

The TRIZ Resource Analysis Tool for Solving Management Tasks: Previous Classifications and their Modification

Sandra Mueller

This paper illustrates different approaches of classifying resources inside the field of TRIZ and in the strategic management with focus on the Resource-based View. The Resource-based View is introduced in order to discuss resources under management aspects. The goal is to integrate the most promising approaches for increasing the effectiveness of the TRIZ-based resource analysis. The TRIZ-based comprehension of resources will be broadened such that the specifications of management problems are sufficiently considered. Based on the proposed classification, a three-step process to analyse resources in well-structured form based on TRIZ is recommended. In that way, the problem-solver can identify resources that might not normally be viewed as such. Furthermore, the proposed classification includes different categories of resources, with examples in the field of management that can be used as a database.

Introduction

Companies have to face several kinds of management problems. In this context, management is defined as an activity of organizing and contains aspects such as planning, controlling, and organization, as well as personal aspects such as leadership (Staehele, 1999). Problems arise from all these areas, and are mainly characterized as management problems. In this context the 'Theory of Inventive Problem Solving' (Altshuller, 1984) becomes more popular, because many problems cannot be solved by known solving methods or techniques. Several experts feel confident about the application of TRIZ to management problems (Pannenbaecker, 2001). The transfer of TRIZ to the field of management is referred to as 'Management-TRIZ'.

TRIZ is based on consolidated findings from extensive research of patents, and offers users the compressed knowledge and experiences of former inventors. In the evolution of TRIZ, a collection of tools has been designed that can be either used separately or in combination with others. The toolkit offers some technical

knowledge-based tools that provide recommendations for system transformation and as well as analytic tools for defining, formulating and modelling (Zlotin, Zusman & Kaplan, 1999). Resource analysis is an analytic tool to direct the user's creativity towards possible resources in the problem situation.

The first basic idea was to apply TRIZ tools through direct analogy to non-technical problems. Even if analytic tools such as resources can be applied easier to any kind of problems than, for example, scientific effects and phenomena, it seems to require some modifications. Orloff (2002) has pointed out that the human as a problem-solver plays a central role, so the success of a problem solution depends on two resources:

- (i) the resources of the problem;
- (ii) the resources of the problem-solver.

For management problems, it is necessary to go even further. Within a management problem, the human being, with individual

characteristics and its own personality, plays an important role.

Socio-technical systems consist of human and technical elements, while social systems only contain human elements. Both systems are different from other systems. They are strongly influenced by moral values, which have an impact on human behaviour. As a consequence, a system culture emerges including expectations of behaviour and roles. Sometimes the company's set of objectives is different from the employee's aims, wherefore a formal and an informal organization can emerge, and conflicts may arise. Technical systems and the appearing problems can easily be divided into system elements. Social or socio-technical systems mainly consist of less-structured problems. Division of system elements is much more complex for this kind of problems (Hill, Fehlbaum & Ulrich, 1994).

From a system perspective, a company can be seen as a dynamic, open socio-technical system that consists of social and technical elements, as well as relationships between them and the company environment (Staehele, 1999). In this system, the work factor is generated by humans – employees. The employees are a work factor for a company, a bearer of motivation and decisions, a cost-causer and a coalition partner, if they belong to different groupings. Furthermore, every company is confronted with different social groupings from the environment. All in all, the complexity of systems decreases considerably by combination of technical and social elements and the manifold relationships between them. This applies increasingly to social systems, from which various management problems could arise.

The search for resources is the basis for every system development. Resources are necessary and sufficient to realize the postulated system attributes and they may solve problems (Orloff, 2002). It is never trivial to think about the use of resources, because their availability and configuration could be changed in the course of time.

The resources in TRIZ are based on a wider understanding compared to other resource definitions. They are regarded as available funds of every description in and around a system, which are not used to their maximum for forming a system, e.g. substances or materials, as well as fields such gravitation (Mann, 2002; Pannenbaecker, 2001). The TRIZ-based resource analysis with a unique resource understanding is a powerful tool to discover resources for solving problems, but the focus so far has been on technical and techno-economical problems. In company practice, the term resources is often used, although in theory, alternative definitions and different classifications within and

outside the field of TRIZ, as well as alternative uses, can be found. Resources and their strategic role have been discussed copiously in the field of management in the context of strategic competition in particular, as well as in mergers and acquisitions.

The questions arise, what kind of resources can be applied to solve management problems, and how could the problem-solver systematically identify resources in the field of management? An analysis of resource-based research in strategic management can give an indication for classifying resources for solving management tasks, because company-internal resources are at the centre of attention in the so-called Resource-based View. In this paper, first the basic resource understanding and the different approaches in the field of TRIZ and in the Resource-based View are introduced. Next, classifications of resources within and outside the field of TRIZ are briefly pointed out, to analyse the availability and applicability for solving management problems. Both resource understandings are finally merged to develop a classification of resources that is suitable for management problems. This proposed classification is supplemented with a recommendation to analyse resources systematically in three steps. Furthermore, lists of example resources are given for further support.

Resources in TRIZ

The analysis tool as a part of the TRIZ-based toolkit can be defined as a special technique for directing creativity. This tool is principally directly applicable to every kind of problem situation (Moehrle, 2003). By drawing attention to all resources currently used and those additionally available and by listing them completely, the analysis tool itself can offer possible solutions to the problem-solver (Pannenbaecker, 2001). In order to solve a problem the problem-solver always reflects on resources. Specific to the analysis tool is the fact that thinking is an aware process. Implicit knowledge is transformed into explicit knowledge. For externalization, analogies are often used to enlarge implicit knowledge to explicit issues. This is because implicit knowledge is often difficult to communicate and formalize (Nonaka & Takeuchi, 1995; Polanyi, 1985, 1982). The externalization also occurs if individuals exchange knowledge in a group, when a constructive discussion can be useful. The analysis tool supports the process of externalization. Hidden implicit knowledge is externalized into visible explicit knowledge.

The resource 'thought' aims at the maximization of every system element. In TRIZ terms,

a resource is anything in and around the system that is not being used to its maximum potential (Mann, 2002). One of the key findings of TRIZ research was that the strongest solutions transform the unwanted or harmful elements of a system into useful resources. Thus, TRIZ requires the consideration of all resources within and outside the system. This refers to traditionally positive resources as well as to negative resources. Both kinds of resource might lead to discovery of problem-solving opportunities. All available resources describe the scope of design for transforming the present state to the target state (Pannenbäcker, 2001).

A problem-solver may identify the resources principally using brainstorming, or within TRIZ, systematically with supporting techniques as well as based on other TRIZ tools such as system analysis or substance-field-analysis. A frequently used and established technique to support the analysis resource is the classification of resources into several categories. Through the classification, the problem-solver should be able to collect resources more easily, because it helps him to think more effectively.

Within the latest developments of TRIZ, several authors have introduced classifications of resources. The classification mainly aims at structuring technical or techno-economical problems. A standard classification has not been accepted yet. In the following, five TRIZ-based approaches of classifying resources will be described briefly:

- Terninko, Zusman and Zlotin (1998), and Pannenbaecker (2001);
- Orloff (2002);
- Pevzner, Kasymov and Savransky (1992–1996);
- Mann (2002);
- Ideation International (2003).

Terninko, Zusman and Zlotin, and Pannenbaecker

Terninko, Zusman and Zlotin (1998) and Pannenbaecker (2001) divide resources in the six categories; (i) substances, (ii) fields, (iii) functional, (iv) informational, (v) time and (vi) spatial.

- (i) Substances are any materials of which the system and its surroundings are composed. Readily available resources include raw materials or semi-finished products, as well as waste or absence of a substance.
- (ii) Fields are any kind of energies inside or around a system, e.g. gravitation, light or electromagnetic radiation.

- (iii) Functional resources are any kind of effects. They include the capability of a system or its surroundings to perform additional functions. A super-effect is an additional (unexpected) benefit that arises as a result of innovation, e.g. producing heat from cow dung (methane).
- (iv) Informational resources are any perceptible information. Additional information about the system could be extracted from existing fields in a system. For example, the crankshaft transports not only strength, but also information, e.g. the speed of pressing together.
- (v) Time resources are any kind of time including time intervals before, during and after a process, e.g. use of online computer access.
- (vi) Spatial resources are free, unused space in a system or in its environment, e.g. use of the interior of spare wheels in a passenger car.

Orloff

Orloff (2002) defines an alternative classification of resources. Instead of substances, Orloff uses 'substantial' in terms of material properties such as chemical composition and the term energy instead of fields. Furthermore, he supplements the categories 'structural resources' and 'system resources' in terms of general system properties such as efficiency. Orloff differentiates between two main categories of resources: system-technical and physical-technical. System-technical resources are abstract, while physical-technical resources are easier to recognize in a system. He emphasizes that system-technical resources are always realized on the base of physical-technical resources. He subordinates the several types of resources in two main categories:

- The category system-technical resources consists of the resources (i) system, (ii) information, (iii) functional and (iv) structure.
- The resources (i) time, (ii) spatial, (iii) substantial and (iv) energy belong to the category physical-technical resources.

Pevzner, Kasymov and Savransky

A further approach that has to be mentioned offers a classification scheme consisting of the nine categories (i) energy, (ii) matter, (iii) space, (iv) time, (v) informational, (vi) functional, (vii) composite (combined), (viii) environmental and (ix) from sub- or super-system, with the three sub-classes; (a) internal, (b)

external and (c) common (Pevzner et al., 1992–1996).

The nine categories are not explicitly described. It is therefore difficult to differentiate between (viii) environmental and (ix) sub- and super-system. The class (a), internal, consists of things, substances and fields that are in the conflict area during or before a conflict time. The class (b), external, consists of things, substances and fields in neighborhood of the conflict area. The class (c), common, contains air, water or gravitation and so on. Overlaps can be interpreted between the categories and the classes, e.g. between the category (viii), environmental, and the class (b), external, or between the category (i), energy, as well as (ii), matter, and the class (c), common.

Mann

Another current approach is the classification of resources in the six categories (i) environment, (ii) low-cost, that is, plentiful, (iii) material, (iv) transforming, that is, modifying, (v) manufacturing and (vi) associated with humans, by Mann (2002). In this approach, the resources of the categories (i) environment, (ii) low cost (plentiful) and (vi) associated with humans are broken down into the three sub-categories (a) space, (b) time and (c) interface. Mann (2002) emphasizes the conceptual thinking in the dimensions (a) space, (b) time and (c) interface as an important part of TRIZ. He provides a considerable database of resource triggers to support a problem-solver. This leads to a new awareness of resources that are usually not taken into consideration such as the constitution of air or the human pulse variation.

Mann's approach considers resources associated with humans. In the context of space, time and interface, this category is not suitable for management problems. This results from the missing reflection of the human itself and its psychology. Each approach, taken separately, can be helpful to discover resources inside a technical or techno-economical system. For management systems, difficulties arise from the resource understanding. For example, substances are defined as any materials and fields are viewed as energy in terms of physical properties. Based on this definition, it is not problem-free to define substances and fields in social or socio-technical systems. There are intangible things as well, and a field can for instance be personnel communication and less physical energy. In addition, a category 'from sub- or super-system' should be handled carefully. With respect to a list of resources, a general attribution of resources fails with the special kind of system with

respect to the point of view. The super-system of a company is different to a departmental environment. Nevertheless, it is helpful to keep a different system view at the back of one's mind to identify resources in the system surroundings as well.

Ideation International

With the aim of solving management problems, Ideation International (2003) provides a classification of resources in the software 'Knowledge Wizard'. This software was developed notably for 'human systems'. Human systems can be organizations, departments or teams. Resources are differentiated basically between four categories (i) financial, (ii) human, (iii) technical and (iv) other business assets such as equipment, facilities, inventory, information and other. Technical resources (iii) are divided into the six sub-categories (a) substances, (b) energy substances, (c) functional, (d) informational, (f) time and (g) spatial according to Terninko, Zusman and Zlotin (1998). This approach is an enhancement of the resource understanding in the context of management TRIZ. It can be seen as a step in the right direction, especially regarding the attempt to take human or financial resources into consideration.

Nevertheless, it seems that this classification needs to be examined closely. Terninko, Zusman, Zlotin (1998) and Pannenbaecker (2001) defined this classification, which is also the basis of the software 'Ideation WorkBench' by Ideation International (2003). This classification is supplemented by the categories financial, human and other business assets, whereby the categories substances, fields -now energy substances-, functional, informational, time and spatial are only integrated into the category technical resources. As mentioned before, substances or energy substances are not clearly definable for management situations. It is questionable, whether energy substances like electromagnetic and magnetic fields can be assigned to management problems. Besides, this term 'technical resources' is not adaptable to management usage. All in all, the described approaches refer to technical or techno-economical problems and it can be helpful to solve them.

In Table 1 the different TRIZ-based classifications of resources and their cohesions based on the given examples are summarized. The approach by Ideation International (2003), from the software 'Knowledge Wizard', is not included. It is a new approach related to management problems and therefore not directly comparable to the already introduced classical TRIZ-based approaches. For clarity reasons,

Table 1. Classifications of TRIZ-based resources

TRIZ										
<p>Basic understanding of the term resource: Positive as well as harmful things inside and around the system, which are not being used to their maximum potential</p>										
Author	Classifications of resources									
Terninko, Zusman, Zlotin (1998); Pannenbaecker (2001); Ideation International WorkBench (2003)	▪ Substances (e.g. raw materials, products, waste, absence of a substance, system elements, substance flow)									
	▪ Fields (e.g. energy inside a system and from its environment, energy flow, energy loss, energy reserves)									
	▪ Functional (e.g. gaps in a function, application of harmful factors, exploit casual provided functions)									
	▪ Informational (e.g. inherent properties of the system and their changes, temporary information, information flow resp. information changes)									
	▪ Time (e.g. preliminary work, scheduled workflow, parallel process, pauses, temporary actions, rework)									
	▪ Spatial (e.g. free and unused space, other dimensions, for- and backside, vertical arrangement, nesting)									
Orloff (2002)	▪ System-technical:									
	– System in terms of general system properties (e.g. efficiency, reliability)									
	– Information (e.g. accuracy, completeness, methods of coding)									
	– Functional (e.g. propose, auxiliary functions, harmful factors)									
	– Structure (e.g. kind of structure like linear, parallel or closed)									
	▪ Physical-technical:									
	– Time (e.g. frequency of occurrence, durability of time intervals, sequence)									
	– Spatial (e.g. shape, height, hollows)									
– Substantial in terms of material properties (e.g. chemical composition, physical property)										
– Energy (e.g. mechanical, electromagnetic, gravitation)										
Pevzner, Kasymov, Savransky (1992-1996)	▪ Energy									
	▪ Matter									
	▪ Space									
	▪ Time									
	▪ Informational									
	▪ Functional									
	▪ Composite (combined)									
	▪ Environmental									
	▪ From sub- or super-system									
<i>With three classes: internal, external and common</i>										
Mann (2002)	▪ Environment , atmosphere (e.g. constitution of air, density) and in the context of space (e.g. mass of earth, river), of time (e.g. cycle of sun, speed of light) and of interface (e.g. sound attenuation, nitrogen cycle)									
	▪ Low-cost/plentiful in the context of space (e.g. rock, biomass), of time (e.g. shadow, resonance) and of interface (e.g. rain, wind)									
	▪ Material (material family e.g. metals/alloys, polymers)									
	▪ Transforming/modifying in the context of space (e.g. asymmetry, bubbles), of time (e.g. constant or variable fields) and of interface (e.g. strong taste or odour)									
	▪ Manufacturing in the context of mechanical (e.g. conventional machine tools, forging) and of chemical (e.g. granulation, nitration)									
	▪ Associated with humans in the context of space (e.g. mass, height), of time (e.g. blink rate, pulse) and of interface (e.g. variation in temperature, sweat)									
<p>Legend:</p> <table> <tr> <td>a Substances, material</td> <td>d Informational</td> <td>—————▶ Directly belonging</td> </tr> <tr> <td>b Fields, energy</td> <td>e Time</td> <td>.....▶ Indirectly belonging</td> </tr> <tr> <td>c Functional</td> <td>f Spatial</td> <td></td> </tr> </table>		a Substances, material	d Informational	—————▶ Directly belonging	b Fields, energy	e Time▶ Indirectly belonging	c Functional	f Spatial	
a Substances, material	d Informational	—————▶ Directly belonging								
b Fields, energy	e Time▶ Indirectly belonging								
c Functional	f Spatial									

the table only represents important cohesions. Because of this, the reader's attention is directed to the resources (i) substances (material), (ii) fields (energy), (iii) functional, (iv) time, (v) informational and (vi) spatial that appear directly and indirectly in the aforementioned approaches. Apart from these repeatedly arising resources, there are specific resources such as composite resources, and resources that arise sometimes such as environmental resources.

The Concept of Resources Inside the Field of Research on the Resource-Based View

The role of resources is frequently discussed in strategic management. The major difference between resource understanding inside the field of TRIZ and inside the field of strategic management is the application of resources. The resources are consulted in strategic management to explain sustainable competitive advantages of companies, while within TRIZ resources are used to solve a problem. Furthermore, the TRIZ-based view has mainly been focused on a technical or techno-economical problem. The analysis of the resource-oriented research inside the field of management could provide incitements to solve social and socio-technical problems. In the following, the basics of the resource-oriented research will be outlined briefly without going further into detail regarding the resource discussion. Attention should be drawn to the basic resource understanding and the classification of resources. It will be amplified on selected approaches.

In the recent past, in particular in the Anglo-Saxon literature, a resource approach of a company, well-named as the 'Resource-based View of a Firm' (Penrose, 1959) – shortened to 'Resource-based View' – has entered strategic management. The basic questions are the development, the protection and the realization of resources. The Resource-based View shows various characteristics. To give a general survey of all different currents in the field of research is impossible. However, all partial approaches are based on the fundamental assumption that internally available resources of companies are the basis for sustainable competitive advantages and for long-term above-average profits. The Resource-based View describes a direct relationship between the resource position of a company and the realization of competitive advantages. Competitive advantages lead not implicitly to above-average profits. Companies are defined as a bundle of tangible and intangible

resources. The heter-organic and specific configuration of a company results from its historic development (Bamberger & Wrona, 1996a, 1996b). Only a specific resource configuration causes sustainable competitive advantages and the base for above-average profits. For sustainability a resource must

- be valuable, in the sense that it exploits opportunities and/or neutralizes threats in a company's environment,
- be rare among a company's current and potential competition,
- be imperfectly imitable, and
- there cannot be strategically equivalent substitutes for resources that are valuable, but neither rare nor imperfectly imitable (Barney, 1991).

Grant (1991) links resources for sustainable competition to four attributes: durability, transparency, transferability and replicability. In this context, Wernerfelt (1989) introduces the term 'critical resource'. A resource is critical, if it can differentiate the company from competition by holding the greatest potential, for which a resource has to be unique.

In the following, eight approaches to classifying resources based on the resource-based view will be briefly described:

- Penrose (1959);
- Wernerfelt (1984, 1989);
- Barney (1991);
- Grant (1991, 2002);
- Hall (1992);
- Prahalad and Hamel (1990);
- Sanchez and Heene (1996);
- Freiling (2003);
- Collis and Montgomery (1995).

Penrose

The strategic discussion about the resources has a long tradition. Penrose (1959) had in first place introduced the idea in her publication, *The Theory of the Growth of the Firm*. She defines a company as a bundle of resources and marks the importance of the inherent characteristics of individuals and the relationships between them. She proposes a classification of resources into (i) physical and (ii) human. In her view physical resources of a company consist of tangible things such as plants or equipment. Available human resources are unskilled and skilled labour, such as administrative or managerial staff. Knowledge is important in order to identify the utilization of physical resources and to co-ordinate the resources and their changes to generate specific performances.

Wernerfelt

Following up the fundamental idea of the bundle of resources, Wernerfelt (1984) differentiates between tangible and intangible assets. In this view, the terms resources and assets are not differentiated; 'By a resource is meant anything which could be thought of as a strength or weakness of a given firm' (Wernerfelt, 1984). Resources include items such as brands, in-house knowledge of technology or machinery. During his scientific work, Wernerfelt has enhanced and revised his classification. Currently he distinguishes between (i) fixed assets, which are resources with fixed long-run capacity, (ii) blueprints, which are resources with practically unlimited capacity and (iii) cultures, which are resources with limited short-run, but unlimited long-run capacity (Wernerfelt, 1989).

Barney

While Penrose (1959) emphasizes human resources and Wernerfelt (1989) accents the cultures, Barney (1991) introduces organizational resources as a stand-alone category, and widens the view on human resources. He classifies three categories (i) physical capital, such as plant or equipment, (ii) human capital, such as training or experience and (iii) organizational capital, such as formal reporting structure, as well as informal relations among groups within a company and between a company and those in its environment.

Grant

Grant (1991) also emphasizes organizational resources. He divides the term resource into six categories: (i) financial, (ii) physical, (iii) human, (iv) technical, (v) organizational and (vi) reputation. Like Wernerfelt (1989), he revised and widened his view on resources as well as his classification scheme. Currently, he groups the three main categories as (i) tangible resources, including financial and physical, (ii) intangible resources, including technology, reputation and culture, and (iii) human resources, which includes specialized skills and know-how, capacity for communication and interactive abilities, as well as motivation. Grant (2002) distinguishes between resources and capabilities of a firm, because 'resources must work together in order to create organizational capability'.

Hall

Hall (1992) points out the capability differentials for sustainable competitive advantages as well, but in his judgement they only result

from intangible resources. According to Hall (1992), intangible resources are (i) assets and (ii) competencies (skills). (i) Assets are broken down into; assets with a legal context for regulatory differential, and assets without a legal context for positional differential. Assets are people independent, except for the reputation and networks assets. In contrast, competencies are people dependent and are divided into know-how for functional differential and organizational culture for cultural differential. Although Hall refers to intangible resources, he lists owned physical resources as assets within a legal context.

Prahalad and Hamel

Prahalad and Hamel (1990) suggested that the organizational resources have an intellectual dimension. Their approach is based on an application-oriented point of view. They introduce the term 'core competencies' as 'the collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies' (Prahalad & Hamel, 1990). Recent developments show the transformation of the Resource-based View towards a knowledge-based view (Fried, 2003). Companies were seen as a 'body of knowledge' (Mueller-Stewens & Lechner, 2001) or as a 'distributed knowledge system' (Tsoukas, 1996). Altogether, various authors define the role of knowledge: sometimes knowledge is apprehended as a resource, in other cases the role of knowledge is emphasized, but it is not regarded as a resource itself (Table 2).

Although tangible resources could make a company distinguishable from others, the Resource-based View directs much more importance to the intangible resources. It supports the view that employees and their knowledge are necessary to form singularity, that is, heterogeneity of a company. This applies accordingly to other intangible resources such as the organizational culture, the patents or the reputation of the particular company. Within the Resource-based View, the human factor, the human interactions and the interactions between organizations as well as the available knowledge created by humans come increasingly to the fore (Freiling, 2001, 2003; Hall, 1992). That is possibly one reason why the Resource-based View is accepted and triggers high interests inside the field of business economics.

Sanchez and Heene

Competitive advantages are explained by the existence of internal resources. Sanchez and

Heene (1996) have brought up the role of 'firm-addressable resources'. These are a firm's available assets and capabilities to perceive market opportunities. 'Firm-addressable resources' are classified in operations such as applications of existing capabilities for research and development, tangible or physical assets such as machines and intangible assets such as knowledge. Resource-based understanding becomes more realistic through this view, because it refers to increasing organizational networking.

Freiling

A further conceptual development in this context is the market orientation, i.e. a company has to interact consistently with its environment to accommodate and develop resources further. 'Firm-addressable resources' could absorb gaps in the resource configuration (Freiling, 2003). The development considers not just customers in the sales market, but also stakeholders, who play an important role. External resources can make content and structural changes. If a company has less ideas or perspectives for example, it may contact persons and/or organizations in its environment. It will be a sustainable effect, if the company ensures the right of disposal of that knowledge, e.g. by long-term contracts.

Collis and Montgomery

It can be deduced from the various partial approaches in the Resource-based View that there are different terms and classifications of resources. A widely accepted definition is in the publication of Montgomery (1995, quoted after *American Heritage Dictionary*): a resource is 'something that can be used for support or help; an available supply that can be drawn on when needed'. Available resources can take a variety of forms. They can be physical, intangible or take the form of an organizational capability (Collis & Montgomery, 1995). According to Bamberger and Wrona (1996a, 1996b), internal resources can be defined by nearly all internal tangible and intangible goods, systems and processes, whereby Sanchez and Heene (1996) include available external resources as well. An accepted classification scheme consists of the categories physical or tangible, intangible and particularly financial, enhanced by organizational and human resources. Table 2 gives an overview of classifications of resources based on the Resource-based View. Direct and indirect cohesions between them are mapped. The attention is directed toward the resources (i) tangible (physical), (ii) human (human

capital), (iii) organizational and (iv) intangible. For the sake of completeness, the earlier approaches by Wernerfelt (1984) and Grant (1991) are also listed.

Apart from Wernerfelt, most authors, e.g. Barney (1991), focus only on a company's positive assets and attributes (Montgomery, 1995). Montgomery (1995) regards this kind of resource as the crown jewels, because they are the minority in all companies. She demands the acknowledgement of 'pedestrian' resources, because 'their common nature does not mean that their assembled presence has no consequence' (Montgomery, 1995). It is also important to consider the resources that have a negative impact on the company. Both types of resources, pedestrian and negative resources, form the majority of resources in a company. This view links to TRIZ-based resource understanding. For solving management problems, it is neither useful to consider only positive resources, nor advisable to define special types of resources too narrow. The fact that there are various resources and their spectrum is wide has to be taken into account. A useful approach can therefore be a combination of the TRIZ-based resource understanding and comprehension on the Resource-based View.

Merging the Resource Understandings in the Field of TRIZ and in the Resource-Based View for Solving Management Problems

On the one hand, the Resource-based View considers management specifications by listing organizational and human resources in particular. On the other hand, resources are in principle furthest defined in the TRIZ-based view, because negative resources are seen as a potent opportunity. However, taking a closer look at the classifications in the field of TRIZ, the technical orientation becomes obvious, despite the wide definition. A combination of both views seems beneficial regarding a useful differentiation of resources that support the problem-solver to list the dominated aspects of a management problem situation and its solution.

The merging of the TRIZ-based resource understanding and the Resource-based View is reflected in three levels: (i) elementary, (ii) concrete and (iii) specific. Every level offers different categories of resources in Management-TRIZ, which are characterized by different abstraction (Figure 1).

The elementary resources are of a very abstract and general nature. They require a

Table 2. Classifications of resources based on the Resource-Based View of a Firm

Resource-based View of a Firm		
Basic understanding of the term resource: Resources -especially internal resources- are the source of sustained competition advantages		
Author	Classifications of resources	
Penrose (1959)	▪ Physical/tangible (plant, equipment, land, natural resources, raw materials, semi finished goods, waste products, by-product, unsold stocks of finished goods)	a
	▪ Human (unskilled labor, clerical, administrative, financial, legal, technical and management staff)	b
Wernerfelt (1989)	▪ Fixed Assets – resources with fixed long-run capacity (plant, equipment, mining rights, employees with specific training, firm specific investments by suppliers or distributors)	c
	▪ Blueprints – resources with practically unlimited capacity (patents, brands or reputations)	d
	▪ Cultures – resources with limited short-run, but unlimited long-run capacity (team effects)	
Barney (1991)	▪ Physical capital (a firm’s physical technology, plant, equipment, <i>geographic location</i> and access to raw materials)	
	▪ Human capital (training, experience, judgment, intelligence, relationships and insight individual managers and workers in a firm)	
	▪ Organizational capital (formal reporting structure, formal and informal planning, controlling, coordinate systems, informal relations among groups within a firm and between a firm and those in its environment)	
Hall (1992)	Intangible resources:	
	▪ Assets:	
	– Assets within a legal context for regulatory differential (contracts, licenses, intellectual property, trade secrets and owned <i>physical</i> resources)	
	– Assets without a legal context for positional differential (reputation, networks and databases)	
	▪ Competencies:	
	– Know-how for functional differential (e.g. employee-, supplier-, distributor know-how)	
	– Organizational culture for culture differential (e.g. perception of quality or service, ability to manage change)	
Collis and Montgomery (1995)	▪ Physical (e.g. wire)	
	▪ Intangible (e.g. brands, technological know-how)	
	▪ Organizational capability (e.g. routines, processes, culture)	
Sanchez, Heene (1996)	“Firm addressable resources”:	
	▪ Intangible assets (capabilities, knowledge, reputation, property rights, relationships)	
	▪ Tangible/physical assets (machines, buildings)	
	▪ Operations (application of existing capabilities for developing, producing, marketing and distributing products)	
Freiling (2001)	Firm’s specific tangible and intangible assets (no production factor) resp. “input goods” (procurable on markets) that are refined to firm’s characteristic	
Grant (2002)	▪ Tangible:	
	– Financial	
	– Physical	
	▪ Intangible:	
	– Technology	
	– Reputation	
	– Culture	
	▪ Human:	
	– Specialized skills	
	– Know-how	
	– Capacity for communication	
	– Interactive abilities	
	– Motivation	
Reworked definitions		
Wernerfelt (1984)	Tangible and intangible (examples of resources (assets) generally: brands, in-house knowledge of technology, employment of skilled personnel, trade contracts, machinery, efficient procedures, capital etc.)	
Grant (1991)	Financial, physical, human, technical, organizational, reputation	
Legend		
a Tangible, physical	c Organizational	→ Directly belonging
b Human, human capital	d Intangible	⋯ Indirectly belonging

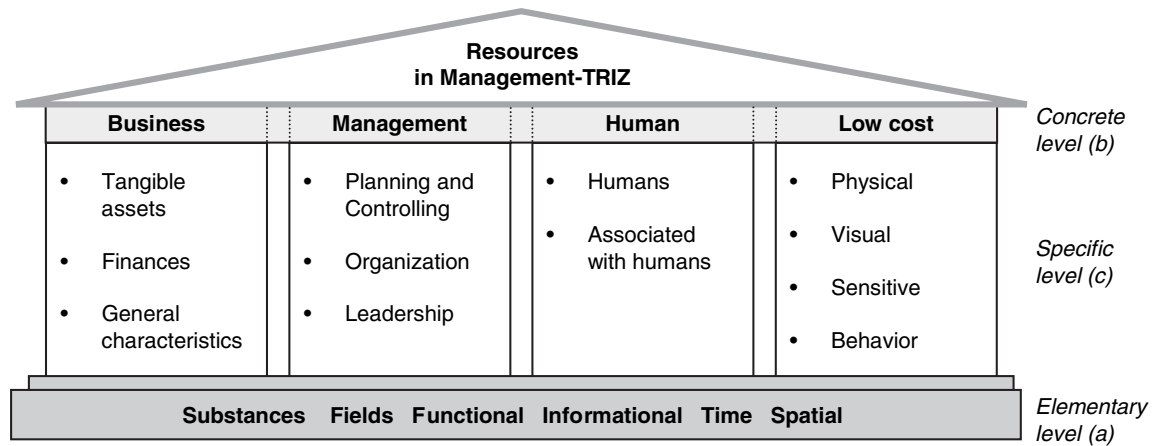


Figure 1. Three Levels of Resources in Management-TRIZ

high analogy, wherefore a three-step deductive process is suggested to support the problem-solver:

- (i) First, the user can work on the elementary level with elementary resources. With a broader understanding, those elementary resources cover the whole spectrum of resources in Management-TRIZ.
- (ii) If this is not sufficient, the user can next go on to a more concrete level. This level consists of the business, management, human and low-cost resources. In relation to management tasks, they are more descriptive and concentrated. With brainstorming the user is able to identify system elements with a useful and harmful impact on the system as resources to solve the considered problem.
- (iii) Third, the user may go on to the specific level, in case he wants a deeper level of support in the process of uncovering resources. For each category of the concrete level, the specific level offers up to four characteristic sub-categories.

These are recommendations. Of course, the user can go directly to the concrete or specific level and, if necessary, descend later to the elementary level. The suggested deductive process can be described as a house with a fundament (elementary level), a crossbeam (concrete level) and four supporting pillars (specific level). Together they form the base course for the roof, which represents the resources in Management-TRIZ resulting from the different categories of each level.

Focusing on TRIZ, six common classical categories of resources defined by Terninko, Zusman and Zlotin (1998) as well as Pannebaecker (2001), are used as elementary

resources for solving management problems. They are principally transferable to management problems provided that their understanding would be widened in some parts. To adapt, the TRIZ resource analysis tool to management tasks, the resources substances, fields and information must be expanded conceptually:

- In classical TRIZ-based understanding, substances are any kind of lifeless material. In the following, substances are considered to be systemic. They are defined as lifeless and alive, because socio-technical systems consist of both: technical elements such products or computer and social elements such individual people or social groupings. A further fragmentation such as tangible and intangible would not be meaningful, because, for example, functions, fields or information would likewise be substances. They should be considered separately.
- In classical TRIZ-based understanding fields are any kind of energy. In the following, fields are interpreted as a relationship between a causer, who acts on the field, and a recipient of the fields. Causer and recipient interact reciprocally. Thus, fields are defined as interactions. They can be, for example, communication or motivation, because humans can be system elements (substances).
- In classical TRIZ-based understanding, informational resources are any kind of perceivable information. In the following, informational resources include explicit and implicit knowledge. Informational resources are fundamental for solving management problems, and can be interpreted as a property of a system as well as of its

Table 3. Elementary resources in Management-TRIZ

Resources in Management-TRIZ	
Elementary level	
Substances	<ul style="list-style-type: none"> ■ System elements ■ Elements of a system's environment (lifeless e.g. products and alive e.g. humans)
Fields (Interactions)	<ul style="list-style-type: none"> ■ Between system elements within a system (e.g. communication) ■ From a system's environment (e.g. competition) ■ Between systems (e.g. networking) ■ Reserves (utilization of the full potential e.g. motivation) ■ Loss (e.g. anger)
Functional	<ul style="list-style-type: none"> ■ Gaps in a function ■ Application of harmful factors ■ Exploit casual provided functions ■ Additional useful functions
Informational	<ul style="list-style-type: none"> ■ Emitted/transmitted information from the system and/or its elements ■ Inherent properties of the system and/or its elements including explicit and implicit knowledge (e.g. behavior or inherent information such a patent or curriculum vitae as information resources as well as efficiency, availability, transparency, shape) ■ Temporary information (e.g. date) ■ Information flow resp. information changes (e.g. reporting structure)
Time	<ul style="list-style-type: none"> ■ Time before the process starts (e.g. preliminary work) ■ Time during the process <ul style="list-style-type: none"> – Parallel work/process (e.g. project organization) – Pauses – Idling ■ Post-process time (e.g. feedback) ■ Scheduled work flow ■ Temporary actions (e.g. projects) ■ Speed (e.g. reduction of training) ■ Duration (e.g. fixed-term contract)
Spatial	<ul style="list-style-type: none"> ■ Unoccupied space <ul style="list-style-type: none"> – Space between elements (e.g. reduction, expansion) – Space inside elements (e.g. interleave of information) – Unoccupied surfaces of elements (e.g. notice board on a wall) ■ Space occupied by unnecessary elements (e.g. office as storage room) ■ Space available in another dimension (e.g. advancement) ■ Another arrangement (e.g. another seating arrangement or different location) ■ Foreside/backside (e.g. using backside of a package) ■ Shape, surface (e.g. display)

elements. Explicit knowledge is of systematic structure and easily transferable. Implicit knowledge applies to problem solving know-how with a less visible structure and is used intuitively (Polanyi, 1985). Both can be organizational (e.g. formal and informal planning) and individual (e.g. publications or social competence).

Inside the field of Management-TRIZ, spatial resources bear less meaning. Regarding human conflicts, their use seldom leads to innovative solutions. Nevertheless, they can be useful. As a result, they are marginal and range at last place. Table 3 shows the six categories of resources; (i) substances, (ii) fields, (iii) functional, (iv) informational, (v) time and

Table 4. Business resources with sub-categories and examples in Management-TRIZ

Resources in Management-TRIZ		
Concrete level	Business	
Specific level		
Tangible assets	<i>Fixed assets</i>	Equipment (e.g. machinery, hard- and software), facilities, plant, land
	<i>Current assets</i>	Inventory (e.g. raw materials, semi finished goods),
Finances	<i>Assets</i>	Investment, cash reserve, trade receivables, factoring
	<i>Capital</i>	Equity capital, liabilities (loans, leasing, salaries and wages), financial incentives (e.g. social contributions, private use of company's car)
General characteristics	Location, areas, type of products and services, size (e.g. turnover, market size, goodwill, physical value, competition position)	

(vi) spatial with examples, which are termed as elementary resources.

Every category of the concrete level is described by various categories on the specific level. For each category on the specific level, sub-categories with diverse examples are listed. The included list of examples, which is expandable, in particular should help the problem-solver to identify easier resources in management. Each of the following tables gives an overview of the levels and their categories. The elementary resources can be recovered in the categories on the other two levels. For example, tangible assets or humans are substances in a socio-technical system. It has to be pointed out that several categories like finances are divided again into further sub-categories as generic terms such as assets and capital, for more clarity.

Business resources and used business capital are issue related, because they give a description of the tangible and financial assets. According to the fiscal management in this concept, business resources are divided into the sub-categories, tangible assets and finances (Table 4). Tangible assets contain both fixed assets and current assets. Finances enclose (financial) assets and capital (equity and loan capital). Both sub-categories, tangible assets and finances, are supplemented with the general characteristics of a company, because they are issue-related resources as well, but neither tangible assets nor finances. General characteristics can be a useful

resource for example, when a company exploits its image or location for applying special employees.

Because of the used management understanding, the management resources consist of management functions. They are defined as planning and controlling, organization and leadership. In this case each function can be divided again (Table 5). According to Steinmann and Schreyoegg (2000), planning can be broken down into strategic and operational planning. Knowledge becomes more and more important. It is already represented inside the Resource-based View. Therefore, organizational knowledge is assigned to management resources in the sub-category organization. In addition to organizational knowledge, the organization sub-category contains organization and environment as well as informal organization, according to Steinmann and Schreyoegg (2000). The interaction between a company and its environment, especially inter-organizational relationships and networks, gains in importance, and an informal organization opens up new paths.

With respect to the specifications of management problems it makes sense, to choose the human resources as separate category (Table 6). On the one hand, humans can be an important resource by themselves. On the other hand, individual properties can be supported as well. Individual properties are termed as associated with humans. In this context, the sub-category associated with humans

Table 5. Management resources with sub-categories and examples in Management-TRIZ

Resources in Management-TRIZ				
Concrete level Specific level	Management			
Planning and controlling	<i>Strategic planning</i>	Strategic options (e.g. diversification, internationalization), strength and weakness analysis, environmental analysis, corporate policy (e.g. philosophy, vision)		
	<i>Operational planning</i>	Budgeting, break-even analysis, project planning		
	<i>Controlling</i>	Coordination (e.g. target/actual comparison, variance analysis), control		
Organization	<i>Company operational structure</i>	Analysis and synthesis of work (personnel, temporal, local), procedures (formal planning), information and communication structure		
	<i>Company organization structure</i>	Hierarchy, coordination system (positions, divisions), communication (reporting structure)		
	<i>Organizational knowledge</i>	Intellectual property rights	Patents, trademarks, brands, trade names, copy rights	
		Internal documents	Contracts, licenses, concessions, forecast studies, estimates, customer list	
		Other explicit know-how	Inventions, programs, databases, processes, methodologies, formulas, core competencies, simulation, training methods, in-house knowledge of technology or of special departments (e.g. R&D or Human Resources Development)	
	<i>Organization and environment</i>	Global	Technical (e.g. technologies and their life cycle), political/legal (e.g. laws, national and international policy), socio-cultural (e.g. education system, social developments), ecological (e.g. water quality), macroeconomic (e.g. competition, economic growth)	
		Stakeholders	Customers, competitors, suppliers, stockholders, banks, trade unions, consume/industry councils, government, media	
		Inter-organizational relationships and networks	Alliances, joint ventures, co-operations, creation of institutions	
		External effects	Reputation, image, publicity, sponsoring, customer loyalty	
	<i>Informal organization</i>	Culture	Perception of service, working atmosphere, form, informational relations, unspoken rules, rituals, sub-cultures, cultural change	
		Learning	Experiences (e.g. successful projects, well past crises and conflicts), capability to development, organizational changes	
		Political processes	Divergent interests, conflicts, exertion of power, oppositions	
	Leadership	<i>Of humans</i>	Informing (e.g. of goals), communication, motivation, representation	
<i>Of the company</i>		Deciding, leadership organization (managerial styles), representation of the company		

Table 6. Human resources with sub-categories and examples in Management-TRIZ

Resources in Management-TRIZ		
Concrete level	Human	
Specific level		
Humans	<i>Interface between internal and external</i>	(Potential) employees, employees with a specific training, people at the top level/at a lower level, people who are able to promote and motivate, stakeholder, shareholder, mediators, broker, experts
	<i>External</i>	Retired people, public people (e.g. politicians)
Associated with humans	<i>Characteristics (personality)</i>	Capability to develop, motivation, aims, wishes, expectations, power of judgment, autonomy, moral values, intelligence, creativity, reliability, trust ability, loyalty, flexibility, handling of stress, stability, hardiness, sensory capacity, visual thinking, experience of life, health
	<i>Qualification concrete</i>	Education, training, specific know-how (e.g. project management, technical competence, languages, intercultural competency)

Table 7. Low-cost resources with sub-categories and examples in Management-TRIZ

Resources in Management-TRIZ	
Concrete level	Low cost
Specific level	
Physical	Unskilled employees, trainees, timber, biomass, natural fibers
Visual	Logo, product presentation, work clothes, sunlight intensity, color, water
Sensitive	Music, sound, smell, temperature, wind, humidity
Behavior	Imitation, kindness, listen, motivation, authority

contains personality and concrete qualifications, while Mann (2002) uses the term in the context of space, time and interface. All in all, human resources represent the personal assets of a company.

The low-cost resources are the last and special category on the specific level (see Table 7). In particular, those resources should be considered that are not regarded as relevant in first place or, which are taken for granted as

they are available for free (Pannenbaecker, 2001). Low-cost resources are plentiful or easily added elements inside and around the system, which are not already used to their maximum. They possess a high availability and low expenditure, which they may bring out separately or in combination. They provide useful solutions with little effort. For example, friendliness as an inexpensive resource may be useful to positively influence a dissatisfied client. While Mann (2002) defines such resources in the context of space, time and interface for solving technical problems, they are divided into physical, visual, sensitive and behaviour-oriented in the context of Management-TRIZ.

Conclusion

Resources play an important role in the field of TRIZ as well as in the field of strategic management. Within TRIZ, the analytic tool resource analysis supports an inventor in solving predominantly technical or techno-economical problems. The Resource-based View is one theory to explain strategic management activities. In this approach, resources are defined as means for explaining sustainable competitive advantages of a company. One of the cornerstones of the TRIZ philosophy is that the search for resources takes into account negative as well as traditional positive resources in a system. The TRIZ-based resource understanding is very broad. Nevertheless, for an adaptation of the TRIZ-based resource analysis to management tasks, the specification of management problems are not considered sufficiently. The Resource-based View is discussed in this article, because particularly human and organizational resources are introduced, and a survey about the basic resource understandings and the fundamental approaches of classifying resources given. The different classifications of resources within and outside the field of TRIZ and their combination lead to a new classification of resources suitable for solving management problems. This classification is supplemented with a three-step process consisting of the elementary, concrete and specific levels, which may help the problem-solver to discover resources more easily.

The adaptation of resources can help in various different management problem situations. The proposed classification of resources is built on the TRIZ-based resource concept of six categories (substances, fields, functional, informational, time and spatial) by Terninko, Zusman and Zlotin (1998), as well as Pannenbaecker (2001). These often-applied, abstract

categories are still useful in supporting the problem-solver in the field of resource discovery. Because of their abstract nature, this concept supports and encourages the problem-solver to start thinking in abstract categories. Therefore, this concept reflects the TRIZ philosophy. Besides this, a conceptual expansion of this fundamental concept is necessary to allow the application of this tool to management tasks adequately. Up until now, the resource analysis is only applied to technical and techno-economical problems. Therefore, a reorientation is required. The proposed classification and the three-step procedure are designed to offer a way to enrich the resource analysis and to show one option for solving management problems. The careful application of the resource analysis leads to:

- new, unfamiliar thinking directions;
- careful preparation of problem-solving space;
- a number of starting points for creative solutions, as well as a combination of ideas.

Acknowledgement

The author would like to thank Darrell Mann for helpful discussions and support. Thanks also to Simon Dewulf, who had enabled the author to stay for a research sojourn at CREAX.

References

- Altshuller, G.S. (1984) *Creativity as an Exact Science*. Gordon & Breach Science Publishers, New York.
- Bamberger, I. and Wrona, T. (1996a) Der Ressourcenansatz und seine Bedeutung für die Strategische Unternehmensführung. *Zeitschrift für betriebswirtschaftliche Forschung (zfbf)*, 48(2), 130–53.
- Bamberger, I. and Wrona, T. (1996b) Der Ressourcenansatz im Rahmen des Strategischen Managements. *Wirtschaftswissenschaftliches Studium (WiSt)*, 25(8), 386–91.
- Barney, J.B. (1991) Firm Resources and the Sustained Competitive Advantage. *Journal of Management*, 17(1), 99–120.
- Collis, D.J. and Montgomery, C.A. (1995) Competing on Resources Strategy in the 1990s: How do you create and sustain a profitable strategy? *Harvard Business Review*, 73(4), 118–28.
- Freiling, J. (2001) *Resource-based View und ökonomische Theorie: Grundlagen und Positionierung des Ressourcenansatzes* Gabler, Wiesbaden.
- Freiling, J. (2003) *Resource-based View der Unternehmung*. Technische Universität Chemnitz, 1–29.
- Fried, A. (2003) *Was erklärt die Resource-based view of the Firm? Anforderungen an einen ressourcentheoretischen Ansatz aus Sicht des Strategischen Managements*. Technische Universität Chemnitz, 1–38.

- Grant, R.M. (2002) *Contemporary Strategy Analysis: Concepts, Techniques, Applications*. Blackwell Publishers, Malden, MA.
- Grant, R.M. (1991) The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation. *California Management Review*, 33(3), 114–35.
- Hall, R.H. (1992) The Strategic Analysis of Intangible Resources. *Strategic Management Journal*, 13(1), 135–44.
- Hill, W., Fehlbaum, R. and Ulrich, P. (1994) *Organisationslehre 1: Ziele, Instrumente und Bedingungen der Organisation sozialer Systeme*. Haupt, Bern.
- Ideation International (2003) *Knowledge Wizard*. Version 2.9.4. Software application Southfield, MI.
- Ideation International (2003) *WorkBench*. Version 2.8.0. Software application. Southfield, MI.
- Mann, D. (2002) *Hands-on Systematic Innovation*. CREAX, Ieper.
- Moehrle, M.G. (2003) *Implementation of TRIZ tools in companies: Results of a cluster analysis*. The R&D Management Conference, Manchester.
- Montgomery, C.A. (1995) Of Diamonds and Rust: A New Look at Resources. In Montgomery, C.A. (ed.), *Resource-based and Evolutionary Theories of the Firm towards a Synthesis*. Kluwer Academic Publishers, Boston, 251–68.
- Mueller-Stewens, G. and Lechner, C. (2003) *Strategisches Management: Wie Strategische Initiativen zum Wandel fuhren*. Der St. Galler General Management Navigator. Schaeffer-Poeschel, Stuttgart.
- Nonaka, I. and Takeuchi, H. (1995) *The Knowledge Creating Company: How Japanese Companies Create Dynamics of Innovation*. Oxford University Press, Oxford.
- Orloff, M.A. (2002) *Grundlagen der klassischen TRIZ: Ein praktisches Lehrbuch des erfinderischen Denkens für Ingenieure*. Springer, Berlin.
- Pannenbaecker, T. (2001) *Methodisches Erfinden in Unternehmen: Bedarf, Konzept, Perspektiven für TRIZ-basierte Erfolge*. Gabler, Wiesbaden.
- Penrose, E.T. (1959) *The Theory of the Growth of the Firm*. Basil Blackwell, Oxford.
- Polanyi, M. (1982) *Personal Knowledge: Towards a post-critical Philosophy*. The University of Chicago Press, Chicago.
- Polanyi, M. (1985) *Implizites Wissen*. Suhrkamp, Frankfurt-am-Main.
- Prahalad, C.K. and Hamel, G. (1990) The Core Competence of the Corporation. *Harvard Business Review*, 68(3), 79–91.
- Sanchez, R. and Heene, A. (1996) A Systems View of the Firm in Competence-based Competition. In Sanchez, R., Heene, A. and Thomas, H. (eds.), *Dynamics of Competence-based Competition. Theory and Practice in the New Strategic Management*. Elsevier Pergamon, Oxford, 39–62.
- Schreyoegg, G. (1999) *Organisation: Grundlagen moderner Organisationsberatung mit Fallstudien*. Gabler, Wiesbaden.
- Stahle, W.H. (1999) *Management: Eine verhaltenswissenschaftliche Perspektive*. Vahlen, München.
- Steinmann, H. and Schreyögg, G. (2000) *Management: Grundlagen der Unternehmensfuehrung*. Wiesbaden, Gabler.
- Terninko, Z., Zusman, A. and Zlotin, B. (1998) *Systematic Innovation: An Introduction to TRIZ*. St. Lucie Press, Boca Raton.
- TRIZ Experts (eds) (1996–2001) *TRIZ Resources of a System: The Types of Resources in TRIZ*. From materials of Pevzner, L.Ch.; Kasymov, A. and Savransky, S.D. 1992–1996
- Tsoukas, H. (1996) The Firm as a Distributed Knowledge System: A Constructionist Approach. *Strategic Management Journal*. 17(Special Winter Issue), 11–25.
- Wernerfelt, B. (1989) From critical resources to corporate strategy. *Journal of General Management*, 14(3), 4–12.
- Wernerfelt, B. (1984) A Resource-based View of the Firm. *Strategic Management Journal*, 5(2), 171–80.
- Zlotin, B., Zusman, A. and Kaplan, L. (1999) TRIZ Beyond Technology: The Theory and practice of applying TRIZ to non-technical areas. Ideation International, Detroit. *TRIZ-Journal*, 6(1), 1–47.

Sandra Mueller works as Research Associate to Professor Moehrle at the University of Bremen (Germany) and holds a degree in economics. She conducts research in the field of TRIZ, specializing in the adaptation of TRIZ tools to management tasks and has experience with TRIZ workshops in companies. Further scientific interests are scenario management in the scope of future research and entrepreneurship. In 2003 she spent a research sojourn at CREAX (Ieper, Belgium). Email: sandram@uni-bremen.de