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The RePro technique: a new, systematic technique for rethinking care processes

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ABSTRACT

Purpose: Redesigning care processes is challenging and requires a well thought-out technique that supports healthcare practitioners in generating process improvement ideas. In this paper, we argue that adequate support is still not available and present a new, systematic technique for rethinking care processes: the RePro (Rethinking of Processes) technique. The backbone of this technique is a set of process improvement principles. These principles are based on solutions that have been applied previously and seem worthwhile to replicate in another situation or setting. By inviting practitioners to go through the list of principles in a systematic way, the RePro technique aims to support practitioners in generating a rich set of process improvement ideas.

Research methodology: The backbone of the RePro technique, i.e. the set of RePro principles, is formed by comparing and integrating two groups of principles: *BPR best practices,* which primarily support rethinking administrative processes, and *TRIZ innovation principles*, which in their original form provide support for innovating products. To enable a systematic comparison and integration of these two groups of principles, four panel experts and a moderator were involved in a Delphi procedure. The resulting set of RePro principles was complemented with an application procedure to support practitioners in applying the principles.

Results: The development of the RePro technique led to a set of 45 RePro principles. All these principles address one of the following aspects of a care process: *customers*, *external environment*, *tasks*, *task order and timing*, *human resources*, *facilities, equipment and material*, *information*, *information and communication technology* or *physical lay-out*. The application procedure, which guides practitioners in applying the set of principles, includes the nominal group technique and multi-level design approach as basic ingredients.

Conclusion: The developed RePro technique has the potential to advance support for rethinking care processes.

Keywords: Health Services Research, Delivery of Health Care, Business Process Redesign, Business Process Reengineering, Business Process Improvement, Workflow Engineering, Lean, Six Sigma, Total Quality Management, Service Engineering, Pathways.

INTRODUCTION

Currently, many healthcare organizations are redesigning care processes to achieve efficient and effective patient care.[1-5] Typically, care processes include several consultations, diagnostic tests and treatments, as well as supporting steps, such as scheduling. In order to support practitioners in generating improvement ideas for these processes, a well thought-out technique is needed.[5,6] In the absence of such support,[6-11] healthcare practitioners must rely substantially on their own experience and intuition to generate process improvement ideas.[7,12] This reliance increases the risk on biased choices and neglecting interesting process alternatives.[7,12]

In this paper, we present a new, systematic technique for rethinking care processes: the RePro (Rethinking of Processes) technique. This technique relies on a set of process improvement principles. These principles are based on solutions that have been applied previously and seem worthwhile to reproduce in another situation or setting. Examples of these principles are “control relocation” (move controls to customers) and “task automation” (consider automating tasks). As part of the RePro technique, practitioners are recommended to go through a list of process improvement principles in a systematic way. As such, the RePro technique aims to support practitioners in generating a rich set of process improvement ideas.

BACKGROUND

A typical process improvement initiative consists of describing the as-is situation, conducting an analysis of the as-is to identify process weaknesses, and constructing the to-be process. Whereas a lot of time is typically spent on describing and analyzing the as-is situation in a systematic way, process improvement ideas (to-be) are often generated in one or a few workshops using traditional creativity techniques such as brainstorming.[13] Unfortunately, these techniques lack any guidance with regard to the kind of process alternatives that need to be considered, and do not provide a solution for the personal inertia to search for process alternatives that are different from familiar directions.[7] These limitations restrict the systematic exploration of the full range of redesign possibilities.

Alternatives for traditional creativity techniques

A systematic literature review revealed that several alternatives are available for traditional creativity techniques.[14,15] In particular, three kinds of techniques are available that, in contrast to traditional creativity techniques, offer guidance regarding the kind of process alternatives that are worthwhile to consider: *repository-based*, *case-based* and *rule-based* techniques.

A *repository-based* technique assumes the existence of a repository that includes specifications of numerous existing processes.[15-19] Practitioners have to determine the core activities of the process under study. Subsequently, practitioners are able to explore the process variants available in the repository in a systematic way. The variants in the repository are structured based on the notions of process specializations, coordination mechanisms and process exception handlers. After a systematic exploration of the variants in the repository, practitioners can select the most suitable process design.

A *case-based* technique makes use of a library of well-documented previous business process redesign projects, i.e. BPR cases.[15,20] This technique enables an efficient identification of relevant earlier BPR cases based on a description of several characteristics of the ongoing BPR case. The identified BPR

cases offer process improvement proposals that can be worthwhile to consider for the process under study.

A *rule-based* technique makes use of generic process redesign rules or principles that have accumulated in literature or practice to develop process alternatives.[15] The premise of this technique is that specific process problems can be translated to generic process problems, for which generic principles can offer generic process solutions. An example of a generic principle is the parallelism principle, which states that redesign participants should consider executing tasks in parallel. As the technique's final step, the generic process solutions have to be translated to specific process solutions.

When comparing the principles of the *rule-based* technique with concrete variants offered by the *repository-based* technique and concrete process improvement proposals provided by the *case-based* technique, it can be concluded that *rule-based* techniques offer more abstract redesign guidance. Although this might be considered a weakness, this higher level of abstraction is likely to enable practitioners to generate more diverse and more original process solutions. In addition, *rule-based* techniques do not require the availability and maintenance of a database with either process descriptions or descriptions of process improvement projects. Based on the reasoning above, *rule-based* techniques form the basis of the new RePro technique that is developed as part of this research endeavour.

Rule-based techniques

In literature, two rule-based techniques that rely on a comprehensive set of process redesign principles can be distinguished: techniques that rely on *BPR best practices*, and techniques that rely on *TRIZ innovation principles*.

BPR best practices

The techniques that rely on *BPR best practices* make use of 29 best practices that are derived from a literature review.[21] The 29 best practices are categorized in a framework containing seven categories (see Figure 1):

- *Customers:* best practices focusing on improving contacts with customers;
- *Business process operation:* best practices considering how to implement the workflow;
- *Business process behavior:* best practices focusing on when the workflow is executed;
- *Organization:* best practices considering both the structure of the organization (mostly the allocation of resources) and the resources involved (types and number);
- *Information:* best practices addressing the information the business process uses, creates, may use or may create;
- *Technology:* best practices focusing on the technology the business process uses or may use;
- *External environment*: best practices focusing on improving the collaboration and communication with third parties.

Although the set of BPR best practices has been successfully applied in healthcare,[22] a critical remark needs to be made with regard to its completeness. The set of best practices has been gathered with a bias towards application in the administrative domain. This bias raises concerns about the completeness of the set of best practices for care processes. For example, in contrast to many administrative processes where digital information objects are mainly processed, many care processes require the active involvement of patients throughout the process. Due to this difference, other process alternatives related to the involvement of patients might become of interest. Consequently, further research is needed to investigate potential enhancements for the existing set of best practices.

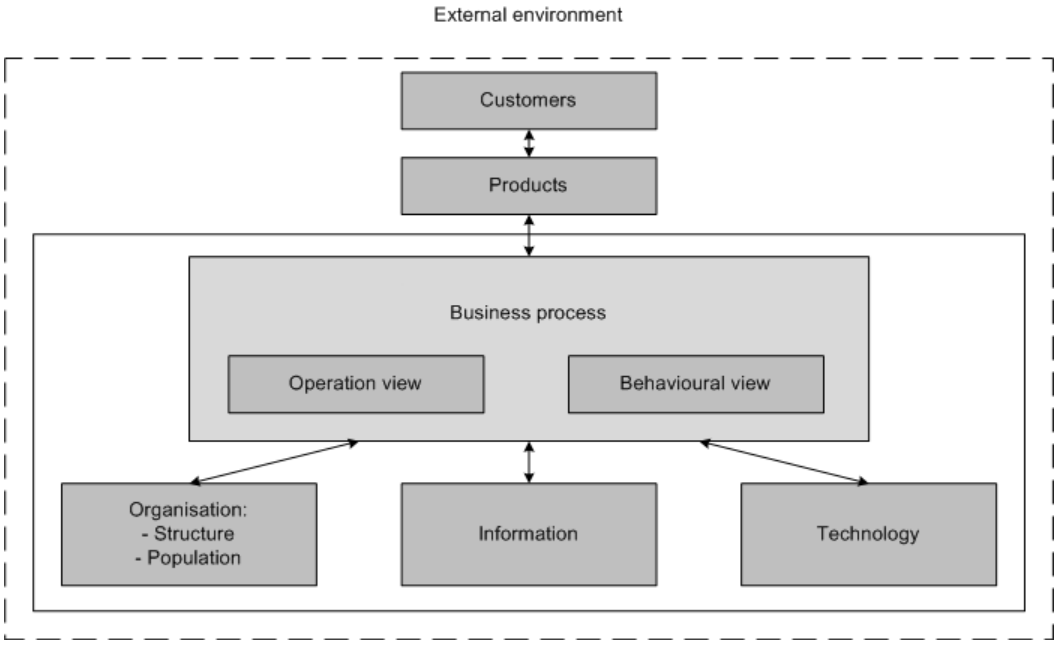

Figure 1. BPR framework.

TRIZ innovation principles

The set of *TRIZ innovation principles* is a source that potentially offers these enhancements. TRIZ is the Russian acronym for "Theory of Inventive Problem Solving".[23] TRIZ was developed by Genrich Altshuller and his colleagues in the USSR in 1946. Based on an analysis of thousands of product patents, product innovation patterns were identified. These patterns were translated into a set of 40 TRIZ innovation principles that provide concrete guidance regarding product innovation options. At first sight, *product* innovation principles do not seem to be directly relevant for rethinking care *processes*. However, care processes share several characteristics with products:

- Care processes face numerous synchronization challenges due to the existence of autonomous medical disciplines and specialized departments that require interdisciplinary cooperation and coordination. Products face, to some extent, similar synchronization challenges due to highly interacting product components.
- Care processes often require the physical presence of patients. Similarly, many products process physical objects (e.g. luggage conveyor systems).
- Care processes as well as products typically have to fulfill strict safety regulations.

Due to these three similarities, we argue that the TRIZ innovation principles have potential to provide new and complementary insights into how care processes can be improved. As far as our knowledge is concerned, the set of TRIZ innovation principles has not been used to improve care processes so far. However, several attempts can be found in literature that use the set of 40 TRIZ innovation principles to improve services or processes in other domains.[23,24] Although promising, a more in-depth investigation of its potential is necessary. In particular, a systematic investigation should reveal whether TRIZ innovation principles (after adaptation to process improvement terminology) provide relevant enhancements for the set of BPR best practices.

RESEARCH METHODOLOGY

In this paper, we outline the development of a new, systematic technique for rethinking care processes: the RePro (Rethinking of Processes) technique. This technique relies on a comprehensive set of RePro principles that is formed by comparing and integrating two groups of principles: BPR best practices and TRIZ innovation principles.

The procedure that was used to systematically compare and integrate the sets of BPR best practices and TRIZ innovation principles was inspired by the Delphi technique.[25] The Delphi technique is a structured discussion technique which relies on a panel of experts who do not need to be in close physical proximity. Typically, the technique contains two rounds of questionnaires and anonymous feedback reports in order to reach consensus about a certain topic. The panel experts are encouraged to revise their earlier answers based on feedback reports that include replies of other panel experts.

A Delphi technique with four panel experts was developed in order to compare and integrate the two groups of principles. This Delphi procedure contained one preparation step and four discussion steps. The preparation step aimed at obtaining a full understanding of the 29 BPR best practices and 40 TRIZ innovation principles. Regarding the four discussion steps that followed, it was decided to take the set of 29 BPR best practices and related categories as a basis. Because care processes typically contain a large administrative component, it is assumed that all BPR best practices and categories are relevant in the context of care processes. During the four discussion steps, it was determined for each TRIZ innovation principle whether (1) it was already captured by one of the existing BPR best practices, (2) it offered a new relevant principle that could be added to the set of BPR best practices or (3) it did not offer a principle that was translatable to a *process* improvement principle. Based on this analysis, new principles and related categories were added to the BPR best practices framework in a systematic way. Each of the four discussion steps contained two individual rounds followed by feedback reports, and one face-to-face consensus round chaired by the moderator. More details with regard to the procedure can be found in Appendix A.

After the comparison and integration of the two groups of principles, a procedure was developed to support practitioners in applying the set of RePro principles.

RESULTS: COMPARISON TRIZ INNOVATION PRINCIPLES AND BPR BEST PRACTICES

In this section, we summarize the results regarding the comparison of TRIZ innovation principles and BPR best practices. All intermediate results of the Delphi procedure can be provided on request.

The results of the Delphi procedure related to the comparison of TRIZ innovation principles and BPR best practices are summarized in Table 1.

Comparison result	Number of TRIZ innovation principles
Principle that is already captured by one of the original BPR best practices.	18 (45%)
Principle that is a valuable addition to the original set of BPR best practices.	8 (20%)
Principle that is not translatable to a process improvement principle.	14 (35%)

Table 1. Summary comparison TRIZ innovation principles and BPR best practices.

The application of the Delphi procedure revealed that 18 out of 40 TRIZ innovation principles (45%) are already (partially) captured by the BPR best practices. More specifically, we identified 14 “is like” association relationships, three “parent-child” generalization relationships and one “child-parent” generalization relationship. An example of the first kind of relationship is the relationship between the TRIZ innovation principle “extraction” (separate an interfering part or property from an object or system, or single out the only necessary part (or property) of an object or system) and the BPR best practice “exception” (design processes for typical orders and isolate exceptional orders from normal flow). An example of the second kind of relationship is the relationship between the (parent) TRIZ innovation principle “partial or excessive action” (if 100% of an object or system is hard to achieve using a given solution method, then, by using “slightly less” or “slightly more” of the same method, the problem may be considerably easier to solve) and the (child) BPR best practice “extra resources” (if capacity is not sufficient, consider increasing the number of resources).

As part of the Delphi procedure, we also concluded that 8 out of 40 TRIZ innovation principles (20%) are valuable additions to the set of BPR best practices. Examples of these TRIZ innovation principles are “prior action” (perform tasks, before they need to be executed, or add tasks to smooth the execution of remaining tasks in the process) and “feedback” (consider introducing feedback). The TRIZ innovation principle “prior action” states that the required change of an object should be performed before it is necessarily needed and prearrangements should be taken to ensure that objects or systems can come into action from the most convenient place and without losing time for their delivery.[23] An example of an application of this principle in healthcare is asking patients to already undress in a preparation room before entering the treatment room. In this way, a medical specialist can immediately start assessing the patient without waiting for the patient to undress. As a result, expensive idle time of the medical specialist is prevented. Similar to “prior action”, the TRIZ innovation principle “feedback” offers a valuable addition to the original set of BPR best practices. An example of an application of this principle is inviting patients to fill in a post-operative questionnaire in order to identify possibilities for improving the quality of the care process.

For 14 out of 40 TRIZ innovation principles (35%), we concluded that the principle is not translatable to a *process* improvement principle. Examples of these principles are “thermal expansion” (use thermal expansion (or contraction) of materials, or if thermal expansion is being used, use multiple materials with different coefficients of thermal expansion) and “composite materials” (change from uniform to composite (multiple) materials). These principles are relevant in the context of *product* innovation, but are not translatable to principles that are relevant in the context of improving *processes*.

RESULTS: REPRO TECHNIQUE

In this section, we explain the final deliverables of the development phase: (1) the RePro framework containing the categories that are used to classify all RePro principles (2) the new RePro principles, and (3) the procedure that supports practitioners in applying the RePro principles.

RePro framework

The identification of the eight TRIZ innovation principles that we considered valuable additions to the original set of BPR best practices led to the extension of the BPR framework with two categories: *facilities, equipment and material* and *physical lay-out* (see Figure 2).

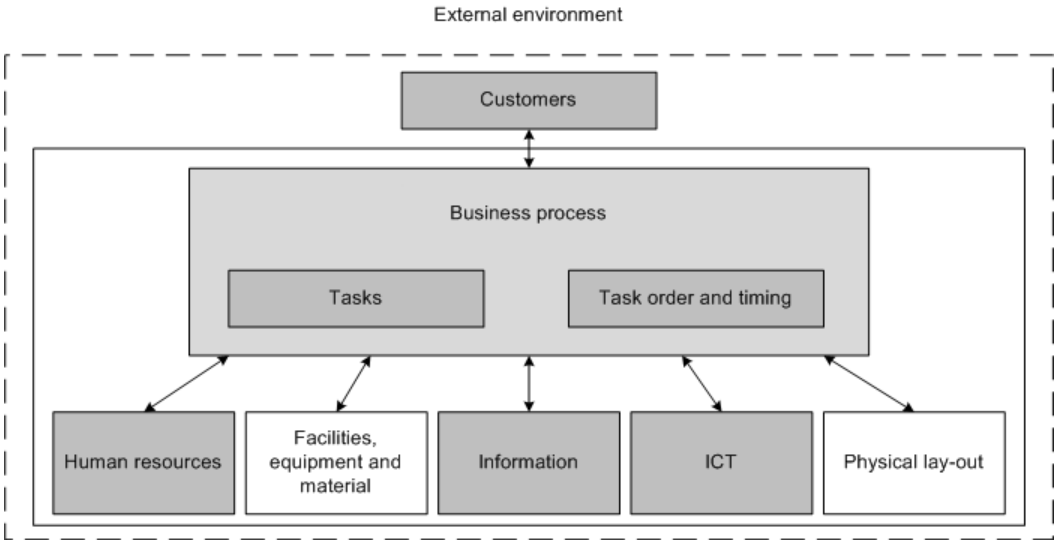

Figure 2. RePro framework.

The first category that we added to the original BPR framework is the category *facilities, equipment and material*. This category includes principles that are related to the number and type of available facilities, equipment and material, as well as the allocation of these non-human resources to patients. In contrast to many administrative processes, care processes typically make use of expensive facilities, equipment and material. Smart usage of them influences process performance in a positive way (e.g. in terms of costs and throughput times). For example, the usage of self-dissolving stitches improves the efficiency of the process by eliminating the need for removing the stitch.

The second category, *physical lay-out*, includes principles that focus on the physical arrangement of the process. Typically, rearrangements of the physical lay-out make other kinds of process changes possible. For example, positioning preparation rooms closer to treatments rooms enables productivity gains by moving preparation activities from treatment to preparations rooms. The absence of the physical lay-out category in the original BPR framework can be explained by the fact that digital objects instead of physical objects / clients are typically transferred in the administrative domain. In contrast to physical transfers, digital transfers are not highly influenced by the physical arrangement of the process.

Besides these two additions, we decided to adjust the name of four original BPR framework categories. More precisely, the original BPR framework categories *operation view*, *behavioural view*, *organisation* and *technology* were replaced by the categories *tasks*, *task order and timing*, *human resources* and *information and communication technology* respectively. We consider these new terms to be better aligned with process redesign terminology (in the healthcare domain). As results of the two additions and four small adjustments, nine RePro categories are distinguished:

- *Customers:* principles focusing on improving contacts with customers;
- *Tasks:* principles considering the (kind of) tasks that are part of the process;
- *Task order and timing:* principles addressing the order in which tasks are executed and the more detailed timing of task execution;
- *Human resources:* principles considering the number and types of available human resources, and the way they are allocated to tasks;
- *Facilities, equipment and material*: principles focusing on the number and types of available facilities, equipment and material, and the way these non-human resources are allocated to tasks;
- *Information:* principles addressing the way information is used or created;

- *ICT:* principles considering how information and communication technology is used;
- *Physical lay-out:* principles focusing on the physical arrangement of the process;
- *External environment*: principles addressing collaboration and communication with third parties.

RePro principles

Besides the eight TRIZ innovation principles and the two new categories that we considered valuable additions to the original set of BPR best practices, we also considered additional enhancements. More specifically, after the identification of eight new TRIZ innovation principles and two new categories, it was decided whether there was added value in adding a TRIZ innovation principle that was in a "generalization" relationship with a BPR best practice to the set of principles. In case of an addition, a decision was made whether keeping the related child or parent BPR best practice in the existing set of principles was valuable or not. In addition, the panel experts were asked to review whether existing principles within a certain category could be copied (with a slightly adapted name and / or definition) to another (new) category. Categories are describing process elements which can be addressed during a redesign project and it might be the case that a certain principle is relevant in more than one category. For example, principles that are relevant in the context of human resources might also be relevant in the context of non-human resources.

In total, 16 new principles were added to the original set of BPR best practices. An overview of these principles is shown in Table 2. The first eight principles are the TRIZ innovation principles that were directly added based on the comparison of the two sets of principles. The other eight principles are the additional enhancements. Besides adding 16 new principles, we also changed the "extra resources" principle (if capacity is not sufficient, consider increasing the number of resources) into "resource adjustment (HR)" (consider changing the number of human resources) based on the identified "parent-child" generalization relationship.

Name principle	Definition	Category
1. Prior counteraction	Add tasks to prevent happening of an undesirable situation or to reduce its impact	Tasks
2. Prior action	Perform tasks, before they need to be executed, or add tasks to smooth the execution of remaining tasks in the process	Tasks
3. Periodic action	Consider making an action periodic or changing the periodicity of an already recurrent action	Task order and timing
4. Shortcut	Introduce process shortcut possibilities	Task order and timing
5. Feedback	Consider introducing feedback	Information
6. Sustainable use	Consider to make use of materials with reusing, dissolving or evaporating characteristics	Facilities, equipment and material
7. Reconstruction	Consider reconstructing the physical lay-out	Physical lay-out
8. Flexible lay-out	Make the physical lay-out flexible	Physical lay-out
9. Substitution (HR)	Replace expensive human resources with less expensive ones	Human resources
10. Buffering (NHR)	Consider to buffer equipment and material	Facilities, equipment and material
11. Flexible assignment (NHR)	Assign non-human resources in such a way that maximal flexibility is preserved for the near future	Facilities, equipment and material
12. Resource adjustment (NHR)	Consider changing the number of involved non-human resources	Facilities, equipment and material
13. Specialist-generalist (NHR)	Consider to replace non-human resources with more specialized or more general-purpose non-human resources	Facilities, equipment and material
14. Substitution (NHR)	Replace expensive non-human resources with less expensive ones	Facilities, equipment and material
15. Copying	Consider to use inexpensive copies of non-human resources instead of expensive original ones	Facilities, equipment and material
16. Physical shortcut	Introduce physical shortcut possibilities	Physical lay-out

Table 2. Overview principles added to the original set of BPR best practices.

A complete overview of all 45 RePro principles can be found at the end of this paper in the Attachment.

RePro application procedure

The application of the set of RePro principles is supported by an application procedure, which describes how the principles can be applied. This procedure is based on the *nominal group technique*[25] and the *multi-level design approach*[26]. Firstly, we explain the design choices for the nominal group technique and the multi-level design approach. Secondly, we discuss the developed application procedure in more detail.

Design choices

Nominal group technique

Typically, multiple persons are involved in rethinking care processes. The *nominal group technique* offers a procedure for groups of individuals that are faced with an idea generating task. This technique is characterized by silent individual idea generation followed by discussion and voting. Van de Ven and Delbecq[25] compared this group technique with the Delphi technique and the traditional interacting group. In their lab experiment, they showed that the nominal group technique and the Delphi technique are significantly more effective than conventional interacting groups in terms of the number of unique ideas generated. In addition, the perceived group satisfaction was significantly higher in the nominal group technique condition than in the two other conditions. Based on these results, Van de Ven and Delbecq[25] recommend the nominal group technique for reaching group consensus in situations where people are easily brought together physically.

Multi-level design

Besides the fact that the RePro application procedure should enable multiple persons to work together on the redesign task, it should also provide a feasible procedure for dealing with the large amount of principles. In previous studies, attempts were undertaken to develop an algorithmic approach to generate a prioritized list of BPR best practices that are worthwhile to consider.[12,22,27-30] Some of the algorithmic approaches require input parameters to be entered by practitioners such as the type of performance improvement dimensions that are most important.[12,22,27,30] Based on the specification of these input parameters and an a-priori determination of the typical impact of a principle on these dimensions, a prioritized list of principles is generated. Although feasible, assigning weights to different improvement dimensions and other input parameters for a business process redesign project is a highly subjective process. Moreover, it is also not straightforward to determine a-priori which principles typically influence a certain process improvement dimension. Other algorithmic approaches make use of process (weaknesses) measures (e.g. a high percentage of control tasks) in combination with condition statements to come up with a list of relevant principles.[28,29] Unfortunately, it turns out to be difficult to identify relevant objective measures for all principles.

Besides the limitations of the algorithmic approaches outlined above, it is also debatable whether the main objective of these approaches targets a highly relevant issue: improving the efficiency of generating process improvement ideas. In many business process redesign projects weeks or months are spent on modelling and analyzing the as-is process, whereas a few hours are typically spent on generating process improvement ideas in a workshop setting. Given this inequality, it seems questionable whether improving the efficiency of generating ideas should be a key objective of a new procedure that supports this task. More important is that the procedure ensures that practitioners do not get overwhelmed by the extensive list of principles and an effective application is facilitated.

Based on the reasoning above, we decided to make use of the *multi-level design* approach. This approach is not an algorithmic approach that leads to a prioritized list of principles, but an approach assuming that service systems can be designed on different levels of abstraction.[26] This approach separates concerns and starts with redesigning the to-be at a relatively high level of abstraction, i.e. the to-be service concept. Subsequently, two lower levels of abstraction related to the to-be process are successively considered. Although such an approach does not necessarily improve the efficiency of generating process improvement ideas, it improves usability by separating concerns.

Outline RePro procedure

The design choices for *nominal group technique* and the *multi-level design* approach led to the RePro procedure as outlined in Figure 3 and 4.

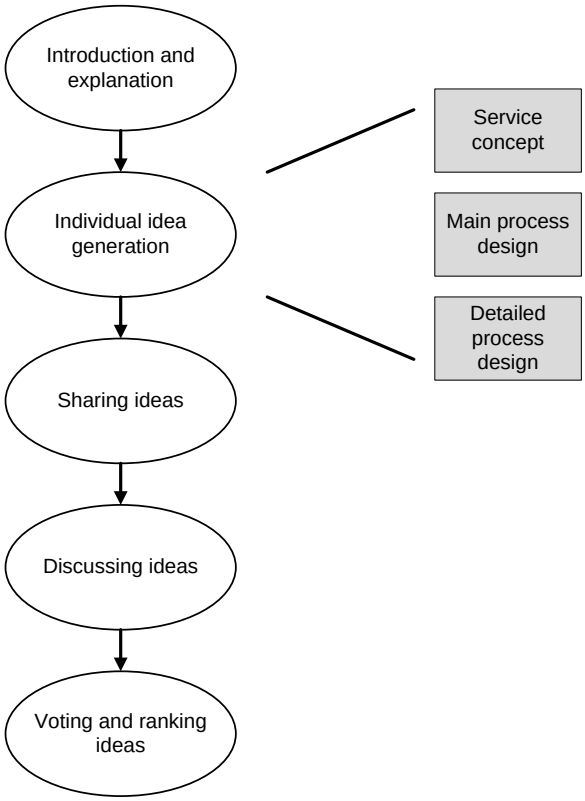

Figure 3. RePro procedure.

As shown in Figure 3, the RePro procedure contains 5 steps:

- Introduction and explanation: The facilitator welcomes the participants and explains to them the objective and procedure of the meeting(s).
- Individual idea generation: Each participant in the redesign session is asked to individually generate and write down a list of process improvement ideas. During this activity, the RePro principles are explicitly considered while following the multi-level design approach as outlined in Figure 4. The participants are asked not to consult other participants or share ideas with each other. This step is discussed in more detail in the next paragraph.
- Sharing ideas: After each participant has generated a list of process improvement ideas based on a careful consideration of the RePro principles, the facilitator invites the participants to share their

process improvement ideas, and records each idea. This round-robin process continues until all ideas are presented. During this activity, there is still no debate about ideas and participants are invited to write down any new ideas that may arise from what others share.

- Discussing ideas: After all participants have received the opportunity to share their ideas and all ideas are recorded by the facilitator, participants are encouraged to seek verbal or further details about any ideas of other participants that are not clear to them. The facilitator needs to ensure that everybody is able to contribute to the discussion, judgment and criticism is prevented, and no ideas are eliminated. New process improvement ideas might be generated during this activity.
- Voting and ranking ideas: After a final list of ideas is recorded, the ideas are prioritized by the participant using a voting and ranking process. Several different voting and ranking processes associated with the nominal group technique can be found in Delbecq, Van de Ven and Gustafson.[31]

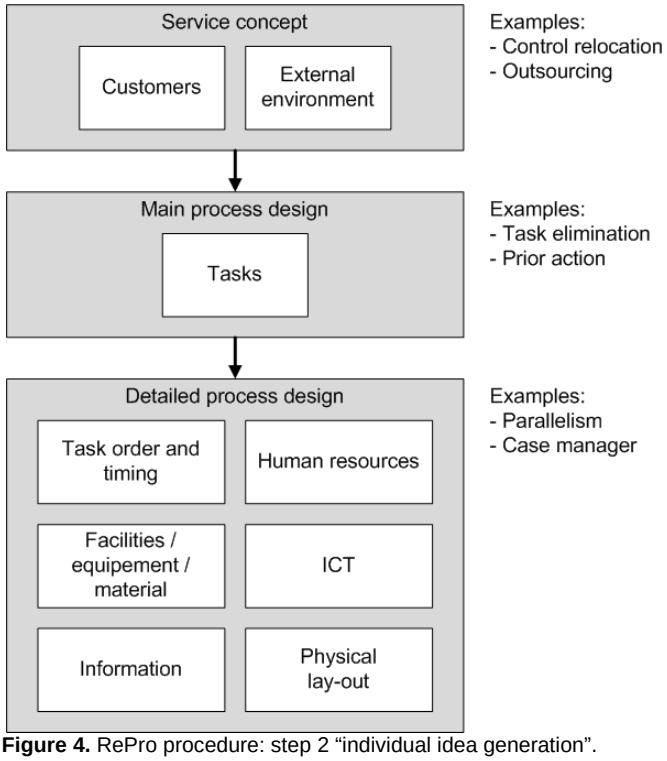

Figure 4. RePro procedure: step 2 “individual idea generation”.

During the second step of the RePro procedure, “individual idea generation”, participants are asked to explicitly consider the set of RePro principles while following the multi-level design approach as shown in Figure 4. The multi-level design approach implies that all RePro principles are assigned to three levels that can be considered successively:

- Service concept: Includes principles that are related to the service concept, i.e. the positioning of the process in relation to its customers and third parties. More specifically, principles at this level focus on improving contacts with customers or try to improve the collaboration and communication with third parties. All principles of the *customers* and *external environment* category are assigned to this level. “Control relocation” (*customers*) and “outsourcing” (*external environment*) are examples of these principles.
- Main process design: Includes principles that are related to the activities that have to be executed in order to fulfill the needs of the customers. The principles of the *tasks* category are assigned to this level, e.g. “task elimination” and “prior action”.
- Detailed process design: Includes principles that are related to the details of task execution, i.e. the

"when, who, with what, where" aspects of task execution. Principles belonging to the *task order and timing*, *human resources*, *facilities, equipment and material*, *information*, *information and communication technology*, and *physical lay-out* category are considered at this level. The "parallelism" (*task order and timing*) and "case manager" (*human resources*) principles are illustrative examples.

Although participants are recommended to consider the three levels successively, iterations between the different levels are allowed. At each level, several RePro principles are available to support practitioners in generating process improvement ideas. For each principle, participants are asked to think about concrete applications, i.e. process improvement ideas related to that principle. After a careful consideration of all principles, the RePro procedure continues with sharing, discussing, and voting and ranking the ideas as discussed in the previous paragraph.

SUMMARY

Improving the performance of care processes is challenging and requires a well thought-out technique that supports healthcare practitioners in generating process improvement ideas. In this paper, we argue that adequate support is still not available and present a new, systematic technique for rethinking care processes: the RePro (Rethinking of Processes) technique. The backbone of this technique is a set of process improvement principles, which is based on a systematic comparison and integration of two groups of principles: *BPR best practices*, which primarily support rethinking administrative processes, and *TRIZ innovation principles,* which in their original form provide support for innovating products. Examples of these principles are "control relocation" (move controls to customers) and "prior action" (perform tasks, before they need to be executed, or add tasks to smooth the execution of remaining tasks in the process). The RePro technique contains an application procedure, which support practitioners in applying the set of RePro principles. This application procedure includes the nominal group technique and the multi-level design approach as basic ingredients.

We contend that the developed RePro technique has the potential to advance support for rethinking care processes.

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ATTACHMENT: OVERVIEW OF REPRO PRINCIPLES

Level 1: Service concept

A. Customers

The principles in the "customers" category focus on improving contacts with customers.

1. Control relocation
'Move controls towards the customer'

2. Contact reduction
'Reduce the number of contacts with customers and third parties'

3. Integration
'Consider the integration with a process of the customer or a supplier'

B. External environment

The principles in the "external environment" category address the collaboration and communication with third parties.

4. Trusted party
'Instead of determining information oneself, use results of a trusted party'

5. Outsourcing
'Consider outsourcing a process in whole or parts of it'

6. Interfacing
'Consider a standardized interface with customers and partners'

Level 2: Main process design

C. Tasks

The principles in the "task" category focus on the (kind of) tasks that are part of the process.

7. Order types
'Determine whether tasks are related to the same type of order (patient group) and, if necessary, distinguish new processes'

8. Task elimination
'Eliminate unnecessary tasks from the process'

9. Prior counteraction
'Add tasks to prevent happening of an undesirable situation or to reduce its impact'

10. Prior action
'Perform tasks, before they need to be executed, or add tasks to smooth the execution of remaining tasks in the process'

11. Triage
'Consider the division of a general task into two or more alternative tasks' or 'consider the integration of two or more alternative tasks into one general task'

12. Task composition
'Combine small tasks into composite tasks and divide large tasks into workable smaller tasks'

Level 3: Detailed process design

D. Task order and timing

The principles in the "tasks order and timing" category consider the order in which tasks are executed and the more detailed timing of task execution.

13. Order-based work
'Consider removing batch-processing and periodic activities from the process'

14. Periodic action
'Consider making an action periodic or changing the periodicity of an already recurrent action'

15. Shortcut
'Introduce process shortcut possibilities'

16. Resequencing
'Move tasks to more appropriate places'

17. Knock-out
'Order knock-outs in an increasing order of effort and in a decreasing order of termination probability'

18. Parallelism
'Consider whether tasks may be executed in parallel'

19. Exception handling
'Design processes for typical orders (patients) and isolate exceptional orders (patients) from normal flow'

E. Human resources

The principles in the "human resources" category are mainly concerned with the number and types of available human resources, and the way they are allocated to tasks.

20. Order assignment
'Let workers perform as many steps as possible for single orders (patients)'

21. Customer teams
'Consider assigning teams out of different departmental workers that will take care of the complete handling of specific sorts of orders (patients)'

22. Case manager
'Appoint one person as responsible for the handling of an order (patient), the case manager'

23. Flexible assignment (HR)
'Assign human resources in such a way that maximal flexibility is preserved for the near future'

24. Centralization
'Treat geographically dispersed human resources as if they are centralized'

25. Split responsibilities
'Avoid assignment of task responsibilities to people from different functional units'

26. Numerical involvement
'Minimize the number of departments, groups and persons involved in the process'

27. Resource adjustment (HR)
'Consider changing the number of human resources'

28. Specialist / generalist (HR)
'Consider to make human resources more specialized or more generalist'

29. Empower
'Give workers most of the decision-making authority and reduce middle management'

30. Substitution (HR)
'Replace expensive human resources with less expensive ones'

F. Facilities, equipment and material

The principles in the "facilities, equipment and material" category are mainly concerned with the number and types of available facilities, equipment and material, and the way these non-human resources are allocated to tasks.

31. Flexible assignment (NHR)
'Assign non-human resources in such a way that maximal flexibility is preserved for the near future'

32. Buffering (NHR)
'Consider to buffer equipment and material'

33. Resource adjustment (NHR)
'Consider changing the number of non-human resources'

34. Specialist / generalist (NHR)
'Consider to replace non-human resources with more specialized or more general-purpose non-human resources'

35. Substitution (NHR)
'Replace expensive non-human resources with less expensive ones'

36. Copying
'Consider to use inexpensive copies of non-human resources instead of expensive original ones'

37. Sustainable use
'Consider to make use of material with reusable, dissolving or evaporating characteristics'

G. Information

The principles in the "information" category focus on the way information is used or created.

38. Control addition
'Check the completeness and correctness of incoming materials and check the output before it is send to customers'

39. Buffering (I)
'Instead of requesting information from an external source, buffer it by subscribing to updates'

40. Feedback
'*Consider introducing feedback'*

H. Information and communication technology

The principles in the "information and communication technology (ICT)" category focus on how information and communication technology is used.

41. Task automation
'Consider automating tasks'

42. Integral technology
'*Try to elevate physical constraints in a process by applying new technology'*

I. Physical lay-out

The principles in the "physical lay-out" category focus on the physical arrangement of the process.

43. Reconstruction
'Consider reconstructing the physical lay-out'

44. Flexible lay-out
'Make the physical lay-out flexible'

45. Physical shortcut
'Introduce physical shortcut possibilities'

Appendix A: Details research methodology Delphi procedure

1. Introduction

This appendix presents the final protocol that supported the execution of the Delphi procedure that was used to compare and integrate two groups of process improvement principles: *BPR best practices,* which primarily support rethinking administrative processes[1], and *TRIZ innovation* principles, which in their original form provide support for innovating products[2]. In section 2 of this protocol, we briefly discuss the composition of the team that executed the Delphi procedure. In section 3, the Delphi procedure itself is described.

2. Team composition

The Delphi procedure team consisted of one *moderator* and four *panel experts*. The *moderator* was responsible for the development of the Delphi procedure. In addition, he was responsible for the coordination of all administrative activities during the execution of the procedure, and for chairing all discussion meetings with the expert panel. The *panel experts* were involved in executing the different steps of the Delphi procedure. All panel experts had followed several university-level courses with regard to Business Process Management, and had been involved in at least two business process redesign projects.

3. Procedure details

The Delphi procedure consisted of five steps:

1. Obtain a full understanding of the 29 BPR best practices[1] and 40 TRIZ innovation principles[2]
2. Consider the atomicity of the 29 BPR best practices
3. Identify relationships between the two groups of principles
4. Identify new principles and related new categories
5. Identify additional enhancements

Except the first step, each step contained two individual rounds and one consensus round. During the first individual round, each panel expert had to execute the step as explained in a detailed instruction document. After the first individual round, the moderator collected the results and provided an anonymous overview of the panel experts' results. During the second individual round, each panel expert was encouraged to revise her / his earlier answers in the light of the replies of other panel experts. After the second individual round, the moderator provided again an anonymous overview of the panel experts' results. This overview was input for the consensus round. During this round, a meeting was organized with all panel experts to reach consensus in a face-to-face meeting chaired by the moderator.

Each step of the Delphi procedure is explained in more detail below.

Step 1: Obtain a full understanding of the 29 BPR best practices and 40 TRIZ innovation principles

As a first step, the 29 BPR best practices and related categories, and the 40 TRIZ innovation principles were studied in detail by the panel experts. The 29 BPR best practices were gathered with the administrative domain as application domain in mind. Because care processes typically contain a large administrative component, it is assumed that all BPR best practices and related categories are relevant in the context of care processes.

The 40 TRIZ innovation principles are based on an analysis of thousands of product patents and support in developing new product designs. As discussed in our main paper, we argue that TRIZ innovation principles have potential to provide new and complementary insights into how care processes can be improved.

Based on the reasoning above, it was decided to compare the 40 TRIZ innovation principles with the 29 BPR best practices (as outlined below). In the remainder of this document, we often use the term "principles" to refer to "BPR best practices" as well as "TRIZ innovation principles".

Step 2: Consider the atomicity of the 29 BPR best practices

Several BPR best practices include dichotomous scenarios (e.g.specialist-generalist: consider to make resources *more specialized* or *more generalist*). In order to facilitate an easy comparison between TRIZ innovation principles and BPR best practices, it was decided to identify the BPR best practices with dichotomous scenarios and to split these practices in two atomic principles (e.g. specialist: consider to make resources *more specialized*; generalist: consider to make resources *more generalist*). Table 1 was used by the panel experts to document their results.

BPR best practice (original)	**BPR best practice (variant 1)**	**BPR best practice definition (variant 1)**	**BPR best practice (variant 2)**	**BPR best practice definition (variant 2)**

Table 1. Documentation step 2.

Step 3: Identify relationships between the two groups of principles

After considering the atomicity of the BPR best practices, relationships between the TRIZ innovation principles and (atomic) BPR best practices were identified. More specifically, each TRIZ innovation principle was compared with the set of BPR best practices and the following relationships were considered successively:

- **Association** – An "is like" association relationship implies that the TRIZ innovation principle has a similar meaning as one of the BPR best practices.
- **Generalization** – A generalization relationship indicates that one principle (child) is considered to be a specialized form of another principle (parent). Both directions are possible in our case: either a TRIZ innovation principle can be a child of a BPR best practice, or a BPR best practice can be a child of a TRIZ innovation principle.
- **None of the above relationships**

The following rules were taken into when identifying relationships between principles:

- It is assumed that each TRIZ innovation principle has an "association" relationship with at maximum one BPR best practice.
- A "generalization" relationship is considered if no "association" relationship is identified.

- For each identified relationship, the panel expert needs to explain her / his choice.

The results of this step were documented by the panel experts in Table 2.

TRIZ innovation principle	BPR best practice	BPR best practice category	Relationship	Comments

Table 2. Documentation step 3.

Step 4: Identify new principles and related new categories

After the identification of the relationships, we investigated possibilities for adding new TRIZ related principles and related new categories to the set of BPR best practices. More specifically, we assessed each TRIZ innovation principle for which neither an "association" nor a "generalization" relationship was identified in the previous step. This assessment was aimed at identifying TRIZ innovation principles that can be translated into a new principle that is not covered by the existing set of BPR best practices. Here, translation refers to aligning the wording of the name and / or definition of the principle with common *process redesign* terminology. The following possibilities were considered successively:

- A TRIZ innovation principle can be translated into a new principle and can be added to an existing BPR best practice category.
- A TRIZ innovation principle can be translated into a new principle, but it cannot be added to an existing BPR best practice category. In this case, a new category has to be defined.
- A TRIZ innovation principle cannot be translated into a new principle (i.e. it is related to a characteristic that is specific for products, such a thermal expansion).

The following rules were taken into account while making the above decision:

- For each TRIZ innovation principle that can be translated into a new principle, the panel expert needs to explain her / his decision (in the form of illustrative application examples).
- For each TRIZ innovation principle that can be translated into a new principle, a decision has to be made whether the name and / or definition of the principle needs adjustment in order to align the terminology with common process redesign terminology.
- When creating new categories, one point of concern is whether several principles can be added to the same new category. Preferably, a category is defined such that it is broad enough to capture multiple principles, but specific enough to be meaningful.

The results of this step were documented by the panel experts in Table 3 and 4.

TRIZ innovation principle	TRIZ innovation principle (renamed)	TRIZ innovation principle definition (renamed)	Existing / new category	Comments

Table 3. Documentation step 4 (new principles).

New category	New category description

Table 4. Documentation step 4 (new categories).

Step 5: Identify additional enhancements

After the identification of new principles and new categories, it was decided whether there was added value in adding a TRIZ innovation principle that was in a "generalization" relationship with a BPR best practice to the set of principles. In case of an addition, a decision was made whether keeping the related child or parent BPR best practice in the existing set of principles was valuable or not. In addition, the panel experts were asked to review whether existing principles within a certain category could be copied (with a slightly adapted name and / or definition) to another (new) category. Categories are describing process aspects that can be addressed during a redesign project and it might be the case that a certain principle is relevant in more than one category.

In line with previous steps, the panel experts had to explain their decisions. Table 5 and 6 were used to document the results of this step.

TRIZ innovation principle	**Relationship**	**BPR best practice**	**Category**	**Addition / substitution**	**TRIZ innovation principle (renamed)**	**TRIZ innovation principle definition (renamed)**	**Comments**

Table 5. Documentation step 5 (added / substituted principles).

TRIZ innovation principle (original)	**TRIZ innovation principle (renamed)**	**Relation-ship**	**BPR best practice**	**Current category**	**New category**	**Principle (renamed in new category)**	**Principle definition (renamed in new category)**	**Com-ments**

Table 6. Documentation step 5 (principles copied to other categories).

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