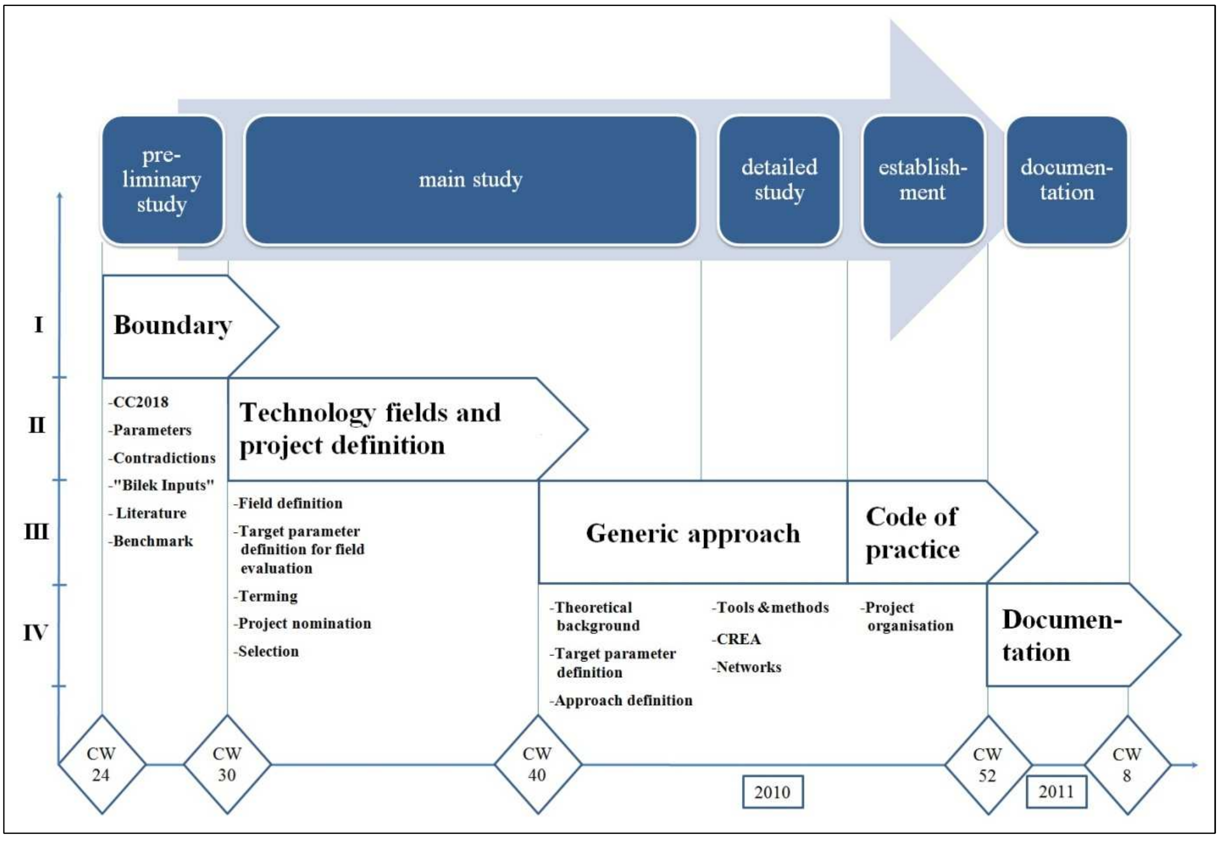

Illustration 1.1: Course of action of the diploma thesis

The thesis itself has been divided into three main sections, each composed by specific chapters, to assure a high extent of clarity and traceability (Ill. 1.2).

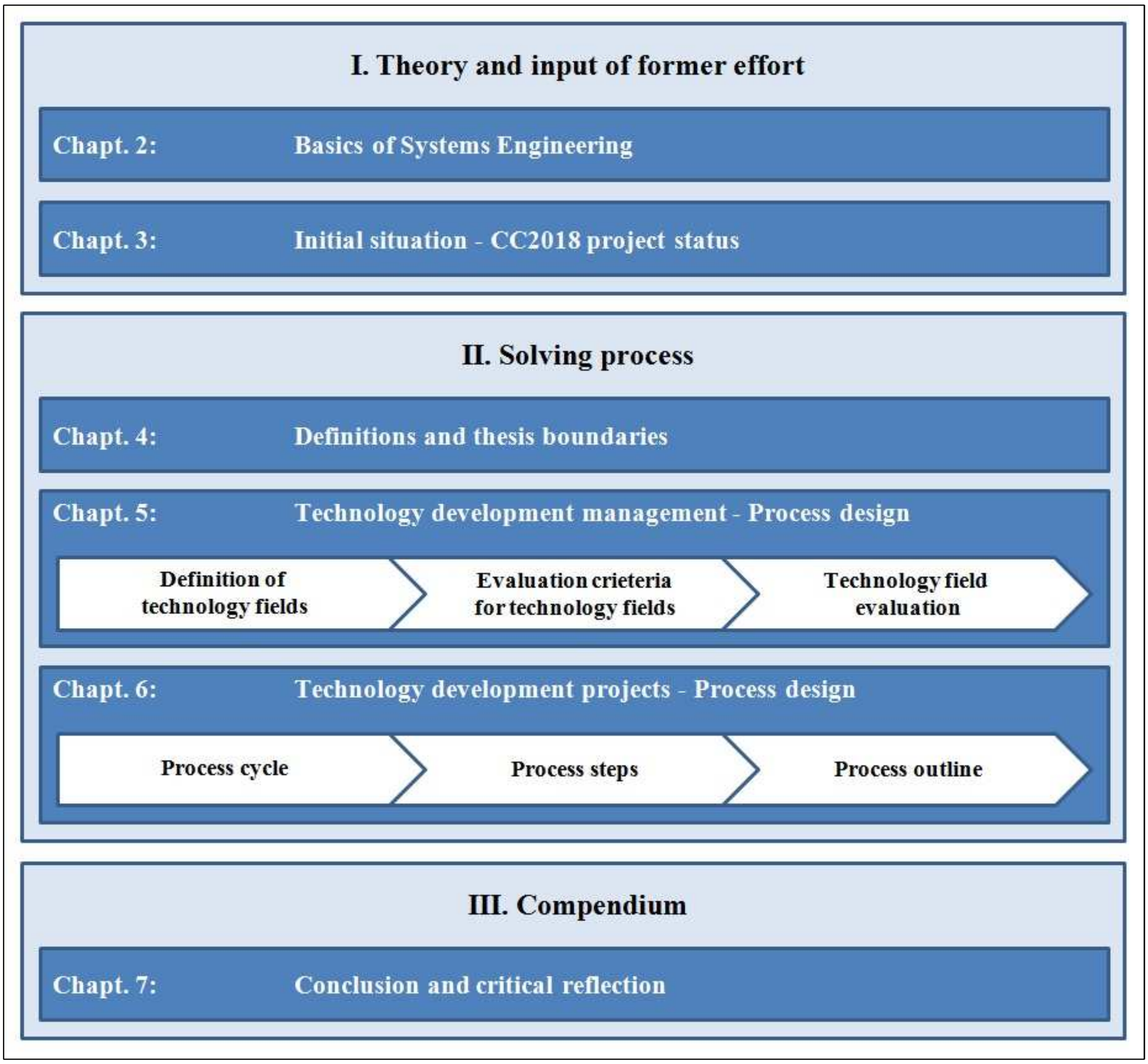

Illustration 1.2: Structure of the diploma thesis

Block one, theory and input of former effort, discusses the basics of Systems Engineering according to Haberfellner first. This specific interdisciplinary methodology to develop complex projects deals as theoretic backbone of the thesis results. Secondly, the state of affairs of the long term product planning project CC2018, the initial situation of the thesis, are presented.

Based on the theoretic SE approach and the input of former CC2018 project effort follow the explanation of the solving process including particular objectives, the respective approach and of course the final outcome. The last part of the thesis gives attention to a conclusion and critical reflection.

2 Basics of Systems Engineering

In general Systems Engineering can be considered as guidance for functional and target oriented design of complex systems based on principles and specific approaches. [Haberfellner et al. 2002, p.XVIII]. The following illustration displays the distinguishable components of Systems Engineering.

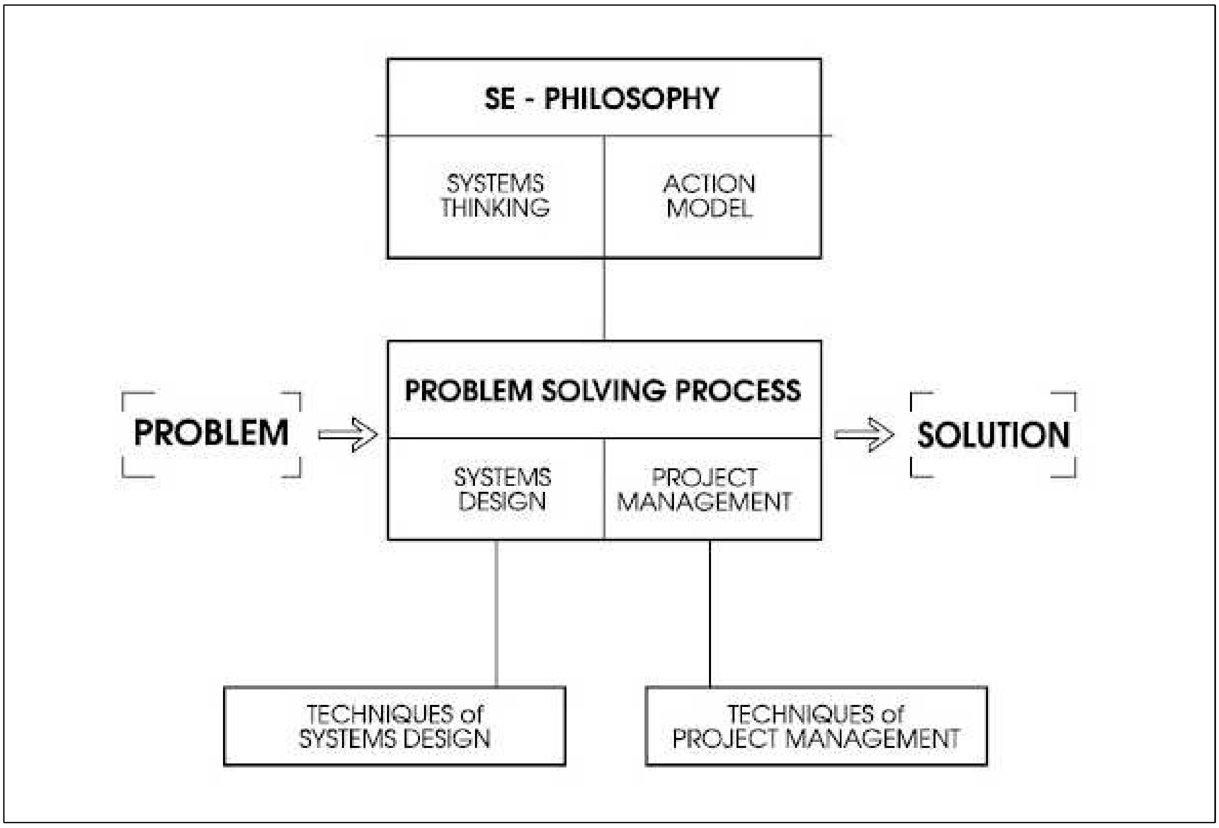

Illustration 2.1: Systems Engineering components [Haberfellner et al. 2002, p.XIX]

The central part of the Systems Engineering methodology is the Problem Solving process with the intrinsic objective to change a, normally not satisfying, present condition. Beside established tools, methods and techniques supporting this process comprehends the SE-philosophy the required way of thinking.

2.1 Systems Engineering-philosophy

The foundations of the SE-philosophy are the two basic modules systems thinking and the SE action model (Ill 2.1). Systems thinking represents an approach to understand and design complex frameworks in a better way and to encourage the holistic thinking idea, first expand the horizon and to reduce it afterwards again. [Haberfellner et al. 2002, p.4ff].

Furthermore systems thinking contains specific key terms for the description of extensive coherencies and entities (Ill. 2.2).

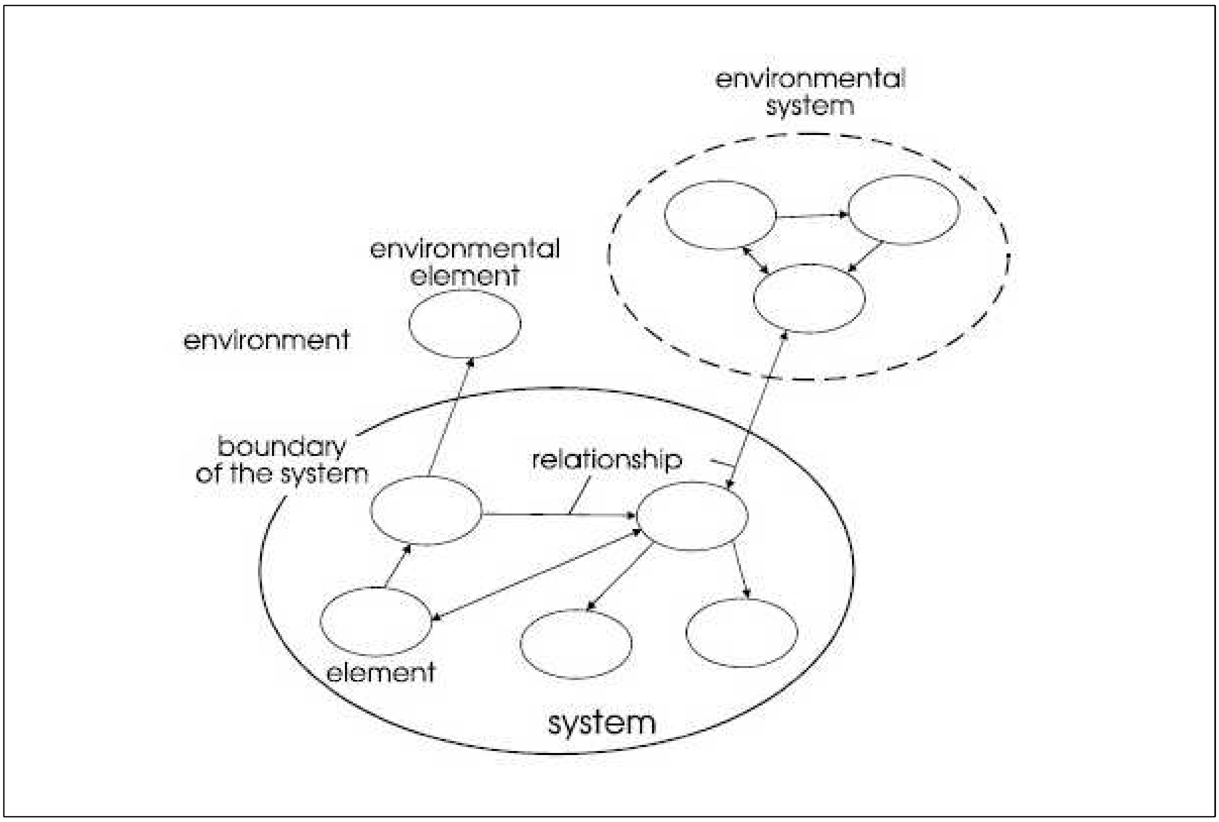

Illustration 2.2: Key terms of systems thinking [Haberfellner et al. 2002, p.5]

In this context a system consists of several elements, whereby also those could be understand as unique systems with accordant relationships, and has a clear boundary, more or less arbitrary, to its environment. This means a system clasps parts that are in relationship with each other and forms a holistic object. To ensure a universal applicability all terms have to be considered in a general way and always problem specific. [Haberfellner et al. 2002, p.4ff].

Each system can be examined and described from different points of view, in other words through special filters or glasses. Such specific characterizations of elements or relationships highlight the particular aspects of a system. Various ways of looking at systems are for example [Haberfellner et al. 2002, p.4ff]:

- Environmental orientation, e.g. the natural environment of a company
- Effect orientation (input-output orientation), e.g. energy balance
- Structural orientation, e.g. flow of material
- System-hierarchy orientation, e.g. first rough structuring and then detailing
- Consideration of subsystems (looking downwards)
- Consideration of suprasystems (looking upwards)

The second part of the SE-philosophy is the so called SE action model. This essential part of the SE methodology is made up of four basic ideas which should be regarded as components to be combined for use. Those ideas are [Haberfellner et al. 2002, p.29ff]:

- Proceeding from the general to the particular ("top down approach")
- Observing the principle in thinking in variants
- Dividing the process of system development into project phases
- Using the problem solving cycle (PSC) as a kind of working and thinking logic

The particular elements of the action model are components of a holistic methodology with reasonable coherencies (Ill. 2.3).

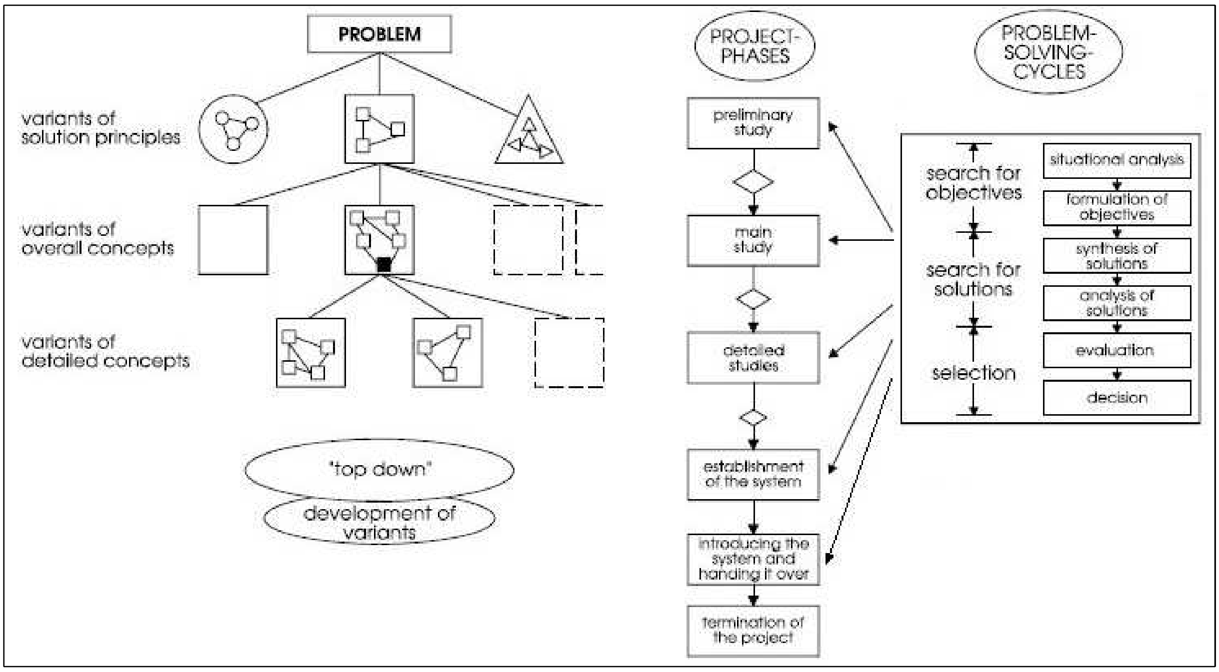

Illustration 2.3: Various components of the SE action model [Haberfellner et al. 2002, p.59]

The so occurring modular structure is representative for the Systems Engineering concept. Thereby concretize and reflect the project phases as well as the development of variants the global approach from the general to the particular. The problem solving cycle acts on the other side as micro logic to go about each problem. Special relevance comes up to the problem solving cycle during the development phases (preliminary-, main- and detailed study) because of the methodical problem solving. In the phases later on, establishment and introduction of the system, routine processes and situational improvisation get more and more important. Nevertheless, in principle it is possible to apply the problem solving cycle also for problems appearing in the realization and implementation. Moreover the SE action model offers space for changes and simplifications without querying its basic statement. [Haberfellner et al. 2002, p.29ff].

2.2 The SE problem solving process

According to the SE methodology (Ill 2.1) the process of handling challenges consists of two notional distinguishable components, systems design and project management. Systems design represents thereby the intrinsic operational activity of finding solutions and project management the organization and coordination of the process behind. [Haberfellner et al. 2002, p.XX].

2.2.1 Systems design

The foundation of systems design is the SE action model, having regard to particular aspects of application. Consecutively those aspects will be exemplified for the basic principles of the action model.

“Top down” excites a way of thinking outside in and is, especially in cases of redevelopment, an absolutely certain approach. In situations of seeking for improvements a converse to “bottom-up” might be reasonable but is rather an exception. [Haberfellner et al. 2002, p.81]. The following illustration describes the narrowing down of the field of consideration with advanced project progress (Ill. 2.4).

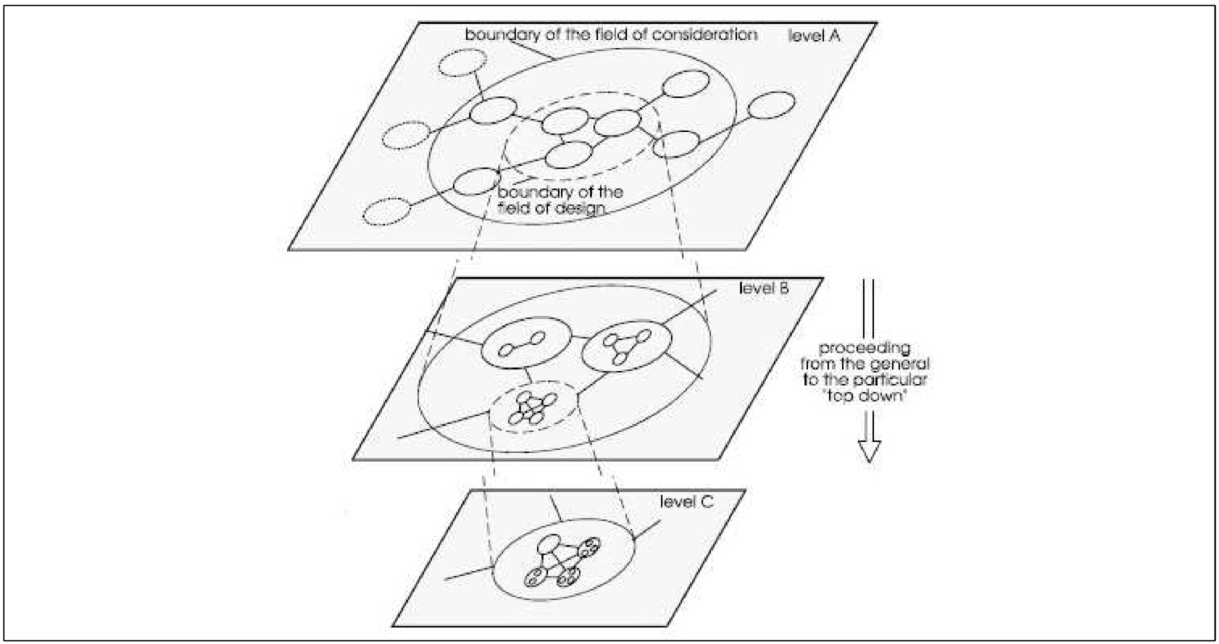

Illustration 2.4: Narrowing down the field of consideration [Haberfellner et al. 2002, p.32]

An indispensable part of the SE methodology is the development of variants because for almost every problem exist several solutions. Therefore it is important not to be satisfied with the first that comes along but to get a general idea of possible solutions. This is the reason why development of variants should be understood as expression of impartiality and a broad mind. [Haberfellner et al.2002, p.33].

The basic idea of subdividing a project into phases is to create a mental framework, in order to structure it into clear parts, to enable a stepwise process of planning, decision making and realization which becomes more and more concrete. Thereby the phases, with the purpose of developing a solution, and the project life cycle stages have to be differentiated (Ill. 2.5). [Haberfellner et al.2002, p.37].

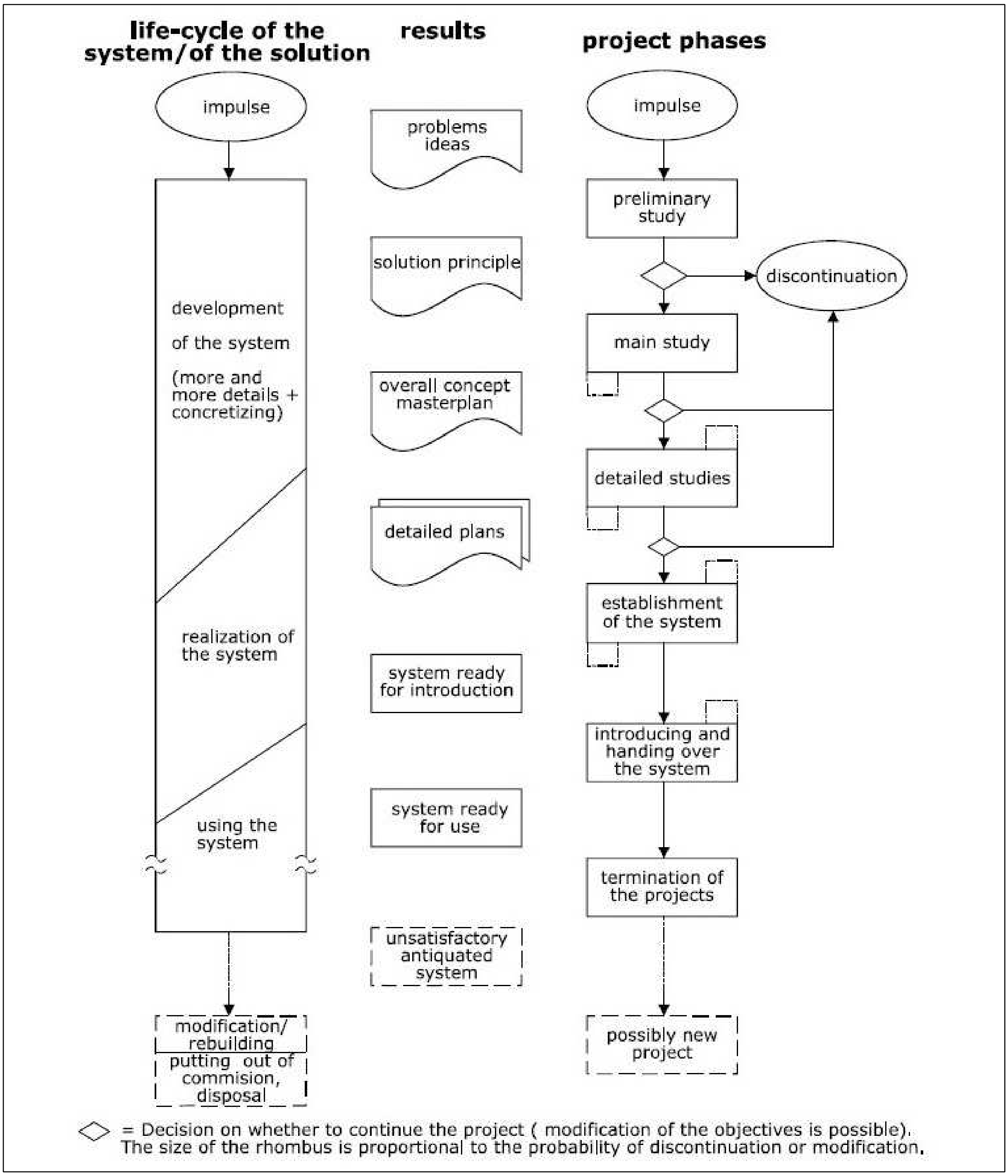

Illustration 2.5: Phase model – basic model [Haberfellner et al. 2002, p.38]

The number of individual phases as well as the formalism of handling them depends on the project type, complexity and its importance.

Out of the fact that the life cycle of a system is a dynamic and flexible process, embedded by a changing environment and afflicted with interdependencies, adjustments and modifications could be necessary according to the knowledge of the system (Ill. 2.6). [Haberfellner et al.2002, p.88].

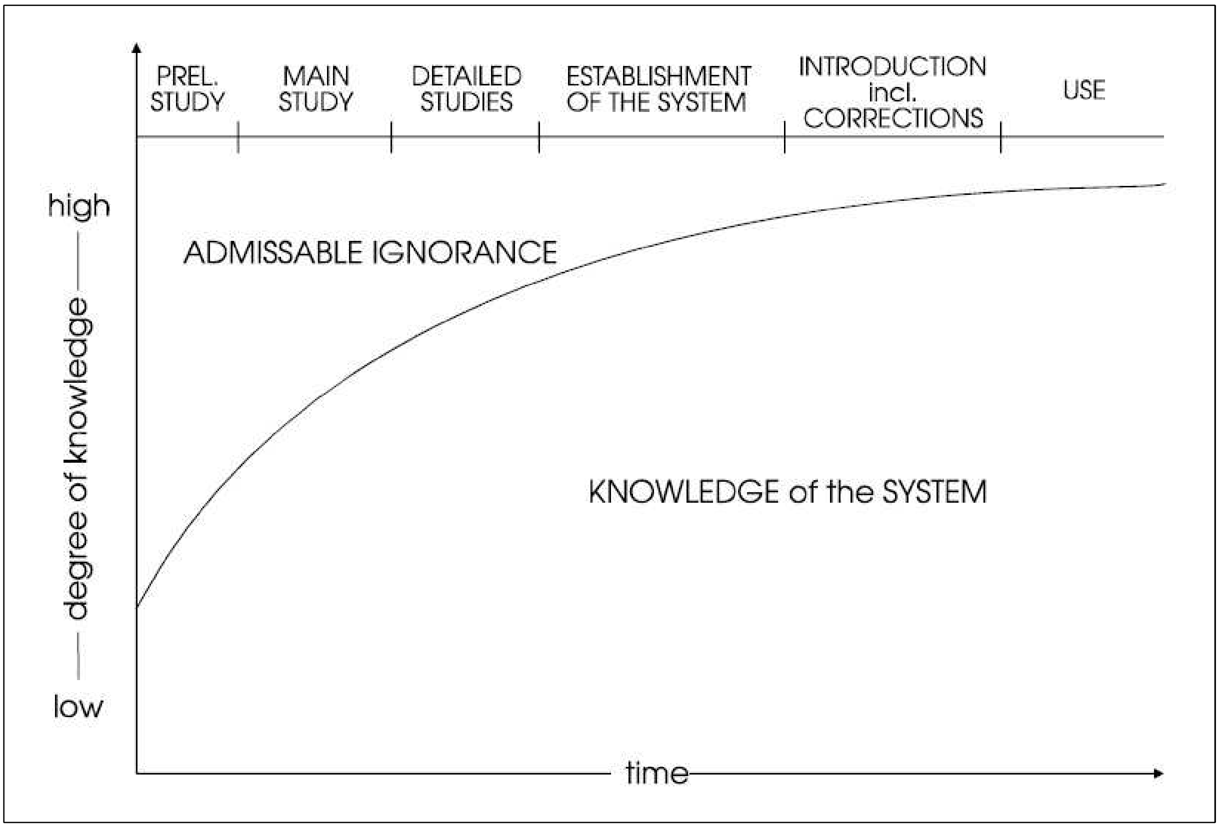

Illustration 2.6: Knowledge curve of a system [Haberfellner et al. 2002, p.88]

In this context the knowledge of a system must not be zero at the beginning because especially in specific industrial areas, like the manufacturing of hermetic cooling compressors, engineers have respective knowledge and even simple users may know at least the current state. [Haberfellner et al.2002, p.88].

According to Haberfellner et al. [2002, p.89] the degree of innovation of a solution (its character of newness) should decrease steadily during progression of the phases. Whereby the degree of innovation involves in general two components, existing and established solution elements that can be combined to a new whole and such that have to be newly developed.

But out of the fact that the human capability of knowledge acquisition has its limits, at least natural, it is not possible to reach all embracing lore of a system or technology. This also explains the character trait of humans to seek for an appropriate solution instead of the best solution.

Completing the aspects of application of the SE action model by embracing the problem solving cycle, the thinking logic underlying the particular phases, the main focus of this procedure is determined by the sub items search respectively concretion of objects, search for solutions and a respective selection (Ill. 2.7).

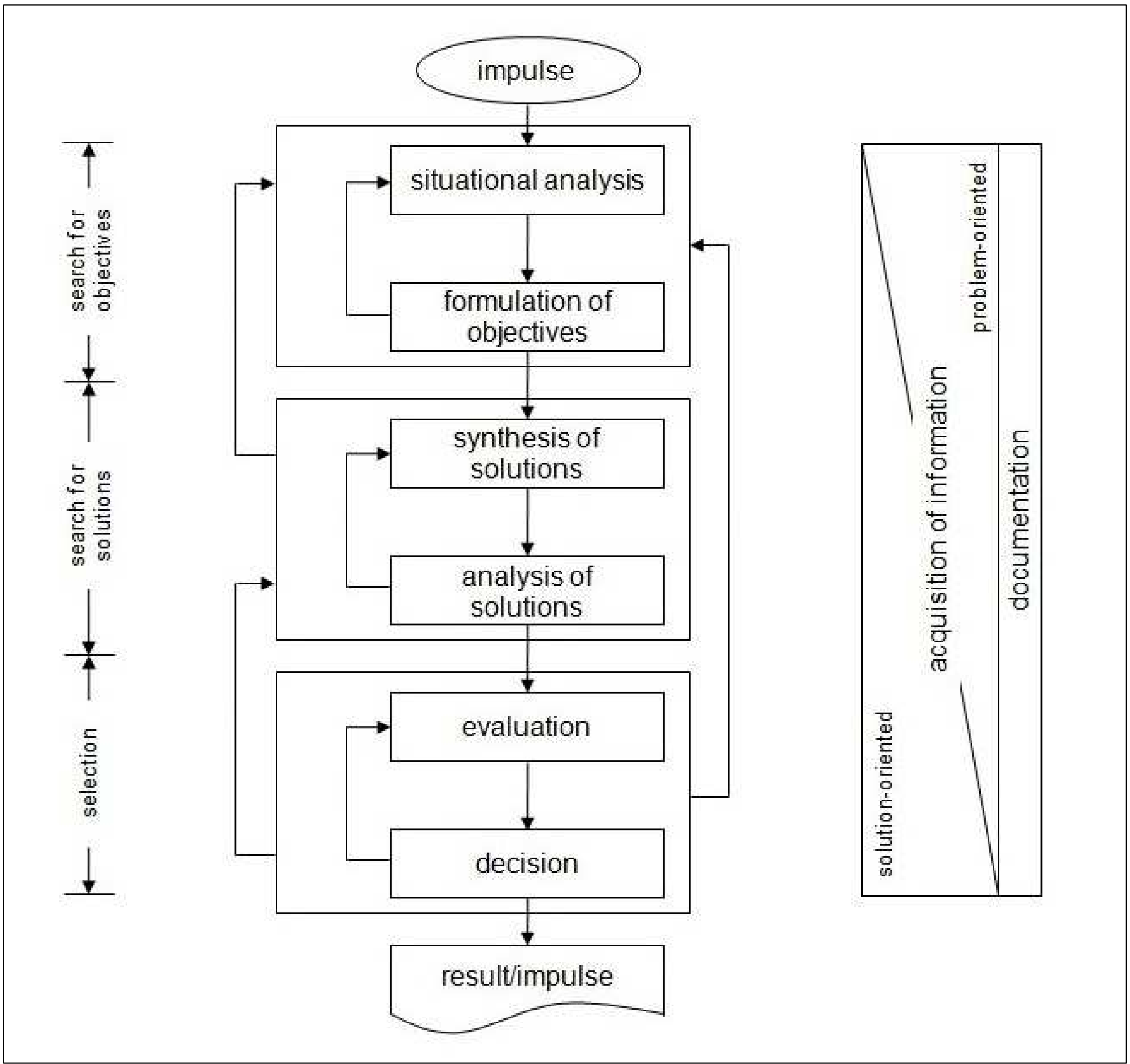

Illustration 2.7: Problem solving cycle – basic model with recourses [Haberfellner et al. 2002, p.98]

This basic structure can be interpreted as universal code of practice for a gradual proceeding by handling the particular steps.

The impulse at the beginning of a preliminary study is a catalyst that puts the approach into operation and is, in this case, identical with the impulse that sets the preliminary study into operation, basically with the ambition to change certain conditions. On the other hand the impulse can have the character of a tangible mission if a result of previous activities should be concretized. [Haberfellner et al. 2002, p.49].

The purpose of the *situational analysis* is the assessment of the state of affairs to examine and understand the initial situation. Thereby, four characteristic points of view can be distinguished which correlate to each other [Haberfellner et al. 2002, p.49f]:

- System-oriented view: Should help to structure the initial situation.
- Effect-oriented view: Deals with the question “What is the background?”
- Solution-oriented view: Should focus on ideas for solutions.
- Future-oriented view: Contains an assessment of future trends.

The *situational analysis* provides quantitative and qualitative information as foundation for the search for objectives and also for solutions and enhances the appreciation of problems. [Haberfellner et al. 2002, p.49f].

Object of the *formulation of objectives* is the systematic collection of aims that should be taken as a basis for the search for solutions and to derivate criteria for the evaluation. Thereby the aspired targets should be neutral referring to the solution, complete, precise and comprehensible and of course realistic what might lead to contradictions or conflicts. To differ in terms of importance of goals it is functional to classify those in compulsory, requested and desirable objectives. [Haberfellner et al. 2002, p.50]

Synthesis and analysis together demonstrate the central operational part of the problem-solving cycle. This stage of the approach represents the generation process of principally capable alternatives. The procedure of searching for options consists of two operations of the same value [Haberfellner et al.2002, p.52]:

- *Synthesis* as creative, conceiving and designing step.
- *Analysis* as critical step with a systematic diagnosing to improve or abolish a respective alternative.

After the identification and composition of potential solutions, it is necessary to compare them to discover the most suitable. The difficulty in going along with the *evaluation* is to make different features and characteristics comparable. To alleviate this situation it is possible to avail oneself of several methods and techniques for support, e.g. utility value analysis, portfolios, cost-benefit calculation etc. But all those methods cannot replace the intrinsic decision, they can just facilitate. [Haberfellner et al. 2002, p.53f].

The *decision* has to determine, based on the result of the *evaluation*, which alternative to follow up. This is either an impulse for the next project phase or the realisation of a variant. [Haberfellner et al. 2002, p.54].

The main focuses of the particular sub-steps of the PSC can also be arranged to different thinking levels (Ill. 2.8).

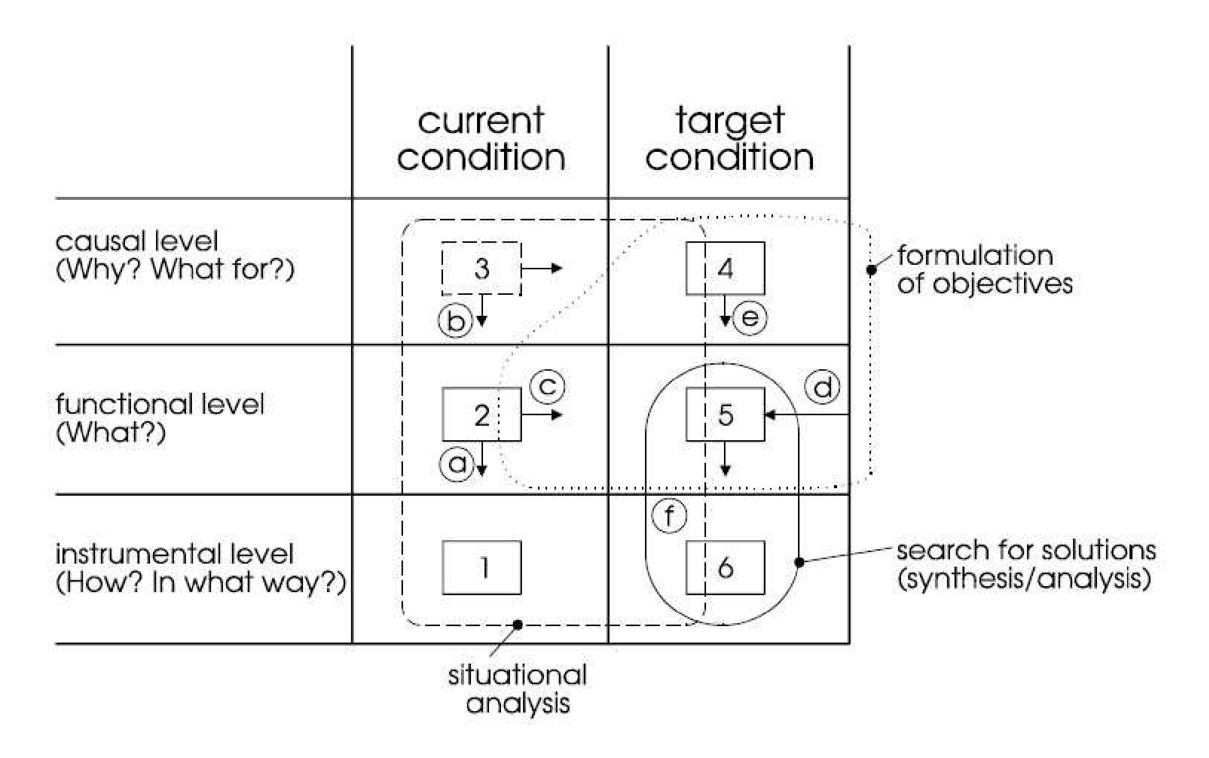

Illustration 2.8: Different reasoning levels in problem solving [Haberfellner et al. 2002, p.95]

Referring to the previous figure, the numbers represent specific conditions and the letters work respectively mental activities [Haberfellner et al. 2002, p.94f]:

1. Current status
2. Current status lifted to the functional level what allows a reconsideration
3. Sense of current functions and duties
4. Causal level of the target condition
5. Requirements to the target regarding the functional level
6. Possible fulfillment of the targeted functions

a. Current resources assessed based on functional requirements
b. Constitute current functions
c. Current functions as source for future functional requirements
d. Additional functional requirements
e. Reasoning for future functions
f. New functions fulfilled with new means

In efficient problem solving it is also essential to drive into the functional and causal level and not only on the instrumental level, asking just the question how.

Another essential point with the application of the problem solving cycle is that an absolute linear structure would be unrealistic and is not intended at all. Anticipations as well as repeat cycles are in most cases necessary and desirable. Ill. 2.7 describes beside the step sequence the most important repeat cycles within the problem solving cycle. [Haberfellner et al. 2002, p.96].

Therefore the PSC methodology should be understand as guidance and represents an agreement between an idealized linear sequence and a realistic, universal and complex proceeding.

2.2.2 Project Management

A key criterion of management of projects in general is that organizations have to separate operations around projects from the common line activities whereby multiple responsibilities of employees' respectively personal complexities are not excluded.

In terms of SE, as second element that makes up the problem solving process (Ill. 2.1), project management can be understood as umbrella term for all planning, monitoring, coordinating and controlling procedures beyond systems design. [Haberfellner et al. 2002, p.240ff]. Thereby the idea of systems thinking, the different procedural principles and appropriate techniques and tools should influence project management as well as systems design (Ill. 2.9).

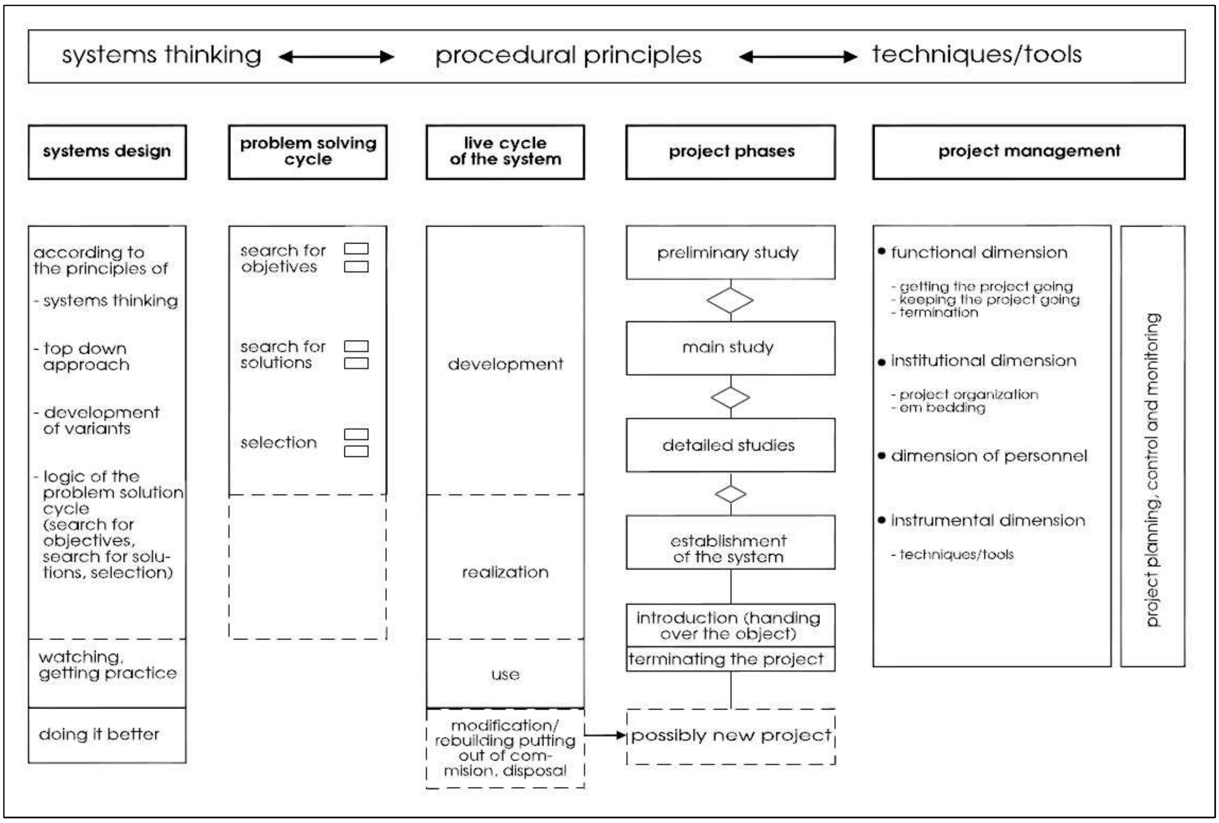

Illustration 2.9: Coherences of systems design and project mgmt. [Haberfellner et al. 2002, p.245]

Referring to the previous illustration, to describe the subject more structured, project management clasps four dimensions that have to act simultaneously to cover all volition creating and accomplishing activities [Haberfellner et al. 2002, p.243f]:

- Functional dimension; centers coordinating and organizing activities.
- Institutional dimension; comprehends especially the project organization and its embedding in the enterprise.
- Dimension of personnel; turns its attention to the people involved.
- Instrumental dimension; deals with the question “how?” in terms of technical execution.

Important is that the causes of success or failure of a project can have their source on each dimension.

Different to systems design, that concentrates on the aspects with regard to the content of the concept and the development of a solution, project management focuses on the management of the problem solving process. But both components are not separable in real life and affect the same group of people. [Haberfellner et al. 2002, p.278].

Altogether the components of Systems Engineering (Ill. 2.1) form a problem solving methodology that [Haberfellner et al. 2002, p.XXIII]:

- Ends not in itself, but serves the development of solutions.
- Is not an alternative for talent, capabilities or knowledge, but requires all those.
- Should be agreeable with reasonable problem solving (psychological component).
- Is not in contrast with intuition and creativity, but utilizes both.
- Is a guideline for complex problem solving, whereby the useful effect is a result of the input of intellectual potential.
- Orientates the necessary effort to the anticipated useful effect.

With these basic principles concerning the application, Systems Engineering provides a broad scope with modular interconnected rationales, which can be undogmatically modified or complemented, to carry problems to creative and stable solutions.

3 Initial situation – CC2018 project status

This part gives an overview of the inputs to the thesis from former efforts and about the limits of the examined area. Even though the modus operandi should be applicable generally, this assignment corresponds to the long term product planning of ACC Austria, namely CC2018, to manifest the usability and to bear reference to industrial operations.

First of all the general strategic orientation of ACC Austria is presented, followed by a compiled action plan to pave the way for the aspired strategic positioning. Furthermore the results of previous activities within the scope of the CC2018 project, as basis respectively predetermined boundary for this thesis, are exemplified.

3.1 Strategic orientation of ACC Austria

An intentional goal of every business strategy is to achieve competitive advantage and so to distinguish on the market. In this context, ACC Austria focuses on segment cost leadership and sees itself as cost leader in the high performance market segment of cooling compressors for household refrigerators. To be more precise, the compressor market can be sub classified into three segments: high-, middle- and low- performance. ACC Austria quests to cost leadership within the high performance cluster through innovative products and processes manufactured in a developed country, contrary to the global trend of production outsourcing to low wage countries.

Porter [1985, p.11ff] describes in his considerations concerning competitive strategies three basic types that influence the competitiveness in a positive way: overall-cost-leadership, overall-differentiation and focus. Moreover, a clear strategic orientation and an admitting to it is a necessity to avoid sticking in the middle (Ill. 3.1).

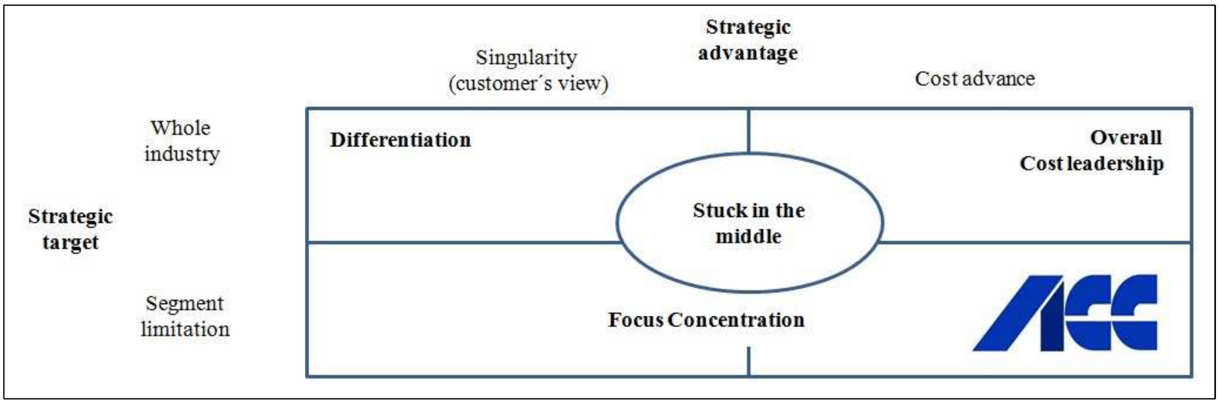

Illustration 3.1: Differences of strategy-types and the orientation of ACC

Organizations without a clear strategy occupy an exceedingly bad competitive position and have in general a deficit adverse to cost leaders or companies that focus on specific market segments.

In reference to Burgelman and Maidique [1988, p.219] a clear strategic orientation requires dedicated technological policies (Table 3.1).

	GENERIC STATEGY			
	Overall Cost Leadership	Overall Differentiation	Focus-Segment Cost Leadership	Focus-Segment Differentiation
	TECHNOLOGY POLICIES			
Product technological change	Product development to reduce product cost by lowering materials content, facilitating ease of manufacture, simplifying logistical requirements, etc.	Product development to enhance product quality, features, deliverability, or switching costs.	Product development to design in only enough performance for the segment´s needs.	Product design to exactly meet the needs of the particular business segment application.
Process technological change	Learning curve process improvement Process development to enhance economies of scale	Process development to support high tolerances, greater quality control, more reliable scheduling, faster response time to orders, and other dimensions that improve the ability to perform.	Process development to tune production and delivery system to segment needs in order to lower cost.	Process development to tune the production and delivery system to segment need in order to improve performance.

Table 3.1: Technological policies and competitive strategies [Burgelman, Maidique 1988, p.219]

As mentioned in the table above this generic course of ACC Austria requires specific minimum standards but demands not the greatest deal of performance.

The strategic target of ACC Austria, demonstrated in Ill. 3.1 and Table 3.1, is to assert on the global market, especially compared to competing organizations with manufacturing in low-wage countries, through cost advantages. Because of the high fixed expenses and ancillary labour costs, this requires an innovative and effective product portfolio, efficient processes as well as an elaborated quality management system.

Those factors for the accomplishment of economic success should be based on a mature product development system that enables continuous innovations.

3.2 Long term aspects of product development

The household compressor system development at ACC Austria has been defined as CC2018. In line with Systems Engineering, the basic concept has been broken down into a three phase process whereby each phase embraces a period of 2,5 years. The end of every phase displays a milestone with concrete objectives. The following Gantt chart shows the terming and planned phase out of the different stages (Ill 3.2).

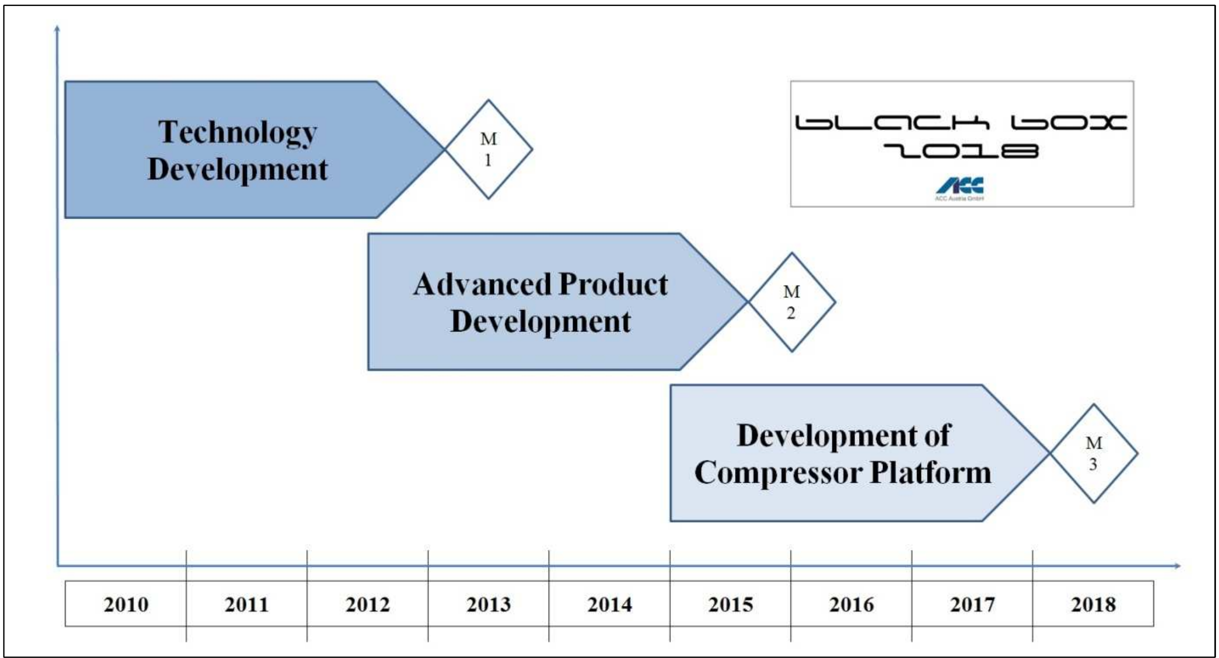

Illustration 3.2: Gantt chart of the CC2018 project

The overall objective of each phase is of general nature but communicates a clear direction selecting:

- Technology development faces the providing of structured technological knowledge for industrial usage, which means this area is construed rather theoretically and scientific.
- The assignment of advanced product development is to provide overall concepts and prototypes.
- The "development of compressor platform" phase is the stage of implementation and industrialization with the final aim to sale the product.

As noted in the basics of Systems Engineering, cf. Chap. 2.2.1, smooth transitions and possible recourses are preferable instead of absolute fixed limits.

3.3 CC2018 current project situation

To expose the initial situation of this thesis in a distinct way it is necessary to illustrate the actual status of the long term product planning process. The following outline of former effort and results of respective activities regarding the CC2018 mission includes:

- Definition of objectives
- Definition of subsystems
- Definition of contradictions
- Definition of transformation factors to enable comparisons
- Allocation of aspired improvements to specific functions and subsystems

The outcome of those examinations forms the approximate framework of the project and defines the main focuses to deal with, as well as the barriers that have to be overcome until the implementation of the final concept.

3.3.1 CC2018 target definition

The organization´s way to the cooling compressor of the future has had its point of origin with the target definition of the cooling compressor system 2018. Therefore the situation has been contemplated through four different glasses, on the one hand to embrace the systems thinking approach and on the other hand to emphasize or disregard specific system characteristics. The distinguishable filters have delivered information from different point of views for the main parameters of the CC2018 without any evaluation or rating, therefore the system of the cooling compressor 2018 has also been termed as black box 2018 (Ill. 3.3).

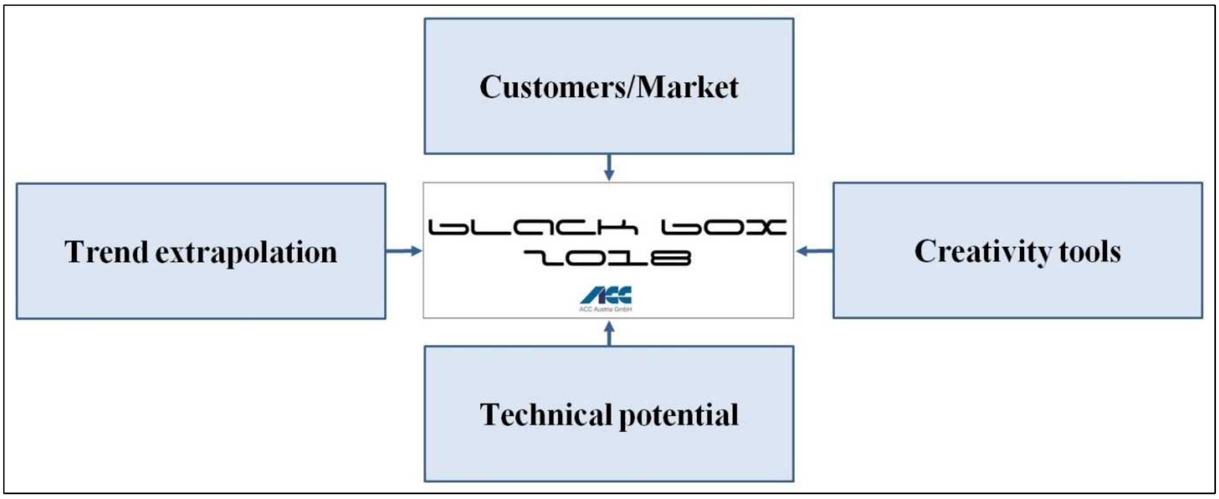

Illustration 3.3: Filters for target definition CC2018

The results of this search for objectives have been the abstract features below:

- Super mini size
- Ultra low energy consumption
- Wide cooling capacity
- Advanced interaction with appliance
- Cost optimized
- One for all
- Plug & Play

Beside those abstract features, figures of target values have been defined. The consecutive table represents a comparison of the main parameters of the CC2018 and the actual, at ACC Austria manufactured, hermetic cooling compressor model Delta, referring to a cooling capacity of 100 W (Table 3.2).

		Discharge line	Crankcase & piston	Head group	Power unit	Shell	Suction line	Control unit	Compressor
Costs	δ VT	0,67	1,88	0,65	4,2[1]	3,23	0,46	17,1[3]	28,2
[€]	CC2018	0,5	1,2	0,4	3,5[2]	2	0,3	4,8[4]	12,7
Space	δ VT	100	750		768	4600	300		
[cm³]	CC2018	70	600		538	3140	200	376	
Noise[5]/Vib[6]	δ VT								
[dB(A)]	CC2018					40/40			
Pressure loss	δ VT	1					0,3		
[W]	CC2018	0,3					0,2		
Valve losses	δ VT			2,5					
[W]	CC2018			2					
Dead volume	δ VT			0,05					
[cm³]	CC2018			0,04					
Leakage	δ VT		0,67						
[W]	CC2018		0,5						
Stroke rate	δ VT								1000-5000
[#]	CC2018								1000-5000
ΔT[7]	δ VT	4							
[W]	CC2018	2							
ΔT[8]	δ VT		8	5			10		
[°C]	CC2018		4	3			1		
Efficiency	δ VT		0,92		0,88			0,92	
[ ]	CC2018		0,93		0,92			0,98	
COP/Equivalent COP	δ VT								1,83/2,1
[ ]	CC2018								2,3/2,76

Table 3.2: Comparison of instantaneous values of Delta and target values CC2018

δ VT……..Standard compressor of the Delta family applied with an electronic driver and a permanent magnet engine

CC2018…Target of the year 2018

[1] Acquisition costs of a permanent magnet engine for the actual Delta
[2] Assumed costs for the engine in 2018
[3] Actual electronic driver (15 €) plus standard terminal board (2,1 €)
[4] Assumed costs for the control unit in 2018
[5] ∑ Degree of airborne sound insulation
[6] ∑ Degree of vibration insulation
[7] Referring to the heat emitted to the hermetic space
[8] Referring to the heating of the refrigerant

According to the actual costs of a control unit for a Delta compressor, it has to be indicated that this number would occur if today an adjustment setting of variable speed would be applied.

The target of the increased coefficient of performance (COP, defined as cooling capacity divided by power input) has to be examined in a more detailed way. Out of a designated usage of a control unit, to make an operation at different driving speeds possible, an equivalent coefficient of performance enhancement can be reached through a reduced overall energy consumption which is described subsequently.

At the moment ACC Austria utilizes two pin asynchronous motors for their compressors without any control unit. This results, at a stationary frequency, in a constant engine speed. But the cooling capacity requirement of a refrigerator is not always the same. Therefore a regulation of the engine speed, what leads straight to a changed cooling capacity, offers the possibility to provide the necessitated cooling capacity of the appliance. Different experiments have shown that through such a speed control system the total energy consumption can be reduced. The basis for that is an almost constant COP over range of speeds, respectively cooling capacity, which can be seen as a one to one increasing of compressors COP (Ill 3.4).

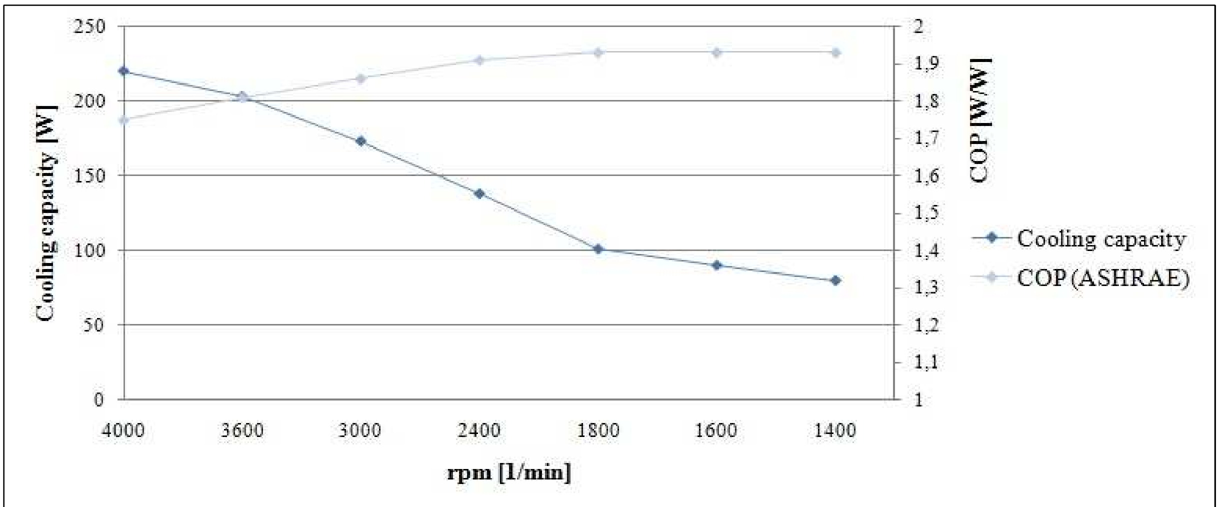

Illustration 3.4: COP and cooling capacity over rotational speed of a Kappa compressor

It follows that a percentage decrement of energy consumption is in accordance with the same percentage rising of the COP. But because of the fact that this coefficient of performance cannot be measured directly at the compressor, this systematic figure of the appliance has been termed as equivalent COP.

The following illustration demonstrates the increasing of the equivalent COP from a simulation of a Kappa compressor with a control unit for variable speed in a freezer appliance (Ill 3.5).

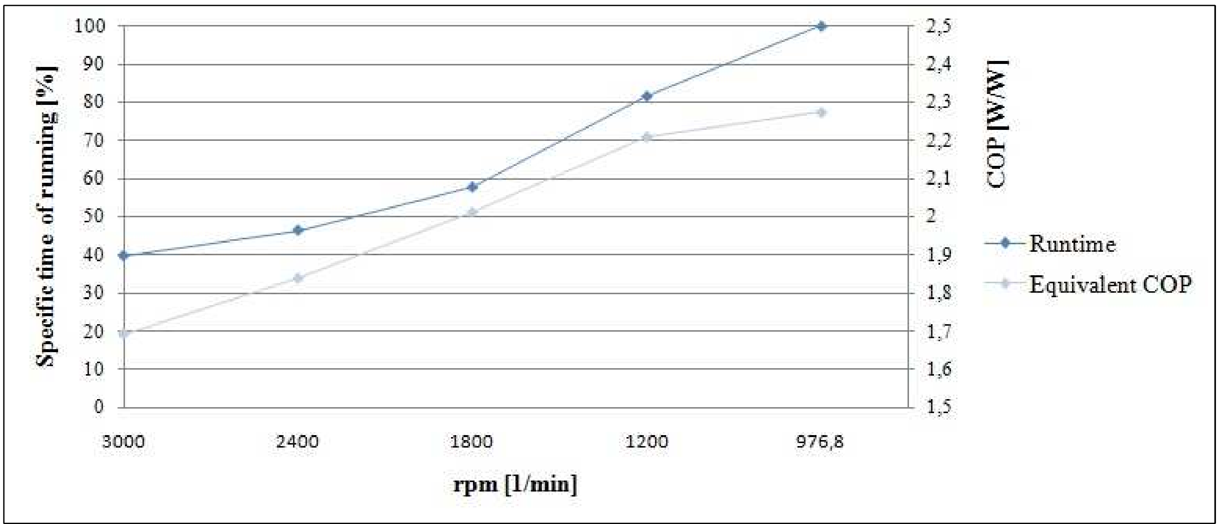

Illustration 3.5: Increasing of equivalent COP through speed control

The graphs show that a rising compressor runtime, up to 100 %, leads to an increasing of the equivalent COP of the refrigerator system, as a result that the compressor provides just the required cooling capacity (Ill 3.5). Based on this calculation, allocated via several experiments, the factor between compressor COP and equivalent COP has been defined with 1,15 for the application of a control unit at a Delta and with 1,2 for the CC2018 because of an assumed further development of the control system. This means that a compressor with variable speed increases the systemic COP today for 15 % and with the new compressor platform it should be possible for 20 %.

Referring to the actual case, again comparing the aspired CC2018 values with an actual Delta with variable transmission, the technical improvements of the compressor should result in a 25 % increasing of COP. Furthermore another 20 % increasing should be achievable by utilizing a control unit (Ill 3.6).

Those targeted improvements end up arithmetically in a more than 50 % higher COP at the final consumer.

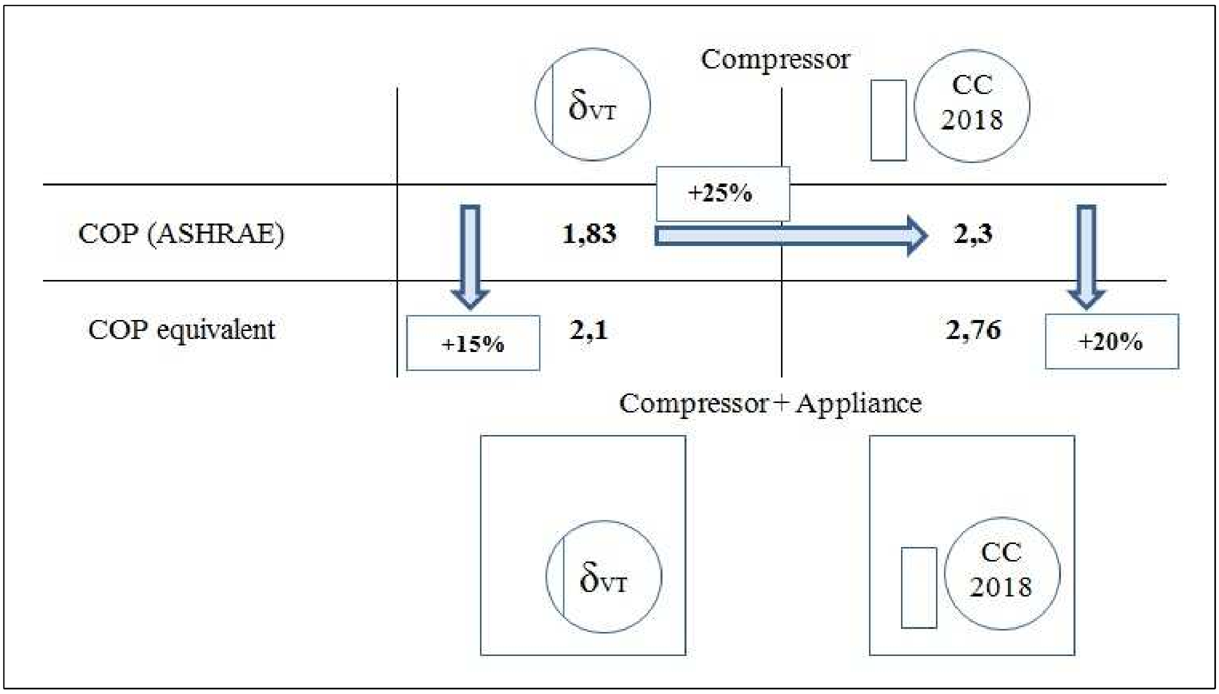

Illustration 3.6: COP comparison of actual Delta and CC2018

Moreover Ill. 3.6 points out the potential of increasing through focusing on and optimizing the overall system by comparing the compressors itself and their application in a refrigeration system.

3.3.2 Definition of CC2018 subsystems

According to the Systems Engineering module, from the general to the particular, the parameters have been allocated to subsystems, a new compressor platform will have by all means at ACC Austria (Ill. 3.7).

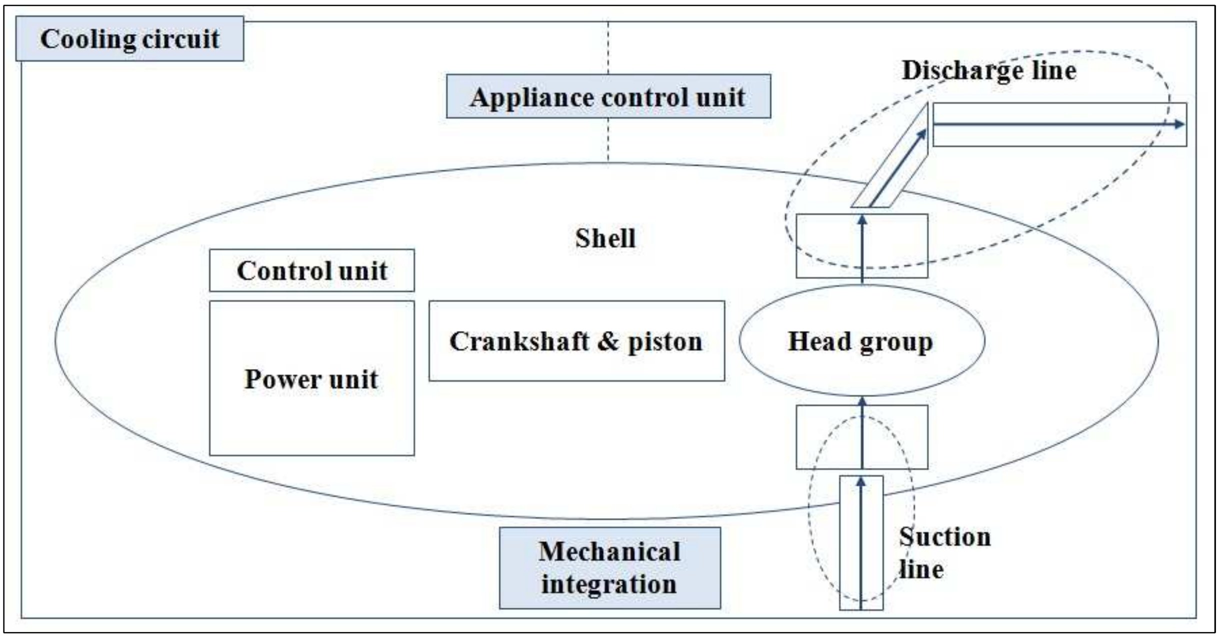

Illustration 3.7: Subsystems of the CC2018 based on Sorger [2008, p.50]

The definition of those subsystems has been made without any specifications or limits of their characteristics.

The primary classification of these functional groups has been extended to highlight the significance of interdependencies between the appliance and the cooling unit with the items:

- Cooling circuit
- Appliance control unit
- Mechanical integration

This was necessary because the interaction of the respective components is of vital importance for the efficiency of the final product. Therefore this determines also a factor of success and has to be considered even beyond compressor´s limits.

3.3.3 Contradictions on the way to CC2018

Thinking in contradictions corresponds to the basics of TRIZ, a creativity- and innovation tool implemented for many years at ACC Austria. In general, TRIZ is a methodic of inventive problem solving and operates with the principles that many inventions deal with a limited number of solution statements and that the evolution of technical systems follow certain laws and patterns. Genrich Altschuller, the father of TRIZ, made during his empiric patent analysis the following conclusions which reflect the basics of TRIZ [Eversheim 2003, p.151]:

- Exact descriptions of problems are often enough to lead to creative solutions.
- Most problems have already been solved by someone else.
- Contradictions are the central, innovation producing element of many patents.
- The development of technical systems follows certain basic rules.

Facing the application of TRIZ it is necessary to abstract the specific problem, search for known solutions and then retransfer it to the concrete level (Ill. 3.8).

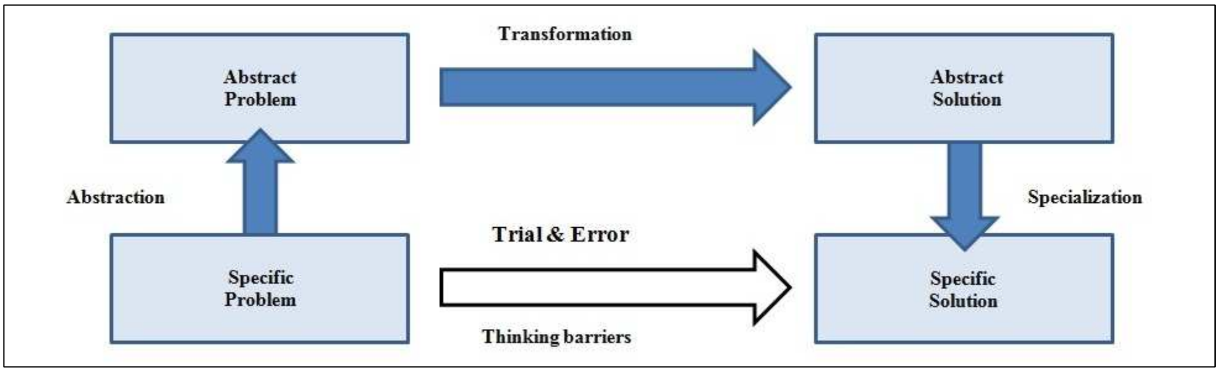

Illustration 3.8: TRIZ general proceeding [Gundlach, Nähler 2006, p.17]

The approach of thinking in contradictions, e.g. low weight vs. high stability or high performance vs. low consumption, should also support an observing of a wider horizon to rise the borders of the own industry.

The strength of TRIZ as innovation tool is its applicability on every way of posing a problem as well as providing different manners of approaching challenges. The user has the possibility to choose among a wide range of methodic tools to tailor the methodology to required exigencies.

Referring to ACC, TRIZ should represent a supporting tool to achieve continuous innovation (Ill. 3.9).

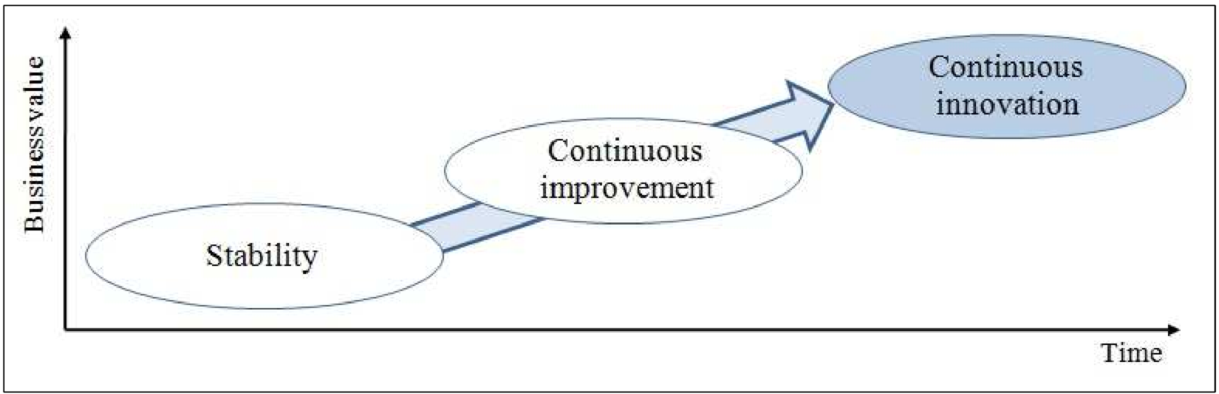

Illustration 3.9: TRIZ core message at CC Austria

Based on this general idea, a mindset cycle has been established, tailored to required exigencies, to ensure a structured course of action and to make the idea of continuous innovation part of the daily business (Ill. 3.10).

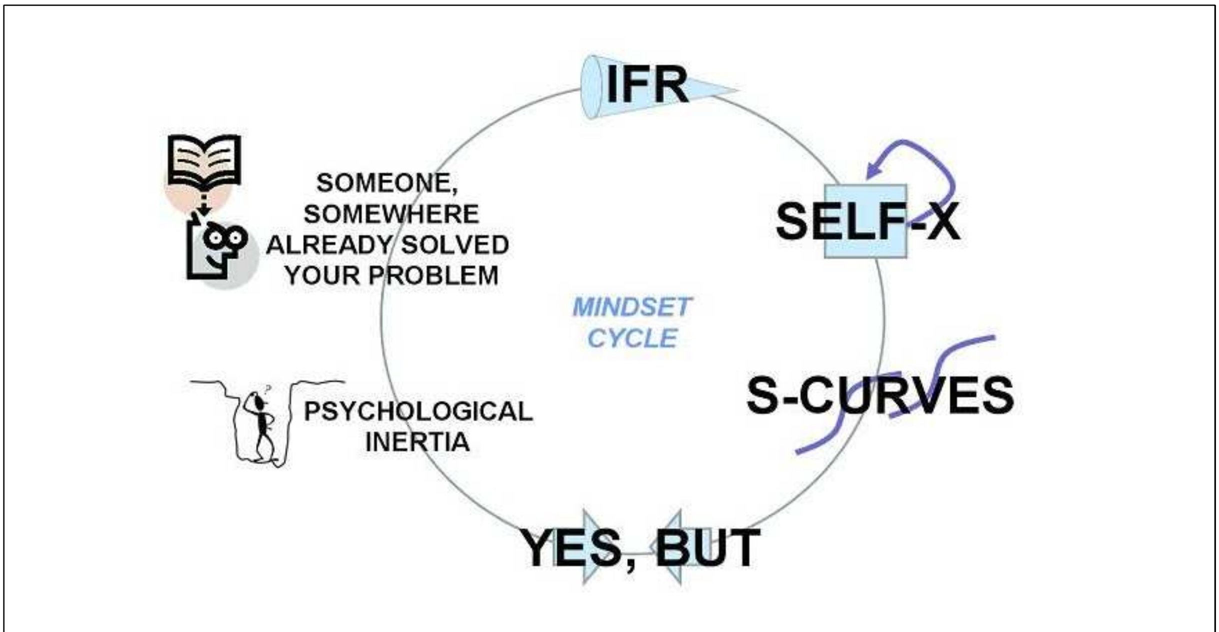

Illustration 3.10: TRIZ mindset cycle at ACC Austria

The upcoming explanation of the different items of the scheme should communicate the underlying basic understanding as an overview but is of course not a detailed description that claims entirety.

- IFR – Ideal Final Result

  The ideal final result should be none plus ultra, it should be without bias and from the current position. The question is what you would like to achieve without any limits.

- Self-X

  The basic idea is to minimize the requirements of external resources. “Self” means a system should solve problems or provide features by itself.

- S-Curves

  The life cycle of a technology follows an S-curve. Therefore a certain technology has its limits, which means that it is sometimes necessary to search for an alternative.

- Yes, But…

  This headline refers to thinking in contradictions and searching for solutions to overcome them. This is a central part of the TRIZ philosophy.

- Psychological Inertia

  Can be described as observing a problem from a different point of view and should help to think outside the black box.

- Someone, somewhere already solved your problem

  Maybe someone else has already occupied himself with an abstract problem that has occurred. Patent or knowledge databases, magazines or general research in different branches might offer an adaptable solution.

This cycle of abstract thinking provides a possibility to solve problems through a “big jump over the wall” instead of further developments created on the drawing board, or at least to put challenges in a different perspective.

Referring to the CC2018, the following contradictions have been classified and allocated to the subsystems as barriers on the path to the achievement of the CC2018 technical parameter objectives (Table 3.3).

System	Contradiction denotation	Number
Overall system	Diversification vs. Standardization	1
	Integrated electronics vs. Compressor "slave"	2
Suction line	Low noise vs. Small size	3
	Low pressure loss vs. Small size	4
	Low temperature vs. Big size	5
Head group	Low suction- discharge work vs. High cost	6
	Self adjusting valves vs. High cost	7
	Selective heat conductibility vs. Current material	8
	Self adjusting dead volume vs. Current material	9
Discharge line	Low pulsation vs. Small size	10
	Lower starting torque vs. Small size	11
	Low temperature vs. Big size	12
Control unit	Many interfaces vs. Low complexity	13
	Speed control vs. Low complexity	14
	Easy approbation vs. High complexity	15
Power unit	Speed control vs. Low cost	16
	High efficiency vs. Low cost	17
	High efficiency vs. Small size	18
Crankshaft & piston	Insulate temperature vs. Conduct temperature	19
	Adjustable for variable speed vs. High cost	20
	Adjustable for variable speed vs. High reliability	21
	Low friction vs. High cost	22
	Low friction vs. Big tolerances	23
Shell	No heat exchange between suction and discharge line vs. Low noise	24
	High heat exchange vs. Low noise	25
	Small size vs. Low noise	26

Table 3.3: CC2018 Contradictions [Sorger 2008, p.63]

Those contradictions have also been evaluated and with adequate factors converted to €- potentials to make an equal comparison and rating possible.

The values of the transformation factors (Ill. 3.11) are based on industry experience and market analysis. They give an approximate reference point regarding the raising of compressor price in case of COP increasing, or because of reduction of noise, space and production costs, referring to a single compressor.

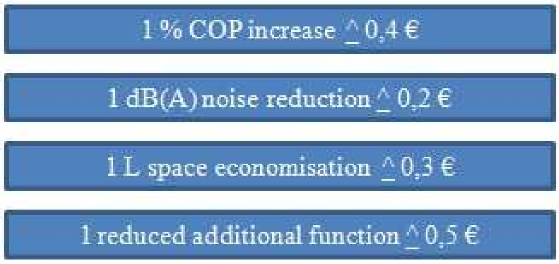

Illustration 3.11: Transformation factors of development potentials

The potential evaluation of the contradictions has been made in numerous TRIZ sessions and customer surveys within the framework of a former diploma thesis. [Bilek 2010, p.39ff]. The following table exhibits the contradiction potentials of the subsystems, referring to units and corresponding to the €- data, established by applying the specific conversion factors (Table 3.4).

	Contradiction potentials of CC2018 compared to actual Delta									
	COP		DM	Noise		Space		Add. Function		Subsystem
	[€]	[%]	[€]	[€]	[dB(A)]	[€]	[L]	[€]	[#]	[∑€]
Overall System	0	0	0	0	0	0	0	0,8	1,6	0,8
Suction Line	1,6	4	0,16	0,2	1	0,21	0,69	0	0	2,17
Head Group	1,2	3	0,25	0	0	0	0	0	0	1,45
Discharge Line	0,8	2	0,17	0,2	1	0,15	0,5	0	0	1,32
Control Unit	2,4	6	12,3	0	0	0	0	0	0	14,7
Power Unit	2	5	0,7	0	0	0,18	0,6	0	0	2,88
Crankshaft and piston	1,2	3	0,69	0	0	0	0	0	0	1,89
Shell	0,8	2	1,23	0,8	4	0	0	0	0	2,83
Appliance	2	5	0	0	0	0	0	0	0	2
Sum System	12	30	15,5	1,2	6	0,54	1,79	0,8	1,6	30

Table 3.4: Subsystem potentials compared to actual Delta

Based on the previous table the upcoming circular charts enable an overview of the fractions of the subsystems and the functions as part of the entire potential (Ill. 3.12).

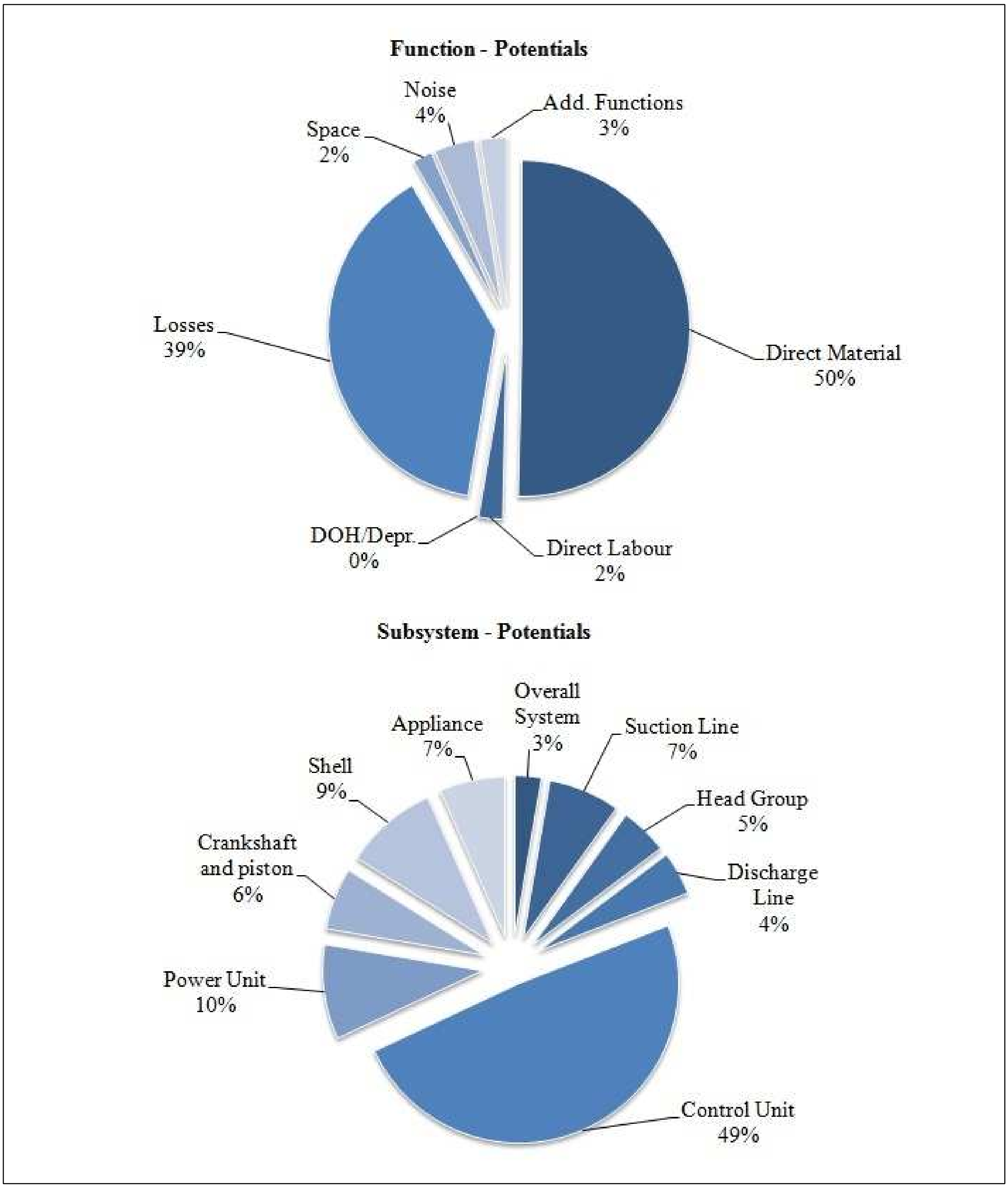

Illustration 3.12: Comparison of function and subsystem potentials

Those charts may create an impression that some function-potentials, as well as subsystem-potentials, are negligible. But it has to be kept in mind that the different domains are often dependent of each other. Therefore this exposure should not be interpreted as evaluation for the necessity to put effort in the processing of several potential fractions.

Based on those potentials, and the former further developments of the product range, the consecutive chart shows a comparison and the tendency of entire system costs of different compressor platforms manufactured by ACC Austria.

A clear trend towards reduced system costs is thereby identifiable. The own outlier can be explained through the today high costs of an additional control unit for the virtual Delta VT with variable transmission (Ill. 3.13).

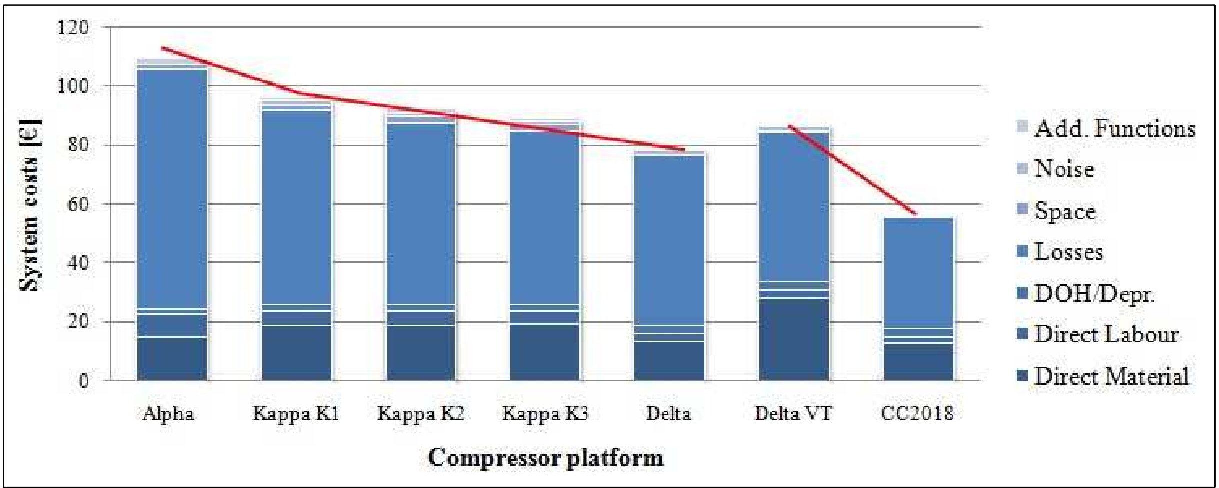

Illustration 3.13: System costs comparison of the different compressor platforms

The numbers this chart is based on can be found in the subsequent table and are predicated on internal information of the company (Table 3.5).

[€]	Alpha	Kappa K1	Kappa K2	Kappa K3	Delta	Delta VT	CC2018
Direct Material	15,4	18,8	19	19,5	13,2	28,2	12,7
Direct Labour	7,27	5,37	5,04	4,19	3,09	3,09	2,38
DOH/Depr.	2	2	2	2,7	2,8	2,8	2,8
Losses	81,1	65,9	62	58,6	57,6	50,2	38,2
Space	2	2	2	2	0,28	0,57	0
Noise	0	1,2	1,2	1,2	1,2	1,8	0,6
Add. Functions	2	1,5	1,5	1,5	0,8	0,8	0

Table 3.5: Comparison of the system costs for the different compressor platforms

For the calculation of the so called losses, the average energy consumption per year of a compressor used in an accordant refrigerator has been consulted.

For this reason a standard Delta compressor has been used as reference, randomized with the according COP to the other compressor platforms. With a factor for usual energy costs in Austria, numeralized 0,18 €/kWh, those consumptions have been arranged to a monetary value (Table 3.6).

	Alpha	Kappa K1	Kappa K2	Kappa K3	Delta	Delta VT	CC2018
Q [kWh/a]	450	366	344	325	320	279	212
COP [ ]	1,3	1,6	1,7	1,8	1,83	2,1	2,76
Losses [€/a]	81,1	65,9	62,0	58,6	57,6	50,2	38,2

Table 3.6: Calculation basis for losses

If this average energy consumption per year, in this case termed losses, is applied over the according COP of the appropriate compressors, the different slopes of the lines point out a decreasing value of a percentage point COP on the market with increasing absolute efficiency of a cooling compressor (Ill. 3.14).

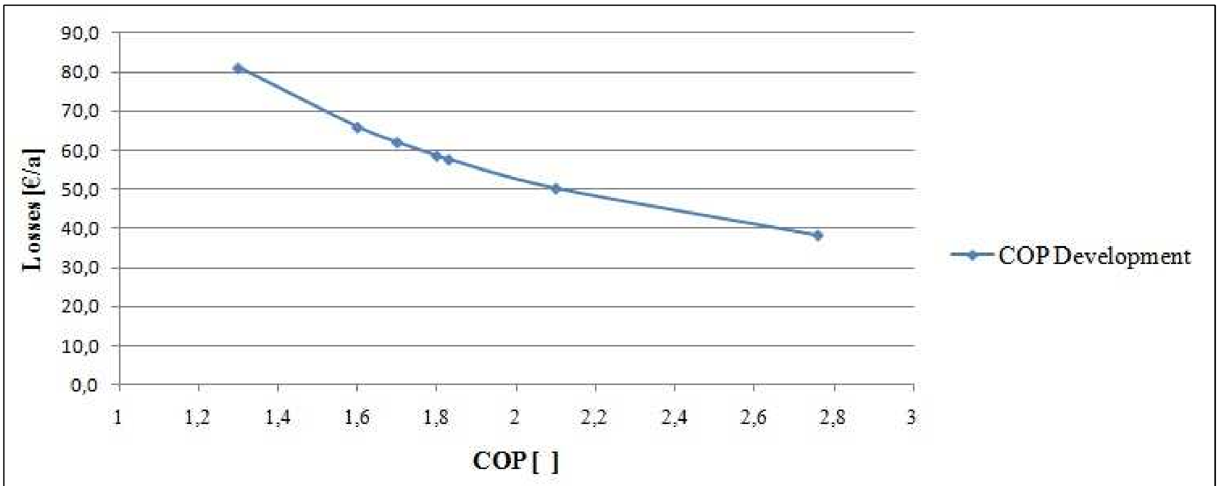

Illustration 3.14: COP development and the resulting decrease of losses

All this information represents the basis and point of origin from where and whereto the product development project CC2018 of ACC Austria should lead, supported by a structured and consistent methodology of processing to avoid leaving progress to chance.

4 Definitions and thesis boundaries

Based on the previously invested effort referring to the long term product planning process of ACC Austria (Ill. 3.2), namely definition of objectives and target improvement evaluation, the main goal of this assignment is to complete the technology development phase in terms of structure (Ill. 4.1).

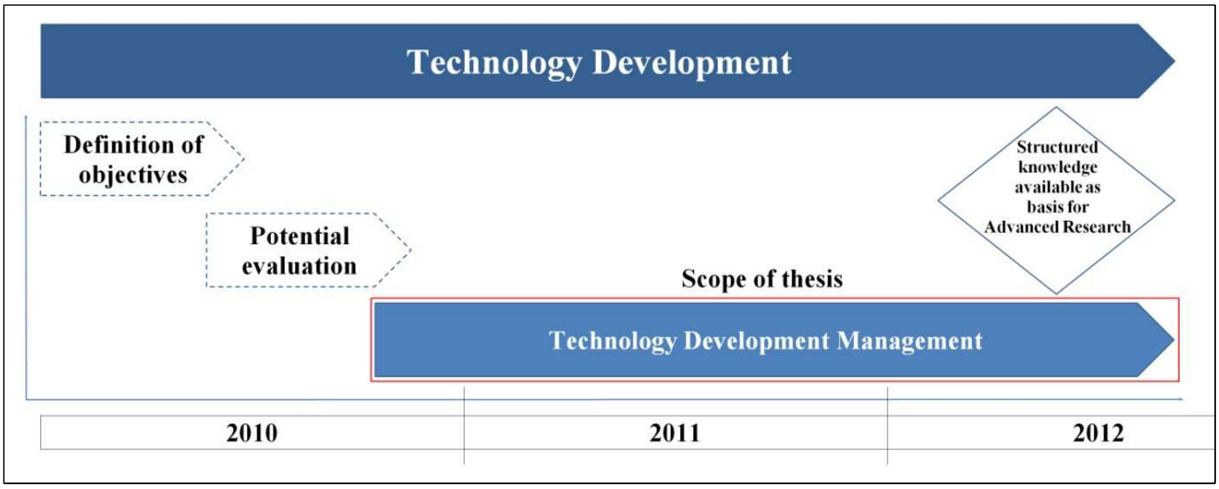

Illustration 4.1: Structure of the technology development phase

Thereby technology development management (TDM) has been defined as generic term for the process that clasps the operational acquisition of technological knowledge.

The following descriptions surrounding technology and the definition of TDM and its content should prevent a possible misinterpretation.

4.1 Technology and its key role in business

Technology has emerged as unique strategic variable in industry, but what is behind this buzzword?

The Duden, a dictionary of German language, considers that *"Technology is the science of transforming raw materials in goods, by applying scientific and technical knowledge."*

According to Lowe [1995, p.6] there is no agreed meaning of technology. It is a constituent of the universe of knowledge and shares the same problems of classification.

He locates technology in the continuum of knowledge beside science, know-how, industrial art and crafts. Technology focuses on opportunities, specific problems or groups of problems what often leads to proprietary knowledge. This distinguishes technology of science, with the objective to obtain general and publishable knowledge. [Lowe 1995, p.6].

Basalla [1988, p.26ff] on the other hand notes that, observed from a historical view, technology is the synonym for “means to ends” (Ill. 4.2).

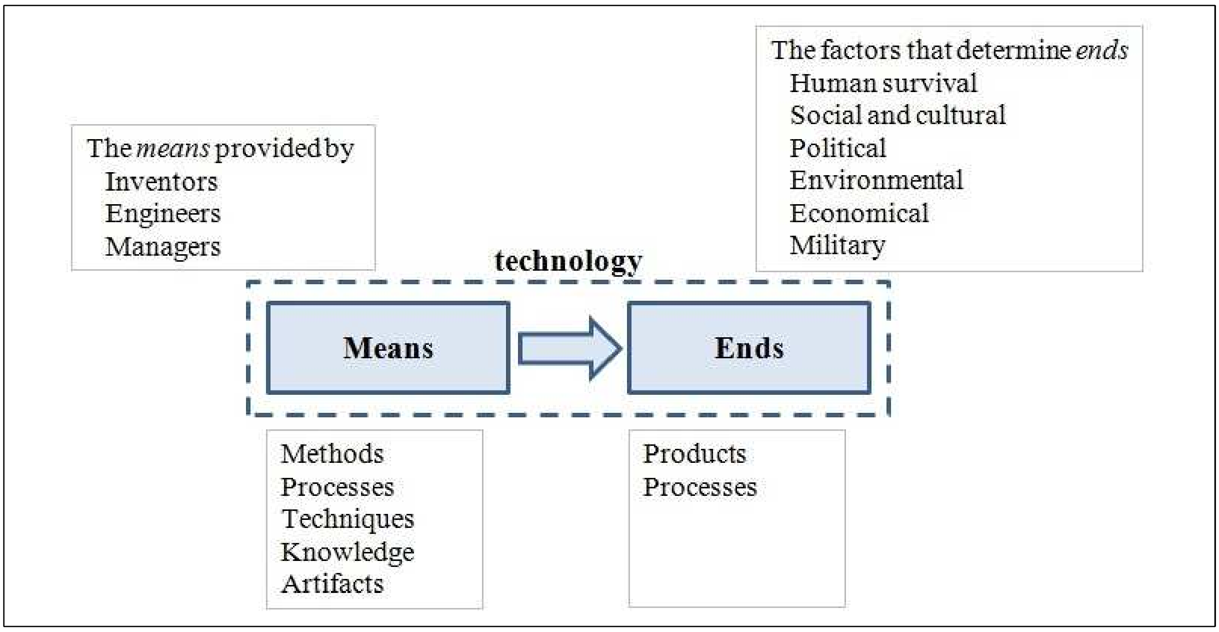

Illustration 4.2: Technology as means to ends [Basalla 1988, p.26ff]

This implies that technology provides the solution from a specific initial point to a defined end, or a way how to make life easier. [Basalla 1988, p.26ff].

Bullinger [1994, p.32ff] substantiates that technology is the knowledge of ways of solving technical problems and defines its scope with a systemic approach (Ill. 4.3).

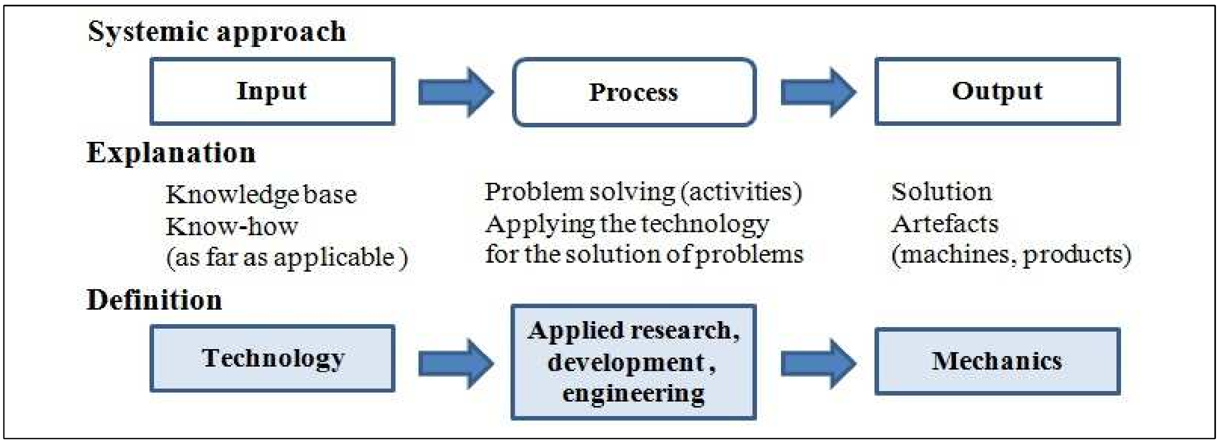

Illustration 4.3: Systemic approach for technology definition [Bullinger 1994, p.34]

Beside those general meanings, technology implies a more extensive significance referring to economic issues.

According to Burgelman and Maidique [1988, p.31ff] technology stands for a key domain to provide distinctive and attractive product functions, distinctive efficiency in performing those functions and to reduce costs of manufacturing and so achieve competitive advantage.

The positioning of technology in the entrepreneurial environment can be found below (Ill 4.4).

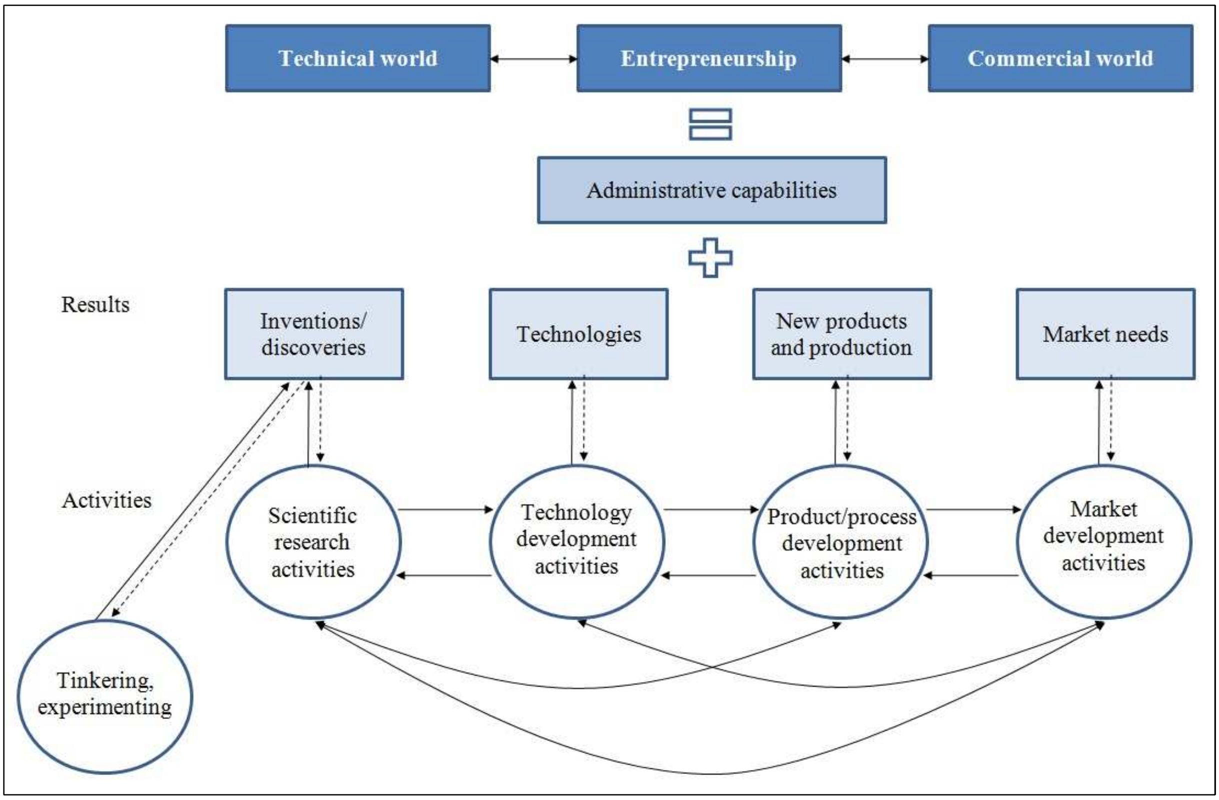

Illustration 4.4: The relationships between technology and the entrepreneurial environment [Burgelman, Maidique 1988, p.33]

This simplified picture represents the tangent fields of expertise to satisfy customer demands, differentiated between results and their basis forming activities. The several arrows exhibit the interfaces and coherences and moreover explain that the steps in real life situations occur parallel and simultaneously and not unidirectional and sequential. [Burgelman, Maidique 1988, p.31ff].

The recognition of technology as key parameter for economic success, and as one element of entrepreneurial capabilities, legitimates an intensive examination of the structuring, and a particular approach definition of the taxonomy surrounding the technology development process.

4.2 Technology development and technology management

In former literature, management of technology has been defined as an industrial activity and an emerging field of education and research that is not generally well established or even consistently defined. It concerns the process of managing technology development, its implementation and diffusion in industrial or governmental organizations. [Herink et al. 1987, p.9].

Furthermore, management of technology must not be understood as classical doctrine with universally valid conclusions like physical laws. It deserves particular study according to the existing factors respectively drivers and objectives at the particular organization. [Herink et al. 1987, p.2].

Technology management has in fact been recognized as important and necessary management function, but very often disregarded even when the management discipline changes as fast as the technologies it is dealing with. Beside the traditional functional management areas, management of technology is dependent on the environment of the industry and its effects as well as on developments and findings on academic side (Ill. 4.5).

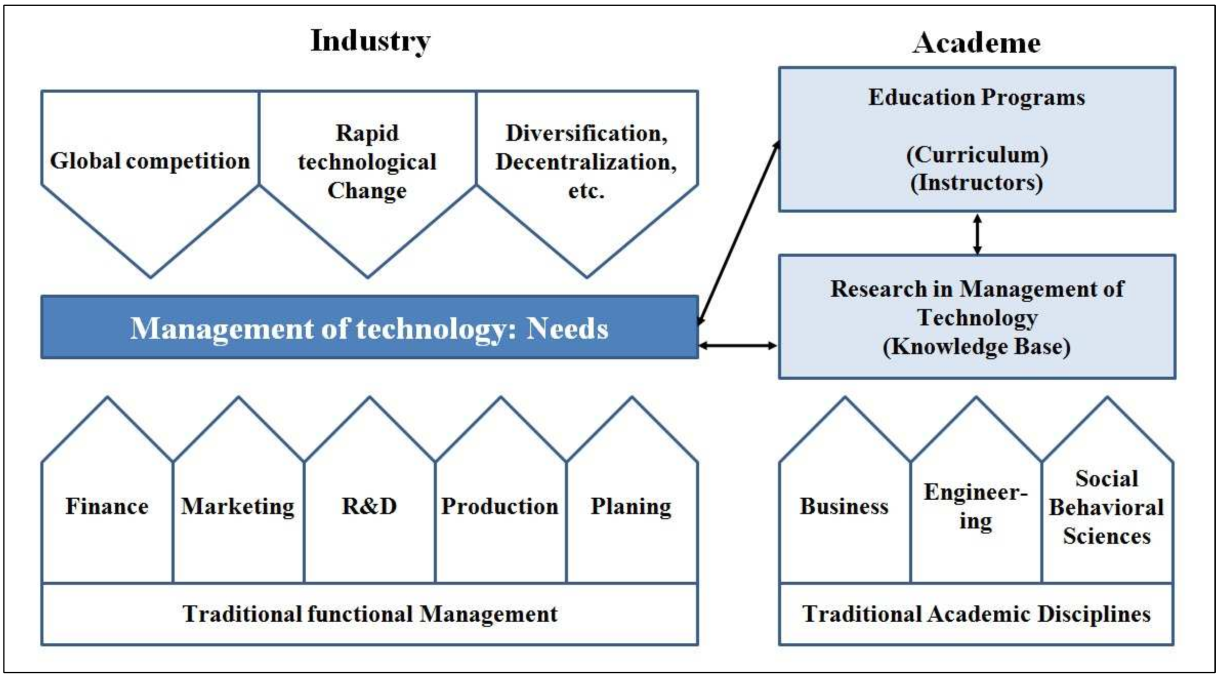

Illustration 4.5: Drivers of technology management [Herink et al. 1987, p.8]

Over time emerged technology management as critical mission for success, especially if technology plays a key role in pursuing organizational targets.

According to Bullinger [1994, p.43] are technology management tasks typical management tasks, which ideally require a combination of science, economic, engineering, technological and social science capabilities. This can be achieved by coordinated planning, implementation and controlling activities. Therefore, technology management represents a distinctive interdisciplinary function (Ill. 4.6).

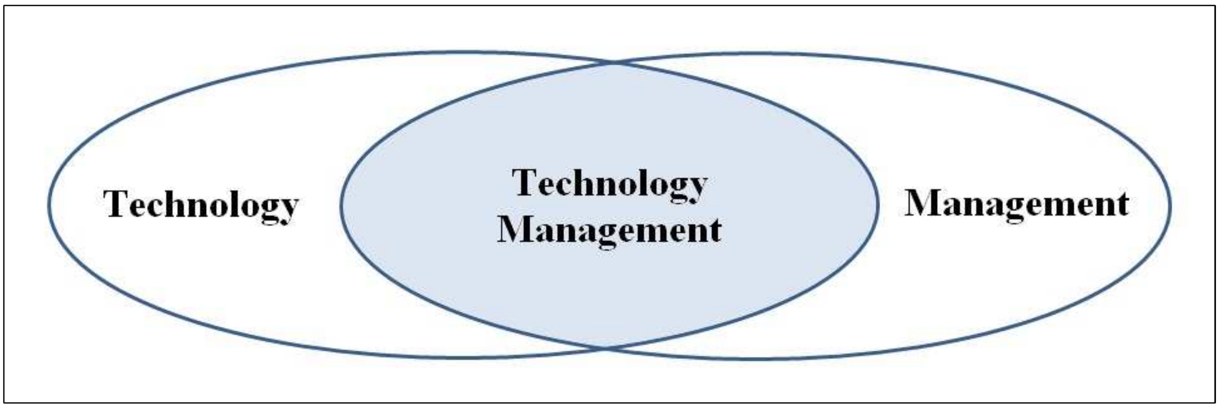

Illustration 4.6: Technology management as interdisciplinary function [Bullinger 1994, p.44]

Following this approach technology management faces only indirect the generation, supply, implementation, storage and utilization of technologies, but those operational activities are necessary to serve as linkage between technology and management. [Perl 2007, p.23].

Regarding the effective part of technology management, the intentional subject matter is technology fusion. Recalling the past (or maybe the conventional imagination) of research laboratories, they were top secret institutions somewhere in the nowhere, totally isolated from the rest of the world and with the ability to develop expertises in every needed discipline.

But things have changed and underlie a continuous change. The development of information technologies have led to a downsizing of distances referring to knowledge and its transfer. The global economic situation these days has also made its contribution to the fact that only the fewest organizations can afford a support of facilities devoted to wide expertise. This results in the striving to cheap profitable advances by combining knowledge from different fields and industries.

The process of combining available knowledge of different areas is called technology fusion. [Phillips 2001, p.21]. This determines the importance of an elementary understanding and then in turn conditioning as well as accordant application of on hand knowledge instead of its generation by one's own. Technology fusion enables an evolution from technologies to final products by an execution of acquired competences (Ill. 4.7).

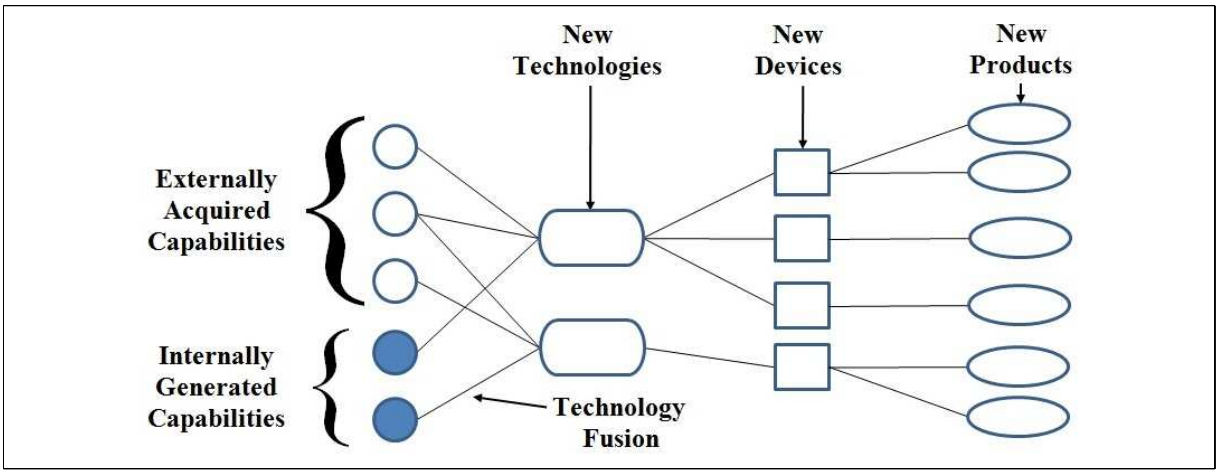

Illustration 4.7: Technology generation, fusion and evolution into products [Phillips 2001, p.30]

Another possibility would be an external acquisition of technologies, devices or components that give occasion to further fusion.

If this topic is considered a bit closer to R&D processes, it becomes apparent that at such cases, both substantial technical solutions and appropriate technical know-how accrue. Bullinger [1994, p.45ff] described those processes as technology emergence and technology development.

But first of all the activities of basic research, which are customarily situated in a theoretical field of examination, take place. The results respectively theories are mainly published as scientific papers or research reports and accessible for the commonality because of their precompetitional character. [Bullinger 1994, p.45ff].

Scholz [1976, p.1ff] differences developing activities furthermore in experimental-, constructive- and routine development. Experimental development tends to realize products with so far not used real phenomena. On the other hand, constructive development combines already used real phenomena and constructive progression deals with formalized application conditions and design principles.

The process of technology development is carried to a large extent by even those mentioned distinguishable developing methods and by practical research based on theories that result in applicable technologies and tangible technical know-how. This leads through R&D processes to the emergence of technologies and in the end to technical solutions for particular problems.

The following figure (Ill. 4.8) demonstrates the coherences between technology development and technology emergence with the underlying processes, the required input and target output. [Bullinger 1994, p.45ff].

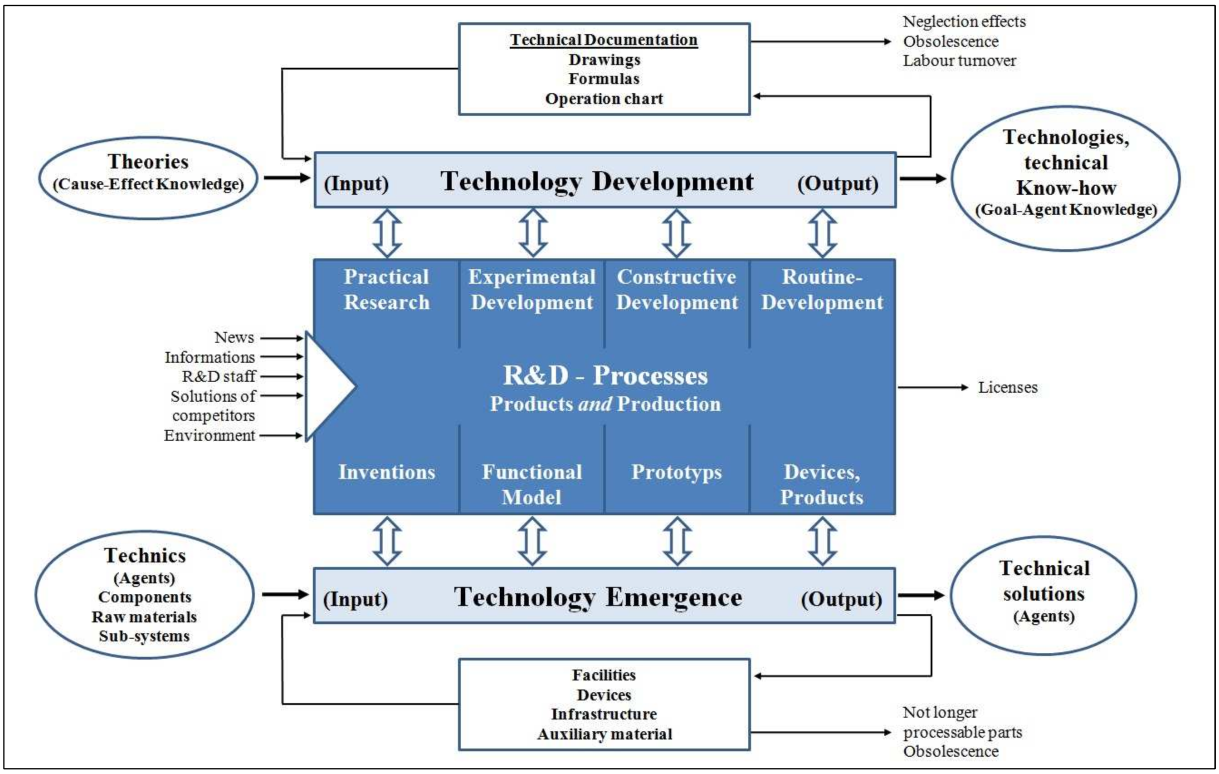

Illustration 4.8: Technology development and technology emergence [Bullinger 1994, p.46]

Particular attention should be paid to the fact that exceptionally importance is given to the impact of R&D processes on products and production in this description.

Unfortunately it has happened and still happens very often that product development and process development operate separated from each other. This mostly results in efficiency forfeits and problems which could be avoided easily by a simultaneous involvement during the development phase. [Bullinger 1994, p.45ff].

In addition, it is evident that technology development, through adequate technical documentation, as well as technology emergence is explicated as closed loop and so might be performed multiple times. [Bullinger 1994, p.45ff].

Another fact is that during research and experimental phases, not only problem relevant and target conform results occur. Nevertheless, those enhancements of the body of experiences through incidental outcomes determine a technological potential which can be used as resource by activating. [Bullinger 1994, p.45ff].

All those underlying basics of active technology development should be kept in mind by the definition of a development process for technological issues at ACC Austria.

4.3 Technology development management

TDM, as process of operational technology development (Ill. 4.1), has now to link engineering, science and management disciplines to find, plan, develop and prepare technological capabilities and structured knowledge. Its outcome, always with respect to strategic and operational goals of the organization, represents the basis for advanced research. This definition is based on Herink [et al. 1987, p.2].

Consequently TDM requires a designing, steering and development of processes according to technology fusion. Finally TDM should devise combination possibilities of technologies to overcome the defined target improvements concerning performance, noise, volume and costs.

4.3.1 TDM – Process design requirements

The approach behind TDM should feature a clear structure and an appropriate arrangement with applicable tools and methods. To live up these expectations it is indispensable to analyze and extinguish the specific requirements for the process design. Thereby it has to be differentiated between systemic and functional exigencies the TDM process should face (Ill 4.9).

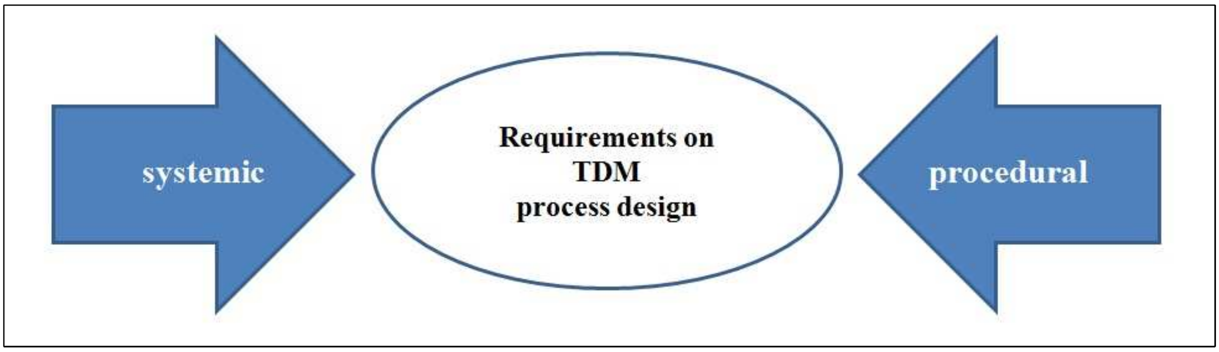

Illustration 4.9: General requirements on TDM process design

4.3.1.1 Systemic TDM process design requirements

The systemic necessities tend to a clear structure and an integrated taxonomy on the side of process organization.

<u>Process based on SE fundamental ideas (Chap. 2.1)</u>

The orientation on SE in general is a corollary of its long lasting application in daily business at ACC Austria. As result of dealing with a special subject, it is of course necessary to adapt, respectively modify, the methodology according to the actual conditions.

The initial point for the process is always the defined target, including all attributes and parameters, with respect to the interfaces.

The systemic view of the structure includes a breakdown from the general to the specific in terms of technology, to meet demands instead of conventional division of a technical system in functional groups and components (Ill. 4.10).

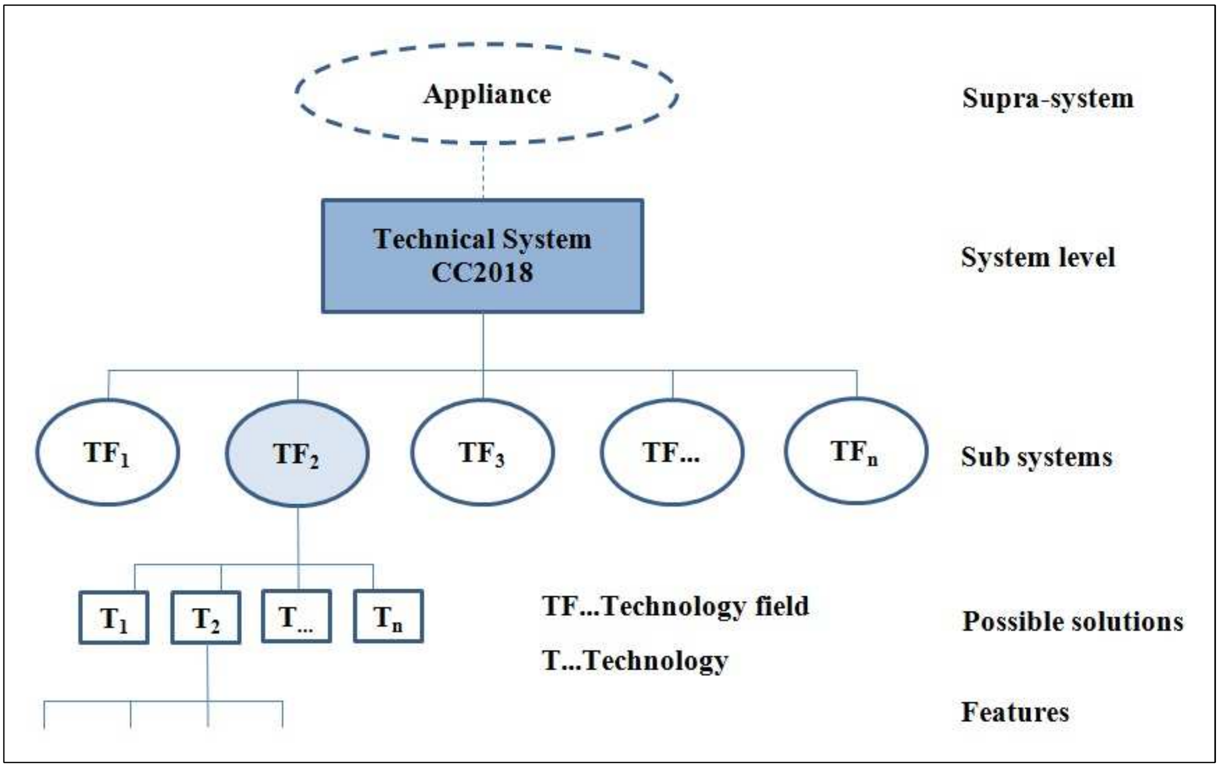

Illustration 4.10: Systemic view of technology development management at ACC

This refinement concretely implies a top down approach from a technological system to specific areas of technology, in the following termed technology fields.

Based on those the searching for possible variants, which of each should provide a solution possibility on the way to the systemic objective, has to take place as assistance for decision making and for the concept composition. Thereby the following questions should be answered: Is it technologically possible, economically reasonable and socially acceptable?

In addition, the compiled general mindset along the technology development management phase should enhance the top down approach.

In principle this means to make a step backwards and to observe also the environment and reasons of the problem and not to focus straight on tunnel vision solutions (Ill. 4.11).

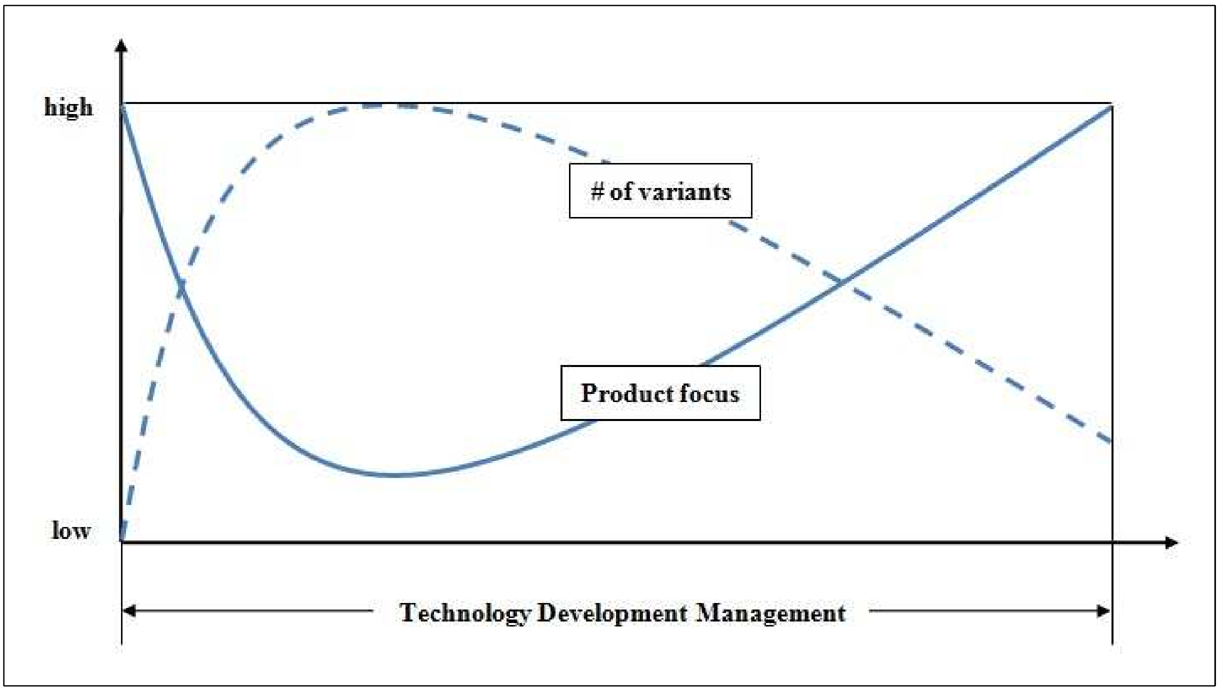

Illustration 4.11: Ideal way of thinking of technology development management

Referring to the CC2018 project, based on the search of objectives and target improvement evaluation (Chap. 3), the definitive goal that is endeavored to be achieved is known. Therefore the product focus in first instance is absolutely high.

To emphasize the attempt to get away from predefined solution approaches, it is necessary that the decreasing of the product focus is as fast and as low as possible to set no limits. In return, the number of technology variants should increase from zero to as many as possible what would be an indication for an effective information seeking.

Both vertexes of the graphs should demonstrate the end of gathering information, whereby on one hand the focus should be most far away from the essential product. On the other hand the number of technologies, centralized in technology fields, should have reached a maximum and then in turn concretize more and more again.

Concretize means in terms of more precise knowledge acquisition of identified technologies and conditioning of them under consideration of organization´s circumstances like production volume, patents and laws, etc. Furthermore the TDM process has to be made up by a structured and comprehensible proceeding.

<u>Process based on CC2018 target definition</u>

TDM should be a process with as less limitations as possible, but still facing the overall objective (Chap. 3).

Process should be reusable

Possible follow-up projects should benefit of a flexible pool of methods and tools, integrated in a stepwise proceeding, to have at least a starting point of how to structure technological knowledge acquisition and its problem specific conditioning.

4.3.1.2 Procedural TDM process design requirements

Beside the systemic aspects, procedural requirements occur because of the correspondence to the overall project CC2018.

Definition of technology fields

Beside the acquisition and conditioning of technological knowledge, TDM should support a breaking up with gridlocked perspectives to follow new paths. Therefore specific technological clusters, as fields of expertise, have to be defined (cf. Ill 4.10).

Handling of interfaces

Referring to the systemic view (Ill. 4.10) the horizontal alignment during the practical going on, especially concerning the examined technologies, is very important and has to be kept in mind in terms of holistic thinking.

Therefore a clear necessity for the TDM process is a balancing of the particular fields of expertise in certain time intervals and procedural advances.

Smooth transitions represent the borders of sub levels of a system (Ill. 4.12). Because of their dependence it is not possible to develop and work on each separated from the others and then put the results together. They have to be observed and formed within a holistic framework.

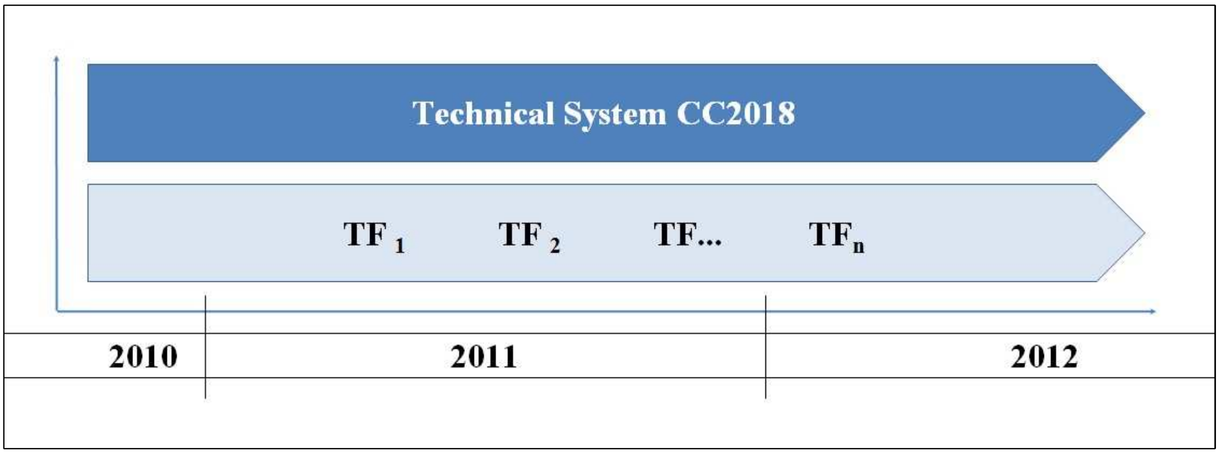

Illustration 4.12: Interfaces of technology fields as smooth transition

The dealing with interfaces and interactions of technology fields, or one step deeper the dealing with specific technologies, is essential for the earliest possible identification of reciprocal dependencies. Furthermore it would also be possible that there are interfaces between the supra level and the operational layers with regard to the specific object and its functional sub systems, for example the appliance control unit with the appliance referring to the former defined functional groups (Ill. 3.7).

Limitation of time

TDM is embedded in the technology development phase of the long term product planning (Ill. 4.1). Therefore the limitation of time is a definitive and known factor. It has to be kept in mind and integrated at all advisements, of course during the generation of a generic approach but notably in the effective proceeding of the technological knowledge composition.

4.3.2 TDM – Process design objectives

Based on the specific requirements, the following listing demonstrates an arranged abridgement of objectives of the TDM approach as basis for the process definition.

Technology development management is based on:

- Fundamental ideas of Systems Engineering
- Long term product planning process (Chap. 3.2)

Technology development management has to provide:

- Tool and method kit for the problem handling
- Maximized involvement of and communication to the people concerned

Technology development management has to contain:

- Defined contradictions on the way to the CC2018
- Defined and evaluated technology fields as areas of expertise
- Milestones with conflict free sub objectives
- Continuous balancing
- Clear time structure and points for decisions

Those parameters have to be fulfilled through the definition of a generic phase plan including sub phases with temporally defined milestones and operational variants of tools, methods and evaluation criteria.

4.3.3 Simultaneous phases to TDM at ACC Austria

Beside the technology development management process another two special fields have to be executed simultaneously: concept decisions of concrete problems and an essential coaching and alignment program (Ill. 4.13).

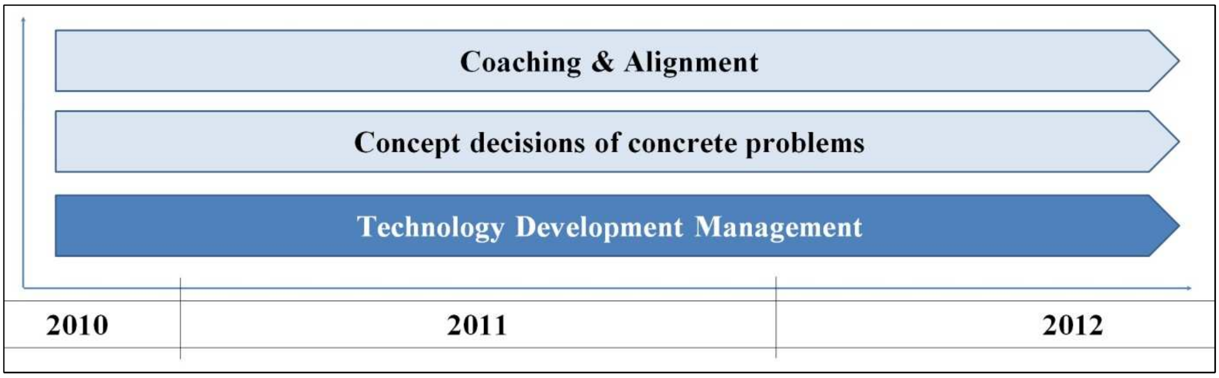

Illustration 4.13: Simultaneous phases to TDM at ACC Austria

As the name implies, the aim of the process concept decisions of concrete problems is the accomplishment of specific technical challenges with a further preparation as knowledge acquisition.

To ensure and emphasize the TDM process, its implementation and acceptation in the organization as well as by the affected staff members a purposeful coaching and alignment phase along with the functional proceeding allegorizes a necessity.

Both additional phases can be understood as special tasks and encouragements in terms of TDM organization and are handled as additional information and knowledge input.

The further course of this thesis focuses on technology development management and will not go into more detail on these special duties and responsibilities.

5 Technology development management – Process design

With regard to the defined objectives and demands made on technology development management at ACC Austria (Chap. 4.3), the executing process of the preliminary stage of product development is made up by a directorial and an operational part.

The directorial or organizational element deals with the sub categorization of a technical system, in this particular case the CC2018, a necessity as result of the limited disposable time and resources in real business life.

This phase of TDM, termed “Definition of technology fields”, demonstrates the disposition of the entire system of the CC2018.

The operational part, designated as “Technology development projects” (TDP), features the field of effective action, or in other words the acquisition of specific, solution oriented technological knowledge and its conditioning.

TDP represents the execution of previously defined superior topics (Ill. 4.10), named technology fields, in terms of active operations in the field of gathering technological knowledge.

Allegorized in a Gantt chart, referring to the actual assignment and scheduled time of the long term product planning process at ACC Austria, these sequenced steps appear as follows (Ill. 5.1).

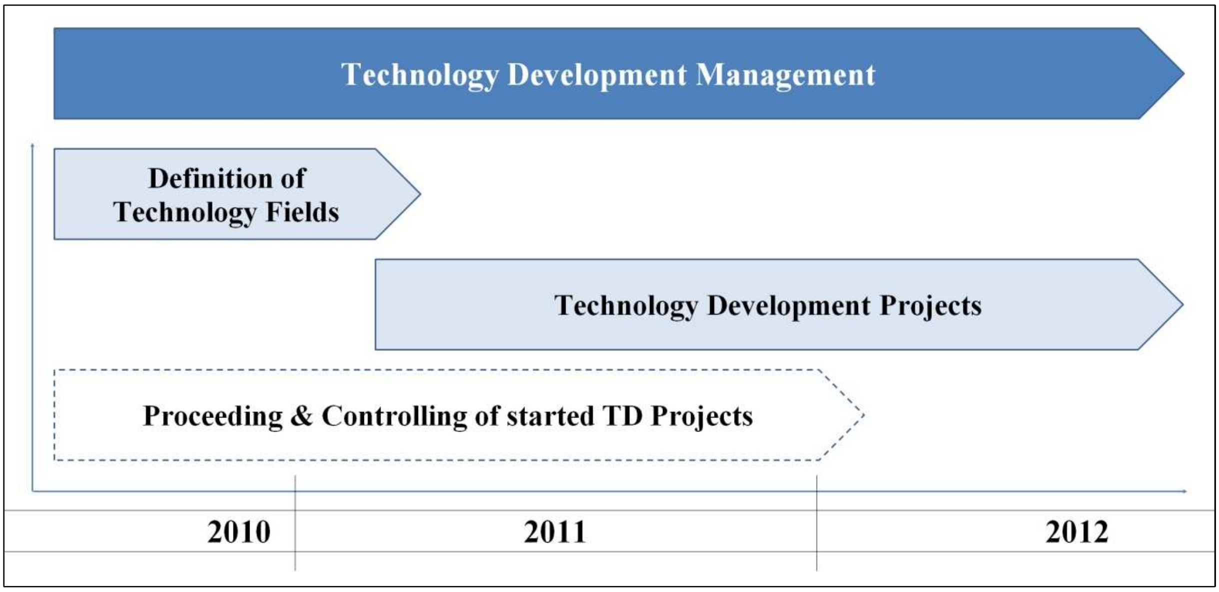

Illustration 5.1: Sub tasks of technology development management

The element "Proceeding and Controlling of started, or already started, technology development projects" follows from the special case at ACC Austria and its network to knowledge establishing institutions. Out of these cooperations several projects, which tend to the direction CC2018, have already been started but without a general classification of the course of action.

The current ventures also have to be in line with the prospective executed technology development projects especially in the face of interfaces and their handling.

The following itemization represents a listing of the actual projects in conjunction with possible technologies for a new cooling compressor development (Table 5.1).

Technology Development Project	Main focus	Project Start	Planned End
Advanced Motor Development	Engine and control unit for variable rotational frequency	29.08.2009	31.08.2011
Dissertation "Ultra Clean Compressor"	New materials for cooling compressors and their methods of joining	18.11.2009	31.12.2012
Ultra Silent Compressor	Matlab-Software for the automatisation of a noise qualification of refrigerators	01.04.2010	31.12.2011
Innovative Gas Exchange II	Cooling Circuit in general and gas exchange of the compressor	30.03.2010	31.12.2011
Advanced Polymer Materials II	Polymer materials as thermic isolator respectively coating material	04.10.2010	30.06.2011

Table 5.1: List of already started technology development projects

All those enumerated projects are characterized by collaboration with scientific research institutions (Ill. 5.2).

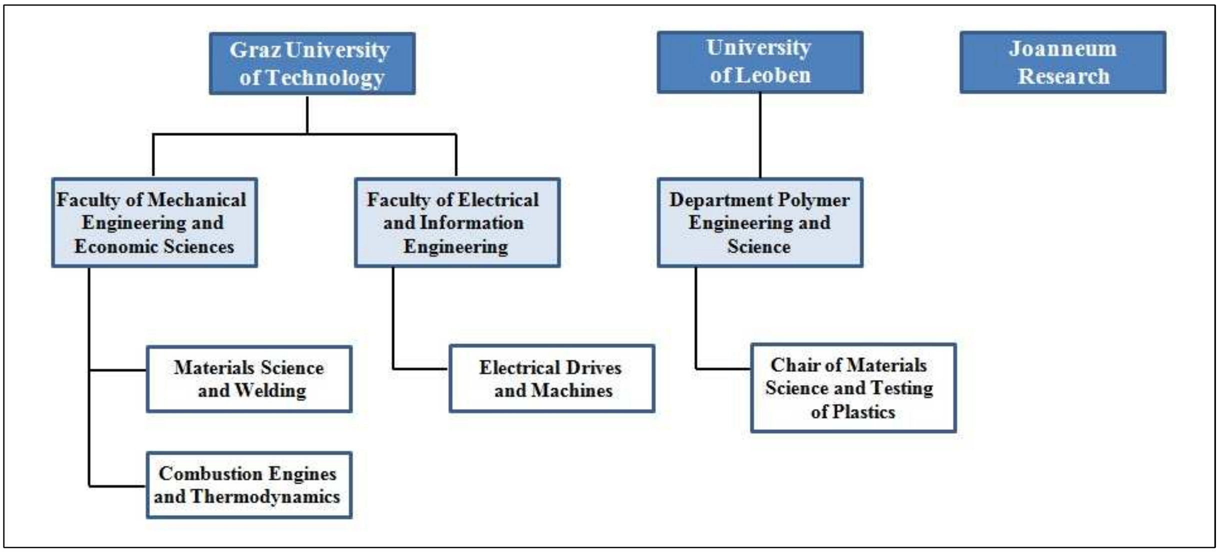

Illustration 5.2: Research partners of ACC Austria

5.1 Definition of technology fields

A clustering of an entire system into smaller parts is required because of the natural limitation of resources. Especially when dealing with such an intangible entity like knowledge it is necessary to follow a direction to avoid trailing away in an endless diversity of possibilities.

To give consideration to this pre-orientation, the first phase or step of TDM is the definition of technology fields. The segmentation of the entire technical system CC2018 to specific sections has to clasp the whole package in terms of technology and technological solutions.

This might be in conflict with the intentional try of an out-breaking of the black box and widening one´s horizon but still a logical consequence of business reality barriers. And even if the “right directions” have been chosen, continuous feedback demonstrates a basic requirement to maintain this dynamic and exceedingly flexible process with essential interdependencies between the particular fields of expertise.

The sub-categorization of such a technical system principally allows a multiplicity of different categorically possible options based on miscellaneous parameters. But additional to the aim of logic structuring the very same thing should enhance new varied mindsets and a breaking up of a rigid framework. Therefore, and to reach an appropriate degree of acceptance, it is necessary to develop and examine a preferably high amount of manifold alternatives as foundation for more detailed definitions.

5.1.1 Comparison of technology field variants for the CC2018

Within the scope of the intensive preparatory work, several possibilities of how the technical system CC2018 could be subdivided have been prepared. Not all of them provide a suggestion of a provisional list of technology fields but at least a reference point for a potential going on.

Corresponding to Sorger [2008, p.81ff] these recommendations are:

- Grouping of contradictions

  The contradictions (Table 3.3), initially allocated to the functional groups (Ill. 3.7), have been arranged differently to facilitate a cross-functional way of thinking.

- Grouping fields of expertise and technologies

  The results of a couple of brainstorming sessions to relate technological sectors to the defined subsystems have been summarized to ten homogenous categories.

- Grouping of branches

  Promising branches as info-source, based again on the brainstorming output.

In reference to the second diploma thesis considering the entire project CC2018, the evaluation of the previously defined contradictions has led to new variants [Bilek 2010, p.61ff]:

- Perception mapping

  Through application of the TRIZ methodology to unify different perceptions of a problem, the contradictions have been sectioned one-time to potential technology fields.

- Contradiction costs, Function analysis, Perception mapping

  The combination of Perception mapping, with the identified improvement potentials as “costs”, with Function analysis, results in another TRIZ technique to determine the number and effective directions of contradiction coherencies and should additionally provide comprehensible ranking.

- Contradictions and branches

  Represents a method proposal whereby the evaluated contradictions are opposed and allocated to the defined list of branches.

- Contradictions and technologies

  As the previous one, but instead of branches referring to technology categories, defined in the previous mentioned alternative grouping of fields of expertise and technologies.

- Contradictions and functional groups

  This method was named (basically) because it would require the least effort to distribute the contradictions and the responsibility involved to functional groups and underlying line management departments, certainly at the expense of creativity.

Those precedent prepared approaches could be interpreted as result of the respective situational analysis and give of course leeway to further processing.

Even if the intentional objective of all mentioned variants is to generate a different, not routine-blinded mindset, they run the risk to fall back into the scheme of solution oriented operating. Therefore it was necessary to formulate more expansive and elementary routines for the completion in addition.

The pool of variants has been extended to satisfy these pretensions with the following corporately elaborated supplemental alternatives for the definition of technology fields:

- Generic objectives

  The intention is to focus just on termed generic objectives (Chap. 3.3.1) without addressing a concrete problem of the cooling compressor. Thereby an additional examination of industrial sectors, which deal with the same, could enhance the process of lateral thinking. For example by analyzing how different branches realize lightweight design.

- University departments

  The background of the consideration to arrange a technical system according to potential research partners is determined by the fact that an exclusive building-up of technological competencies, especially in context of emerging technologies, requires an immense investment of resources. Furthermore the particular problems would be regarded from various perspectives.

- Patent classification

  In many fields and also in literature references it is absolutely common to orientate a sub-classification with regard to patent structures, for example in automotive industry.

The problem referring to the present case is that the cooling compressor is handled as entire system and so patents of components or in fact subsystems are attached to other domains. That is the reason why this option has been discussed but abolished again.

- Physical parameters

  Another feasibility to enlarge the latitude would be to focus in general on physical parameters on which the aspired improvements are based on, e.g. an examination of how to minimize the coefficient of friction η. Analogical to the idea behind the generic objectives.

Contrary to the general process of taking decisions respectively selecting variants, those options should not be the basis for yes-no questions where finally one is chosen and all the others neglected. Moreover it is necessary to organize the structuring as open system and as flexible as possible to allow potential changes at any time.

A comparison of the numerousness of recommended alternatives and especially of the fundamental ideas behind has demonstrated that the compositions differ not so much as it may seem.

Basically the variants content the parameters:

- Contradictions (Table 3.3)
- Functional groups (Ill. 3.7)
- Technological sectors and branches according to the brainstorming result [Sorger 2008, p.84ff]
- Generic objectives (Chap. 3.3.1)
- University departments; the correspondent composition can be found in Appendix B
- Physical parameters (Appendix C)

For the intention to orientate not only on the classical functional groups, they have not been considered for further detailed definition as well as physical parameters for reasons of congruence with generic objectives.

All the other parameters have been combined to create a temporary final variant for the definition of technology fields (Table 5.2).

No.	Variant	Fundamental idea
1	Grouping of contradictions	- Contradictions - Functional groups
2	Grouping of fields of expertise and technologies	- Functional groups - Technological sectors (Brainstorming)
3	Grouping of branches	- Technological sectors (Brainstorming)
4	Perception mapping	- Contradictions - Functional groups
5	Contradiction costs, Function analysis, Perception mapping	- Evaluated contradictions
6	Contradictions and branches	- Technological sectors (Brainstorming) - Evaluated contradictions
7	Contradictions and technologies	- Technological sectors (Brainstorming) - Evaluated contradictions
8	Contradictions and functional groups	- Functional groups - Evaluated contradictions
9	Generic objectives	- Generic objectives
10	University departments	- List of departments
11	Patent classification	- Classes of running patents
12	Physical parameters	- Physical parameters
↓	↓	↓
13	Final combination	- Combining the different underlying ideas

Table 5.2: Comparison of technology field alternatives

5.1.2 Technology fields facing the CC2018

Based on the determinants mentioned before, the following technology fields that clasp the entire system of the CC2018 and its application have been defined.

The process of definition was made in a discussion of R&D team leaders and people involved. Thereby different clusters of technology fields, in dependency of the targeted system, have been distinguished in addition (Ill. 5.3).

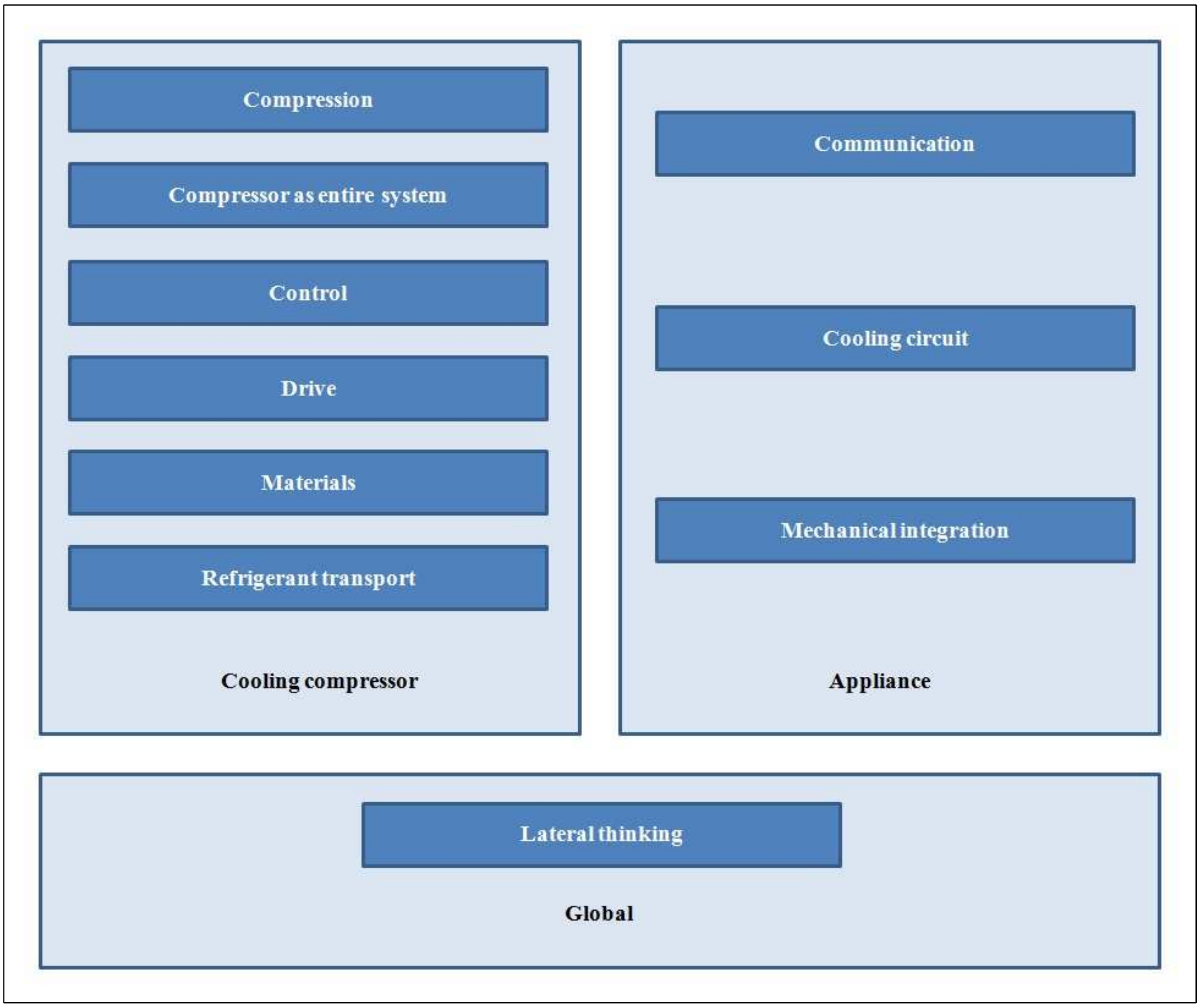

Illustration 5.3: Technology fields of the project CC2018

The list of technology fields represents a result for the present and should be adapted according to variations in the course of process progression. This means that it is absolutely possible to add new blocks or cancel existing ones referring to the illustration but as well to split particular areas if their content drifts away.

Nevertheless, in first instance those segmented fields are the definitive source for the orientation of functional projects. Each specific technology field embraces a different range of considered variables. Also the already started technology development projects (Table 5.1) are reflected in this technological clustering.

Important for the general acceptance is that objects comprehended by the selected technology fields are stated clearly and in round terms. This is a necessity even though the terming allows a derivation respectively implication of their content. The following figure describes this kind of orientation in few but concise words.

	Technology field	Technological orientation
Cooling Compressor	Compression	Refrigerant pressure increase
	Compressor as entire system	Interfaces in terms of modular concepts and enhancing the variability
	Control	Covers the whole package piloting (not only limited to engines)
	Drive	Transformation of electrical- in mechanical (rotatory) energy
	Materials	Materials science for specific applications
	Refrigerant transport	Refrigerant flow in both states
Appliance	Communication	Input, Output, Throughput between Compressor, Appliance and User
	Cooling circuit	Thermodynamic and overall concepts
	Mechanical integration	Connection of compressor and appliance
Global	Lateral thinking	Technological breaking out based on: Branches, Contradictions, Generic objectives

Illustration 5.4: Orientation of technology fields

In this connection, especially the technology field lateral thinking strives for general technological analysis apart of a product or component focus.

All the other fields refer either to the compressor as technical system or one level above to the appliance as supra system with the cooling compressor as one component.

Principally it is possible that a technology field as unique system includes, or is made up by, several technology projects. But at the beginning of the operational part of technology development each field at the same time represents a specific project with the intention to allocate particular technological knowledge.

Therefore, and due to continuity, the running projects will not be influenced by that and at first executed as scheduled.

The discovered contradictions can be allocated directly to the technology fields, whereby multiple nominations are of course possible (Table 5.3).

			Technology fields											
			Compression	Compressor as entire system	Control	Drive	Materials	Refrigerant transport		Communication	Cooling circuit	Mechanical integration		Lateral thinking
Contradictions	1	Diversification vs. Standardization		x	x					x	x			x
	2	Integrated electronics vs. Compressor "slave"		x	x					x	x			x
	3	Low noise vs. Small size	x	x		x	x	x						x
	4	Low pressure loss vs. Small size						x						x
	5	Low temperature vs. Big size						x						x
	6	Low suction- discharge work vs. High cost						x						x
	7	Self adjusting valves vs. High cost						x						x
	8	Selective heat conductibility vs. Current material					x	x						x
	9	Self adjusting dead volume vs. Current material					x	x						x
	10	Low pulsation vs. Small size						x						x
	11	Lower starting torque vs. Small size			x	x		x						x
	12	Low temperature vs. Big size						x			x			x
	13	Many interfaces vs. Low complexity			x					x	x			x
	14	Speed control vs. Low complexity	x		x	x				x				x
	15	Easy approbation vs. High complexity			x					x	x			x
	16	Speed control vs. Low cost	x		x	x				x				x
	17	High efficiency vs. Low cost	x	x	x	x	x	x		x	x	x		x
	18	High efficiency vs. Small size	x	x	x	x	x	x		x	x	x		x
	19	Insulate temperature vs. Conduct temperature	x				x							x
	20	Adjustable for variable speed vs. High cost	x	x							x			x
	21	Adjustable for variable speed vs. High reliability	x	x							x			x
	22	Low friction vs. High cost	x				x							x
	23	Low friction vs. Big tolerances	x				x							x
	24	No heat exchange between suction and discharge line vs. Low noise		x			x	x						x
	25	High heat exchange vs. Low noise		x			x							x
	26	Small size vs. Low noise		x			x							x
Line organisation		Advanced Development		x										x
		Electrical Equipment		x	x	x	x			x				x
		External		x			x					x		x
		Gasline		x			x	x			x			x
		Kinematics	x	x			x							x
		Maintenance		x										x
		Simulation and Laboratory		x			x							x

Table 5.3: Contradictions and line departments allocated to technology fields

Additionally to the contradictions also the teams of the R&D line organization have been related to the particular future fields of examination.

The other determinants underlying the screening of technology fields have been consciously not subjected to this allotment to avoid every further control. Moreover they should be consulted during the execution of projects as support in different activities:

- List of branches respectively technology sectors as potential source of information or ideas. [Sorger 2008, p.84ff].
- Generic objectives to approach the problem without concrete solutions in one´s mind (Chap. 3.3.1).
- Recommended university departments as competence centres of technologies and possible potent partners to place external perceptions (Appendix B).

As a result of the dynamic oriented configuration of the list of technology fields it is not required imperatively that this selection represents the categorically best solution, but at least a statement that covers the whole system and might lead to the aspired end.

Nevertheless, for the practical initiation of development projects, the question appears on which one it is most advisable to focus, because along with the potential in the future the demand for effort and resources arises.

To be able to answer this question, and also for a predication of the intensity of required resources to overcome the specific challenges in each area of engagement, the process of technology field definition requests a catalogue of criteria for the assessment.

5.2 Evaluation criteria for technology fields

The process of criteria definition or identification distinguishes from case to case and has to be examined for each specific problem.

Referring to strategic issues, attributes for an appraisal have to go along with the general concept or orientation of the organization.

Out of the fact that many processes of business economics and industrial management cannot, or only under high effort, be operationalized and quantitatively evaluated, those features should at least be rateable qualitatively.

5.2.1 Criteria definition for technology field evaluation

In the present case, a brainstorming session with the team leaders of the product development department of ACC Austria has been held in first instance to identify possible assessment features for the rating of technology fields. The own default for any answer was the required bearing upon the cooling compressor 2018. The result of this classical creativity method was a list of multitude possibilities to classify particular areas of interest. Those suggestions have then been clustered to the generic terms: contribution, effort, feasibility and practicability.

The following illustration demonstrates this allocation without any bias of exigency or expedience (Ill. 5.5).

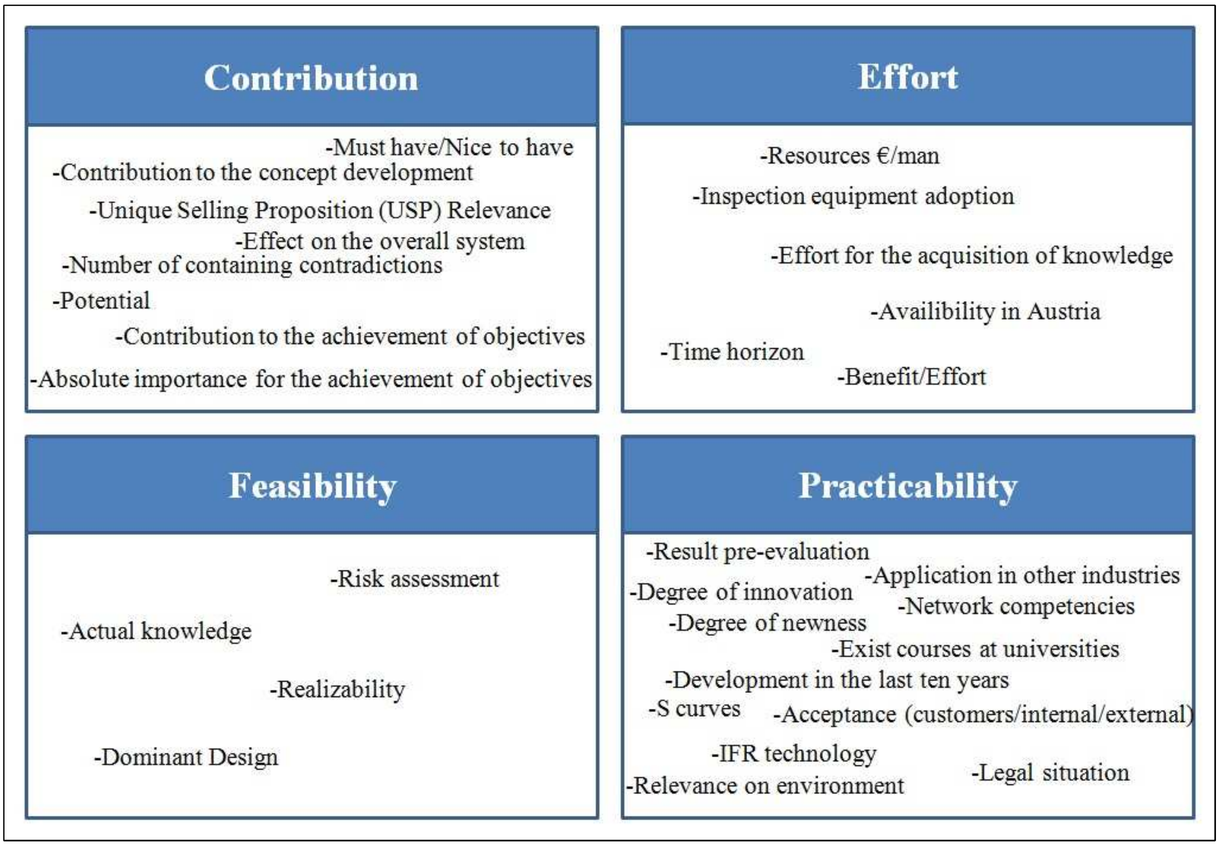

Illustration 5.5: Brainstorming result for technology field evaluation criteria

Moreover no unit or appearance has been related to any term, also methods and potential tools for the application or implementation have not been discussed so far with the ulterior motive not to constrict oneself at an early level of proceeding. The sum of all those mentioned evaluation criteria represents just the foundation for further detailing and elaboration. Due to the fact that they are required to appraise technologies and technological development, a subject with an exponential increasing dynamic and a global operating range, these list has to be understood as open source and has to be expandable respectively adaptable at anytime.

The result of brainstorming in general is always more or less unsystematic and it provides no information about the importance of every singular input. To raise the degree of organization, to shortcut the list and also to assess a weight of each nomination, a pair wise comparison of the criteria has been made in a first step.

Therefore the following points have been given:

- 3, if a criterion was appraised more important than the compared one
- 1, if the compared criteria were equal
- 0, as counterpart to 3

Ill. 5.6 represents the outcome of this pair wise comparison, relative to the criterion with the highest weighting.

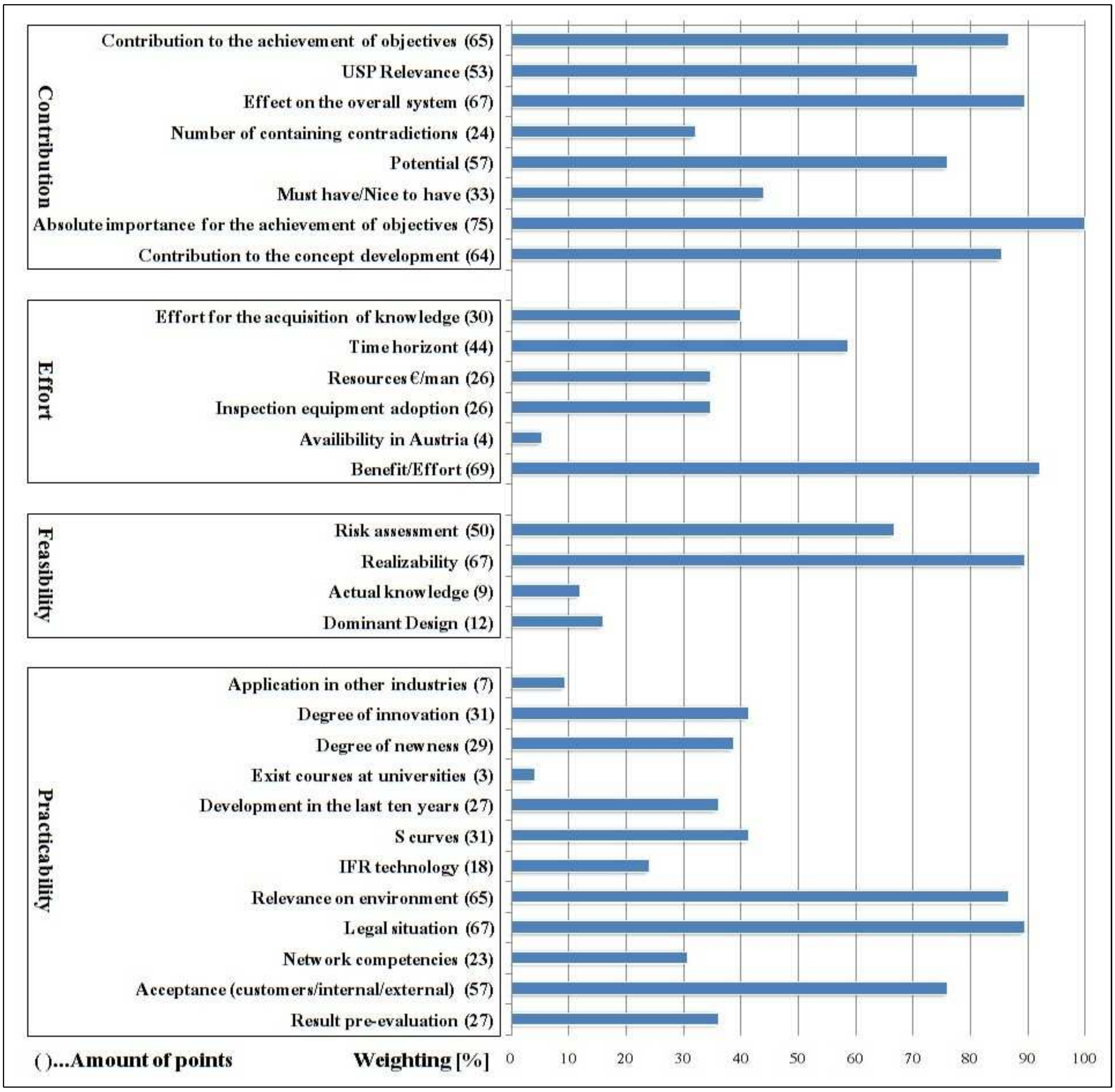

Illustration 5.6: Result of the pair wise comparison of evaluation criteria for technology fields

The precedent chart (Ill. 5.6) displays the average result in relative percentage of the most important characteristic (absolute importance for the achievement of objectives) according to the ACC R&D team leaders. Based on this weighting, the particular criteria have been clustered or disregarded to enhance the clarity and practicability of this evaluation catalogue (Ill. 5.7).

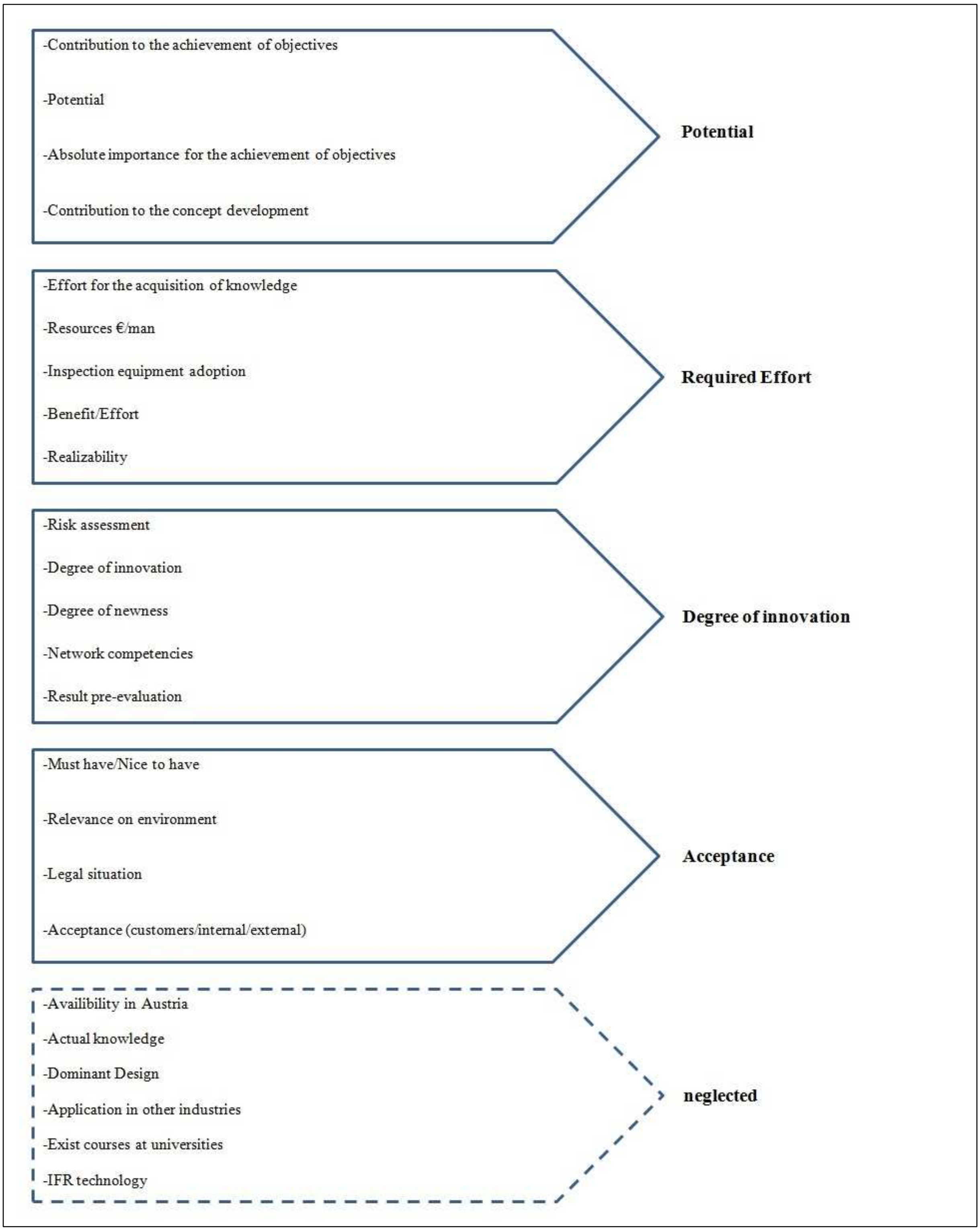

Illustration 5.7: Clustering of evaluation criteria

Finally the following criteria were selected to represent the cadre for the evaluation of technology fields at ACC Austria (Table 5.4).

No.	Criterion	Evaluation method	
		quantitative	qualitative
1	Acceptance	-	•
2	Degree of innovation	-	•
3	Number of covered contradictions	•	-
4	Potential	•	-
5	Required effort	-	•
6	S curves of Technology fields	-	•
7	System interaction	-	•
8	USP relevance	-	•

Table 5.4: Final evaluation criteria for technology field assessment

5.2.2 Evaluation criteria specifications

The, at this time definitive, list of evaluation criteria for technology fields includes items that allow a quantitative assessment. But some criterions necessitate a qualitative validation because the input for estimations can only hardly be operationalized. Through the extensive and profound preparatory work respectively the engagement with the initial goals of the CC2018 and the contradictions on the way of achievement (Chap. 3) it is possible to execute the subsequent points directly as output factor of the particular technology fields.

- Number of covered contradictions

  This feature allegorizes the summation of specific contradictions which can be assigned to an explicit technology field (Table 5.3).

- Potential

  The evaluation criterion "Potential" describes the allotment of target improvements of a technology field referring to the previously defined and valuated objectives of the overall system.

All the other mentioned characteristics are in fact of vital importance but they require a qualitative assessment and do not provide a parameter corresponding to a distinct unit. Nevertheless, especially regarding to market and customer development as well as for the estimation of risk, required effort and resources for the necessary knowledge acquisition, the upcoming criteria are indispensable.

- Degree of innovation

  Referring to ACC and not with regard to industry competitors or market novelties. Therefore it is an absolute internal and subjective criterion assessed by responsible decision makers of the management.

- Acceptance

  Contrary to the valuation feature mentioned before, acceptance relates predominantly to external or market parameters also concerning environmental and ecological matters. Regardless attention is also given to some in-house affairs like for example the strategy conformance of technological fields of expertise in the future.

- Required effort

  In this context, the term describes the limitation of time and because of the infinite yields of knowledge an additional estimation in consideration of a fifty percent target achievement.

- USP Relevance

  This criterion tends to the direction of industry competitiveness, what are the product offers and specifications of business rivals and what they will be in a couple of years comparable to prospective benchmarking.

- System interaction

  The compressor is not only the part of the cooling circuit that determines the highest cost intensity. It is also the centre of technology and development because it represents the reason for energy consumption.

  People all over the world recognize the seriousness of global warming and environmental pollution. This leads to the certainty that the mankind has to deal with the resources of our planet economically.

  One small tessera could be represented by low energy refrigeration. But this necessitates an “intelligent” compressor and appliance communication with required in-, out- and throughput.

To make these criteria tangible it is necessary to avail oneself of a clear structured and conceptional tool to assure that accordant choices and decisions are comprehensible on all accounts. The so called "Utility Value Analysis" has emerged and widely spread as efficient planning method for the consideration of essential but not quantifiable decision criteria, especially in central Europe. In general this technique operates according to the following systematic [Adam 1996 p.413]:

1. Definition of evaluation criteria and sub-criteria.
2. Weighting of sub-objectives, this is in accordance with the numerical expression of the relevance of the target-criteria to each other.
3. Assessment of the alternatives referring to the fulfilment of their sub-objectives (score evaluation).
4. Determination of sub-ordinate utility values, carried out by multiplication of the stage-weightings with the assessed points of the previous step.
5. Determination of the entire utility value by adding the sub-ordinate utility values and generating of an alternative ranking.

In the present case, an assessment of each specific sub criteria between zero and five points, weighted according to defined fractions of importance, leads to the sub-ordinate utility values.

The resulting evaluation sheet, including additional sub criteria, leads through accumulation to an overall utility value of an area of technology respectively technology field between zero and 500 and permits a direct comparison and a support for the resource rationing (Table 5.5).

Technology Field:						
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15		0
Required effort	25	Time limit 2013 (50% target achievement)		25		0
Degree of innovation (ref. ACC)	20	Running patents	20	4		0
		Experience	50	10		0
		Available resources	30	6		0
			100			
Acceptance	25	Conditions of law	10	2,5		0
		Strategy conformance	30	7,5		0
		Market estimation	60	15		0
			100			
System interaction	15	Design "master" or "slave"	50	7,5		0
		Interaction with appliance	50	7,5		0
			100			
	100			**100**	Σ	**0**

Table 5.5: Utility value analysis scheme for technology field evaluation

The outcome of the utility value analysis can be graphically opposed by the use of a classification profile. The advantage of this method is the possibility of a direct comparison of all evaluated domains of an area concentrated in one illustration. The following raw profile shows the highest possible utility values of each criterion according to the defined weighting and the overall one in percent (Ill. 5.8). To complete this procedure, a scheme has to be replenished with data for each technology field.

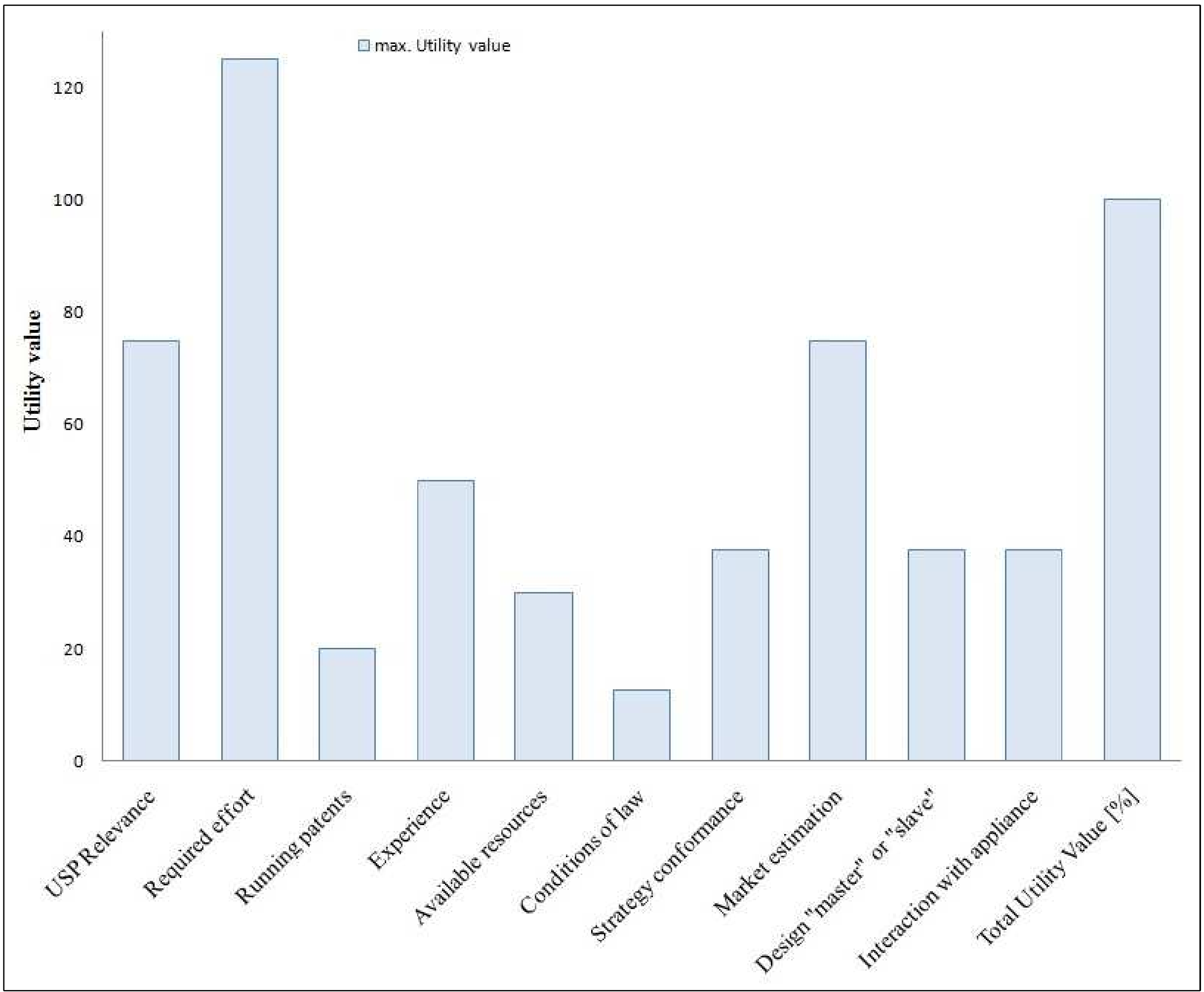

Illustration 5.8: Classification profile of the utility value analysis applied on technology fields

The filled charts of the evaluated technology fields provide a clearly arranged comparison, correspondent to the selected criterion. This comparison serves as support function, together with the other criteria, for the allocation of resources with the intentional goal to overcome the specific challenges.

The possibility of such an assessment of an intrinsically qualitative evaluation makes the utility value analysis a highly effective support tool for long ranging decisions. Nevertheless it is still a qualitative method and the resulting figures are not to be understood as absolute values but as basis for a direct comparison.

One criterion is still missing to complete the list for the assessment of technology fields:

- S-curves of technology fields

  According to Foster [1986, p.87ff] the performances of a technical system or a specific technology plot versus the expended effort or time results in an S-shaped curve progression. This curve represents the technology life cycle and is also known as S-curve (Ill. 5.9).

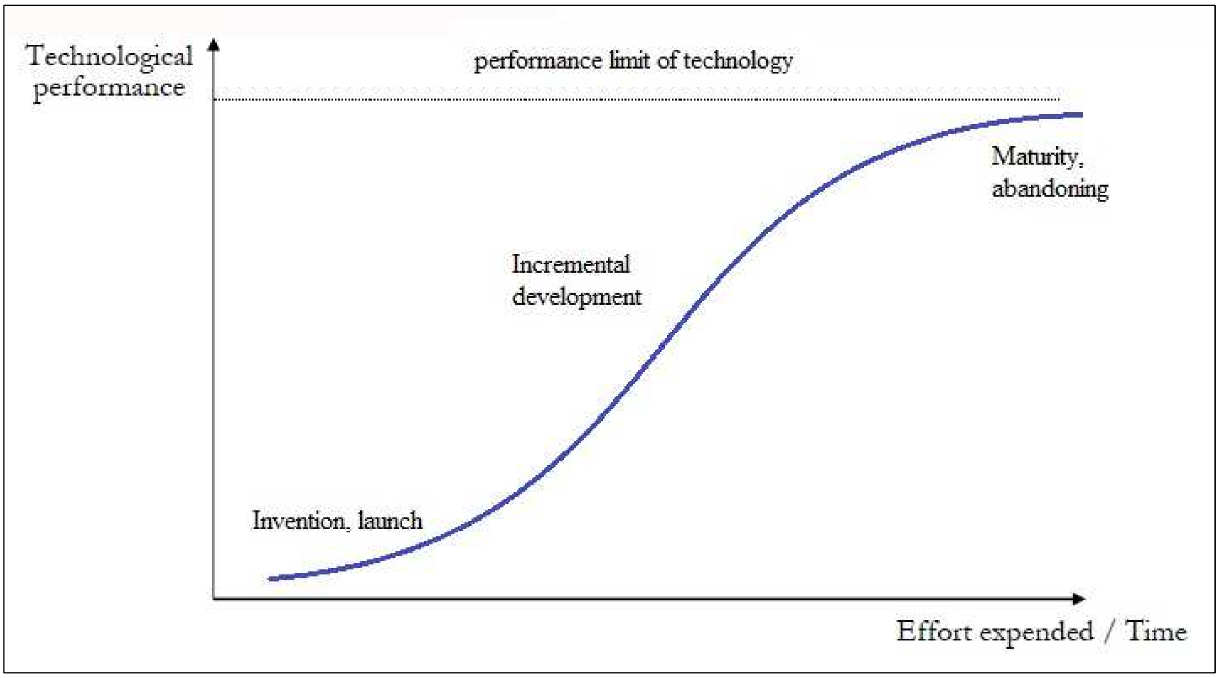

Illustration 5.9: Technology life cycle [Sarkar 2007, p.120]

The special resulting shape of this model leads to three distinguishable phases a technology goes through during its lifetime.

In the first phase, the invention or launch, the progress is quite slow until enough knowledge is obtained. A lot of effort and energy has to be spent for only incremental gains. Out of the increased familiarity with the technology, in the incremental development stage the progress allows reduced effort per performance improvement. This might result in a variety of new products based on the particular technology. Along the last stage, called maturity or abandoning, the technical advance is slowed down because the limit is approached. Furthermore, stagnation is quickened by radical developments and also by spending a lot of effort and resources in other technologies to achieve a technological breakthrough. In other words, resources are diverted to new technologies and the old ones are abandoned. [Sarkar 2007, p.119ff].

Focusing on organizational considerations, technology should be developed along the S-curve and when the change comes closer it is time to refocus on newer technologies because the organization would be disadvantaged by retaining a dying technology.

The challenge and at the same time the question is how to know when a particular technology approaches its end.

The technological lifecycle, contemplated as entire system, is a dynamic process with smooth transitions and the reaching of the performance limit is characterized by discontinuities respectively technological breakthroughs. At this point in time the variation, in for example a product class, increases because of the prevailing of competition between old and new technologies. [Foster 1986, p.87ff].

In the case of ACC, the further development of their products over such a long period requires estimations of the development of possible solution technologies and their sub levels.

Therefore it is of vital importance to include the assessment of the stage on the S-curve of potential technologies that might be used and their prospective advancement as evaluation criterion if it is basically purposeful and reasonable.

The decision referring to this difficulty should be taken by the, with the specific abandonments entrusted, responsible and accountable people.

5.3 Technology field evaluation

In the end, the objective of the definition and as following step the evaluation of technology fields represents a structured and well-founded basis for decisions regarding required resources.

The issue should be a list of evaluated areas of technology to set a temporary starting point for the operative processing of the instant subject.

The assessment procedure consists, referring to the criteria and tools mentioned before, of three blocks as shown in the upcoming figure (Ill. 5.10).

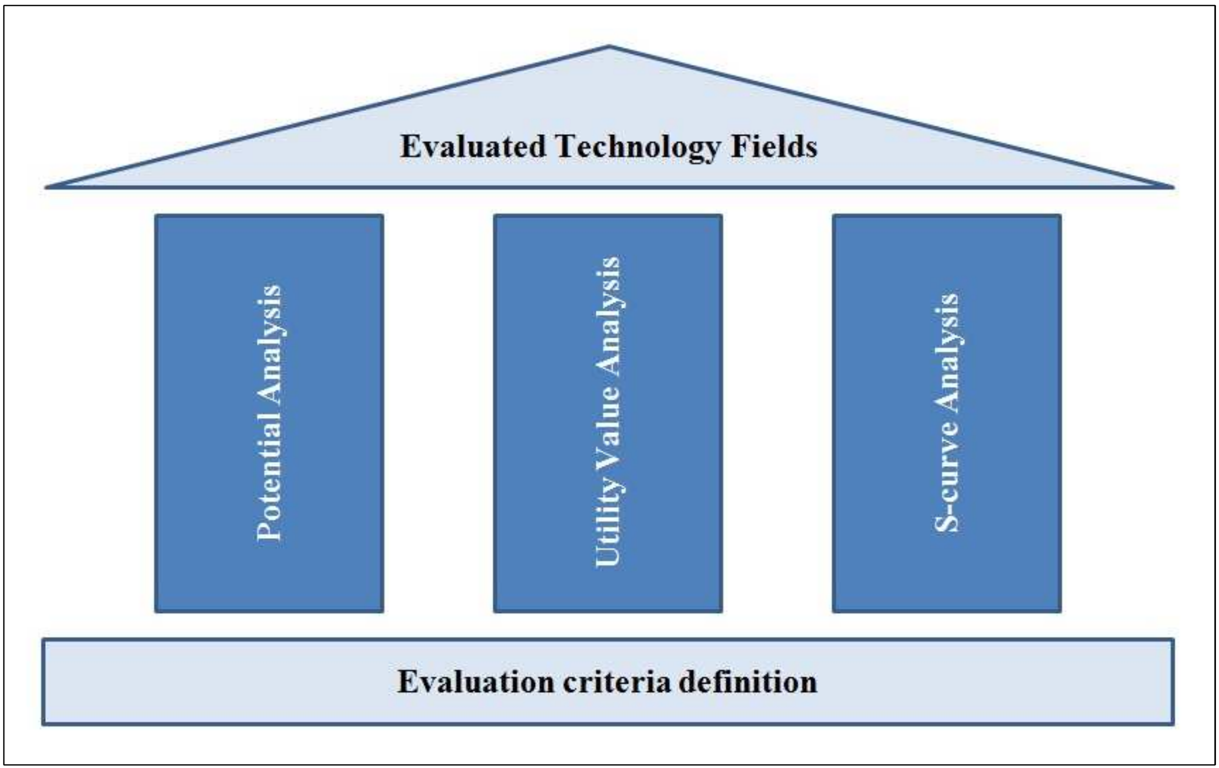

Illustration 5.10: Three Columns of the evaluation procedure

The column "potential analysis" represents the noted quantitative part of the evaluation (Chap. 5.2.2) and unifies the criteria number of covered contradictions and the assessed potential that results from the scope of improvements which has been attributed to the prepared contradictions.

Alongside, the previously specified utility value analysis determines the basis of the evaluation process that is completed by an estimation of the life cycle stage of a technological area.

This S-curve analysis allows an appraising of the plausibility for further development steps or shows whether a replacing technology is nearby.

According to that, the concrete inputs for the technology field evaluation are:

- Potential analysis

  The number of covered contradictions results from the particular allocation (Table 5.3).

  This allocation is furthermore the foundation of the appraisal of improvement potentials that additionally require a compilation of aspired enhancements by accomplishing the respective contradictions (Table 5.6).

	Contradictions	Contradiction potentials in € compared to actual Delta VT					
		COP	DM	Noise	Space	Add. Fct.	∑
1	Diversification vs. Standardization	-	-	-	-	0,4	0,4
2	Integrated electronics vs. Compressor "slave"	-	-	-	-	0,4	0,4
3	Low noise vs. Small size	-	0,05	0,2	0,07	-	0,32
4	Low pressure loss vs. Small size	1,12	0,05	-	0,07	-	1,24
5	Low temperature vs. Big size	0,48	0,06	-	0,07	-	0,61
6	Low suction- discharge work vs. High cost	0,2	-	-	-	-	0,2
7	Self adjusting valves vs. High cost	0,84	0,13	-	-	-	0,97
8	Selective heat conductibility vs. Current material	0,08	0,12	-	-	-	0,2
9	Self adjusting dead volume vs. Current material	0,08	-	-	-	-	0,08
10	Low pulsation vs. Small size	0,28	0,06	0,2	0,09	-	0,63
11	Lower starting torque vs. Small size	-	0,06	-	0,06	-	0,12
12	Low temperature vs. Big size	0,52	0,05	-	-	-	0,57
13	Many interfaces vs. Low complexity	-	-	-	-	-	0
14	Speed control vs. Low complexity	2,4	12,3	-	-	-	14,7
15	Easy approbation vs. High complexity	-	-	-	-	-	0
16	Speed control vs. Low cost	-	0,7	-	-	-	0,7
17	High efficiency vs. Low cost	1	-	-	-	-	1
18	High efficiency vs. Small size	1	-	-	0,18	-	1,18
19	Insulate temperature vs. Conduct temperature	0,24	-	-	-	-	0,24
20	Adjustable for variable speed vs. High cost	0,68	0,6	-	-	-	1,28
21	Adjustable for variable speed vs. High reliability	-	-	-	-	-	0
22	Low friction vs. High cost	0,24	0,09	-	-	-	0,33
23	Low friction vs. Big tolerances	0,04	-	-	-	-	0,04
24	No heat exchange between suction and discharge line vs. Low noise	0,4	0,1	0,4	-	-	0,9
25	High heat exchange vs. Low noise	0,4	0,13	0,2	-	-	0,73
26	Small size vs. Low noise	-	1	0,2	-	-	1,2

Table 5.6: Aspired improvement potential of CC2018 contradictions

- Utility value analysis

  The outcome of the examinations and their visualization require a specific assessment of the criteria, underlying the defined scheme (Table 5.5), to get a meaningful value for the confrontation.

  The detailed schemes and charts of each technology field can be found in the appendix (A).

- S-curve analysis

  The positions on the S-curve represent the development stages of the technology fields. Facing for example the field “Compressor as entire system”, the reciprocating type compressor, as the CC2018 will be, is already well developed (Ill. 5.11). This means the probability that different cooling concepts could establish on the market tends towards certainty. A situation that might requires a rethinking for further development projects.

  The upcoming figure demonstrates the, by R&D team leaders, estimated life cycle states of the technology fields (Ill. 5.11).

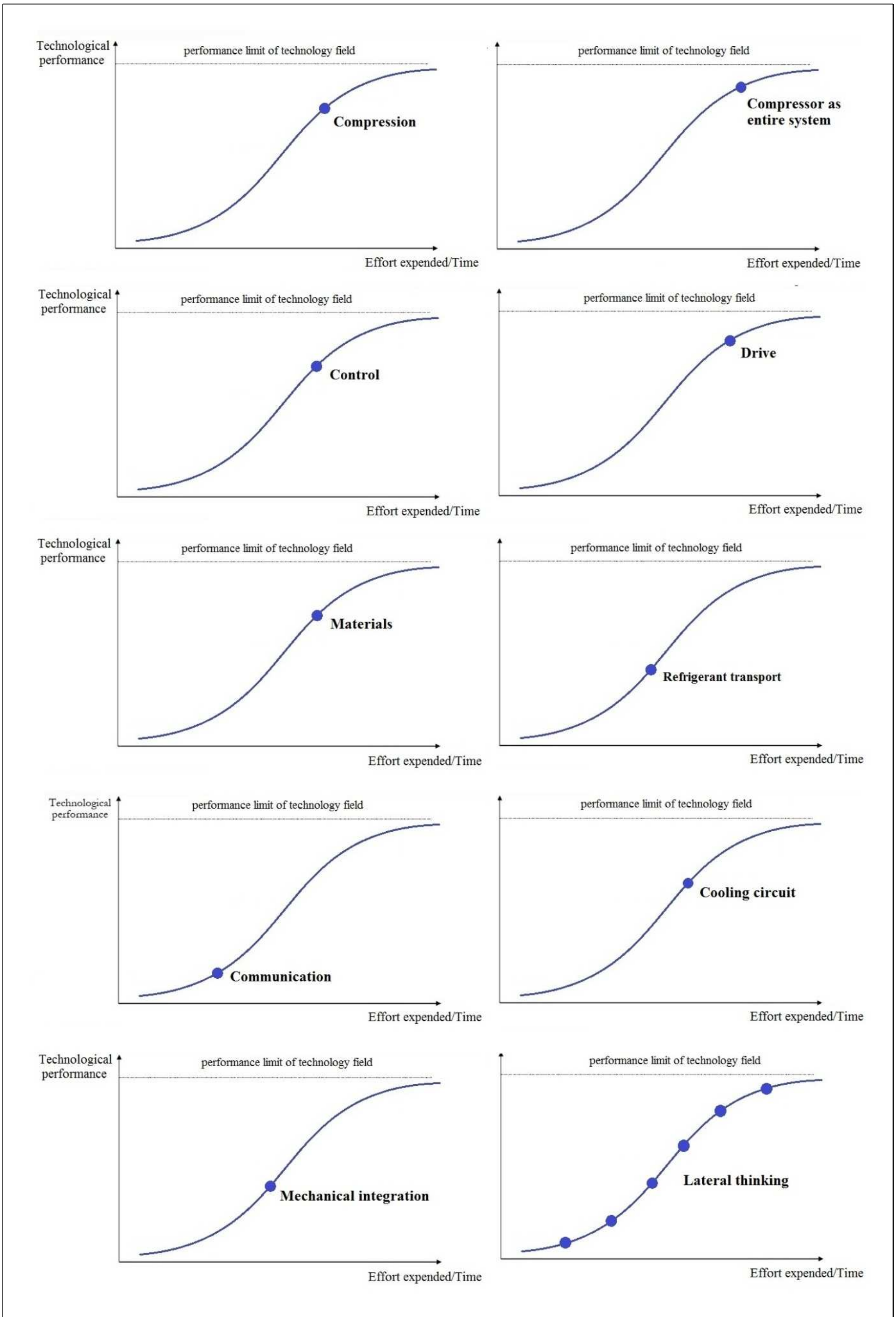

Illustration 5.11 Assessed S-curves of technology fields

A comparison of the results of those points leads to the envisaged list of evaluated technology fields (Table 5.7) whereby the S-curve analysis has been rated in three stages (high, middle and low) according to the development potential.

			Evaluation criteria		
		No. of contrad. [#]	Improvement potential [€]	Utility value [%]	S-curve potential [high/middle/low]
	Compression	10	19,8	62,7	middle
Technology fields	Compressor as entire system	10	7,4	57,9	low
	Control	9	18,5	74,6	middle
	Drive	6	18,0	66,3	low
	Materials	11	6,2	67	middle
	Refrigerant transport	13	8,0	72,2	high
	Communication	8	18,4	63,4	high
	Cooling circuit	9	4,83	76,3	middle
	Mechanical integration	2	2,18	59,2	high

Table 5.7: Comparison of evaluated technology fields

This table represents the background for the creation of a certain kind of technology field ranking whereby “lateral thinking” is disregarded because of its status of a special case and so it is innately arranged as project with the highest priority level. The classification has been effected to three categories A, B and C (Ill 5.12).

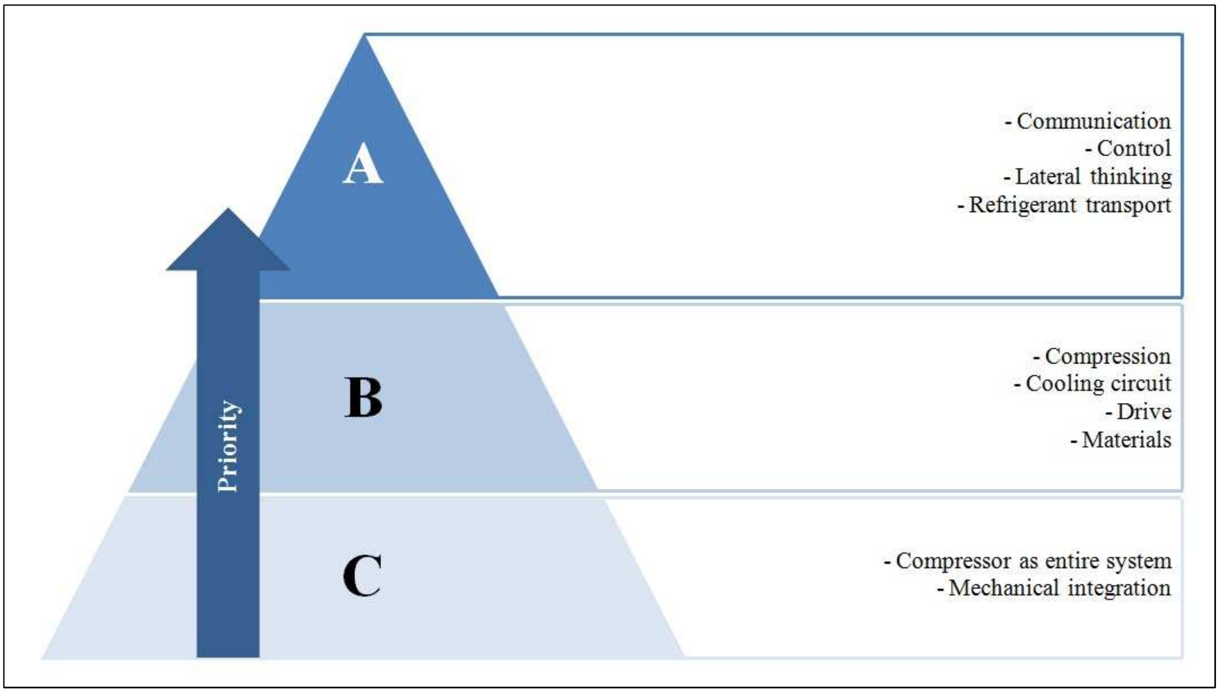

Illustration 5.12: ABC ranking of technology field priorities

The intention of this ranking is not to depreciate certain technology fields but to give an overview of different technological areas having different potentials.

6 Technology development projects – Process design

“Technology development projects” determine the operational, the practical phase of technology development management at ACC for future technology projects with the objective of knowledge acquisition. As noted, in first instance technology fields and projects are consistent and serve as basis for the concept developments of the CC2018 and constitute therefore the finishing activity of the technology development phase (Ill. 3.2).

The workpackages underlying the projects have important influence for the further success and the development of the new cooling compressor platform. To assure an execution with a clear organization, a phase plan as structural foundation has been created within the framework of this thesis.

6.1 Technology development projects – Process cycle

Effective accomplishment of technology development at ACC adds up in a project organization.

As basis for the project structuring serves the SE phase model, described in Chap. 2.2.1 (Ill 2.5).

Referring to the actual situation, it is not conducive to transfer this model to the existing problem directly. This means to focus on the development of the system (referring to the life-cycle of the system according Ill. 2.5) and leave, at this point of the overall development challenge, the realization and usage of the system out.

By the use of such a division in phases the previously devised ideal way of thinking of technology development management (Ill. 4.11) should be enhanced. But for an efficient application and to demonstrate an energetic support for the organization, it is moreover necessary to allocate aspired targets to the structural configuration.

In addition, the chance of a heterogeneous structure has to be admissible. An allowed inhomogeneous and flexible structure is required to maintain as much freedom of actions as possible and not to constrain fields of examination or methods from the beginning or even before.

The upcoming exposition displays the adopted phase model for the execution of technology development projects at ACC including the individual phases with the appropriate objectives respectively aimed results.

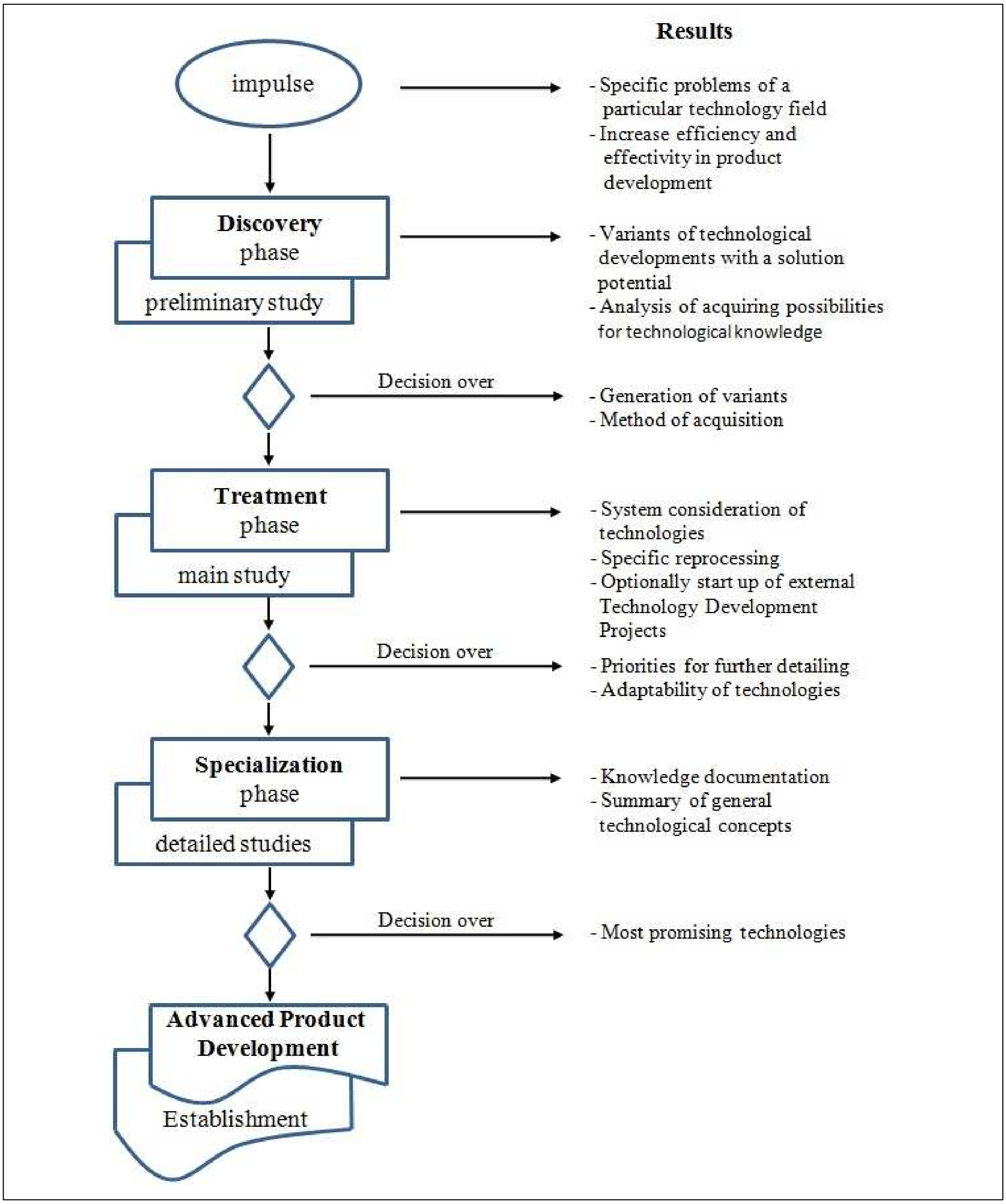

Illustration 6.1: Adapted phase model for technology development projects based on Haberfellner [et al. 2002, p.38]

Because of the precise focusing on technological issues and knowledge, the individual phases are not entirely in line with the intrinsic purposes [Haberfellner et al. 2002, p.38ff] and require certain modifications.

The *impulse* covers the duration between the recognition of a problem and the concrete decision to change this situation, usually unstructured but in place well prepared.

Due to this copious preparatory work, many questions the preliminary study should basically give attention to are already anticipated in the present case. This can be for example the limits of the particular fields of examination or the requirements on solutions. As starting point of the execution of technology development projects, the intention and necessity of the so called *“Discovery phase”* is to:

- Categorize potential alternatives of solutions and conclusions of their realizability.
- Define which solution principle is the most promising?

Therefore, the discovery phase represents a process of clearance.

Subsequent to the first phase, the structure of the identified alternatives as overall concepts should be refined. In reference to the CC2018 project, this means the *Treatment phase* has to concentrate on the configuration of specific technological answers whereby particular technologies occupy the status of a system and should be broken down. The result of the main study should be the knowledge and competence about new emerging, or not yet applied, technologies related to ACC as well as the identification and definition of priorities for the execution of detailed studies.

Functions of those particularizing examinations, termed *Specialization phase*, are the elaborateness of concrete aspects of technologies, or in general:

- Detailed solution concepts and decisions over accordant design options.
- Concretizing of partial solutions for an unobstructed implementation.

This concretizing implies the arrangement of technological budding potentials in such a manner that it is possible to utilize the so generated and acquired knowledge directly for the following phase of establishment. In other words this means the prototyping and testing of realized application alternatives with the target of a finalized design which is ready for the implementation and the market.

The problem that occurs if active technology development is not conceived as cyclical sequence of operations is that organizations run the risk to lose sight of the entire package.

This in turn could result in unsatisfactory or problem afflicted interactions and complicacies at a sophisticated point in time. But by spending marginally more effort at a previous stage, such a situation can easily be avoided.

Therefore, the generic plan of procedures for technology development projects at ACC, oriented in line with the long term product planning process for the CC2018, is scheduled as succession with three cycles.

The following phase plan, including the arranged underlying process sequence, straightens again that particular attention is paid to the interaction of individually analyzed technologies (Ill. 6.2).

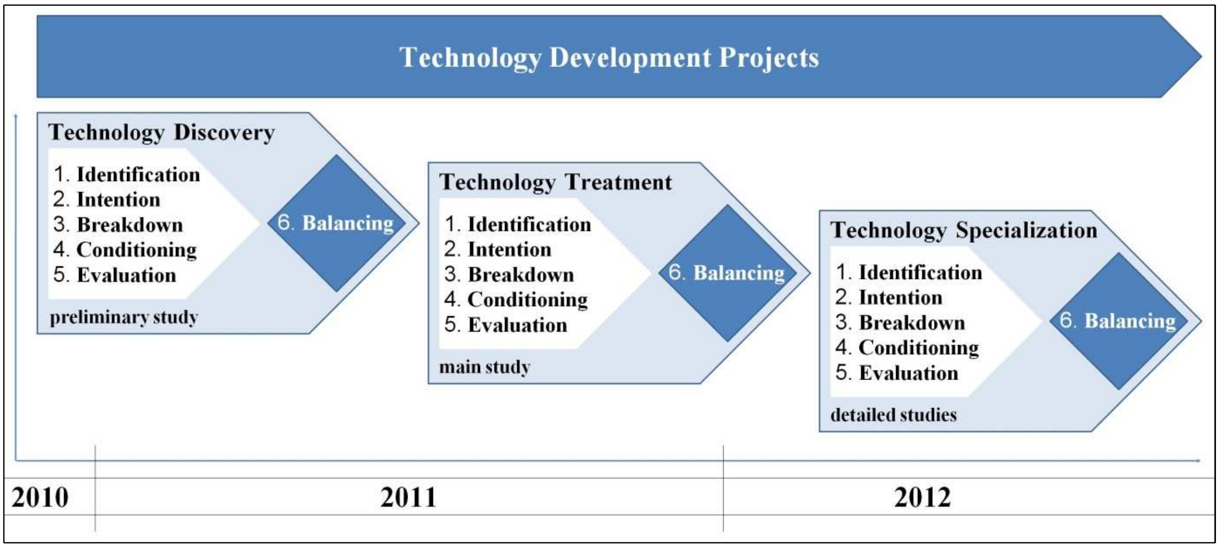

Illustration 6.2: Generic phase plan for the execution of technology development projects

This pattern requires a simultaneous proceeding for different technology fields and tends to a development progress in cadence, which demonstrates a big challenge on practical site.

The reasons for the difficulties with “staying on-line” have their origin in the different levels of development and experience on all stages of application because of varying interest, and so willingness to spend resources and execute investments.

But often it is not possible to reduce this complexity just on missing assets or effectiveness and efficiency. In many cases results a sagging coming forth in elementary drawbacks of a sub system that limits the performance of the entire system.

The performing of the defined process sequence (Ill. 6.3) multiple times in each phase (Ill. 6.2) should result in the target to implement not the singular best technological solutions for a particular problem, but moreover to identify the best package of technologies.

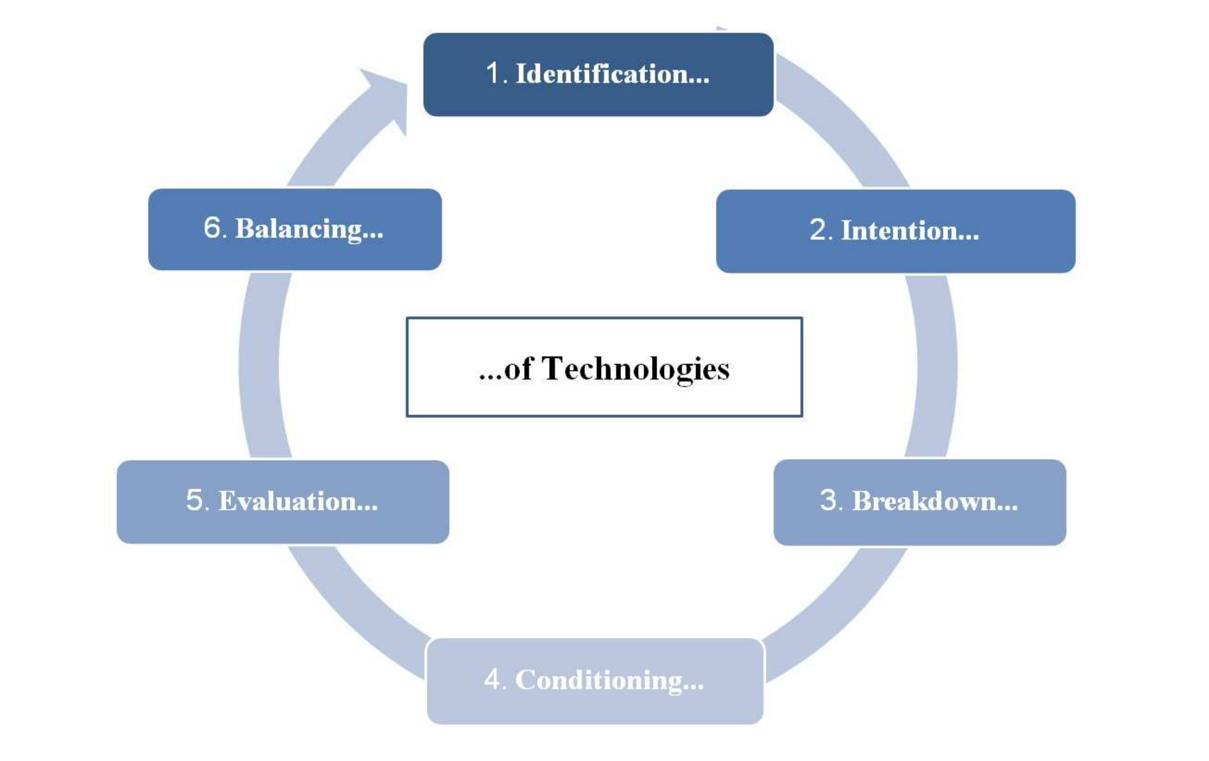

Illustration 6.3: Cyclical processes of technology development projects

Particular point of interest is the balancing of specific technologies to highlight the focusing on the overall concept, respectively final aspired objective.

Such a handling of interactions between certain technologies, technology fields and especially the subsystems (Ill. 3.7) is very complex and requires a lot of know-how and technical understanding.

Nevertheless it constitutes a fundamental and necessary process at an early stage to avoid serious problems in sequel, when the flexibility and dynamic to act has had to accept forfeits.

The upcoming figure (Ill. 6.4) demonstrates that the defined process steps underlying technology development projects reflect the elements of the Systems Engineering problem-solving cycle.

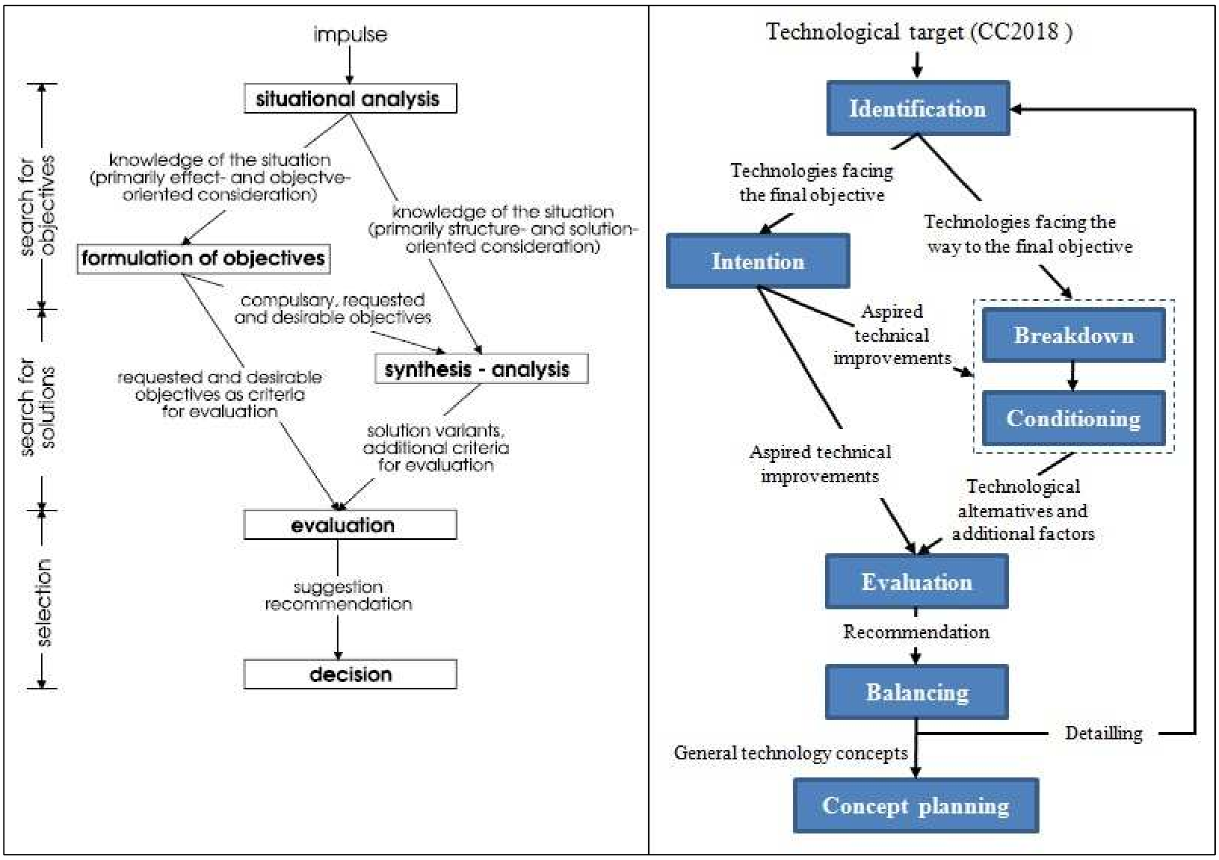

Illustration 6.4: Comparison of PSC and technology development project process steps

Basically the narrow difference of those two approaches arises because of the clear focusing on handling specific technological problems in reference to the developed steps that should be passed through during a technology development project at ACC.

To express the importance and indicate the complexity of respective interdependencies of combined technologies that build up an entire technical system, the general problem-solving cycle has been extended with a step termed “Balancing of technologies”.

This supplemental action faces the identification, an analysis of possible effects and mutual influences as well as a contemplation of potential overall technological concepts as impulse for further detailing. Furthermore the balancing step operates as source for structured technological knowledge as input for the next phase of the long term product planning process (Ill. 3.2).

An extensive illustration of how to handle the separate process steps follows in the next chapter.

6.2 Technology development projects – Process steps

Technology development projects at ACC comprehend particular processes (Ill. 6.3) which are described in more detail in the following sections, including methods and tools that offer a way to perform each step.

6.2.1 Technology identification

Most organizations, also ACC, are not science creating institutions- they are science using ones. Therefore the point of origin of every development step apart from advancements of already implemented technologies in actual or former products is an identification of technologies for the accomplishment of particular requirements.

6.2.1.1 Objectives of technology identification

In the present case, available technologies for the handling respectively the solution of contradictions are requested.

It is important that this search for information is absolutely free of any prejudices in reference to their application to avoid taking an intuitive pre-decision and to be accordant to the technology development management mindset (Ill. 4.11). Moreover this process should help to create a sufficient and uniform understanding of the problems.

It is elemental that such a search for information can be carried into execution through an endless number of possibilities. Thereby the way of acting is profoundly dependent of the personal characteristic traits like education, experience, culture or environmental circumstances of the people involved. Furthermore, the implemented routine methods of an organization influenced by general orientation, strategy, available resources and in turn again human traits are crucial for the proceeding.

6.2.1.2 Tools and Methods

The ways how to identify technological solution potentials for special problems are versatile and have a personal reference in the majority of cases. But for all that exist a cadre of possibilities that have emerged to obtain respective information. Without doubt those methods include differences in quality but also in the unavoidable expenditures, especially in terms of the, to a sufficient extent not always present, resource time.

This so called cadre of tools adds up, without claiming completeness, to the potential information sources:

- Internet
- Classic literature study
- Networks
- Benchmarking

<u>Internet</u>

Meanwhile, when dealing with information and its diffusion, no one can get around the biggest and fastest growing knowledge base in the world, the internet. This global system of interconnected computer networks offers the communication of many with many at any time. [Castells 2001, p.10].

The quality of the provided knowledge is not always exhausted and is liable to differences. But it can be a fast and efficient source of information that is accessible all around the world, at least to recover hints for further examination. Due to the fact that a multitude of scientific papers on respective sites, in part for some charge, can be seen, the internet provides also scientifically accredited information. The access to this data would have been unimaginable a couple of years ago because of national borders and restrictions, marking some of the convenient effects of globalization.

The boundless sources of information allow a multifarious search for solution ideas referring to the defined targets of the particular technology fields (Table 5.3) as contribution potential and technological basis of the entire project.

<u>Classic literature study</u>

Beside the postmodern media as most important global distributor of knowledge, the conventional specialist literature as well as respective textbooks offer a well-tried alternative at least or especially to enhance the problem of understanding.

Field related journals in addition provide reports about actual areas of application of emerging technologies. On the other hand academic assignments like dissertations or research papers represent the technological state of art. They enable in many cases inferences of direction tendencies for further research. It is elemental that this centuries-old method of retaining and spreading scientific accomplishments has also been encouraged by the development of modern information and communication technologies. Online libraries, miscellaneous forums or patent databases constitute an incredible conglomeration of almost all lore of mankind with all its chances but also risks.

Networks

A strong and extensive network of the organization itself and also, or maybe especially, of the people involved supports the process of identifying technologies in an immense way.

But networking, or more precise “business networking”, as socioeconomic discipline is much more far-reaching. It involves all levels and departments of an organization as well as all employees and demonstrates a support function of all business activities. According to Burg [2006, p.1] networking is the cultivating of mutual beneficial, give-and-take, win-win relationships. Therefore, many companies understand it as general requirement of management capabilities and it is often part of an organization´s strategy in these days. In this context the continuous contact to science respectively knowledge creating institutions has to be mentioned as important column and legitimates miscellaneous expenses that might not always result directly in a financial gain.

Fleisch, Österle and Alt [2000, p.5] describe the networkability in general as the ability to cooperate internally and externally and further that organizations are able to do networking if their dimensions can be integrated into other networks quickly and economically for example by establishing stable customer relationships in an efficient and effective way.

Illustration 6.5 represents the dimensions to which networkability refers.

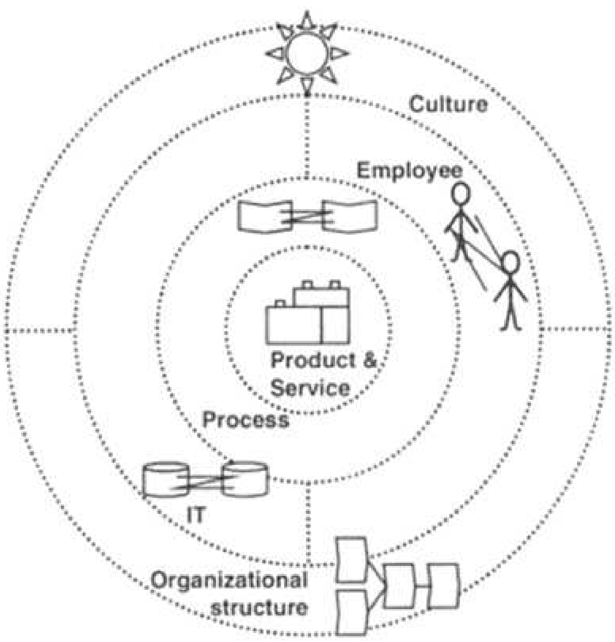

Illustration 6.5: Dimensions of networkability [Fleisch, Österle, Alt 2000, p.397]

Over the last years online business networking has more and more emerged. This fact makes it easier to keep in touch with contacts around the world. Nevertheless, face-to-face networking provides the higher potential for quality relationships and many people prefer to see the gestures and facial expressions of their respondents. Summarized all this means that networks, like expert circles, may offer the basis for hints to the right direction or in this case the right technology.

<u>Benchmarking</u>

“Benchmarking is the continuous process of measuring products, services and practices against the toughest competitor or those companies recognized as industry leaders.” [Camp 1989, p.12].

Principally, benchmarking is a holistic improvement method for all levels of an organization, often used in management and intrinsic strategic management, not only as one-off event. The advantages are the generation of a better understanding of the own business processes and the enhancing of competitiveness. The opposite is the necessity of specific information that is essential for successful benchmarking. Because of the wide appeal and acceptance of this tool, no single methodology has emerged over the years. One of the oldest and still most often used approach is the benchmarking process, a ten step methodology, according to Camp (Ill. 6.6).

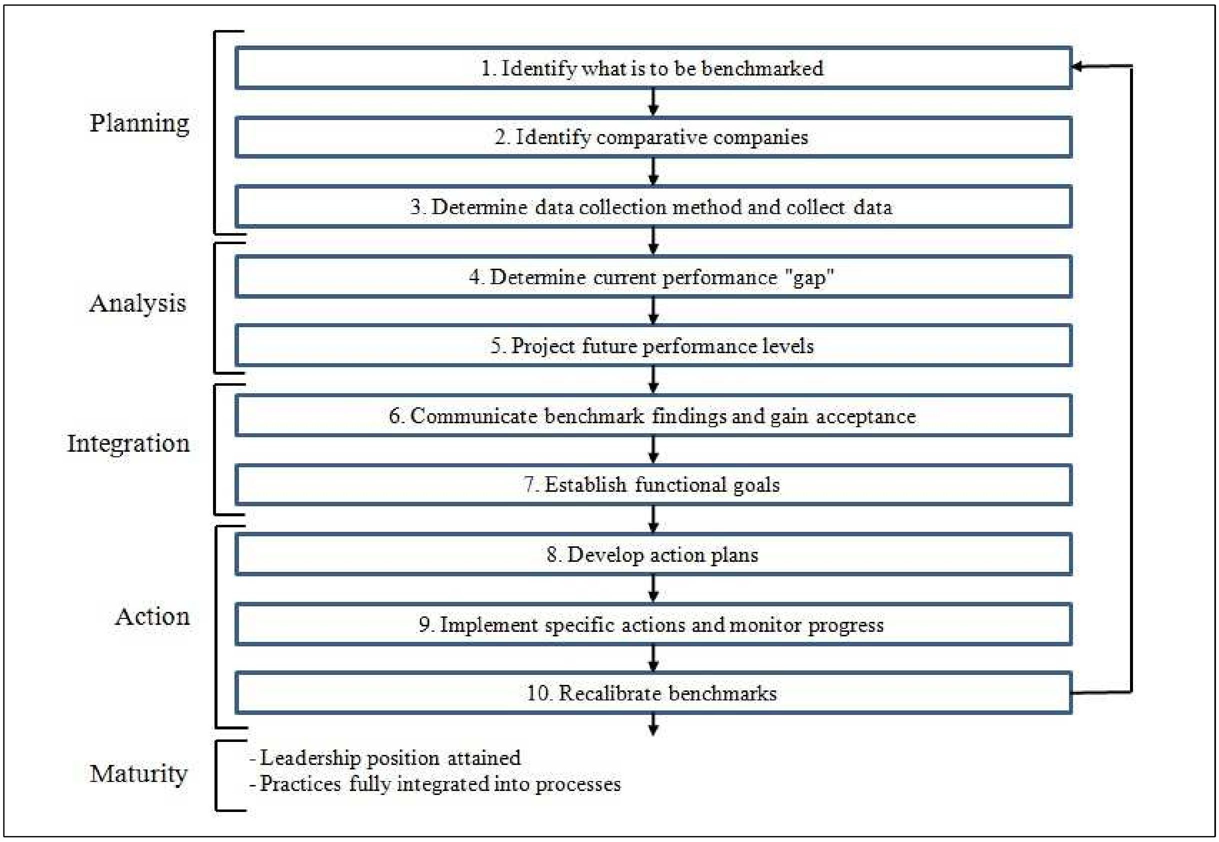

Illustration 6.6: Benchmarking process steps [Camp 1989, p.17]

In reference to the targeted business or management areas, many different types of benchmarking, as for example process-, financial-, performance-, energy-, strategic-, operational-benchmarking and so on can be distinguished and exhibit certain singularities. Referring to the present conceptional formulation, the technique of comparing corporate strategies has to be extended to the comparison of technical products, usually referred as product- or technical-benchmarking. But at such an early stage of product development respectively even one step before, it is not necessary to perform step by step of a cyclical benchmarking methodology with continuous proceeding. In this context it should rather be understood as pure method for information procurement of established and approved technologies. Also here, as well as at all other types of benchmarking, the dissimilar varieties have to be differentiated (Ill. 6.7). [Siebert, Kempf, Maßalski 2008, p.32ff].

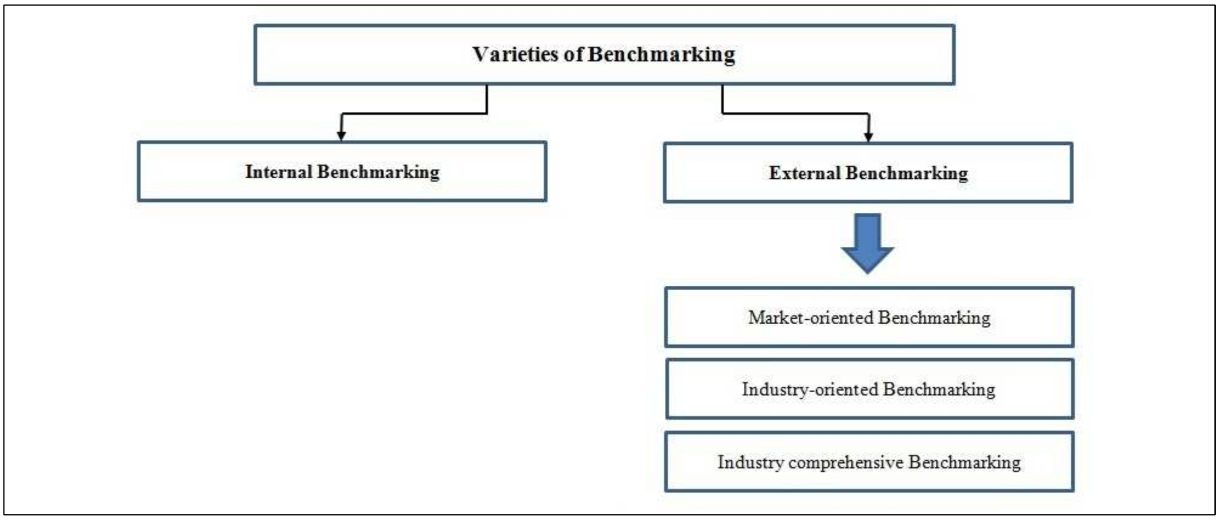

Illustration 6.7: Varieties of benchmarking [Siebert, Kempf, Maßalski 2008, p.34]

Internal benchmarking corresponding to the technology identification process indicates a fallback on the company´s knowledge base, especially on previous work packages that have disappeared in the drawers as result of various reasons, maybe because the time wasn't ripe for the one or other technology. External benchmarking is in this case the general heading for an examination of the market, the cooling compressor industry and various other branches for potential technologies.

The intensity and deepness of all those mentioned ways of identifying technologies and further information in reference to more detailed phases (Ill. 6.2) vary according to the effort spent. Needless to say that there exists an almost endless number of other different possibilities like trade fairs, direct mails or inputs of the field staff, just to name a few.

But maybe more important than the utilized method or methods is the capability and imaginativeness of people involved to discover technological potentials without tunnel vision or a personally internalized solution.

6.2.2 Intention of technologies

In principle the impulse (Ill. 6.1), initialized for reasons of necessity to change a certain condition, is already attended by global targets. But as the name suggests, those objectives are elementarily and rather defined broadly. To face the specific problems in a more detailed way and to provide inputs on what to focus, a definition of explicit, distinct and repeatable objectives is a necessary demand for subsequent process steps. Possible attributes of an operational target formulation and questions involved are [Haberfellner et al. 2002, p.138]:

- Target object – Whereby are targets tied?
- Characteristics of the target object – What should be achieved?
- Target extent – How much should be achieved?
- Timing – When should it be achieved?
- Point of effect – Where should it be effective?

Not all of those components have to be available categorically. As sources for the answering, corresponding to technology development projects, the criteria defined in the context of technology field evaluation (Chap. 5.2.1) can be applied:

- Objectives are linked to the specific technology fields and range within the scope of the overall technical system.
- The number of, by a technology covered, contradictions, and for this reason the allocated aspired improvement potential, describe what should be achieved.
- The target extent is determined by a fifty percent target achievement of the aimed improvements, defined as basis for the required effort assessment.
- Beside the evaluation criteria, the available time is defined by the master plan of the long term product planning process (Ill. 3.2).
- The defined CC2018 subsystems (Ill. 3.7) represent the different points of effect.

Important for the formulation of objectives for identified technologies is that people are involved in the problem solving process and accept the specific targets. In addition it is necessary that it goes more and more into detail, according to the respective phase (Ill. 6.2).

Objectives represent besides not originally an obvious subject, they have to be prepared.

6.2.3 Technology breakdown

The big challenge of predevelopment respectively technology development is the required forecasting of technological processing and the assessment of trends. This results because technical systems feature a strong dependency of the development of their components and on the same level of the combined technologies that make up the final product.

6.2.3.1 Intention of technology breakdown

Strategic far reaching decisions in an organization might be taken spontaneously, subjective and so are due to bigger imponderability without a well founded information basis. But they could be right. Nevertheless, henceforth market environment, sustainability as well as chances and risks of technologies are liable to a steady change. To achieve a continuous competitive advantage, to enhance core competencies and to establish innovative capabilities and so new market entries, an accordant information pool as basis for determinations is an indispensable requirement.

Referring to the effectiveness of technology decisions, the so called technology intelligence, the systematic sourcing and evaluation of information about technological trends, is of fundamental relevance and represents the content of technology breakdown. [Lichtenthaler 2008, p.59ff].

The advantage of technology intelligence is not only dependent of the completeness of monitoring and the quality of assessment. Essential in the end is the improvement of how decisions are taken as result of an enhanced “info-board” or if organizational learning is initiated. [Lichtenthaler 2008, p.59ff].

Lowe [1995, p.95] mentioned, that the success of technological intelligence or forecasting can be seen in terms of the contribution it makes to the effectiveness of a system and therefore to the corporate technology strategy.

Because of that technology intelligence demonstrates, also in this term, a core function of technology development. Through this process it should be possible to recognize technology potentials with the subsequent intention of a specific conditioning for concept developments and in the end their implementation.

The difficulties of this area on the one hand lie in the assessment of prospective developments and the interpretation of information in this context and on the other hand in the selection of the right method out of a multiplicity of options.

6.2.3.2 Tools and Methods

The organization of the technology intelligence procedure is of elemental importance for its success whereby the use of capable methods can support this in an essential way. Many distinguishable possibilities are described in literature, all with intrinsic pros and contras, but in general without answering the question when to apply which one.

This is the reason why within the scope of this diploma thesis the main focus is placed on the parameters that influence the choice of methods and responds only peripheral and exemplarily to the execution.

In this context, Lichtenthaler [2008, p.59ff] has insistently been engaged with the identification of influencing determinants through an empirical research in twenty-six international acting technology-intensive corporations. He has reasoned that in a specific situation where it is necessary to carry out technology intelligence, an appropriate method as well as a type of evaluation has to be defined. It also has to be differentiated between individual and group appraisal. Those two design parameters are dependent of numerous factors (Ill. 6.8). Furthermore, the choice of methods is strongly influenced by the chosen evaluation-type and the other way round, because not every method allows a group evaluation as a result of its ambitious methodology.

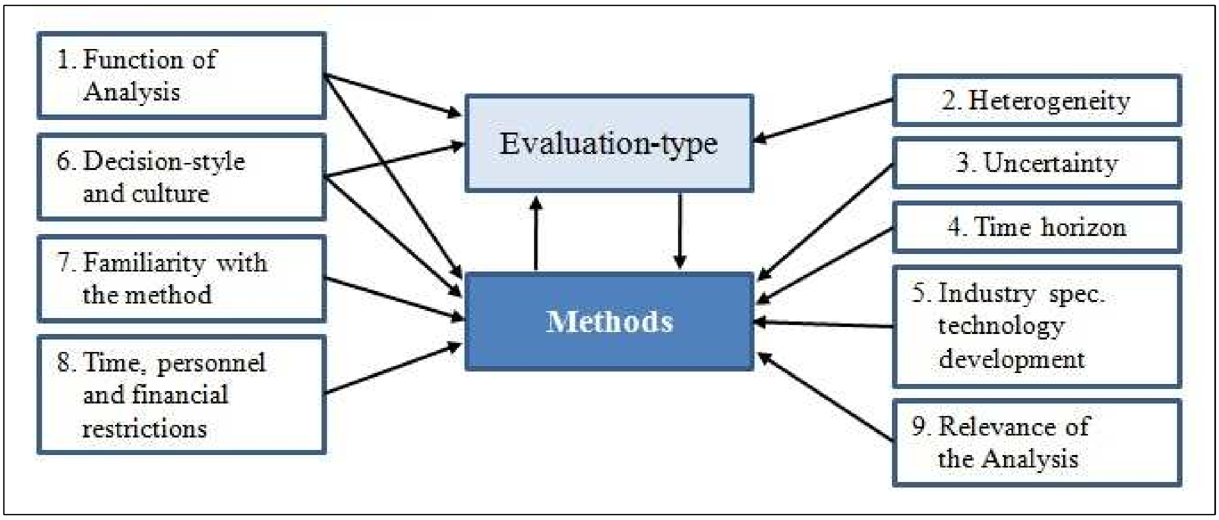

Illustration 6.8: Influencing factors of method selection [Lichtenthaler 2008, p.66]

In general all those mentioned determinants are more or less organization, resources and problem specific and vary according to the respective application.

Referring to the particular problem at ACC, the function of analysis aims the acquisition of technological information.

In consideration of prospective information retrieval, three elementary types can be differentiated: the extrapolative, the explorative and the normative. The extrapolative information acquisition carries current developments forward and creates so pictures of the future. [Lichtenthaler 2008, p.68ff].

Contrary to that, the explorative tend to identify possible developments and to design several different future scenarios to enable a derivation of an appropriate strategic orientation. The normative information retrieval describes the analysis of an intended future and targets the identification of ways how to get there, often a possibility to create radical new ideas. A list of the most common methods for technological forecasting results from the consideration of those factors as follows (Table 6.1). [Lichtenthaler 2008, p.68ff].

I...Individual I/G...Individual & Group	Information retrieval			Learning		Evaluation-type
	extrapolative	explorative	normative	organizational	individual	
Publication-frequency analysis	•	-	-	-	•	I
Publication-networking analysis	•	-	-	-	•	I
Quantitative conference monitoring	•	-	-	-	•	I
Patent-frequency analysis	•	-	-	-	•	I
Patent-networking analysis	•	•	-	-	•	I
S-curve analysis	•	-	•	•	•	I/G
Benchmarking	•	-	-	•	•	I/G
Portfolios	•	-	•	•	•	I/G
Delphi-studies	•	•	-	-	•	I
Expert panels	•	•	-	•	•	I/G
Expert interviews	•	•	-	-	•	I
Technology Roadmaps	•	-	-	•	•	I/G
Product Technology Roadmaps	•	-	-	•	•	I/G
Product Roadmaps	•	-	-	•	•	I/G
Experience-curves	•	-	•	•	•	I/G
Simulations	-	•	-	-	•	I
Option Pricing	-	•	-	•	•	I/G
Scenaries	-	•	•	•	•	I/G
Lead-User-Analysis	•	•	-	•	•	I/G
Quality Function Deployment	•	-	-	•	•	I/G

Table 6.1: Methods of technology intelligence [Lichtenthaler 2008, p.69]

Very important regarding the selection of methods is that they are consistent with the time horizon of the specific planning process. With an increasing period of time, also a rising of the uncertainty goes hand in hand. But therefore trends might be influenced and new markets could be established. [Lichtenthaler 2008, p.72ff].

With the continuous application of all those different forecasting technology tools, their special appropriateness for varying time frames (Ill. 6.9) have become apparent and has to be taken into account. [Lichtenthaler 2008, p.72ff].

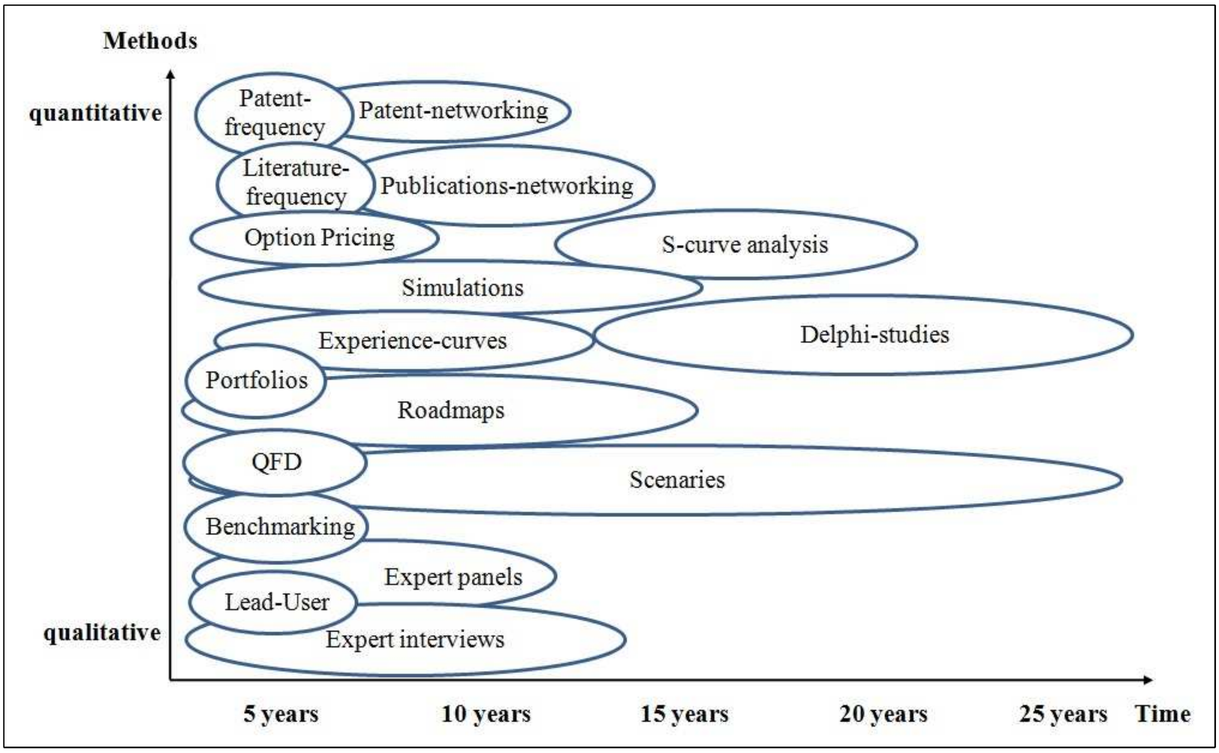

Illustration 6.9: Applicable time frames for forecasting methods [Lichtenthaler 2008, p.73]

This figure may create the impression that the estimated time frame till product launch is defined too short at ACC for meaningful conclusions of many stated methods. Most tools of course target a much longer time horizon than the technology- and advanced product development phase (Ill. 3.2), but the average time of production of a compressor platform covers two to three decades, generation steps included.

Especially for those further developments of the particular generation of one compressor family, long-term and continuous forecasting could provide a source of important information. Furthermore, such long running assessments can be interpreted as tools for strategic decisions and might support the achieving of competitive advantage.

In due consideration of the highlighted determinants, the final selection which method to utilize should be object of the executing and so accountable team members.

Therefore, the used methods vary also according to branches as a result of diverse product lifetimes, the velocity of industry development, patent rights as well as the dynamic of chief markets and essentially of the strategic orientation.

Several forecasting techniques that are often adopted in mechanical engineering industry are for example [Lichtenthaler, p.74ff]:

- Patent analysis
- Benchmarking studies
- Interviews with experts
- Portfolio analysis
- Technology Roadmapping

Whereby the last mentioned procedure is more and more on advance.

Patent analysis

Patent analyses are typically used in automotive industry. [Lichtenthaler 2008, p.74ff]. But for the present case the patent structure of cooling compressor business offers an unsuitable foundation due to a not very profoundly structured arrangement of the system. This leads to the fact that many patents intrinsically refer to the application surrounding cooling units but are classified within other fields like electronics or electrical drives. Nevertheless, patent trend analysis in special areas of compressor components could represent a powerful method for technological forecasting.

Benchmarking

Benchmarking is potentially the most used and miscellaneous tool in the context of technology management. [Lichtenthaler 2008, p.74ff]. It provides an inference of the orientation of competitors and market developments. Moreover it can be extended across the borders of industry and utilized for trend assessment. A general benchmarking process sequence has already been examined within the scope of technology identification (Chap. 6.2.1) which emphasizes once more the universalism of this management method.

Interviews with experts

Expert surveys strongly tend to the direction of networking (Chap. 6.2.1.2), referring to external estimations. The intended purpose of organizing interviews with experts is the reconstruction of expert knowledge. A problem that might occur is that experts could implement high-grade diffuse knowledge. [Pfadenhauer 2007, p.449ff]. Regardless, the analysis of experts can definitely be an effective instrument for the assessment of prospective developments, because in the end those movements result also from human actions.

Portfolio analysis

The portfolio analysis represents a method which is principally used for the formulation of organization´s strategy and its examination of advisability in the daily business. Traditionally, business segment portfolios are generated and their content contrasted in matrices with correspondent criteria. In conjunction with portfolio analysis three basic theories named according to their developers are generally distinguished.

- BCG Matrix

The Boston Consulting Group Matrix opposes the attractiveness respectively the growth of a certain market to the relative market share (Ill. 6.10), representing the organization dimension. [Schneider 2001, p.19f].

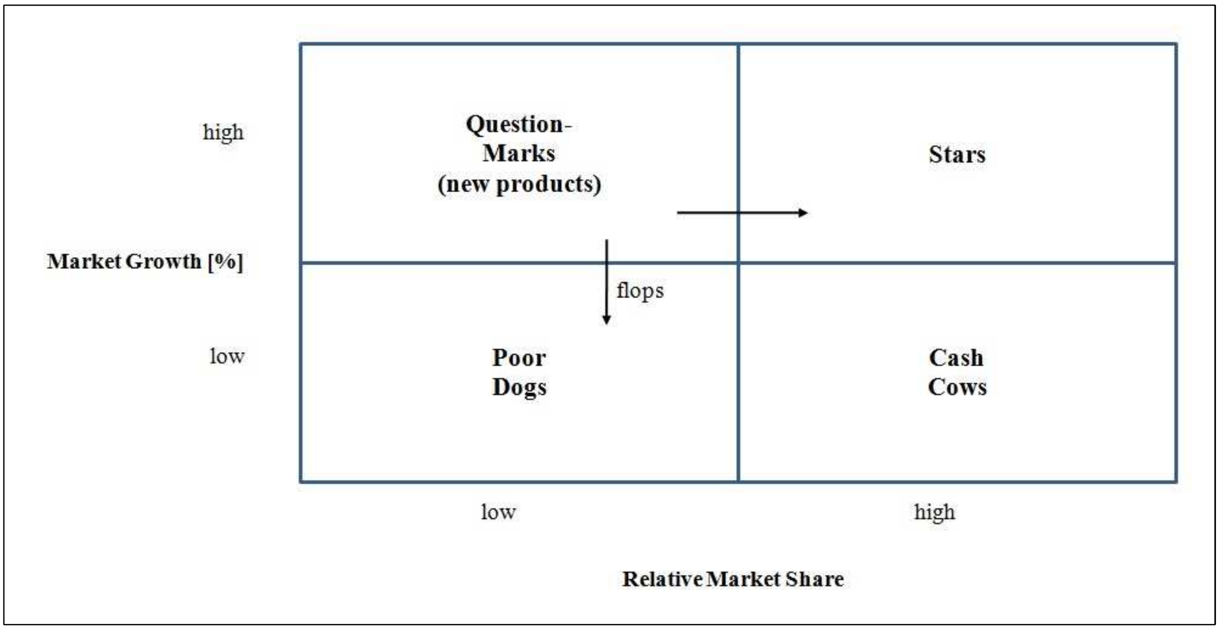

Illustration 6.10: BCG Matrix [Schneider 2001, p.20]

The classification to the respective fields should support investment decisions. This means investments for Stars, selections for Question marks, divestments for Dogs and a siphoning off tactic for Cash cows as strategic recommendations. [Schneider 2001, p.19f].

But it is not sufficient to evaluate the singular products according to the generic strategies, it is necessary to observe the entire portfolio in terms of revenue sharing. Important is that this technique provides also a possibility for the derivation of future trends even though not directly for technological decisions. [Schneider 2001, p.19f].

- ADL Portfolio

ADL is the abbreviation of Arthur D. Little, a global acting consulting organization that has introduced a portfolio management method based on product life cycle thinking. It makes use of dimensions of environmental assessment and also business strength estimations visualized like the BCG analysis in form of a matrix (Ill. 6.11). [Sewing 2009, p.86f].

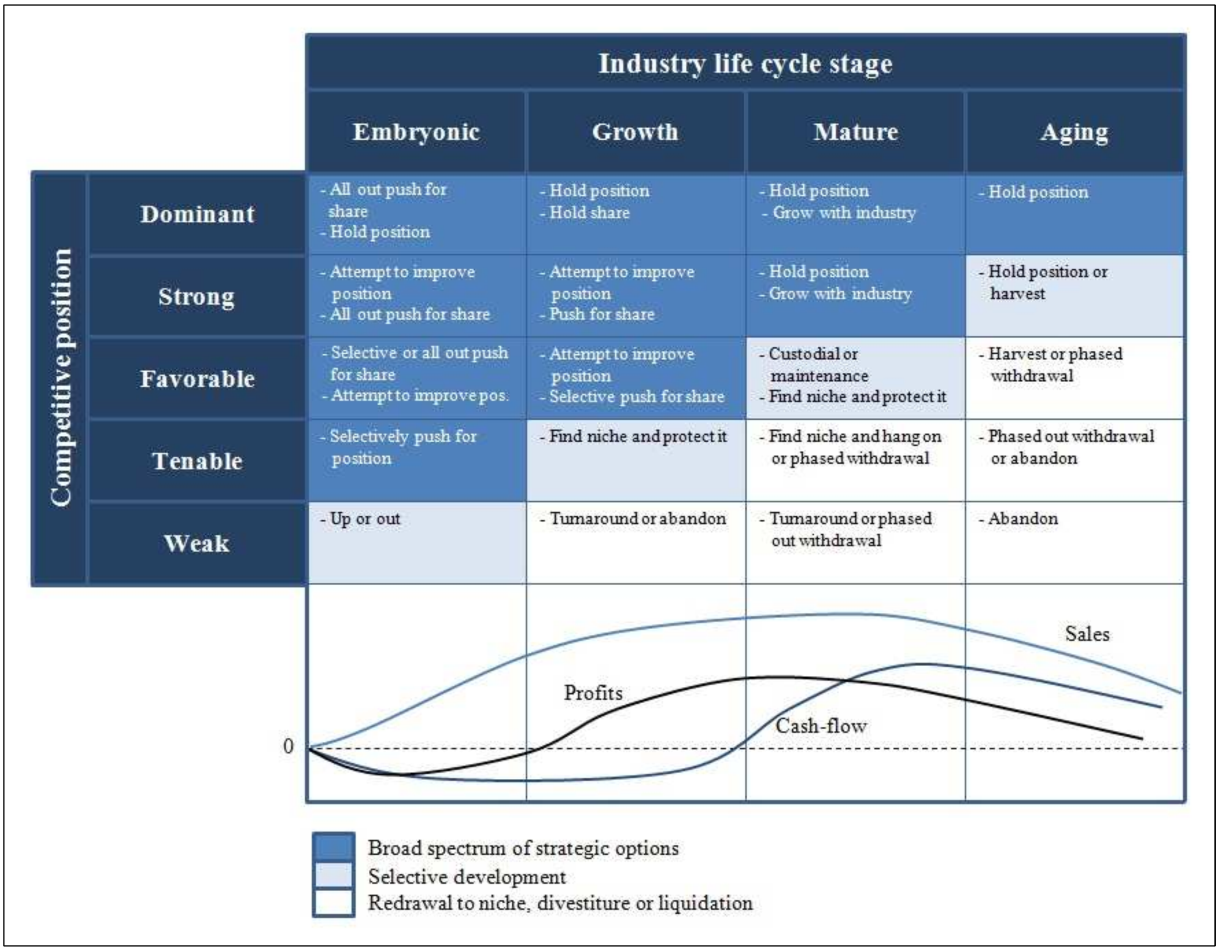

Illustration 6.11: ADL portfolio [Sewing 2009, p.86]

The general strategy how to act is identified by the appreciated position of the product in the matrix. The problem of this matrix is that there are some limitations. For example the period of the life cycle, which is dependent on many external factors, or that it deals categorically with a finished product. In this shape it is not possible to apply the ADL portfolio as support function for singular technological decisions. [Sewing 2009, p.86f].

As stated initially, the traditional portfolio analysis is business segment oriented and allows an assessment of trends based on expected changes. Nevertheless, it is possible to prepare technology portfolios analogical.

- Technology portfolio according to Pfeiffer

At this portfolio analysis corresponding to technology, the criteria attractiveness and strength of resources are contrasted. Accordant to Pfeiffer [1982, p.85ff] the attractiveness of a certain technology is defined by the following indicators:

  - Advancement potential
  - Application spectrum
  - Compatibility

And in return the strengths of resources are determined by Pfeiffer [1982, p.89ff]:

  - Technical-qualitative degree of control
  - Potentials
  - Reaction rate

The assessed technologies are again charted in a matrix (Ill. 6.12) for the derivation of generic strategies referring to investments in R&D respectively product sector.

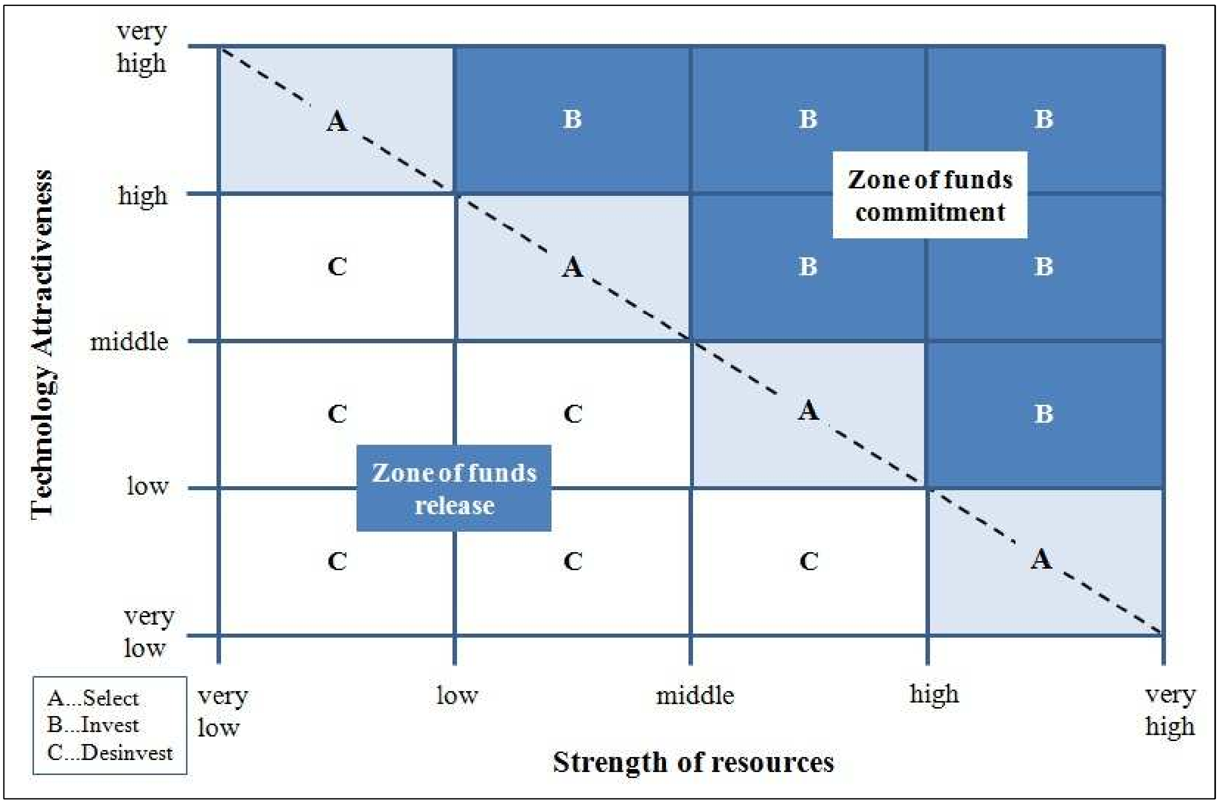

Illustration 6.12: Technology Portfolio in dependence on Pfeiffer [1982, p.99]

The technology portfolio analysis reflects the present technological situation. For a prospective examination it is necessary to transform the current status, what allows an assessment of potential chances and risks. [Bullinger 1994, p.161].

This planning technique targets directly the estimation of technological trends. It is not conducive to adopt it exclusively because some essential factors of success are not adequate considered. Such factors are, for example, the acceptance or the legal situation of a certain technology. Even though it is not an independent tool for strategic planning, this methodology indicates at least the relevance of technology and continuous innovation. [Hofmann 2006, p.38]. Moreover the concept provides an opportunity for additional conclusions regarding the optimization of R&D resources or the detection of imbalance in the internal transfer of technology.

Technology Roadmapping

Roadmapping in general is a method for the generation of prognoses and facilitates a systematic procedure as well as the possibility of an appropriate visualization of results. It is a creative tool for the analysis of anticipated development paths through a methodical gathering, bundling and adjustment of divergent opinions of expertise. [Specht, Behrens 2008, p.145ff].

A Roadmap in this context displays a two-dimensional area of research and within it the development steps of examined objectives (Ill. 6.13) like technologies, products or services, ideally across the limits of the respective organization. [Specht, Behrens 2008, p.145ff].

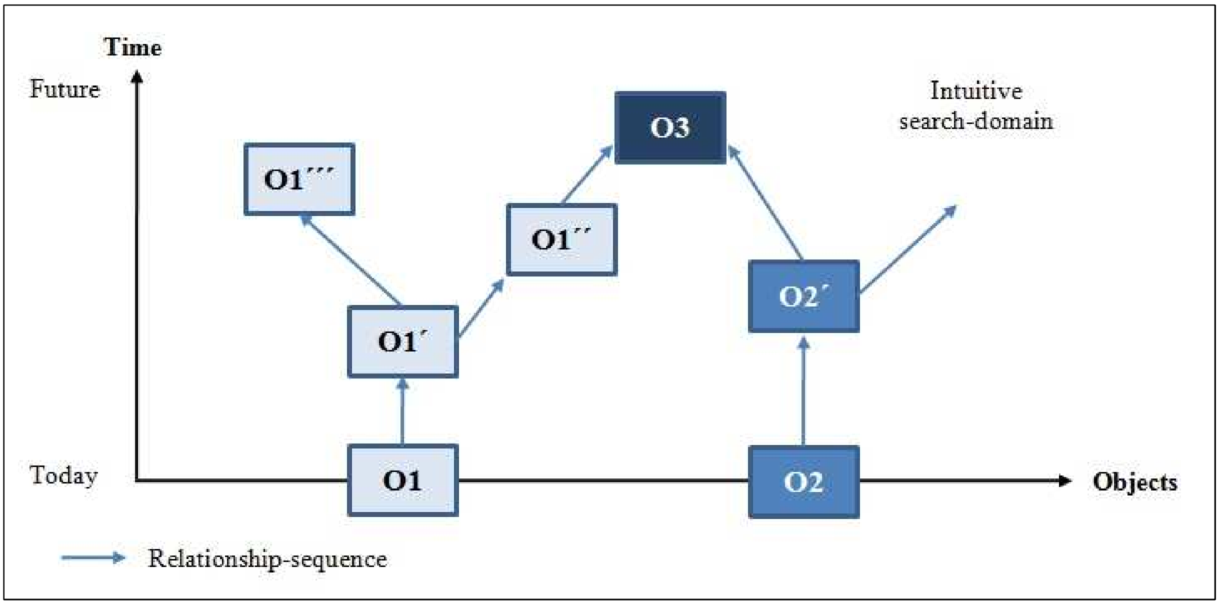

Illustration 6.13: Elements of a Roadmap [Specht, Behrens 2008, p.148]

Essential for the preparation of a Roadmap as forecasting tool is the handling of interactions between knowledge, technologies as well as products and applications, whereby technologies and products could be either potential or requirement (Ill. 6.14). [Specht, Behrens 2008, p.154ff].

As a result of those interdependencies, especially between technologies and products, it should be principally aspired to perform Technology- and Product Roadmapping as integrated process. [Specht, Behrens 2008, p.154ff].

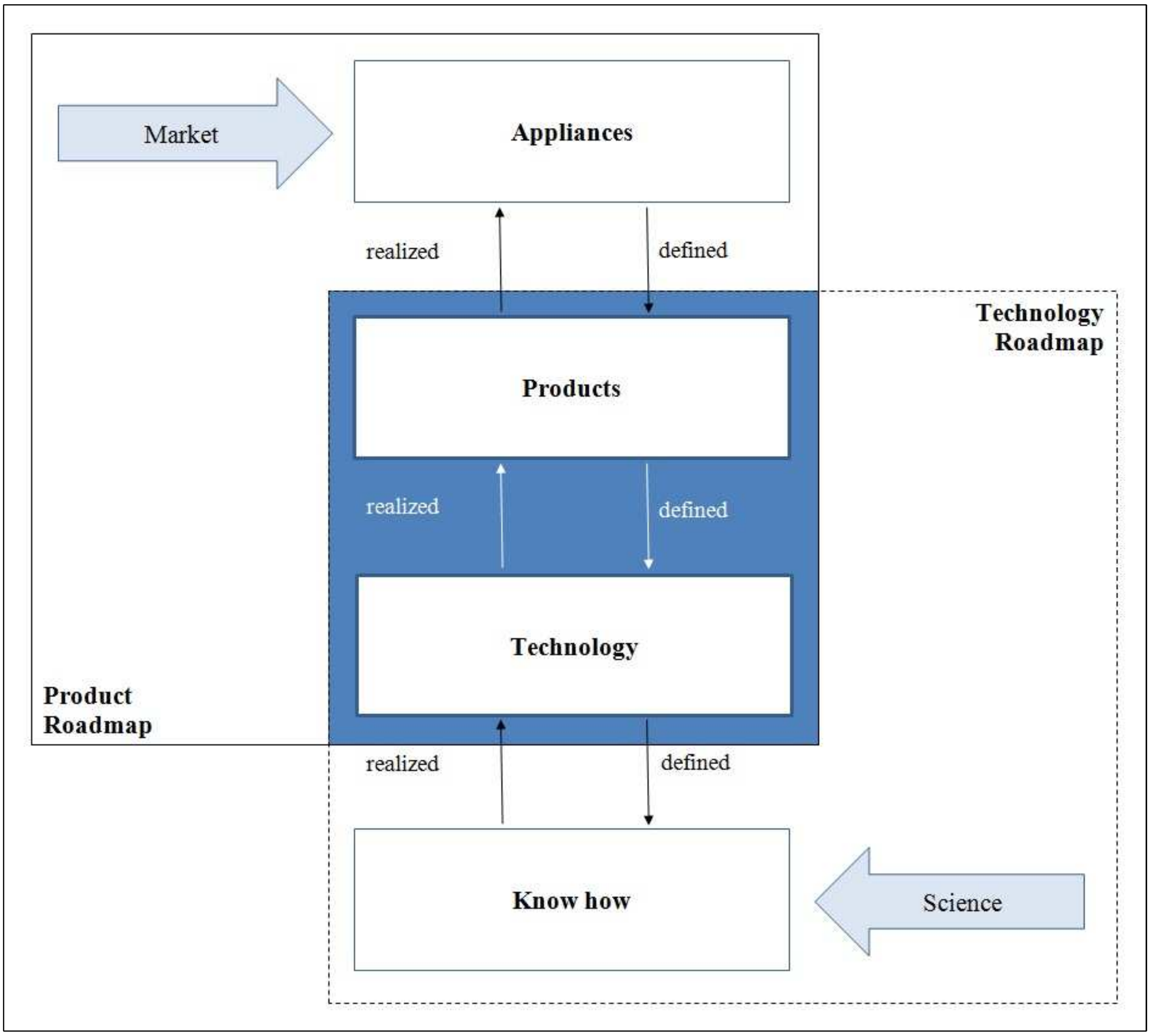

Illustration 6.14: Perspectives of Roadmaps [Specht, Behrens 2008, p.156]

In reference to the particular problem represent the defined objectives of the CC2018 the demand. The technologies, from product´s view the potentials, are the objects to rate. This means that the next step of the Product Roadmap has already been established what allows a focusing on technological issues.

Because of the active implementation of TRIZ as creativity tool at ACC, especially in the product development department, it is also obvious in this coherence to orientate on a TRIZ based methodology for Technology Roadmapping.

Especially the development models of technical systems corresponding to the TRIZ mindset provide a chance to support technological forecasting in an essential way.

Accordant to Möhrle [2008, p.197ff] the approach of a TRIZ based Technology Roadmapping consists of a five stepped process as the following figure demonstrates (Ill. 6.15).

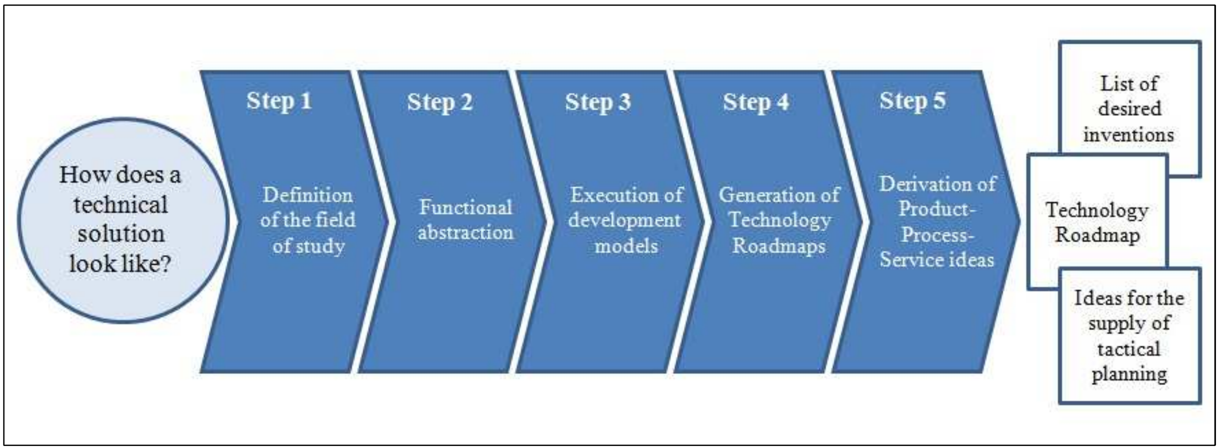

Illustration 6.15 TRIZ based Technology Roadmapping procedure [Möhrle 2008, p.198]

Referring to the definition of a specific field of study it is practical to differ and define on what to focus mainly. Concerning a singular technology this results in an assessment of chances and risks independent of the sector´s vendors. [Möhrle 2008, p.197ff].

Additional Product Roadmaps are required if conclusions on business activities of an organization or certain divisions are targeted. At all events a founded and apportioned situational analysis should determine the basis of successional actions. [Möhrle 2008, p.197ff].

The functional abstraction tends to the direction of morphologic thinking, a subdivision of the examined system in today´s and desired future characteristics. To attain marketable solutions, the functional abstraction should be made from a customer's point of view. [Möhrle 2008, p.197ff].

Step three of this process deals with the intrinsic fulfillment of the inventive problem solving through the execution of TRIZ methods. To allow free space for creativity it is not necessary to suggest, or even less to construct, which proceeding to apply. [Möhrle 2008, p.197ff].

Moreover, always when dealing with creativity tools, a preferably relaxed atmosphere, but also an analysis situation with the least possible restrictions should be aspired. Therefore it is elemental, that such tools enhance the capacity for teamwork. [Möhrle 2008, p.197ff].

To improve the structure of analysis, it is beneficial to assign created ideas to a rating framework (Ill. 6.16) to obtain a list of weighted inspirations as basis for the Roadmap generation. [Möhrle 2008, p.197ff].

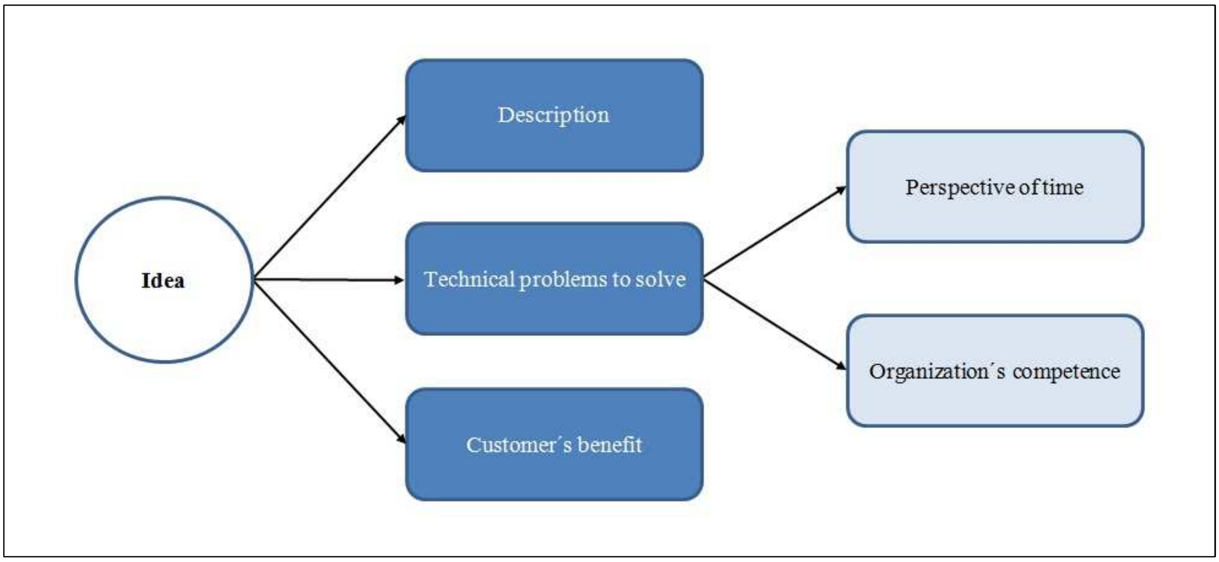

Illustration 6.16: Rating framework for TRIZ results [Möhrle 2008, p.202]

In addition it is possible that appearing technological problems require new inventions, whereby realistic time horizons and internal competencies have to be assessed. [Möhrle 2008, p.197ff].

With the information of the previous actions as input, the generation of Technology Roadmaps has to overcome the consolidation of the identified technological problems to technology clusters. Therefore it is necessary to define times of realization also dependent on economic aspects.

This means that technologies are not only scientifically described and principally available. They have to be applicable in the examined system.

Additional information could be provided by research institutes or other know-how carriers. Also the definition of interdependencies between the different technologies is required.

Based on this data it is possible to create technological Roadmaps eventually complemented with other technologies and to think about ideas of respective actions for the realization.

These ideas could for example be integrated in strategic R&D decisions or the marketing plan of an organization.

This versatile management kit, including in the standard repertoire, has established to alleviate strategic-, product-, innovation-, marketing-, and of course technology decisions. Nevertheless, the results are a prognosis and rapid change is part of daily business. Therefore, a continuous observation of developments and corrective actions at an early stage enhance the flexibility and the chance to be successful. The early detection of, especially in this case, technological trends offers furthermore the chance to force particular directions and tendencies to a certain degree.

Considering the potentials and also the limitations of technology intelligence as breakdown systematic it could, by serious accomplishment, contribute to the achievement or protection of performance- alternatively cost leadership, the strategic target of ACC.

6.2.4 Conditioning of technologies

Consecutively to the identification and forecasting of possible technological potentials or new technologies and the assessment of chances, risks and technology tendencies it is necessary to formulate a strategy. This includes where it could be conducive to invest resources or to build partnerships to ensure that the required knowledge of specific technologies is available.

6.2.4.1 Intention of conditioning of technologies

In this context the conditioning of technologies represents one of the central bricks for the orientation of technological activities with the intended target to clarify important questions for strategic technology decisions.

As a matter of principle technology strategies always tend to support the general strategic direction of an organization. In literature many different approaches and core concepts, how to handle technology management strategically might be detected but most of them are based on the same background, the trilogy of technological decisions according to Brodbeck [Abele 2006, p.36]. This trilogy consists of the following questions:

- Which way to go?
- Make or buy?
- Keep or sell?

Referring to the concrete problem this means technology conditioning has to provide channels, predicated by forecasting methodologies of how the desired information about specific technologies could or should be acquired.

Although when at this point a divestiture of technological capabilities is not at all in plan at ACC, the ways of utilization of technologies have to be broached for the sake of completeness.

It is common for ACC Austria to place emphasis on collaboration with external institutions in the execution of development projects (Table 5.1). This condition is also aspired to be retained in future in order to enhance and maintain networks and to manifest the organization across the limits of business sector.

But also in this case a generic and progressive comprehensible structure is aspired to force certain continuity and to facilitate a mutual win-win situation.

6.2.4.2 Which way to go?

This decision in general covers the process of selecting specific technologies for the application in a corporation to fulfil dedicated product- or process requirements or also for the configuration of technology potentials in the future. The importance of the “which way to go” approach results in the increasing demand of expenditures for more and more multidisciplinary technologies but also because of the opportunity to differentiate from competitors through technological advance. Brodbeck [1999, p.84ff] distinguishes between four target dimensions to deal with for the description of the characteristics, their extent and chronological order of the targeted object.

- Technological fields of activities

  Necessitates statements of the significance of technologies and in which areas internal competencies should be available.

- Competitive relevancy of technologies

  The generation of competencies has to orientate on the internal strengths and weaknesses and the external chances and risks of a specific technology. Furthermore, the aimed potential for differentiation has to be distinguished.

- Proficiency level of technologies

  Regarding strategic issues, the proficiency level differentiates between the orientation technology leadership and technological presence. Thereby it is imperative to scrutinize, what effort is necessary to achieve distinctive technological application know-how and differ so in terms of quality and costs compared to competitors.

- Timing

  In this context timing refers to invention timing, the availability of a marketable application of an accordant technology, and innovation timing, related to market launch.

The adaptation of those objective groups uses and requires a global breakdown of technologies and its assessment of appropriate developments and trends as basis to consult for the derivation of dimensions. [Brodbeck 1999, p.84ff].

6.2.4.3 Make or buy?

The “make or buy” technology decision is today often extended to make, collaborate or buy and faces the process of acquisition of technological knowledge including sourcing of alternatives, evaluation and recommendation. [Abele 2006, p.37].

An external procurement of technologies becomes continuously more inevitable because of the increasing focusing on core competencies, elongated development times, rising of R&D fix expenses and eventually shortened market cycles, whereby this is especially in the refrigeration and therefore cooling compressor industry accelerated by an increasing ecological- and energy awareness. In doing so, two different goals can be distinguished [Brodbeck 1999, p.99]:

- Strategic goals, for an effectiveness oriented selection of technologies.
- Economical goals, for an efficiency oriented selection of technologies.

The content of economical targets is made up by performance-, time-, and objective concerning costs. But the estimated prospective significance of a specific technology and its contribution to the achieving of a competitive advantage has to be considered as well. [Brodbeck 1999, p.99].

In addition, referring to Tidd [2005, p.374ff], the rapid pace of technological change means that companies are increasingly being forced to look at combinations of internal production and external acquisition.

It is essential that it is not necessary to have all technological competences or resources in-house. In most cases it is not possible or at least it would demand so much effort and resources that it is beyond question. But it is necessary for a company to know external sources from which it is possible to obtain technological knowledge as well as how and when to obtain it. [Tidd, Bessant, Pavitt 2005, p.374ff].

The present economical condition directs to a new market situation where knowledge and technological competences are traded as common goods. Thereby, not only new sectors of economy are created, also organizations concentrated on a specific field are enabled to avail themselves of an opportunity to apply their explicit know how gainful. [Tidd, Bessant, Pavitt 2005, p.374ff].

The selection which technologies or competences to outsource, respectively to create through collaborations, and which to retain in-house determines a difficult and selective strategic decision, with eventually far reaching consequences for a long duration. [Tidd, Bessant, Pavitt 2005, p.374ff].

A method to support this decision process is the classification of technological knowledge based on Arthur D. Little into four groups (Ill. 6.17) according to their availability and potential to achieve unique selling propositions and competitive advantage. [Tidd, Bessant, Pavitt 2005, p.374ff].

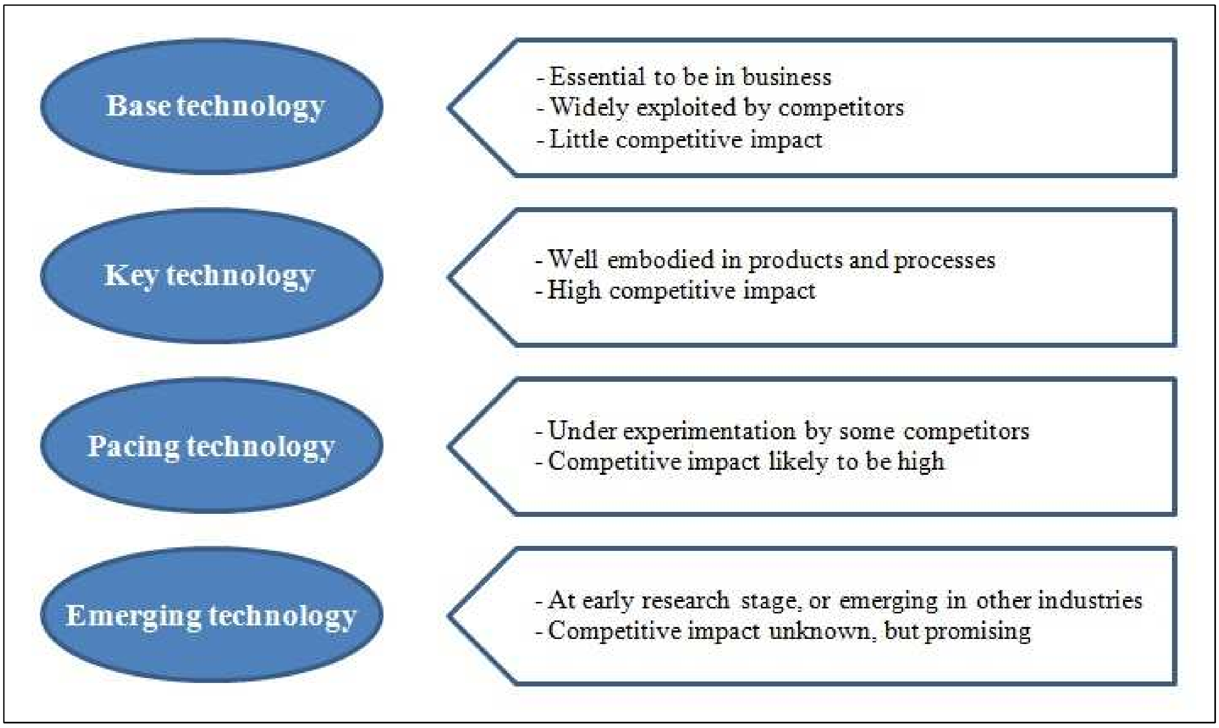

Illustration 6.17: 4 types of technologies [Tidd, Bessant, Pavitt 2005, p.375]

Base technologies are widely spread therefore it may make sense to outsource them to competence centres. Contrary key technologies implicate a high competitive effect, as result should an in-house focusing or carefully selected strategic alliances be preferred in order to preserve the potential competitive advantage. For the handling of emerging technologies, it is obvious for an organization to strive for collaboration with research institutions, such as universities or specialized competence carrying companies and to persecute an observing and deliberated strategy. [Tidd, Bessant, Pavitt 2005, p.374ff].

This categorization of technologies can also be linked to the technology life cycle model (Ill. 5.9) in dependence of the life cycle stage respectively the point on the S-curve (Ill. 5.11). Such a cross-linking and a consideration from a different perception can also support the definition process of specific technology life cycles or demonstrate necessary adaptations.

Beyond doubt it is not possible to take such strategic decisions without any kind of risk and all methods and tools reproduce the reality just as models and are not free of errors respectively are not absolutely complete. Nevertheless, the approaches facilitate the decision process and anticipated actions through most likely occurring expectations. [Tidd, Bessant, Pavitt 2005, p.374ff].

The following figure demonstrates that a variety of internal and external sources for the acquisition of technological knowledge exist (Ill. 6.18).

Mechanism	Strengths	Weaknesses
Mobilicing tacit knowledge	- Internal, highly specific knowledge - Hard to copy	- Hard to mobilize - Needs processes to articulate and capture
In-house R&D	- Strategically directed - Under full control - Knowledge remains inside the firm - Learning by doing	- High cost and commitment - Risks - no guarantee of success
In-house R&D and network links outside	- As above but with less control over knowledge unless there is a clear contract on intellectual property rights	- Costs and risks
Reverse engineering	- Lower costs - Offers insight into competitor´s processes and products - Knowledge can be inferred, but needs a level of skill to do so	- Depends on ability to infer knowledge - Knowledge may be protected anyway, e.g. in patent or copyright
Covert acquisition (industrial espionage!) plus internal R&D	- Fast access to knowledge and relevance of that knowledge can be managed through internal capability	- Illegal - Costs of internal R&D
Covert acquisition	- Fast access to knowledge	Illegal - Risk of not being able to translate external knowledge to internal needs
Technology transfer and absorption	- Easier access to knowledge - someone else has developed and packaged it	- Costs - Risks of not understand or being able to make full use of technology

Illustration 6.18: Different mechanism for acquisition of technology [Tidd, Bessant, Pavitt 2005, p.376]

The most common ways of sourcing knowledge around the subject technology is in-house R&D combined with an external network, a methodology many companies operate successful with. [Tidd, Bessant, Pavitt 2005, p.374ff].

Mobilizing tacit knowledge focuses on creativity tools. [Tidd, Bessant, Pavitt 2005, p.374ff]. By the application of specific techniques, as for example TRIZ (Chap. 3.3.3), the intrinsic and subconscious knowledge is activated and enhances an outbreak of one´s learned and experienced mindset.

Another quite effective and not too expansive technology acquisition possibility is reverse engineering, but with the disadvantage of being always the follower. An important factor when dealing with the acquisition of technological knowledge is the organizations ability for the acceptance and effective usage of the information. Therefore it is necessary that real knowledge is transferred and not simply hard facts or licenses, what is even valid within a company. [Tidd, Bessant, Pavitt 2005, p.374ff].

But it is not only enough that an organization has the ability to absorb technological knowledge. In order to be economical successful a distinct consumer insight is required what necessitates also a market-related absorptive capacity (Ill. 6.19).

Whereby absorptive capacity represents a firm´s ability to recognize the value of new information, assimilate it and apply it to commercial ends. [Cohen, Levinthal 1990, p.128ff].

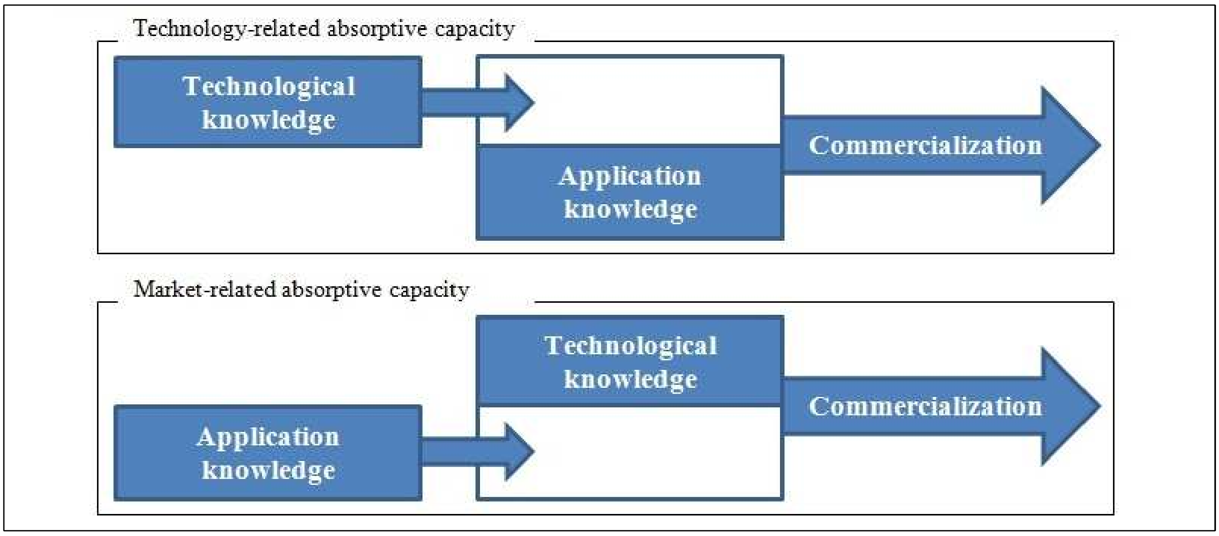

Illustration 6.19: Two types of absorptive capacity [Herzog 2007, p.43]

Bröring [2005, p.270] states that technology-related absorptive capacity is strongly related with R&D and external technology sourcing.

Market-related absorptive capacity on the other hand builds on existing market knowledge. It is needed to understand and assess certain market trends and to benefit from them. [Bröring 2005, p.270]. Subsequent to the acquisition it is imperative to devote these resources.

6.2.4.4 Keep or sell?

If an organization has compiled or purchased the competence to handle a specific technology it is necessary to exploit this technological knowledge in a dedicated manner. [Brodbeck 1999, p.110]. Possible types for the utilization are:

- Self-exploiting
- Cooperation
- Commercialization

Basically, the external commercialization of technologies represents for many companies no strategic subject to persist in competition, especially if a lot of in-house effort and experience has been required to develop the knowledge. Most organizations focus on the own employment and the commercialization of technologies by offering a balanced product portfolio. [Brodbeck 1999, p.110].

In order to acquire technologies from external sources, some other has to offer that technology. Referring to Herzog [2007, p.40] technology transfer beyond company´s boundaries is a deliberate action and its commercialization does not account for involuntary loss or leakage of technological knowledge. Furthermore an organization must have the opportunity to exclusively use and apply a technology internally because if there is no possibility to exclude others from using a technology there is also no chance for external technology commercialization.

6.2.4.5 Collaborations and coalitions in technology development projects

According to Chesbrough [2003, p.xx ff] happens (or has happened) a shift in how companies commercialize industrial knowledge. He describes this situation as change from a closed to an open paradigm for managing industrial R&D.

The closed paradigm demonstrates an internally focused logic where companies generate, develop, build, market, distribute, service, finance and support their own ideas. Those ideas are screened and filtered during the research process, and the surviving ones are transferred into development and then taken to market (Ill. 6.20).

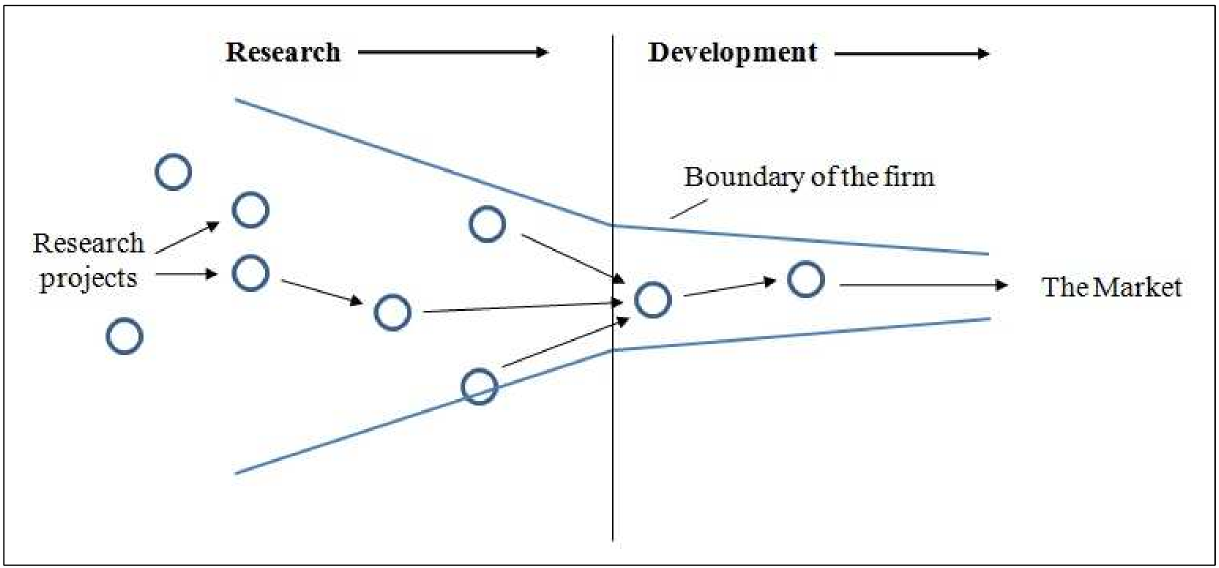

Illustration 6.20: The closed paradigm for managing industrial R&D [Chesbrough 2003, p.xxii]

The resulting discoveries, out of internal R&D investments, enable companies to bring new products and services to market, to realize more sales and then to reinvest. And because the so created internal property is closely guarded, others cannot exploit it for their own profit. [Chesbrough 2003, p.xx ff].

But this logic was challenged by the growing mobility of highly experienced and skilled people, the growing presence of private venture capital and the increasingly fast time to market for many products and services, which shortens the shelf life of a particular technology. Chesbrough [2003, p.xx ff] argues, that in situations where those erosion factors have taken root a new approach, called “open paradigm for managing R&D”, is emerging. This paradigm assumes that firms can and should use external as well as internal ideas to advance their technologies (Ill. 6.21).

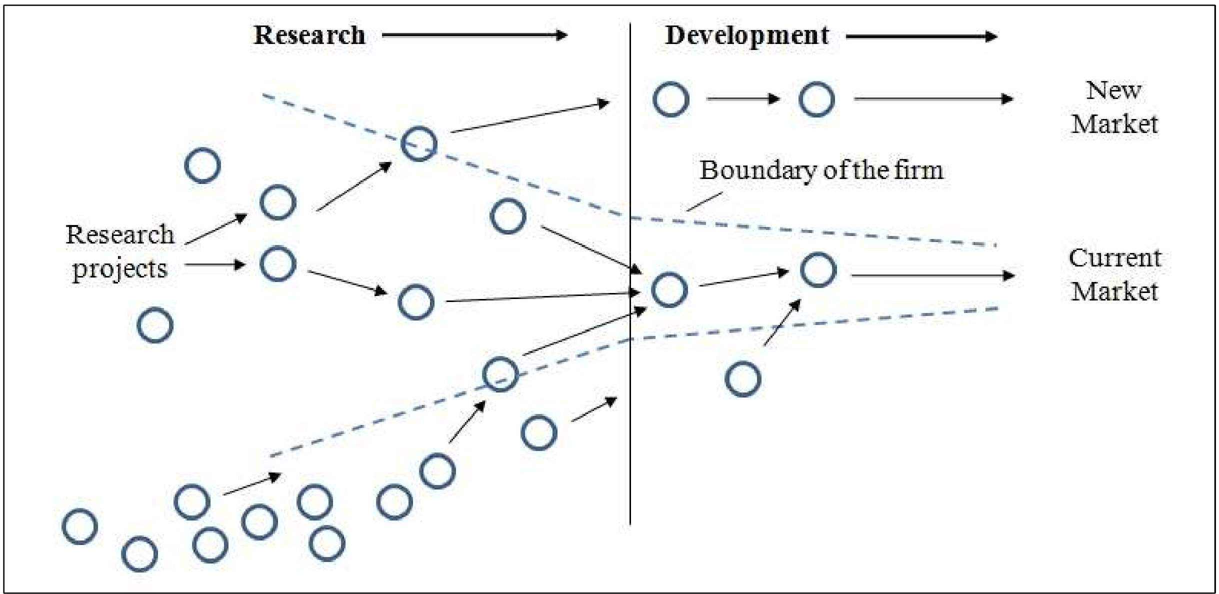

Illustration 6.21: The open paradigm for managing industrial R&D [Chesbrough 2003, p.xxv]

As demonstrated in Ill. 6.21, there are many potential ideas outside the firm. The difference between the closed and the open paradigm are the more porous boundary of the company (illustrated by dotted lines in Ill. 6.21) at the open logic. [Chesbrough 2003, p.xx ff].

This boundary has now to be understood as interface between what is done inside the firm and what is accessed from outside the firm, instead of an insurmountable barrier. [Chesbrough 2003, p.xx ff].

In technological oriented organizations, collaborations are nowadays respected as supporting instrument for the fulfilment of company´s objectives and to achieve a competitive advantage. But not all partnerships are based on the same preconditions and business levels.

Abele [2006, p.48ff] termed a variety of cooperative collaboration possibilities:

- Belonging to certain industry levels

  In general three different types of cooperations are distinguished. Vertical cooperation is the term for succeeding production or trading levels of collaborating organizations. Cooperation at the same level are described as horizontal or complementary if the organizations are not in a direct competing situation. Collaborations between corporations with different fields of business activity determine lateral partnerships.

- Form of integration

  This criterion for the characterization of collaborations is based on the bisection of human acting in centralization and exchange. The partners have a reciprocal cooperation if they adopt duties and responsibilities alternating. An example would be an arrangement of the production program at which each partner can distribute the whole portfolio. At a joint cooperation, activities are taken on together and the results are allocated during, or at the end, of the collaboration project.

Moreover collaborations could be interpreted as project similar intentions and therefore their organization and structures are represented by phase- or life cycle models, as for example developed by Staudt [1992, p.3] (Ill. 6.22).

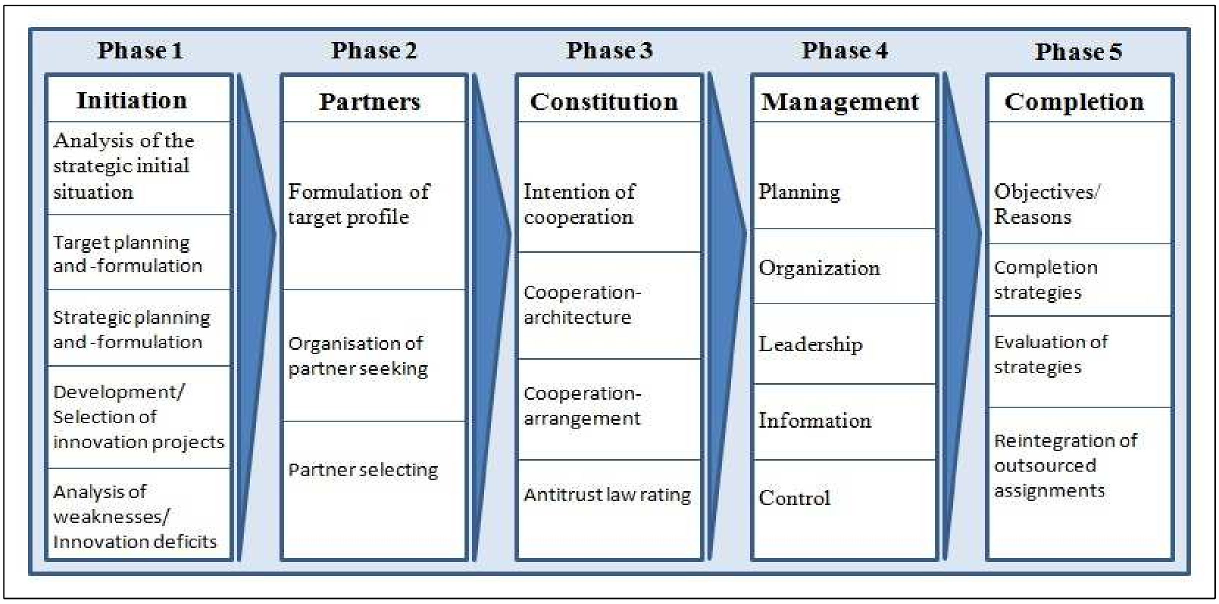

Illustration 6.22: Concept of cooperation organization according to Staudt [1992, p.3]

Referring to the precedent figure, the first phase of the approach determines the intrinsic pre-stage of the model because of the identification and evaluation of value creation projects for what the cooperation demonstrates a solution alternative. [Fuchs 1999, p.110].

The seeking of partners includes an evaluation and an assessment. The discovery of a potential partner and reaching an agreement often symbolizes a core problem of the development of alliances as well as not well defined communication structures. [Staudt 1992, p.90ff].

The organization of the cooperation is defined in the constitution phase. Staudt [1992, p.115ff] subdivides this phase in the steps: Intention of cooperation, Cooperation-architecture and Cooperation-arrangement to allocate detailed aspects.

Stage four, the management phase, is the operating segment of the process and represents the point, where value is or should be added. A particular important part of this phase is the controlling as evidence for continuous improvement of processes and performance and for a new starting or cancelling of the cooperation in the completion phase. [Fuchs 1999, p.181].

Important in the arrangement of collaborations is that after the selection of a potent partner, a permanent and corporate examination of targets as well as orientation and accomplishment of the cooperation process follows. Especially referring to technological issues, the capability to manage such networks can itself be understood as source of competitive advantage. If a firm has the ability to build up a successful network of external resources complementary to its own, this may be just as effective as having all the resources in-house [Tidd, Bessant, Pavitt 2005, p.374ff].

Cooperations in consideration of established and structured proceedings offer a basis for long ranged proceedings and protect the partners from a one-sided exploitation. Because of an increasing diversity in almost all market areas, funded and honest business relationships might be a key to success and therefore a strong network should be aspired in every sphere of activities, especially in the technological one.

A specific characteristic corresponding to the cooling compressor industry is the status of being a supplying industry of cooling device manufacturers. The offered product is a sub element of an overlying technical system. The compressor is “only” one component of the cooling circuit beside evaporator, condenser and restrictor.

To enable the best adjustment possible, efficiency and performance of the final product collaborations, at least on technical side, are indispensable and part of the business. An effective shaping and organization of information and technology transfer to and from a company can thereby facilitate the cooperation process and the reciprocal understanding.

In further processing it is for all intents and purposes envisaged that conditioning of technology does not deal only with strategic decisions in terms of technology.

As a result, this stage determines the intrinsic execution stage of a technology development project. It is important to continuously go into more detail and at the same time to focus more and more on the practical relevance of the problem.

6.2.5 Evaluation and recommendation

After completion of the Breakdown and the following conditioning of technologies, a comparison of the detected technological potentials appoints the next step in the technology development project execution-approach (Ill. 6.3). For the implementation of an evaluation and to derivate recommendations, three requirements have to be fulfilled principally [Haberfellner et al. 2002, p.190]:

- Distinguishable solution alternatives have to be known.
- Criteria are necessary to classify those options.
- The capability to classify according to the criteria is required.

Alternatives of potential technologies are provided by the technology identification process and the following editing respectively conditioning. The criteria defined for the evaluation of technology fields (Chap. 5.2.1) can be used as assessment parameters without further adaption.

The information generated through forecasting and acquisition possibilities represents the necessary input. These activities are the basis for features, operating conditions and anticipated effects of technologies, but also for an ability to judge.

To recommend potential technologies, the analysis of strength, weaknesses, opportunities and threats, the so called SWOT analysis, offers a suitable methodology.

The basic SWOT analysis focuses on the examination of strengths and weaknesses as internal factors and an external analysis of the environment via opportunities and threats. [Hörlesberger, El-Nawawi, Khalil 2007, p.76].

Principally this tool is applied as situational analysis for the planning of a strategic concept in an organization.

Nevertheless, through an accordant adaption of considered features and a highlighting of technologies, the method can be expanded to support the technological orientation. Therefore it is necessary to refer the internal and external determinants to the particular technologies to compare and link them with the attributes of the technology itself (Ill. 6.23).

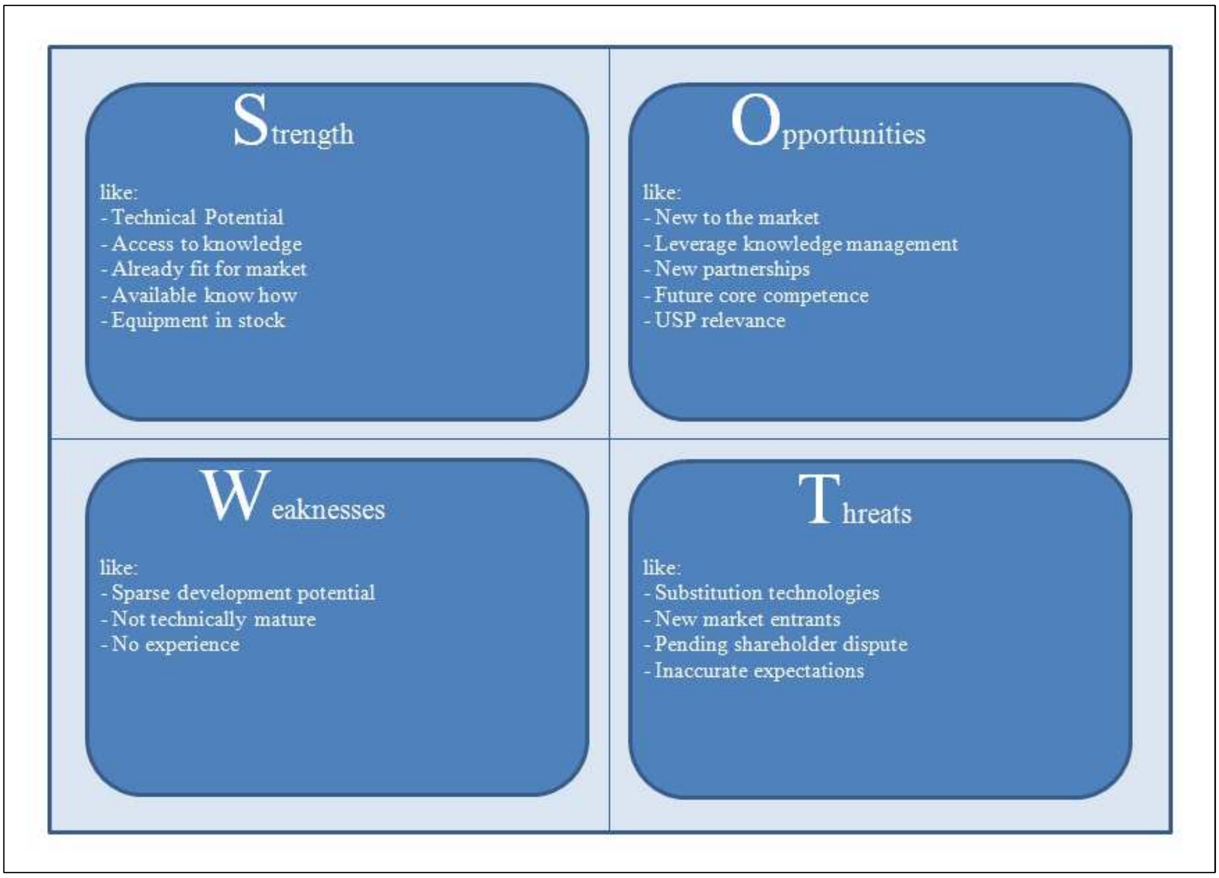

Illustration 6.23: Technology focused SWOT analysis for CC2018 project requirements

Because of the global economic area, it is not useful to classify the relevant surrounding of a comparison field according to regions or national borders, in particular referring to knowledge or handling of technologies.

Environmental factors or trends in contrast might be categorized to economical, ecological, political and social factors. A technology is of course influenced by other technological developments which the organization cannot influence.

This specific SWOT analysis, exercised on each identified possible solution variant of an overlying technology field, allows a confrontation of these technological alternatives for the overcoming of allocated contradictions. Based on this comparison, decisions over the elimination or respectively the continuation of processing with an intrinsic technology should be taken.

Important at the generation of such a “ranking” is that not only technological potentials are considered. In the case of ACC and their future project CC2018, this would add up exemplarily to factors such as:

- Series manufacturing and low cycle times.
- A conservative market which requires a well-balanced innovation strategy.
- Ten years product warranty demands technologies with long term stability.
- No maintenance because of a hermetic system.
- Restrictiveness of materials as result of contact with lubricant, if required.

Because of the focusing on singular technologies, and at this point not on the already combined technologies of the entire system, it is absolutely possible to return again, at a later date respectively phase, to downgraded technologies. Therefore, amongst other reasons, it is necessary to structure the procedure of technology development projects as cyclical and recurring process (Ill. 6.3).

The result of this comparative evaluation should be the basis for a recommendation of a certain technology out of a group of technological alternatives.

An explanatory statement and documentation of the reasons why one technology is preferred and of the underlying circumstances, wherefore it should be aspired to force exactly this expertise are essential for the sustainability and the further proceeding.

6.2.6 Balancing of technologies

The balancing of recommended technologies determines the arbitrative step to complete the technology development project process sequence. Even though the so far singular contemplated technologies that have gone through the process steps identification, objective formulation, analysis and conditioning have emerged as first class and have to be examined referring to their ability of mutual compatibility.

Therefore it is necessary to analyze possibly occurring different impacts on the entire system and as well on other technologies. Important at the execution of this explicit technological balancing is the handling of the following points:

- Identification of interdependencies.
- Assessment of interactions on functional level but also in terms of efficiency.
- Derivation of general restrictions and requirements of certain technologies for the design, if existing.
- To guarantee a two-sided flow of information, an estimation of the degree of requirement fulfilment of the entire system of technologies is necessary.

This mentioned backflow of information could be realized by a continuously performed concretizing respectively completing of a so called requirement matrix.

For the present case, the defined subsystems (Ill. 3.7) are opposed to the determinants materials, assembly, functions and components (Ill. 6.24).

	CC2018									
	Appliance control unit	Control unit	Cooling circuit	Discharge line	Head group	Mechanical integration	Piston & crankcase	Power unit	Shell	Suction line
Materials										
Assembly										
Functions										
Components										

Illustration 6.24: Technological requirement matrix

Several boxes could already be filled in because of the identified contradictions and boundary conditions of the product development project CC2018.

An accomplished matrix should represent an aligned and entire basis for the technical realization.

These requirements result on the one hand from the noted previous definitions and influencing parameters as for example:

- Strategic orientation
- Experience
- Market requirements
- Competences

On the other hand, the aspired utilization of specific technologies leads to an arising of requests. As mentioned, in the end an ideally complemented matrix reflects the compressor in its properties and underlying technologies.

This finally determines the foundation of advanced product development, the second phase of ACC´s long term product planning process (Ill. 3.2).

In other words the finished balancing of the respective phases should offer a summary of technology alternatives including technological overall concepts as well as a knowledge documentation that allows a drawing of conclusions for further detailing and proceeding.

The procedure of technical alignment and handling of interdependencies should be bound to fixed points in time, independent of the respective stage of the technology development projects. The following image demonstrates in a qualitative way how to enable timely graded projects and consider different durations (Ill. 6.25).

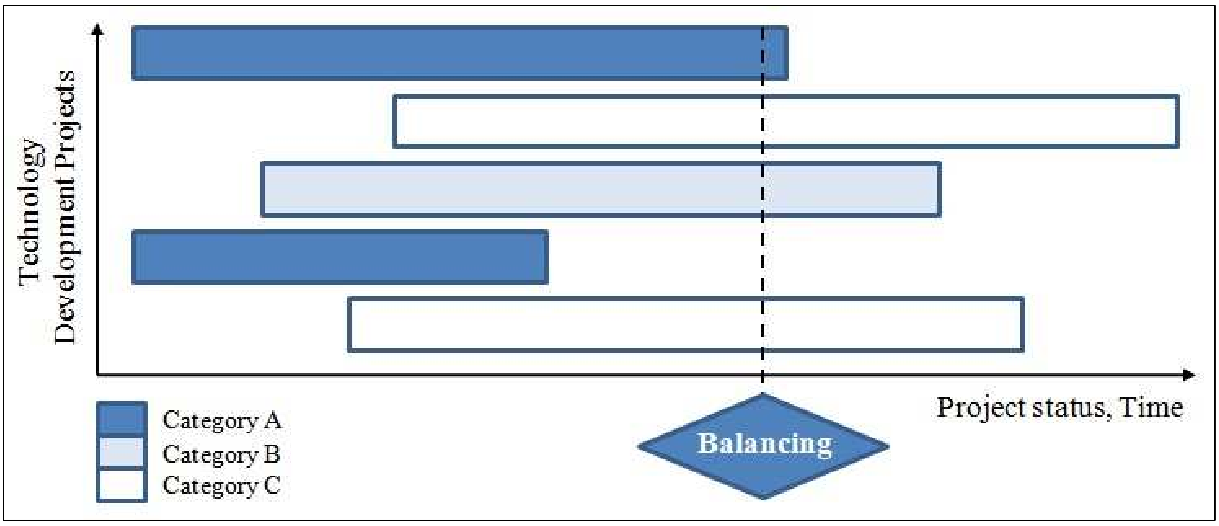

Illustration 6.25: Perspective of time in terms of the Balancing process

The managing of interdependencies and their complexity in technical systems is on the way to a more and more important subject and encourages the approach to never lose sight on the essential respectively the overall system.

6.3 Technology development projects – Process outline

For reasons of practicability, this part should represent a short but concisely and holistic overview of the previous chapters.

This chapter should summarize the structure for the handling respectively execution of CC2018 technology development projects with methods and tools as well as important aspects.

Out of the fact that not only the constitutive but also the operational part of technology development at ACC Austria is based on Systems Engineering, its basic ideas [Haberfellner et al. 2002, p.29] act and have to be understood as fundamental components with validity at any time or stage of the technology development process and beyond. Those fundamentals are again:

- From the general to the particular ("Top down")
- Thinking in variants
- Divide the process into project phases
- The problem solving cycle as working- and thinking logic

As logical consequence of handling knowledge acquisition projects, the basic conditions surrounding the practical accomplishment have been defined.

This resulted in a sub categorization of technology development projects in the phases (Ill. 6.2):

1. Technology discovery (preliminary study)
2. Technology treatment (main study)
3. Technology specialization (detailed study)

In every project phase (Ill. 6.2) the process steps of the specific adopted problem solving cycle (Ill. 6.3) should be run through to assure an explicit and comprehensible proceeding structure.

Each element of this cyclical sequence features self-contained objectives even though the crossovers are fluent and liable to respective dependencies.

The upcoming synoptical table (Table 6.2) demonstrates the sub steps of the methodology of system design with pursued intentions and applicable tools and techniques as part of the problem solving process (Ill. 2.1) on the way to the CC2018.

Process step	Overall objective	Main criteria	Possible tools & methods
1. Identification	- Recognition of technological potentials	- Search without prejudices and precasted solution approaches - Not every examined area has to be applied in concept develop-ments or the final product - Targeted is technical knowledge, not solutions	- Internet - Classic literature study - Networks - Benchmarking - Creativity tools
2. Intention	- Scope/potential of technologies	- Unambiguous and clear interpre-tation - Integrated acceptance on different levels	- Attributes of an operational target formulation [Haberfellner et al. 2002, p.138]
3. Breakdown	- Product-strategic conclusions	- Technological forecasting (Selection, long term application and continuous documentation of respective methods) - Well funded and comprehensible assumptions - Assessment of technology development and emerging technologies	- Patent analysis - Benchmarking studies - Interviews with experts - Portfolio analysis - Technology Roadmapping
4. Conditioning	- Clarification of strategic technology decisions	- Acquisition of specific techno-logical knowledge - Handling of collaborations or possible coalitions - Step by step increasing of the product focus and so facing the application of technologies	- Different mechanism for acquisition of technology (Ill. 6.18)
5. Evaluation	- Recommendation of technologies	- Variety of alternatives - Field evaluation criteria	- SWOT analysis - Criteria catalogue
6. Balancing	- Reflection of the complete technological system	- Identification of interdependencies and their effect - Balancing at fixed points in time, independent of the status of Technology Development Projects	- Technological requirement matrix

Table 6.2: Compendium of technology development projects underlying process steps

A detailed description respectively exemplification of the specific content can be found in the previous part (Chap. 6.2).

It is not always possible to distinguish the borderline of each unique element or even project phase exactly from the adjoining one but it is indispensable to define or set definitive and stringent milestones with clear expectations and objectives to assure a continuous advancement.

The entity of the previous noted process steps represents the sequence of the adopted problem solving cycle, extended with the functions of the decision-making body (Ill. 6.26).

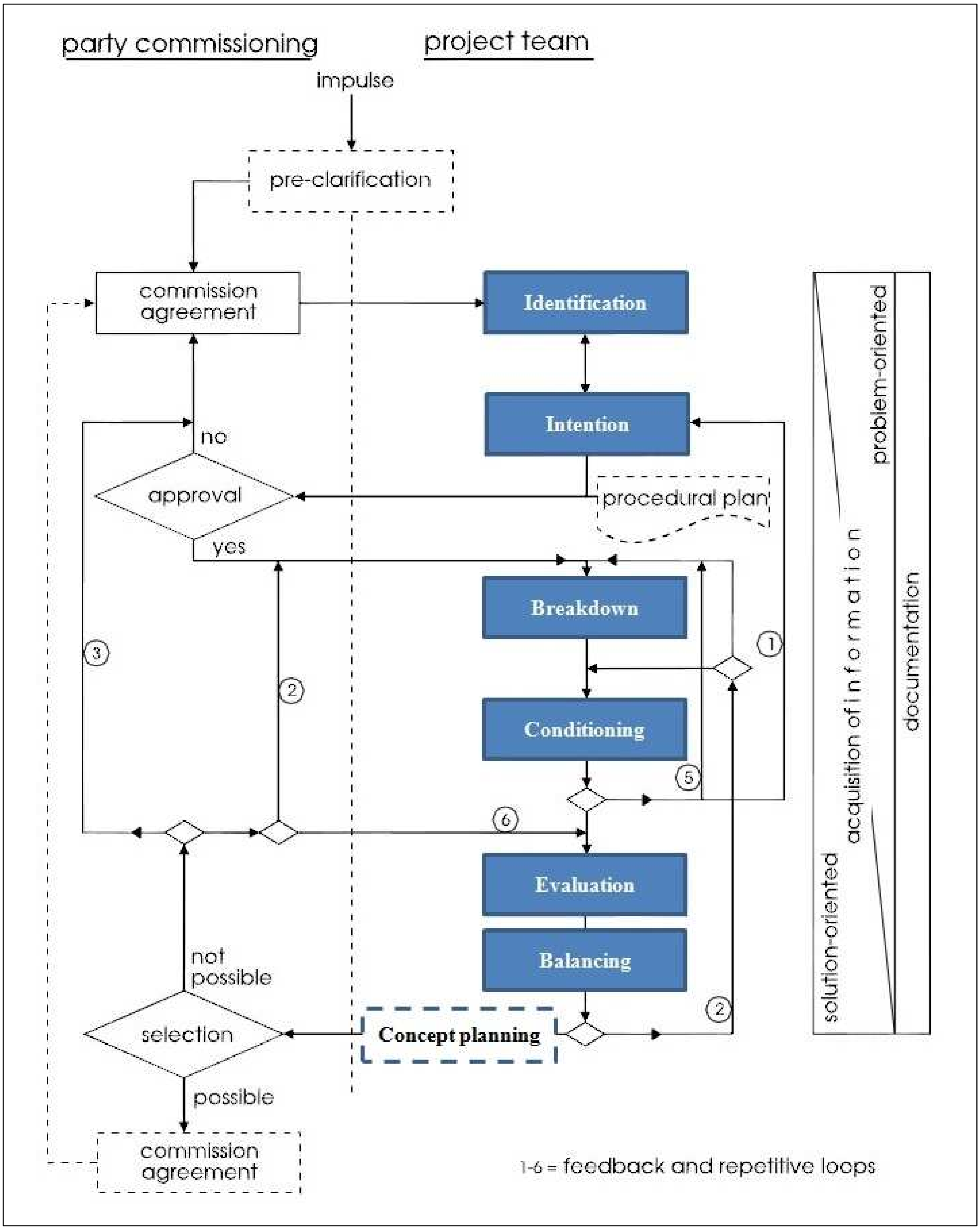

Illustration 6.26: Extended and adopted PSC [in dependence on Haberfellner et al. 2002, p.100]

But beside all those constructing aspects, the organization or management of a project itself determines an essential part of its success.

For the execution of technology development projects, ACC envisages matrix organizations with dual subordination of their staff.

In daily business matters, project members have their line superior. In project affairs, the project manager has the agreed right of authority. [Haberfellner et al. 2002, p.259].

The upcoming figure demonstrates the extension of the common line organization of the product development department with technology development projects to a matrix organization (Ill. 6.27).

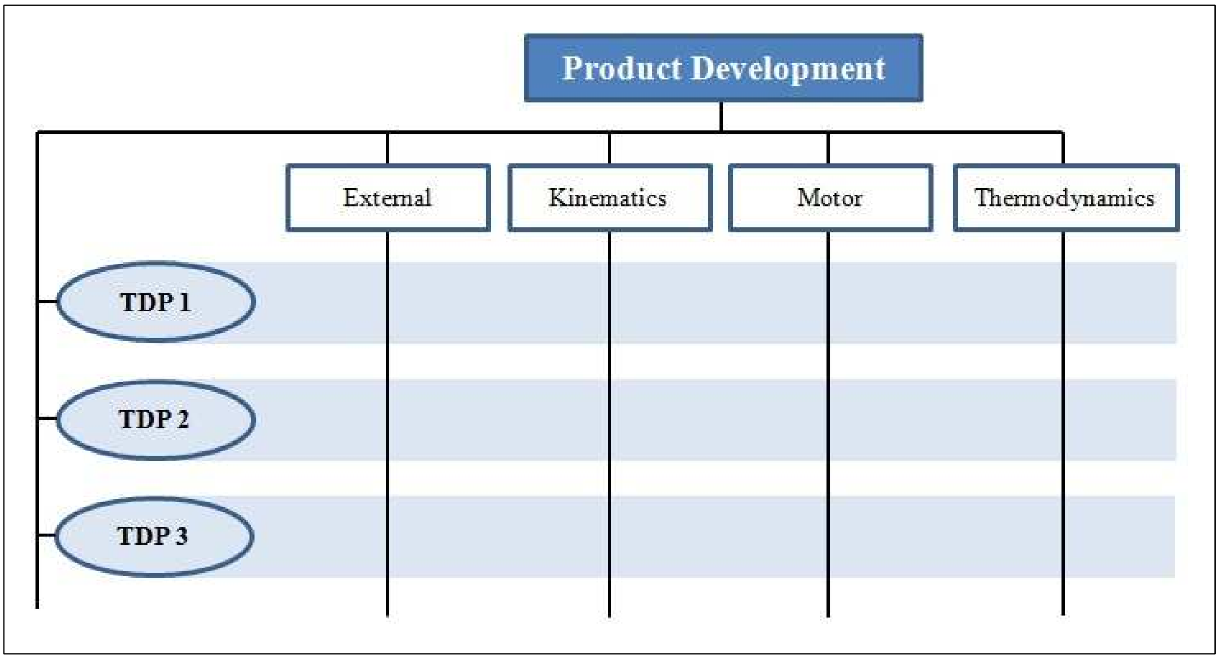

Illustration 6.27: Matrix organization of technology development projects

According to Gido and Clements [2008, p.409], the matrix type project organization offers an effective utilization of company resources and a minimization of costs.

The functional components (Systems Engineering, testing and so forth) provide a pool of expertise, whereby it is not unusual that individuals are assigned part time to several projects.

7 Conclusion and critical reflection

Hundred years ago, in 1911, J.A. Schumpeter [1911, p.100] defined the term innovation as:

“...innovation, that is the process of finding economic application for the inventions...”

A century later, many companies still understand striving for innovation as one or even the key role to achieve competitive advantage. But the answers to the question how to structure and organize development processes to achieve continuous innovation systematically are versatile, complex and require consideration of a multiplicity of parameters. Especially on that account it is indispensable to avail oneself of a multilayer thinking logic, respectively approach, such as Systems Engineering.

In the case of ACC and its future project CC2018, the results of previous effort, mainly in direction creativity tools and their application, have been taken up and acted as base for further operations for the system design of technology development at ACC.

The clear clustering of respective topics concerning technology to certain fields of expertise represents the coverage of promising areas. The so called technology fields have the intention to overcome technological duties on the way to the CC2018 as product innovation, an often neglected preparation activity of essential relevance. The problem occurring in several team leader meetings to define those fields as well as representative criteria for the evaluation was a classical chicken-egg-problem, but nevertheless activator of several discussions. In the end the problem is relativized because of its interpretation as open system. Therefore it is necessary to achieve a high flexibility and to be prepared as good as possible for prospective developments.

All those factors have been integrated in the composition and definition of an execution approach for technology development projects, based on Systems Engineering principles, to assure a continuous and unambiguous methodology adapted to concrete requirements.

This proceeding structure, especially the execution of its underlying specific process steps, is facilitated with several tools and methods that have emerged through long time applications under similar conditions. This highlighted pool of techniques has to be understood as expandable kit that has to be adapted personally or by responsible teams.

Nevertheless, the best methodology is dependent and influenced by environmental circumstances of the organization itself, the industry sector and more and more by the global economic situation and market conditions especially if it is “just” one part of a long way with many barriers to business success.

The intention of a structured and stepwise project organisation, as first phase of an innovative product concept, is to minimize these difficulties and to increase the potentials.

Another valuable capability reasonable to enhance and adopt effectively is networking. Nothing is as powerful as a system of masterminds from many different fields.

In particular, referring to knowledge and technological understanding, the objective of shaping the future requires a break out of the borders of the own organization and a widening of one´s horizon.

Admittedly, those actions are set to achieve competitive advantage, to be economically successful and to enable people to earn their living. But alongside these business goals we have a duty, a guilt to our children and grandchildren to economize our given resources and protect in this way our place for living. And this is not possible by marking time, leaning back and adhering rigidly to established technologies.

For that reason it is necessary to break new grounds. Alterations in all fields, not only in technology affairs, offer at least the possibility of getting ahead and therefore dealing with improvements, and trying to understand the complexity of being innovative, can never be wrong.

In the end it can be summarized that innovation is adjunctive with chances and of course also with risks and in many cases with investments. Those ventures might be handled and get into control with appropriate tools. Nonetheless means an abandon of tradition as counterpart of innovation to put oneself on the line. But who will not take the risk will also disclaim the chance, or how Nils Goltermann [J. Beck, N. Beck 2011, p. 66] said:

“Who does today just the same he did yesterday,
will stay tomorrow what he already is today.”

List of Abbreviations

ACC..Appliances Components Companies

ADL...Arthur D. Little

ASHRAE..American Society of Heating, Refrigerating and Air-Conditioning Engineers

BCG...Boston Consulting Group

CC2018..Cooling Compressor 2018

COP..Coefficient of performance

IFR...Ideal final result

PSC..Problem solving cycle

R&D..Research and development

SE..Systems Engineering

TDM...Technology development management

TDP...Technology development projects

TRIZ...Theory of inventive problem solving

USP...Unique selling proposition

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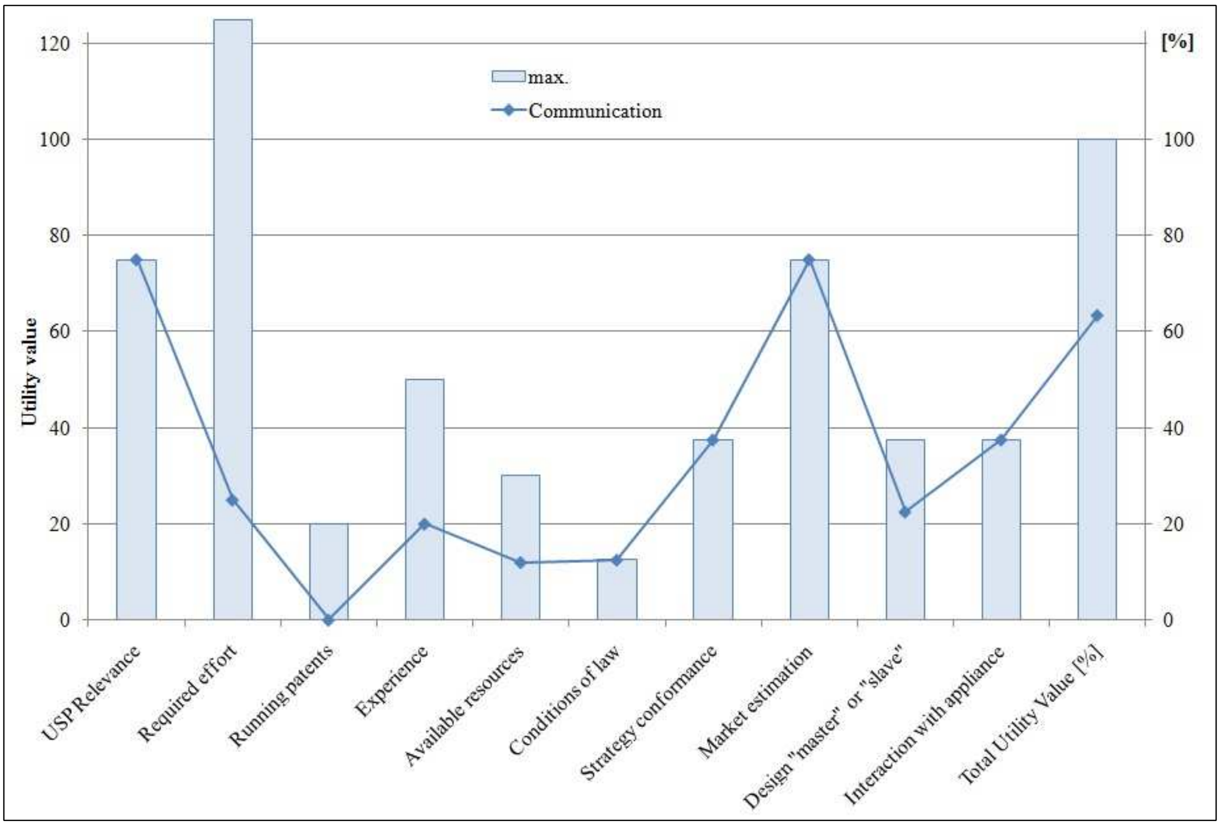
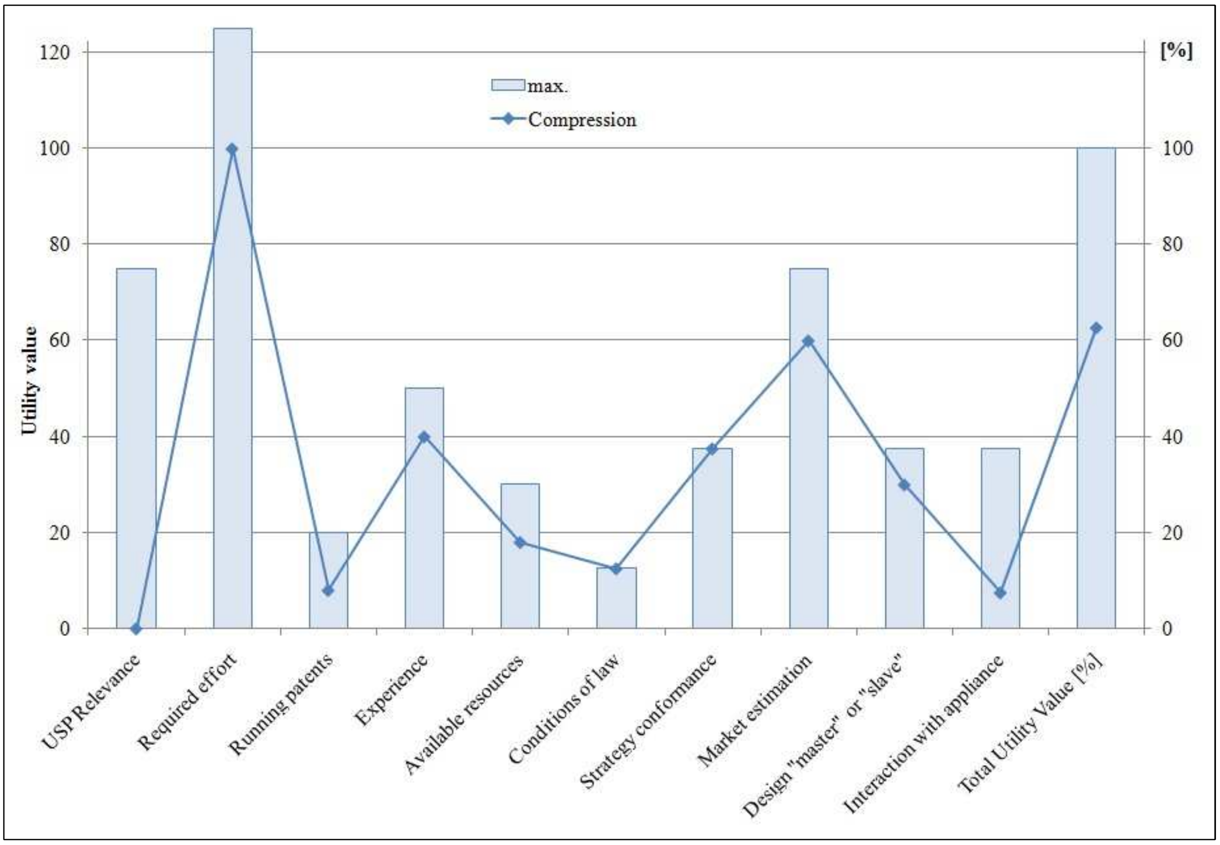
A Technology field evaluation

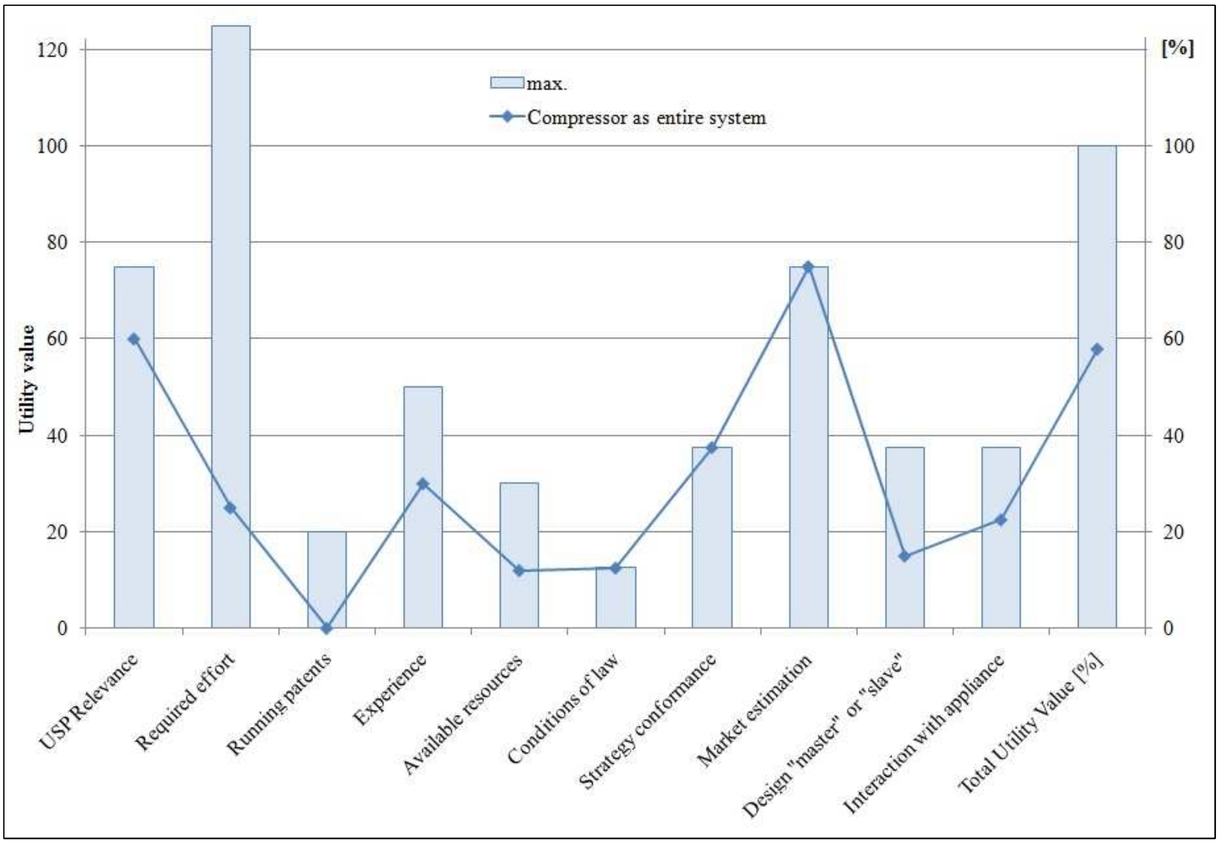
Technology Field:	Communication						
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15	5	75
Required effort	25	Time limit 2013 (50% target achievement)		25	1	25
Degree of innovation (ref. ACC)	20	Running patents	20	4	0	0
		Experience	50	10	2	20
		Available resources	30	6	2	12
			100			
Acceptance	25	Conditions of law	10	2,5	5	12,5
		Strategy conformance	30	7,5	5	37,5
		Market estimation	60	15	5	75
			100			
System interaction	15	Design "master" or "slave"	50	7,5	3	22,5
		Interaction with appliance	50	7,5	5	37,5
			100			
	100			**100**	Σ	**317**



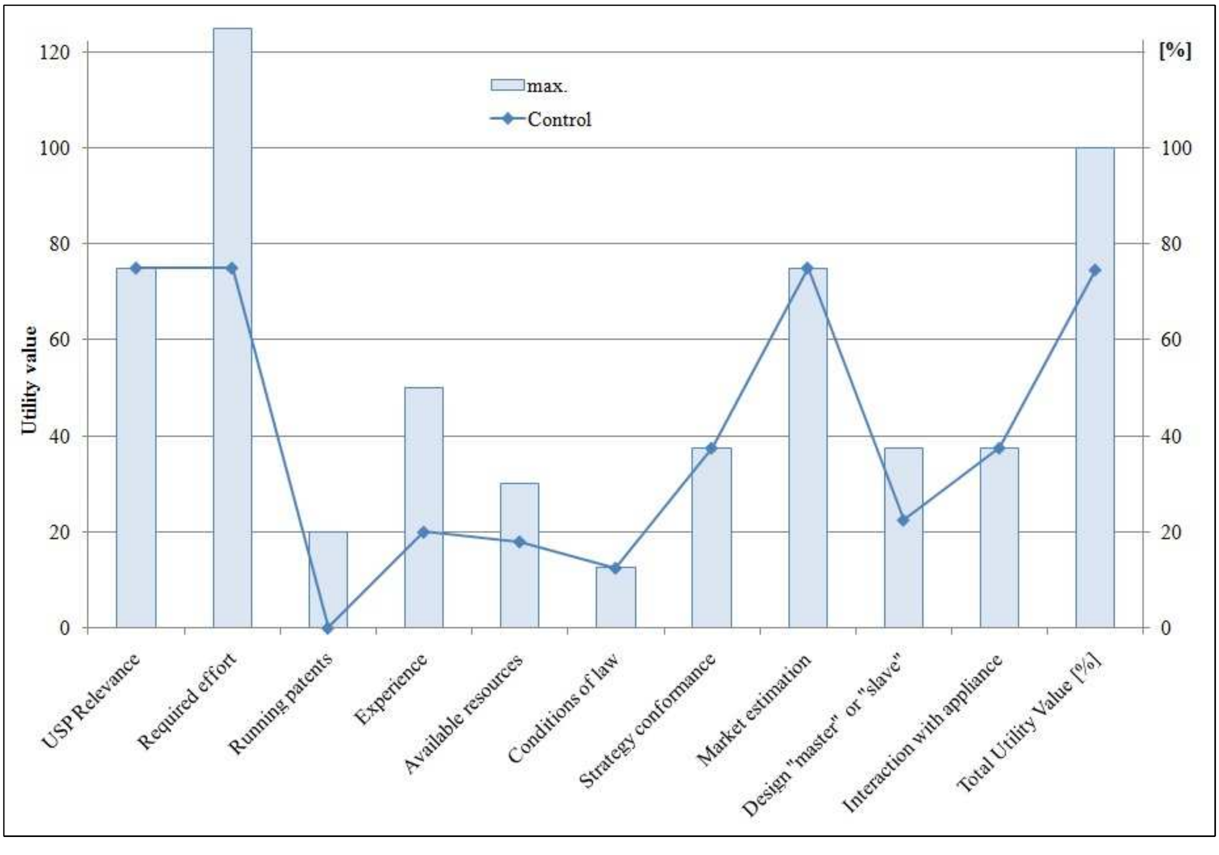
Technology Field:	Compression						
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15	0	0
Required effort	25	Time limit 2013 (50% target achievement)		25	4	100
Degree of innovation (ref. ACC)	20	Running patents	20	4	2	8
		Experience	50	10	4	40
		Available resources	30	6	3	18
			100			
Acceptance	25	Conditions of law	10	2,5	5	12,5
		Strategy conformance	30	7,5	5	37,5
		Market estimation	60	15	4	60
			100			
System interaction	15	Design "master" or "slave"	50	7,5	4	30
		Interaction with appliance	50	7,5	1	7,5
			100			
	100			**100**	∑	**313,5**



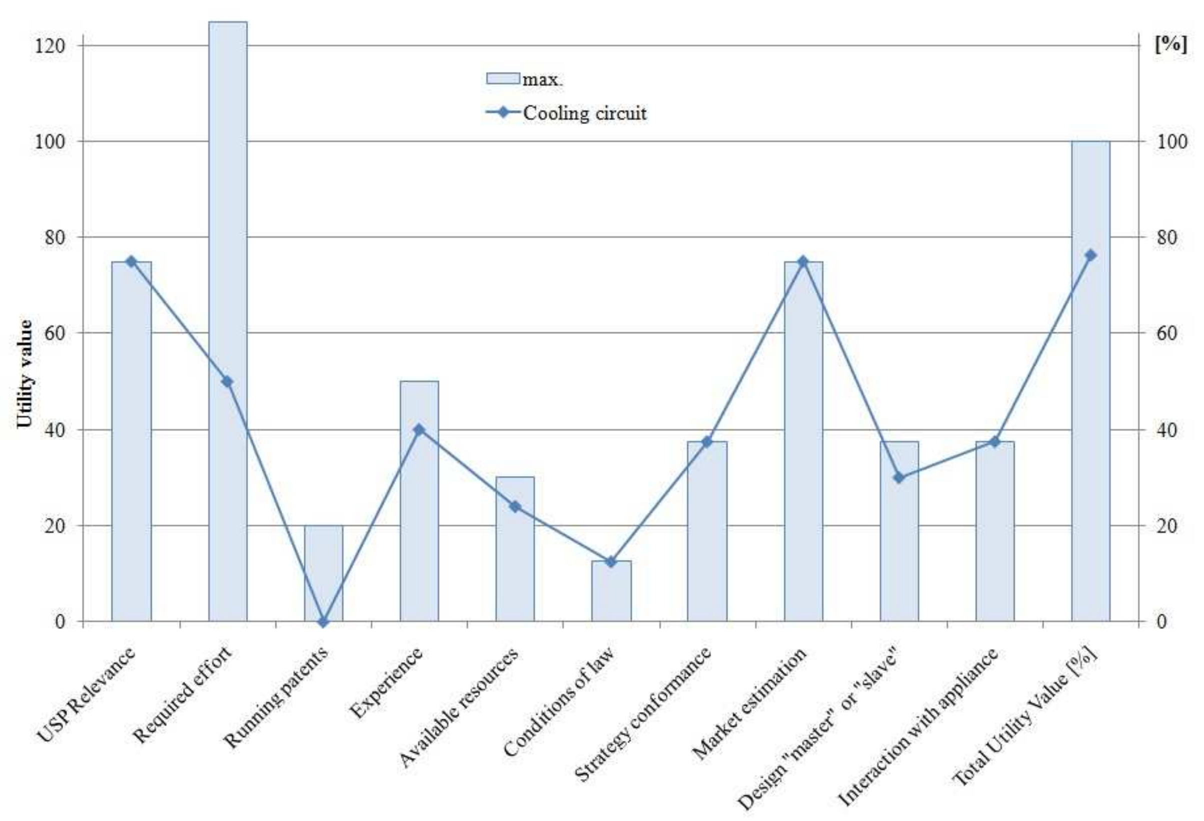
Technology Field:	Compressor as entire system					
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15	4	60
Required effort	25	Time limit 2013 (50% target achievement)		25	1	25
Degree of innovation (ref. ACC)	20	Running patents	20	4	0	0
		Experience	50	10	3	30
		Available resources	30	6	2	12
			100			
Acceptance	25	Conditions of law	10	2,5	5	12,5
		Strategy conformance	30	7,5	5	37,5
		Market estimation	60	15	5	75
			100			
System interaction	15	Design "master" or "slave"	50	7,5	2	15
		Interaction with appliance	50	7,5	3	22,5
			100			
	100			**100**	∑	**289,5**



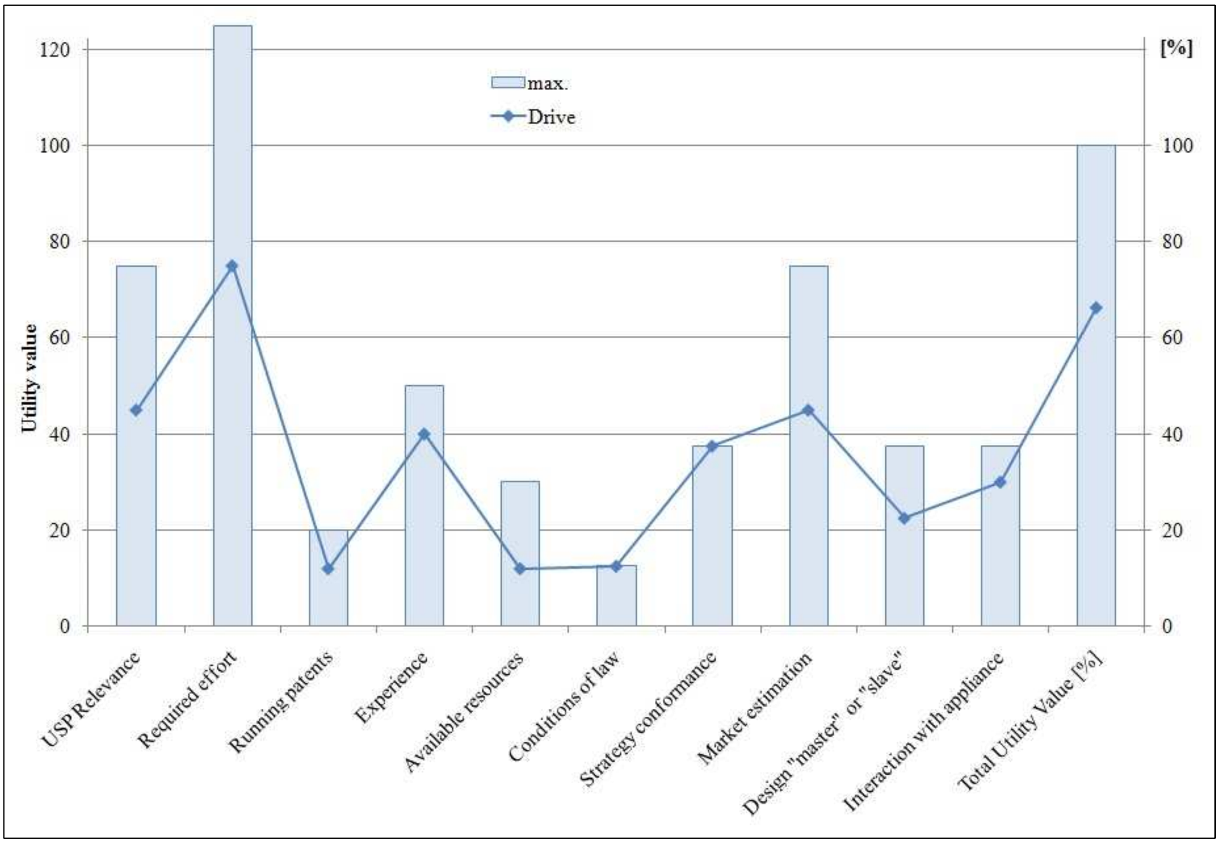
Technology Field:	Control						
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15	5	75
Required effort	25	Time limit 2013 (50% target achievement)		25	3	75
Degree of innovation (ref. ACC)	20	Running patents	20	4	0	0
		Experience	50	10	2	20
		Available resources	30	6	3	18
			100			
Acceptance	25	Conditions of law	10	2,5	5	12,5
		Strategy conformance	30	7,5	5	37,5
		Market estimation	60	15	5	75
			100			
System interaction	15	Design "master" or "slave"	50	7,5	3	22,5
		Interaction with appliance	50	7,5	5	37,5
			100			
	100			**100**	∑	**373**



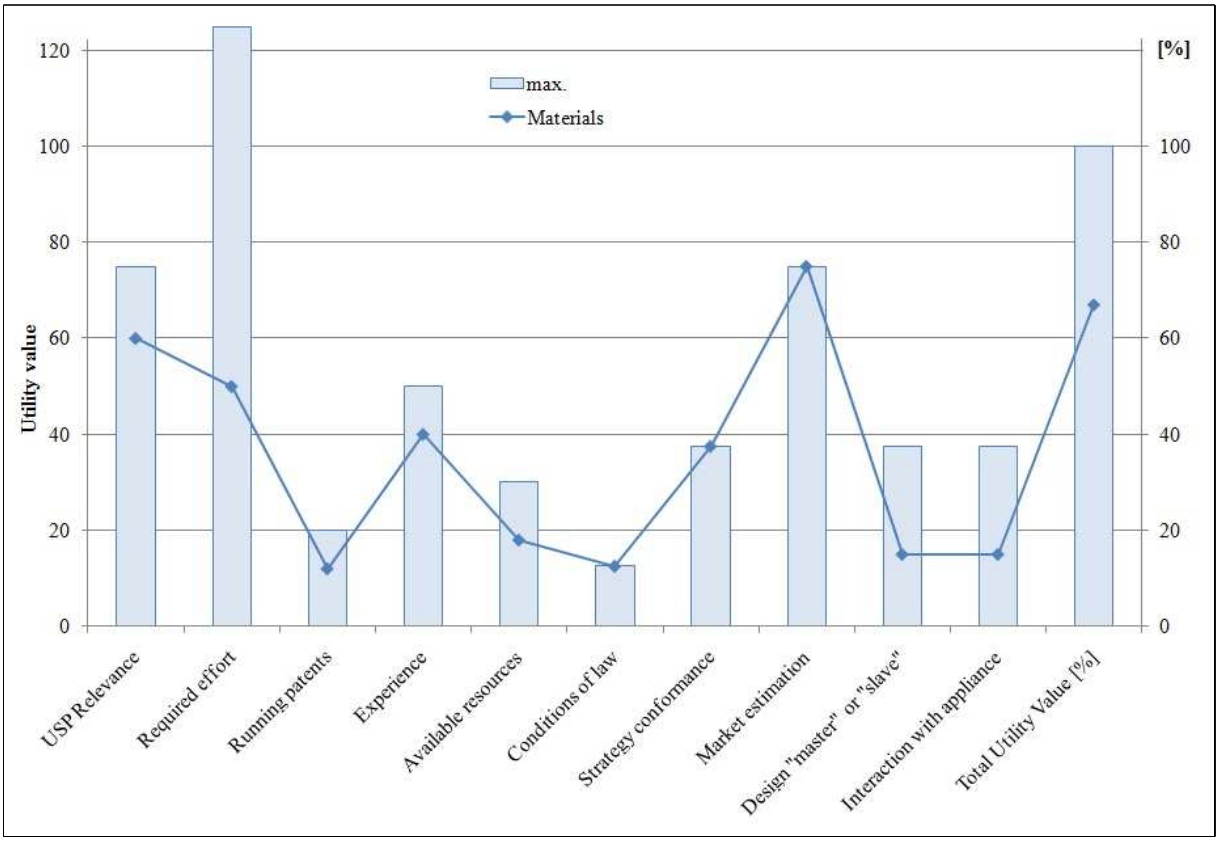
Technology Field:	Cooling circuit					
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15	5	75
Required effort	25	Time limit 2013 (50% target achievement)		25	2	50
Degree of innovation (ref. ACC)	20	Running patents	20	4	0	0
		Experience	50	10	4	40
		Available resources	30	6	4	24
			100			
Acceptance	25	Conditions of law	10	2,5	5	12,5
		Strategy conformance	30	7,5	5	37,5
		Market estimation	60	15	5	75
			100			
System interaction	15	Design "master" or "slave"	50	7,5	4	30
		Interaction with appliance	50	7,5	5	37,5
			100			
	100			**100**	∑	**381,5**



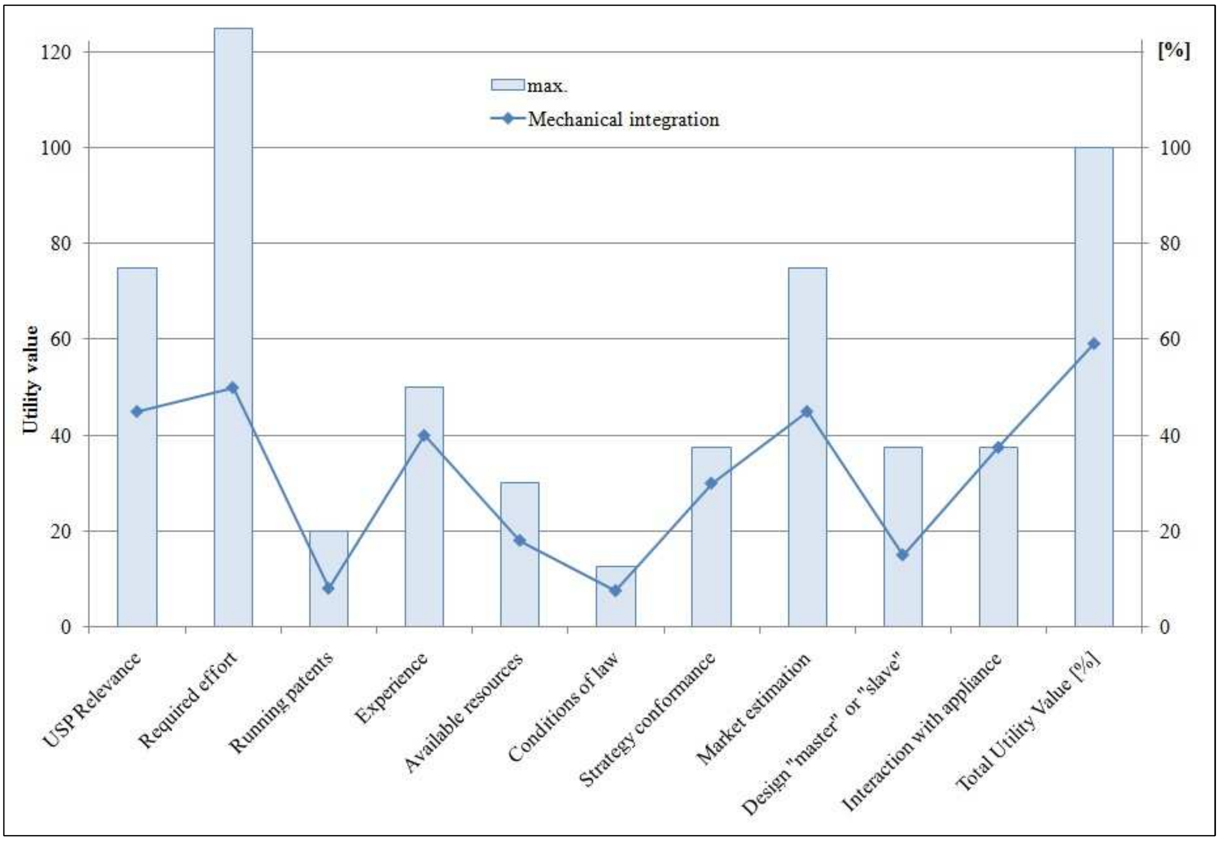
Technology Field:	Drive					
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15	3	45
Required effort	25	Time limit 2013 (50% target achievement)		25	3	75
Degree of innovation (ref. ACC)	20	Running patents	20	4	3	12
		Experience	50	10	4	40
		Available resources	30	6	2	12
			100			
Acceptance	25	Conditions of law	10	2,5	5	12,5
		Strategy conformance	30	7,5	5	37,5
		Market estimation	60	15	3	45
			100			
System interaction	15	Design "master" or "slave"	50	7,5	3	22,5
		Interaction with appliance	50	7,5	4	30
			100			
	100			**100**	∑	**331,5**



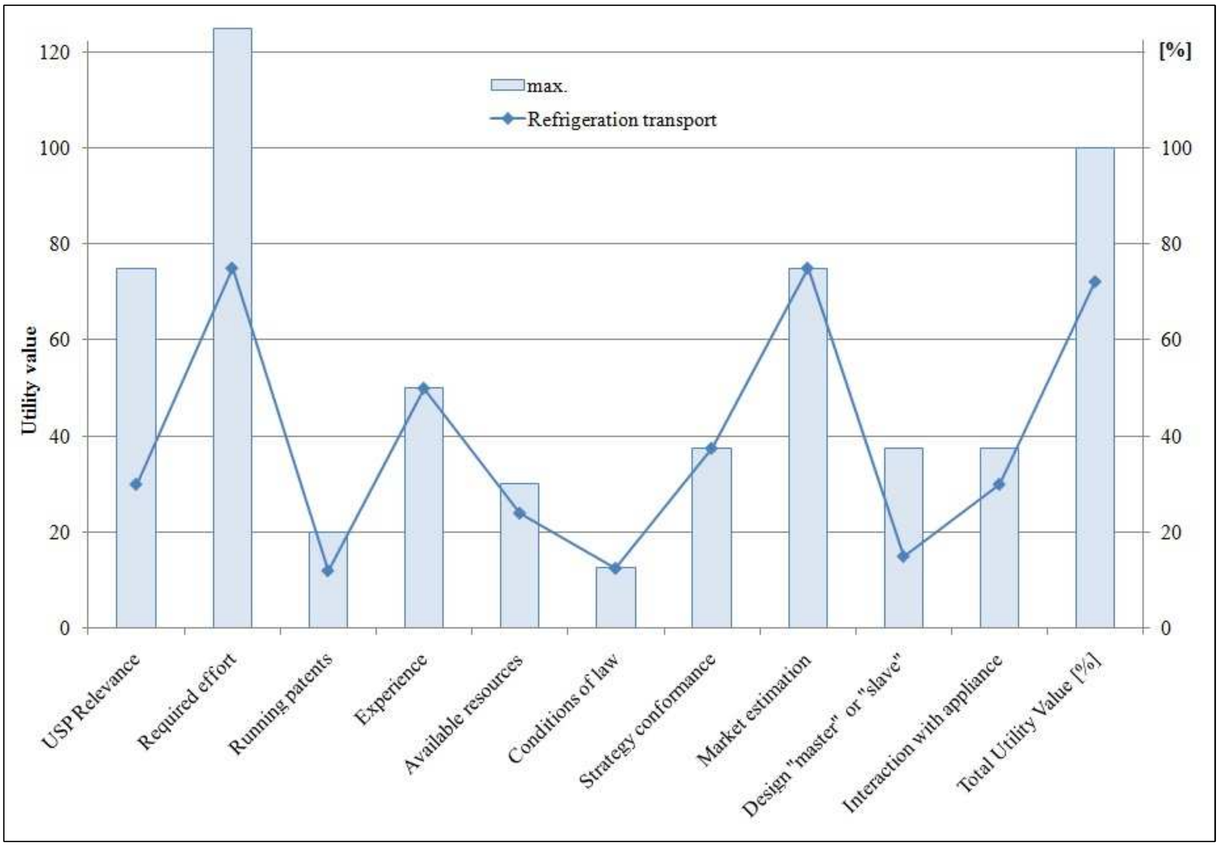
Technology Field:	Materials					
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15	4	60
Required effort	25	Time limit 2013 (50% target achievement)		25	2	50
Degree of innovation (ref. ACC)	20	Running patents	20	4	3	12
		Experience	50	10	4	40
		Available resources	30	6	3	18
			100			
Acceptance	25	Conditions of law	10	2,5	5	12,5
		Strategy conformance	30	7,5	5	37,5
		Market estimation	60	15	5	75
			100			
System interaction	15	Design "master" or "slave"	50	7,5	2	15
		Interaction with appliance	50	7,5	2	15
			100			
	100			**100**	∑	**335**



Technology Field:	Mechanical integration					
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15	3	45
Required effort	25	Time limit 2013 (50% target achievement)		25	2	50
Degree of innovation (ref. ACC)	20	Running patents	20	4	2	8
		Experience	50	10	4	40
		Available resources	30	6	3	18
			100			
Acceptance	25	Conditions of law	10	2,5	3	7,5
		Strategy conformance	30	7,5	4	30
		Market estimation	60	15	3	45
			100			
System interaction	15	Design "master" or "slave"	50	7,5	2	15
		Interaction with appliance	50	7,5	5	37,5
			100			
	100			**100**	∑	**296**



Technology Field:	Refrigeration transport					
Main criteria	**Weighting**	**Sub criteria**	**Weighting [%]**	**Intent weight. [%]**	**Assessment (0-5)**	**Utility Value**
USP Relevance	15	-		15	2	30
Required effort	25	Time limit 2013 (50% target achievement)		25	3	75
Degree of innovation (ref. ACC)	20	Running patents	20	4	3	12
		Experience	50	10	5	50
		Available resources	30	6	4	24
			100			
Acceptance	25	Conditions of law	10	2,5	5	12,5
		Strategy conformance	30	7,5	5	37,5
		Market estimation	60	15	5	75
			100			
System interaction	15	Design "master" or "slave"	50	7,5	2	15
		Interaction with appliance	50	7,5	4	30
			100			
	100			**100**	∑	**361**



B University departments

<u>Technical University Graz</u>

- Faculty of Computer Science
  - Applied Information Processing and Communications
  - Knowledge Management
  - Software Technology
  - Theoretical Computer Science

- Electrical and Information Engineering
  - Automation and Control
  - Electrical Drivers and Machines
  - Electrical Measurement and Measurement Signal Processing
  - Electrical Power Systems
  - Electronics
  - Signal Processing and Speech Communication
  - Technical Informatics

- Mechanical Engineering and Economic Science
  - Business Economics and industrial Sociology
  - Engineering and Business Informatics
  - Fluid Mechanics and Heat Transfer
  - General Management and Organisation
  - Industrial Management and Innovation Research
  - Internal Combustion Engines and Thermodynamics
  - Lightweight Design
  - Machine Components and Methods of Development
  - Materials Science and Welding
  - Mechanics
  - Production Engineering
  - Production Science and Management
  - Strength of Materials
  - Thermal Engineering
  - Thermal Turbomachinery and Machine Dynamics
  - Tools and Forming

- Technical Chemistry, Chemical and Process Engineering, Biotechnology
    - Chemical Engineering and Environmental Technology
    - Chemistry and Technology of Materials
    - Fundamentals of Chemical Engineering and Plant Design
    - Process and Particle Engineering
- Technical Mathematics and Technical Physics
    - Materials Physics
    - Solid State Physics

<u>Montan University Leoben</u>

- Materials Physics
    - Functional Materials and Materials Systems
    - Materialphysics
- Physical Metallurgy and Materials Testing
    - Metallography
    - Physical Metallurgy and Materials Testing
- Polymer Engineering and Science
    - Chemistry of Polymeric Materials
    - Designing Plastics and Composite Materials
    - Materials Science and Testing of Plastics
    - Plastics Processing

C Physical parameters

- Degree of Damping
- Flow and charge exchange loss (referring refrigerant transportation)
- Leakage
- Standardized interfaces
- Weight
- α (referring to gasline materials)
- η
- μ (between moving parts)