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# Why risk management matters in IT outsourcing - A systematic literature review and elements of a research agenda

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# PROBLEM SOLVING PATTERNS IN DESIGN SCIENCE RESEARCH – LEARNING FROM ENGINEERING

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## Abstract

*Within information systems the design science research (DSR) paradigm aims at the development of useful artifacts, e.g. models or methods, with which relevant IS problems can be solved. In analogy to the engineering discipline construction processes have been proposed for DSR. Although different phases of such construction processes are explicated in several articles, contributions are missing that propose patterns/principles that support the constructor during the different phases of the construction process. Vaishnavi and Kuechler (2007) address this issue by proposing DSR patterns. Their contribution is a substantial one; however, it does not include comparable pattern approaches from the engineering discipline for the foundation of the proposed patterns. Bearing in mind that DSR has its roots in engineering, it is important to analyze so called problem solving patterns from engineering and to compare them to the DSR patterns. Using this as a basis, it is our research goal to examine whether it is possible to expand the existing DSR patterns to include patterns from engineering. As a result, 14 additional DSR patterns are proposed which originate from engineering, have not been discussed so far, but promise to be useful for DSR in information systems.*

*Keywords: Design Research, Design Science, Research Methodology*

# 1 INTRODUCTION

## 1.1 Problem Statement

The information systems (IS) discipline differentiates two main research paradigms: behavioral research and design science research (DSR) (Hevner et al. 2004, p. 76). In contrast to behavioral research that focuses on the development of theories, DSR is a problem solving paradigm which does not only have its roots in the sciences of the artificial (Simon 1996) but also in the engineering discipline (Hevner et al. 2004, p. 76). The goal of the DSR discipline is the development of useful artifacts with which IS-related problems can be solved (March & Smith 1995, p. 253). Within DSR the artifact types of March & Smith (1995, p. 256 ff.), i.e. constructs, models, methods and instantiations, have been established as artifacts of the DSR discipline (e.g. cf. Hevner et al. 2004, Vahidov 2006, vom Brocke & Buddendick 2006). Lately, design theories have been discussed as DSR artifacts as well (e.g. cf. Kuechler & Vaishnavi 2008, Venable 2006b).

For the development of such artifacts, construction processes have been proposed in analogy to the engineering discipline (e.g. cf. Pahl et al. 2007, p. 53). In recent years, the construction process developed by March & Smith (1995) has achieved wide acceptance (e.g. cf. Cao et al. 2006, Hevner et al. 2004, Venable 2006a). This construction process consists of a "build" (develop artifact) and an "evaluate" phase (evaluate artifact) (March & Smith 1995, p. 258 ff.). In addition, articles have been published (e.g. cf. Peffers et al. 2006, Rossi & Sein 2003, vom Brocke & Buddendick 2006) that detail these phases, e.g. by explicitly defining an "identify a need" phase (Rossi & Sein 2003) which has to be conducted prior to the development of the artifact. Besides, Hevner et al. (2004, p. 82 ff.) propose seven DSR guidelines that assist researchers and reviewers to understand the requirements for effective DSR. Moreover, the literature analysis shows that some articles also put their focus on solution patterns, i.e. patterns that represent parts of the result of the construction process, but do not support the construction process itself. To give an example, Schermann et al. (2007) propose three patterns that form a design theory for IT service data management systems (result of the construction process).

It is doubtless that the identified contributions are very useful. However, there are hardly any contributions that contain patterns/principles guiding the constructor within the different phases of the construction process in order to solve the research problem through the development of a DSR artifact. Within our literature analysis we only identified the contribution of Vaishnavi & Kuechler (2007) who propose DSR patterns that support the constructor in each phase of the construction process, e.g. the "build" or the "evaluate" phase. In addition to the construction process further phases of the whole research process are supported as well. To give an example, Vaishnavi & Kuechler (2007) identified patterns for the "conclusion" phase, which assist researchers in writing up and publishing their results. Next to patterns that are assigned to a certain phase of the construction/research process, they also proposed so called meta patterns, such as "Brain Storming" or "Stimulating Creativity", that support more than one or even all construction/research phases. Although the contribution of Vaishnavi & Kuechler (2007) is a substantial one, the underlying foundation of the identified patterns has not been made visible in their publication. Based on a statement of Vaishnavi, both authors have engineering backgrounds but did not use concrete engineering approaches for the foundation of the DSR patterns.[1] Hence, for the proposition of their patterns DSR literature was used without including comparable approaches from engineering. Due to the fact that DSR has its roots in engineering – as e.g. stated by Hevner et al. (2004, p. 76) – it is important to analyze so called problem solving patterns from engineering and to compare them to the DSR patterns of Vaishnavi & Kuechler (2007). The identification of analogous patterns provides a solid foundation and improves the validity of the corresponding DSR

[1] E-mail conversation with Vijay K. Vaishnavi between 1 Oct 2008 and 29 Oct 2008.

patterns as they are backed up by their root discipline. This comparison is following the line of arguments developed in (Gericke 2009). Based thereupon, in this paper it is our research goal to examine whether it is possible to expand the existing DSR patterns to include patterns from engineering.

### 1.2 Research Methodology

In the paper at hand, an argumentative analysis is used as research method to address the proposed research goal. In order to develop new DSR patterns based on patterns from the engineering discipline convincing arguments will be derived from literature/relevant research and presented in a logical as well as comprehensible order. Due to space limitations of this paper we focus on the "build" phase.

Before new DSR patterns can be developed, the DSR patterns of Vaishnavi & Kuechler (2007) and pattern approaches from the engineering discipline need to be analyzed. Therefore, a structuring approach already successfully used in both disciplines is used (for engineering e.g. cf. (Günzler & Vilbig 2003, Jarke et al. 2003), for method engineering (a sub-discipline of DSR) e.g. cf. (Brinkkemper 1996)): Following this approach the object or matter under consideration is structured regarding a product view and a process view. Applying this structuring approach to problem solving patterns implies, that patterns referring to the product, i.e. the result of a construction process, ("product view") and patterns supporting the construction process itself ("process view") can be differentiated.

Following the described research goal and research methodology we structured our paper as follows: In the second section we describe and analyze problem solving approaches/patterns from the engineering discipline. Thereafter, we introduce and analyze the DSR patterns of Vaishnavi and Kuechler (2007) in detail. In section 4 the results of the comparison of problem solving patterns from engineering and the DSR discipline are presented. Using this as a basis, we attempt to expand the DSR patterns by problem solving patterns from engineering. The paper closes with a summary and an outlook.

## 2 PROBLEM SOLVING PATTERNS IN ENGINEERING

In engineering it was already recognized in the beginning of the last century that the trial-and-error method is not the most efficient way to develop a problem solution (Altschuller 1986, p. 12, Orloff 2006, p. 34). Instead problem solving approaches should be used in order to reduce the number of errors and to solve problems more efficiently (Altschuller 2005, p. 36, Crețu 2007, p. 7, Teufelsdorfer & Conrad 1998, p. 14). Realizing this, Altschuller developed the TRIZ approach, which is the Russian acronym for the "Theory of Inventive Problem Solving" (TIPS) (e.g. cf. Altschuller 2005, Altschuller 2006, Altschuller & Shulyak 2002, Orloff 2006). This approach is well established – in academia as well as in industry (Altschuller 2005, p. 15 ff., Herb et al. 1998, p. 18). Many other approaches addressing inventive problem solving in engineering, such as WOIS (German acronym for contradiction-oriented innovation strategy), the PI concept (Concept of Problem-Oriented Invention) or SIT (Systematic Inventive Thinking), are based thereupon (Pannenbäcker 2007, Teufelsdorfer & Conrad 1998, p. 10). Beside TRIZ, other problem solving approaches have been developed as well (e.g. cf. Hürlimann 1981, Kelley 2003). However, they are either single contributions and/or did not achieve wider acceptance. That is why we restrict our focus to the TRIZ approach for the analysis at hand.

"TRIZ is a comprehensive, systematically organized invention knowledge and creative thinking methodology" (Crețu 2007, p. 8). The methods and concepts belonging to TRIZ can be divided into four independent groups (Gimpel et al. 2000, p. 7, Löbmann 2002): (1) Analysis (2) Knowledge (3) Analogy, and (4) Vision. The analysis group contains methods that are used to analyze problems and to overcome mental blocks. The second group refers to knowledge bases, e.g. a scientific effects data base. The third group deals with analogies by containing different solution principles/patterns, e.g. 40 innovation principles used to overcome technical contradictions. Finally, the vision group describes development trends and contains e.g. the S-curves of evolution.

The 40 innovation principles belonging to the analogy group are one of the most famous concepts of TRIZ (Rietsch 2007, p. 14). They are patterns which support the constructor in solving technical problems efficiently and effectively (Chen & Lin 2008, p. 14, Rietsch 2007, p. 14 f.). The 40 innovation principles are empirically well founded, because they were derived from more than 40,000 reviewed and analyzed patents of inventions (Altschuller 2005, p. 137). Knowing this, the question arises whether these principles can be transferred to DSR since the DSR discipline cannot build on a comparable empirical basis which can be used to derive such principles/patterns. Though, next to their use in the engineering discipline these principles have already been transferred to other disciplines using conclusions by analogy. Examples can be found for management (Ruchti & Livotov 2001), marketing (Pustogow 2007), human resource management (Müller 2006), etc. Following this argumentation we transfer the innovation principles of TRIZ to the DSR discipline using conclusions by analogy. Regarding the transfer of the 40 innovation principles to other disciplines, Zobel (1991, p. 111) recognizes that the principles are not coequal, but that some principles are more universal than others. Following him such universal principles can be transferred to other disciplines whereas the remaining specific principles are of a rather technical nature and are less suitable to be transferred to other disciplines (Bannert & Warschat 2007, p. 64, Zobel 1991, p. 114 f.). That is why only 22 universal innovation principles will be considered in the following (Zobel 1991, p. 114 f.).[2]

To give an overview of all 40 innovation principles, Table 1 contains their names and gives an exemplary description for every principle. A number (E1, E2, etc.) is assigned as well in order to ease recognition in the remainder of the paper. The last two columns refer to the analysis of the patterns which is presented at the end of this section. The 18 specific principles are shaded in grey and will not be considered in the remainder of this paper.

| **Problem Solving Patterns in Engineering – The TRIZ Approach** | | | | |
|---|---|---|---|---|
| **No.** | **PSP[1]** | **Exemplary Descriptions** | **Prod.[2]** | **Proc.[3]** |
| E1 | Segmentation | Divide an object into independent parts. | X | X |
| E2 | Extraction | Extract the “disturbing” part or property from an object or extract only the necessary part or property from an object. | X | X |
| E3 | Local Quality | Transition from homogeneous to heterogeneous structure of an object. Different parts of an object should carry out different functions. Each part of an object should be placed under conditions that are most favorable for its operation. | X | X |
| E4 | Asymmetry | Change the shape of an object from symmetrical to asymmetrical. | X | X |
| E5 | Merging/ Consolidation | Bring closer together (or merge) identical or similar objects, assemble identical or similar parts to perform parallel operations. Make operations contiguous or parallel; bring them together in time. | X | X |
| E6 | Universality | Make a part or object perform multiple functions; eliminate the need for other parts. | X | X |
| E7 | Nesting | Place one object inside another; place each object, in turn, inside the other. | X | X |
| E8 | Counterweight | To compensate for the weight of an object, merge it with other objects that provide lift or make it interact with the environment (e.g. use aerodynamic, hydrodynamic, and other forces). | X | X |
| E9 | Prior Counter-action | If it will be necessary to do an action with both harmful and useful effects, this action should be replaced with counteractions to control harmful effects. Create beforehand stresses in an object that will oppose known undesirable working stresses later on. | X | X |
| E10 | Prior Action | Perform, before it is needed, the required change of an object (either fully or partially). Pre-arrange objects such that they can come into action from the most convenient place and without losing time for their delivery. | X | X |
| E11 | Cushion in Advance | Prepare emergency means beforehand to compensate for the relatively low reliability of an object. | X | X |

[2] Zobel (1991, p. 114 f.) originally characterized 23 of the 40 innovation principles as universal. Due to the fact that the principle E18 “Mechanical Vibration” seems to be very specific for the engineering discipline we assign it to the category of specific principles and do not consider it any further.

| Problem Solving Patterns in Engineering – The TRIZ Approach | | | | |
|---|---|---|---|---|
| **No.** | **PSP[1]** | **Exemplary Descriptions** | **Prod.[2]** | **Proc.[3]** |
| E12 | Equipotentiality | In a potential field, limit position changes (e.g. change operating conditions to eliminate the need to raise or lower objects in a gravity field). | X | X |
| E13 | Do It in Reverse | Invert the action(s) used to solve the problem (e.g. instead of cooling an object, heat it). Turn object "upside down". | X | X |
| E14 | Spheroidality, Curvature | Instead of using rectilinear parts, surfaces, or forms, use curvilinear ones; move from flat surfaces to spherical ones. Go from linear to rotary motion, use centrifugal forces. | X | X |
| E15 | Dynamics | Divide an object into parts capable of movement relative to each other. If an object (or process) is rigid or inflexible, make it movable or adaptive. | X | X |
| E16 | Partial or Excessive Action | If it is difficult to obtain 100% of a desired effect, achieve more or less of the desired effect. | X | X |
| E17 | Another Dimension | To move an object in two- or three-dimensional space. Tilt or re-orient the object, lay it on its side. Use "another side" of a given area. | X | X |
| E18 | Mechanical Vibration | Cause an object to oscillate or vibrate. Increase its frequency (even up to the ultrasonic). Use an object's resonant frequency. Use piezoelectric vibrators instead of mechanical ones. Use combined ultrasonic and electromagnetic field oscillations. | X | X |
| E19 | Periodic Action | Instead of continuous action, use periodic or pulsating actions. If an action is already periodic, change the periodic magnitude or frequency. | X | X |
| E20 | Continuity of Useful Action | Carry on work continuously; make all parts of an object work at full load, all the time. Eliminate all idle or intermittent actions or work. | X | X |
| E21 | Rushing Through | Conduct a process, or certain stages (e.g. destructible, harmful or hazardous operations) at high speed. | X | X |
| E22 | Convert Harm Into Benefit | Use harmful factors (particularly, harmful effects of the environment or surroundings) to achieve a positive effect. | X | X |
| E23 | Feedback | Introduce feedback (referring back, cross-checking) to improve a process or action. | X | X |
| E24 | Intermediary | Use an intermediary carrier article or intermediary process. | X | X |
| E25 | Self-Service | Make an object serve itself by performing auxiliary helpful functions. Use waste resources, energy, or substances. | X | X |
| E26 | Copying | Instead of an unavailable, expensive, fragile object, use simpler and inexpensive copies. Replace an object, or process with optical copies. | X | X |
| E27 | Cheap Short-Living Objects | Replace an expensive object with a multiple of inexpensive objects, comprising certain qualities (such as service life, for instance). | X | X |
| E28 | Mechanics Substitution | Replace a mechanical means with a sensory (optical, acoustic, taste or smell) means. Change from static to movable fields, from unstructured to those having structure. | X | X |
| E29 | Pneumatics/ Hydraulics | Use gas and liquid parts of an object instead of solid parts (e.g. inflatable, filled with liquids, air cushion, hydrostatic, hydro-reactive). | X | X |
| E30 | Flexible Shells/ Thin Films | Use flexible shells and thin films instead of three dimensional structures. | X | X |
| E31 | Porous Materials | Make an object porous or add porous elements (inserts, coatings, etc.). If an object is already porous, use the pores to introduce a useful substance or function. | X | X |
| E32 | Color Changes | Change the color of an object or its external environment. Change the transparency of an object or its external environment. | X | X |
| E33 | Homogeneity | Make objects interacting with a given object of the same material (or material with identical properties). | X | X |
| E34 | Discarding/ Recovering | Make portions of an object that have fulfilled their functions go away (discard by dissolving, evaporating, etc.) or modify these directly during operation. | X | X |
| E35 | Parameter Changes | Change an object's physical state (e.g. to a gas, liquid, or solid). Change the concentration or consistency. Change the degree of flexibility. | X | X |
| E36 | Phase Transition | Use phenomena occurring during phase transitions (e.g. volume changes, loss or absorption of heat, etc.). | X | X |
| E37 | Thermal Expansion | Use thermal expansion (or contraction) of materials. If thermal expansion is being used, use multiple materials with different coefficients of thermal expansion. | X | X |
| E38 | Strong Oxidants | Replace common air with oxygen-enriched air. Replace enriched air with pure oxygen. | X | X |
| E39 | Inert Atmosphere | Replace a normal environment with an inert one. Add neutral parts, or inert additives to an object. | X | X |

| Problem Solving Patterns in Engineering – The TRIZ Approach | | | | |
|---|---|---|---|---|
| **No.** | **PSP[1]** | **Exemplary Descriptions** | **Prod.[2]** | **Proc.[3]** |
| E40 | Composite Materials | Change from uniform to composite (multiple) materials. | X | X |

[1] Problem Solving Pattern, [2] Product View, [3] Process View

*Table 1. Problem Solving Patterns in Engineering – The TRIZ Approach*

After presenting the 40 innovation principles of TRIZ, we analyze them regarding the proposed structuring of "product view" and "process view". Studying the descriptions of the principles, e.g. E1 – "Divide an *object* into independent parts." or E2 – "Extract the 'disturbing' part from an *object* …" (see Table 1), it becomes obvious that the innovation principles basically refer to the *object*, i.e. the result/product, of the construction process. Hence, the innovation principles of the TRIZ approach are patterns possessing a product view, as they refer to the product/artifact which will be developed in the construction process (see fourth column in Table 1). However, looking from a process perspective it can be realized that the innovation principles can also be interpreted as actions that have to be conducted in a construction process. That is why all innovation principles are also marked with an "X" in the "process view" column in Table 1.

# 3 PROBLEM SOLVING PATTERNS IN THE DESIGN SCIENCE RESEARCH DISCIPLINE

In DSR Vaishnavi & Kuechler (2007) were the first proposing problem solving patterns. Amongst patterns for other phases of the construction process, they identified 27 patterns that support the constructor in the "build" phase of the construction process. Each of these patterns is characterized by a name and described in various dimensions: (A) For each pattern the *intended* field of use is described. (B) This is followed by a short statement about the *context and applicability* of the pattern and (C) a *description* about how to use it. (D) This goes together with a short explanation about the *consequences* of the usage of the pattern. Most pattern descriptions are accompanied by (E) *examples* and (F) lists of *sources/references*. (G) Sometimes referrals to *related patterns* are stated as well.

To make an example, the pattern "Approaches for Building Theory" (DSR2) will be explained according to the above listed dimensions (Vaishnavi & Kuechler 2007, p. 122 f.). Due to space limitations (F) *sources and references* are omitted and the description of (E) *examples* is reduced to one example; referrals to (G) *related patterns* are not available for this pattern. This pattern is (A) *intended* to encourage researchers to obtain a general understanding of the different approaches for developing theories. This research pattern can be used after identifying and developing the research problem ((B) *context and applicability*). In order to develop theories the researcher can choose from four different general approaches: (1) hypothetical/deductive, (2) prototyping (hermeneutical/inductive), (3) case-based and (4) historical, whereas each general approach is described in more detail in the book of Vaishnavi & Kuechler (2007) ((C) *description*). As a (D) *consequence* of the use of this pattern, the researcher should assess the suitability of the taken general approach based on the research problem and research area. Maybe corrective actions are necessary in such a way that approaches have to be combined or completely new approaches have to be taken into consideration. As one (E) *example* the research of Chen (1976) is referenced as he used the hypothetical/deductive approach to build theory.

Table 2 contains an overview of the 27 pattern of Vaishnavi & Kuechler (2007) supporting the "build" phase of the construction process. Each pattern is listed by its name and a short description referring to the *intent* of the pattern. Analogous to the innovation principles of TRIZ each pattern is accompanied by a number (DSR1, DSR2, etc.) and two columns indicating the product or process view of a pattern.

| DSR Patterns to Support the "Build" Phase | | | | |
|---|---|---|---|---|
| **No.** | **PSP[1]** | **Description (Intent)** | **Prod.[2]** | **Proc.[3]** |
| DSR1 | Theory Development | Explicitly state the theory that underlies the problem solution. | X | X |

| DSR Patterns to Support the "Build" Phase | | | | |
|---|---|---|---|---|
| **No.** | **PSP[1]** | **Description (Intent)** | **Prod.[2]** | **Proc.[3]** |
| DSR2 | Approaches for Building Theory | Obtain a general understanding of the different approaches for building theory. | | X |
| DSR3 | Hermeneutical and Inductive Approach | Get a complete understanding of the hermeneutical and inductive approach to building theory. | | X |
| DSR4 | Incremental Theory Development | Develop theory in an incremental fashion that addresses the research problem. | X | X |
| DSR5 | Problem Space Tools and Techniques | Identify tools and techniques applicable to the problem space. | | X |
| DSR6 | Research Community Tools and Techniques | Identify the tools and techniques that the relevant research community uses for solving problems similar to one's own research problem. | | X |
| DSR7 | Empirical Refinement | Develop a solution to the research problem through iterations of system development, empirical observation, and refinement. | X | X |
| DSR8 | Easy Solution First | Try an easy solution first. | | X |
| DSR9 | Elegant Design | Design an artifact that is general and can be described functionally. | X | X |
| DSR10 | Divide and Conquer with Balancing | Manage complexity by dividing the problem into identical smaller problems. | | X |
| DSR11 | Hierarchical Design | Design a complex system using the divide and conquer strategy. | X | X |
| DSR12 | Building Blocks | Divide the given complex research problem into smaller problems that can form the building blocks for solving the original problem. | | X |
| DSR13 | Sketching Solution | Sketch the solution to a given research problem (or the design of a complex system). | X | X |
| DSR14 | Emerging Tasks | Identify the next task that can contribute to the solution of the research problem and let the succeeding tasks emerge. | | X |
| DSR15 | Modeling Existing Solutions | Model existing solutions to similar problems to develop a solution approach. | X | X |
| DSR16 | Combining Partial Solutions | Find and combine partial solutions to parts of the research problem to form the entire solution. | X | X |
| DSR17 | Static and Dynamic Parts | Separate the static and dynamic parts of the research problem and solve them separately. | | X |
| DSR18 | Simulation & Exploration | Understand and predict the behavior of a designed system. | | X |
| DSR19 | Interdisciplinary Solution Extrapolation | Explore the possibility that a solution or solution approach to a problem in one discipline or domain can be applied in or adapted to a different domain. | | X |
| DSR20 | Different Perspectives | Look at the research problem from different perspectives. | | X |
| DSR21 | General Solution Principle | Construct a general solution for a class of problems. | X | X |
| DSR22 | Abstracting Concepts | Abstract concepts from existing solutions to generalize the solutions and to theorize. | X | X |
| DSR23 | Using Surrogates | Use surrogates to aid research. | X | X |
| DSR24 | Using Human Roles | Use human roles for ideas and concepts. | | X |
| DSR25 | Integrating Techniques | Integrate existing techniques, models or solutions in areas of their respective strengths. | X | X |
| DSR26 | Technological Approach Exemplars | Use known exemplars to aid solution development. | X | X |
| DSR27 | Means-End-Analysis | Use means-ends analysis to reach a desired solution state. | | X |

[1] Problem Solving Pattern, [2] Product View, [3] Process View

*Table 2. Problem Solving Patterns in the "Build" Phase in DSR (Vaishnavi & Kuechler 2007)*

In analogy to the innovation principles of the TRIZ approach, we analyze the DSR patterns of Vaishnavi & Kuechler (2007) regarding the proposed structuring of "product view" and "process view" as well. Studying the first pattern DSR1 "Theory Development" (see Table 2), it becomes obvious that this is a pattern containing a product view because it suggests that next to the solution, i.e. a construct, model, method or instantiation, another product, i.e. the underlying design theory, should be explicated. Equivalent to the TRIZ principles this DSR pattern can also be regarded as a pattern containing a process view, because it can also be interpreted as an action that has to be conducted in a construction process. Studying the second pattern DSR2 "Approaches for Building Theory" reveals that this pattern only possesses as process view as it tries to support the researcher in obtaining a general understanding of the different approaches for developing theories throughout the construction process. In contrast to the process view of the pattern DSR1 at which the action is directly conducted on the later solution/product of the construction process, the process view of DSR pattern 2 refers to actions that a researcher conducts within a construction process but that are only indirectly related to the later result. The complete analysis of all DSR patterns shows that all DSR patterns contain a process view that is directly or indirectly related to the final solution/result and guides the researcher through the construction process (see Table 2). Furthermore, 13 of these 27 DSR patterns possess a product view as well.[3] Irrespective of being directly or indirectly related to the result of the construction process, patterns that contain a process view will be in the focus of our research. Due to space limitations the product view of the above listed patterns is not compared or expanded any further.

# 4 VERIFICATION AND EXPANSION OF DESIGN SCIENCE RESEARCH PATTERNS

## 4.1 Design Science Research Patterns Verified by the Engineering Discipline

So far the DSR patterns of Vaishnavi and Kuechler (2007) that support the build phase have been based on DSR literature. In order to back them up by their root discipline, they were compared to the 22 universal TRIZ innovation principles (cf. Gericke 2009). Thereby the focus was put on DSR patterns that refer to the process view (see Table 2). Based on the comparison of DSR patterns and the universal innovation principles of the TRIZ approach in (Gericke 2009), Table 3 shows the results of that comparison: Nine DSR patterns could be verified by TRIZ innovation principles of the engineering discipline, which builds the roots of DSR. In Table 3 the first two columns present DSR patterns. The next two columns contain the corresponding TRIZ principles. Finally in the fifth column an explanation about the comparison of the DSR and the TRIZ pattern is given.

| **Comparison of Problem Solving Patterns in DSR and Engineering (TRIZ)** | | | | |
|---|---|---|---|---|
| **No.[1]** | **PSP DSR[2]** | **No.[3]** | **PSP TRIZ[4]** | **Explanation** |
| DSR5 | Problem Space Tools/Techniques | E10 | Prior Action | The identification of problem space tools and techniques can be interpreted as a preliminary action in the construction process. |
| DSR6 | Research Community Tools/ Techniques | E10 | Prior Action | The identification of tools and techniques that the relevant research community uses for solving similar problems can be interpreted as a preliminary action in the construction process. |
| DSR7 | Empirical Refinement | E23 | Feedback | The results of an empirical observation which was conducted on an artifact developed beforehand can be interpreted as feedback and results in the refinement of the artifact. |
| DSR10 | Divide & Conquer with Balancing | E1 | Segmentation | Dividing a problem into smaller problems of identical size is (partly) equivalent to dividing an object into parts (segmentation). |
| DSR11 | Hierarchical Design | E1 | Segmentation | Dividing a complex system into a hierarchy of sub-systems is (partly) equivalent to dividing an object into parts (segmentation). |
| DSR12 | Building Blocks | E1 | Segmentation | Dividing a problem into smaller problems of unequal size is (partly) equivalent to dividing an object into parts (segmentation). |
| DSR20 | Different Perspectives | E17 | Another Dimension | The TRIZ pattern "Another Dimension" is equivalent to the Vaishnavi/Kuechler pattern "Different Perspectives". |

[3] Following a relaxed understanding of "product view", the number of patterns that possess a product view as well can be reduced by three.

| Comparison of Problem Solving Patterns in DSR and Engineering (TRIZ) | | | | |
|---|---|---|---|---|
| No.[1] | PSP DSR[2] | No.[3] | PSP TRIZ[4] | Explanation |
| DSR21 | General Solution Principle | E6 | Universality | An object that performs multiple functions (universality) is comparable to the "General Solution Principle" aiming at the development of a general solution for a class of problems. |
| DSR23 | Using Surrogates | E26 | Copying | The use of simpler and inexpensive copies can be compared to the DSR pattern "use of surrogates". |
| DSR23 | Using Surrogates | E27 | Cheap Short-Living Objects | The replacement of an expensive object by cheap short-living objects is equivalent to the "use of surrogates". |
| DSR23 | Using Surrogates | E28 | Mechanical Substitution | The replacement of mechanical means can also be interpreted as a special case of the DSR pattern "use of surrogates". |

[1] Number of the DSR Pattern (Vaishnavi & Kuechler 2007), [2] Problem Solving Pattern in DSR (Vaishnavi & Kuechler 2007), [3] Number of the Problem Solving Pattern of the TRIZ Approach, [4] Problem Solving Pattern of the TRIZ Approach

*Table 3. Comparison of Problem Solving Patterns in DSR and Engineering (TRIZ) (cf. Gericke 2009)*

## 4.2 Transfer of TRIZ Patterns to the Design Science Research Approach

Based on the comparison of the patterns, we try to transfer the remaining 14 universal innovation principles of TRIZ to DSR. Studying the first remaining TRIZ principle E2 "Extraction", disturbing parts or only the necessary part of an object should be extracted. Transferred to DSR this could be interpreted in such a way that the researcher has to concentrate on solvable parts of the research problem whereas unsolvable parts are (temporarily) not considered. Table 4 presents the results of the transfer of TRIZ patterns. In the first two columns of the table the remaining TRIZ principles are presented. The next two columns of the table contain the new DSR patterns (new number and new name of the pattern) that result from the transfer of the TRIZ principles. Finally in the fifth column an explanation is given on how the TRIZ principle can be used in DSR.

| Transfer of TRIZ Patterns to the DSR Discipline | | | | |
|---|---|---|---|---|
| No.[1] | PSP TRIZ[2] | No.[3] | new PSP DSR[4] | Explanation |
| E2 | Extraction | $DSR^n28$ | Focused Artifact Construction | Concentrate on the construction process and eliminate (temporarily) unsolvable parts of the problem. |
| E3 | Local Quality | $DSR^n29$ | Construction Process Adaptation | Consider contingency aspects in the development phase of an artifact construction process. For example, adapt the construction process to the culture of the research team. |
| E5 | Merging/Consol. | $DSR^n30$ | Multiple Tasks | Bring together the input of multiple researchers on one research problem. |
| E9 | Prior Counteraction | $DSR^n31$ | Side Effect Evaluation | Before evaluating/using a constructed artifact, explore possible negative effects of its use and propose counteractions that have to be conducted prior or parallel to the use of the artifact. |
| E11 | Cushion in Advance | $DSR^n32$ | Rough Solution First | Iteratively develop an artifact to have a rough solution as soon as possible. In the remaining time improve and refine your solution step by step. |
| E12 | Equipotentiality | $DSR^n33$ | Reduce Research Efforts | Reduce your research efforts within the "build" phase by falling back on existing (parts) of solutions stored in construction catalogues, such as method repositories for the construction of methods used in the field of method engineering within the DSR discipline. |
| E13 | Do It in Reverse | $DSR^n34$ | Unconventional Approach | Do something other than expected within the "build" phase. |
| E15 | Dynamics | $DSR^n35$ | Loose Coupling | Use "loose coupling" as a design paradigm. |
| E16 | Partial or Excessive Action | $DSR^n36$ | Partial or Excessive Action | If 100 percent of an artifact is hard to achieve using a given method then, by using "slightly less" or "slightly more" of the same method, the problem may be considerably easier to solve. |
| E20 | Continuity of Useful Action | $DSR^n37$ | Continuous Construction Process | Try to continuously work on the solution of the research problem. Avoid long breaks in order to stay familiar with the problem, your ideas and the planned research procedure. |

| Transfer of TRIZ Patterns to the DSR Discipline | | | | |
|---|---|---|---|---|
| No.[1] | PSP TRIZ[2] | No.[3] | new PSP DSR[4] | Explanation |
| E21 | Rushing Through | DSR$^{n}$38 | Idea Tracking | If you spontaneously got an idea regarding the solution of a given problem, immediately pursue this idea. |
| E22 | Convert Harm Into Benefit | DSR$^{n}$39 | Provocation | Provoke your research team with wrong assumptions in order to improve idea generation regarding the solution of the problem. |
| E24 | Intermediary | DSR$^{n}$40 | Intermediary | Call a mentor or consultant in your construction process that can support you in different activities. |
| E25 | Self-Service | DSR$^{n}$41 | Re-Use Ideas | Document all ideas during the construction process, even if you dismiss them, to take them up in future research projects. |

[1] Number of the Problem Solving Pattern in Engineering (TRIZ), [2] Problem Solving Pattern in Engineering (TRIZ), [3] Number of the new DSR Pattern, [4] new Problem Solving Pattern in DSR

*Table 4. Transfer of TRIZ Principles to DSR*

The attempt to expand the existing DSR patterns by the remaining universal TRIZ innovation principles from the engineering discipline successfully resulted in 14 new DSR patterns. Hence, all 22 universal TRIZ innovation principles could either be used to back up existing DSR patterns or to serve as a basis for the derivation of new DSR patterns.

# 5 SUMMARY AND FURTHER RESEARCH

Analyzing the body of literature of DSR it became obvious that there are patterns/principles missing that guide a constructor within the different phases of the construction process. To address this issue, we took up the DSR patterns of Vaishnavi & Kuechler (2007). Due to the fact that their foundation is limited to DSR literature and comparable concepts from the engineering discipline, which form the roots of DSR, have not been used for their foundation, we analyzed problem solving patterns from the engineering discipline. TRIZ, which is the most established problem solving approach in this discipline, was chosen and the included 22 universal innovation principles presented and analyzed in detail.

To support the analysis of both, the problem solving patterns from TRIZ and the DSR patterns of Vaishnavi & Kuechler (2007), a structuring approach which differentiates between patterns referring to a product perspective (the result of the construction process) and patterns referring to a process perspective (the construction process itself) was used. All DSR patterns possess a process character, whereas only some of them contain a product view as well. In a next step, the DSR patterns referring to the process perspective were compared to the universal innovation principles of TRIZ trying to verify the DSR patterns. In doing so, nine DSR patterns could be verified (cf. Gericke 2009). Using this as a basis, we attempted to expand the DSR patterns of Vaishnavi & Kuechler (2007). The remaining 14 universal innovation principles of TRIZ were additionally transferred to the DSR discipline, i.e. the existing DSR patterns of Vaishnavi & Kuechler (2007) could be successfully expanded to include further patterns from the engineering discipline.

In further research works these new patterns should be evaluated. On the one hand, evidence for these new patterns should be adduced by analyzing existing DSR literature and trying to retrieve these patterns from former research. On the other hand, these patterns can be used in future construction processes and the extent to which the efficiency of the construction process was improved by their use should be evaluated. Furthermore it would be helpful and improve usability of the patterns if the new identified patterns would be described as detailed as the existing DSR patterns, e.g. by describing intent, context and applicability, consequences etc. of the patterns. In addition, further research could address the identification of further DSR patterns. First, it is possible to try to transfer the 18 specific innovation principles of TRIZ to the DSR discipline. Second, the DSR patterns referring to a product perspective could be expanded by including the TRIZ innovation principles. Finally, next to problem solving methodologies from the engineering discipline such approaches from other disciplines, e.g. psychology, could be included in DSR as well.

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