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TRIZ-REVERSE FOR PSS POTENTIAL DETERMINATION

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Abstract: *Product Service Systems (PSS), can be considered as mass customization business models with an extended time horizon. For the development of such customer-specific hybrid value propositions, small and medium-sized enterprises (SME) face the challenge of identifying relevant potential for PSS in their areas of competence, as they often lack capacities, experts or the appropriate tools and methods. In order to counteract this, the paper presents an approach which allows to identify the potential on the basis of the products and services already offered by the company and the individual customer requirements. For this purpose the contradiction formulation and resolution of the Theory of Inventive Problem Solving (TRIZ) included the TRIZ-Reverse approach is used and adapted for the PSS application. The original TRIZ contradiction matrix as well as existing PSS-TRIZ approaches are analyzed and enhanced to a PSS-specific contradiction matrix, which is integrated into the procedure of the specific potential determination according to TRIZ-Reverse. So this paper provides a method which supports SME to analyse the potential of different PSS solutions by showing resolvable contradictions. And moreover to identify the most promising offers for a further development and extension to a PSS.*

Key Words: ***Product Service System, PSS, TRIZ, TRIZ-Reverse, Potential Determination, Small and Medium-sized Enterprises (SME)***

1. INTRODUCTION

Due to increasing technological progress, digitalization and growing competitive pressure as a result of globalization, companies are facing great challenges in order to maintain their economic position in the future [1]. For traditional mechanical engineering, the integration of products and services opens up new value creation potential [2]. Through the combination of product and service components, Product Service Systems (PSS) offer companies the opportunity to better adapt to customer needs and to differentiate themselves from the competition due to increasing digitalization [3]. However, many companies do not use the given potentials. The Monitoring Report of the Federal Ministry for Economic Affairs and Energy 2018 shows that only about one-third of German mechanical engineering companies use digitally driven services to expand their own offerings. And only one fifth use technological progress to establish new business models. The obstacles to this do not usually arise from technological causes, but rather have economic or organizational reasons [4].

To counteract this, an approach to determine the potential for PSS implementation is necessary. This should be done with respect to the products and services already offered by the company and regarding the customer needs to be satisfied. This is particularly advantageous for small and medium-sized enterprises. The obstacles to changing the business model are relatively high for these companies, because this process is always risky [42]. Therefore, potentials must be identified, which can be implemented with small changes and little effort. PSS offer new approaches for companies to implement functions of a value proposition. For product development, this results in the ability to find novel solutions for constructive problems. The ability to satisfy conflicting requirements is enhanced by the service and digitization components [1].

One approach to determining the potential of new technologies is TRIZ-Reverse, which is based on the Theory of Inventive Problem Solving (TRIZ). It was originally developed in the Collaborative Research Center (CRC) 1153 - Tailored Forming to investigate the potential of multimaterial forming components. It is used to analyze which contradictions in conventional components can be resolved by the new technology [5, 6].

The aim of this paper is finding an approach to determine the potential of PSS by using an adapted TRIZ-Reverse. To realize this, the inventive principles contained in TRIZ must be translated into PSS-specific principles.

Accordingly, the first part of the paper introduces PSS as well as TRIZ and TRIZ-Reverse. Subsequently a procedure for Systematic Literature Review (SLR) is presented in which already developed PSS principles are analyzed and summarized in an expert workshop. The results of the SLR and the workshop are presented in the following part 4. Then the TRIZ-Reverse approach for PSS is explained and how it is used to discover PSS potentials. Finally a conclusion and an outlook are given.

2. STATE OF THE ART

2.1. Product Service Systems (PSS)

For PSS, different characterizations and approaches for the development are discussed in literature [7, 8, 9, 10, 11]. A frequently used characterization was developed by Tukker [11] and distinguishes three different types of PSS (product-, use- and result-oriented) and the corresponding business models depending on the content of the physical product and service components of the value chain (Fig. 1):

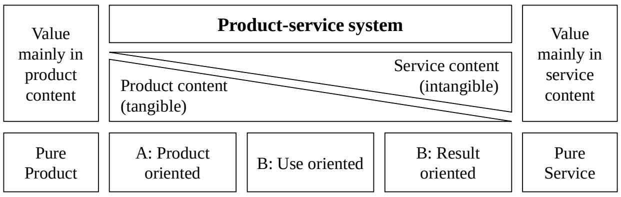

Fig. 1. *Main PSS categories based on Tukker [11]*

For the research and development of PSS, multidisciplinarity and thus the involvement of researchers from different fields of interest is a great challenge. So far, none of the existing approaches can be considered as a generally accepted and standardized approach for the development of PSS [12, 13]. Nevertheless, it is necessary to integrate these different views and to consider the components of the system equally [14].

When considering and developing PSS, four dimensions or relevant areas can be identified, the most obvious being product and service. Which should be considered coequal in the development [15]. **Products** that are tangible goods and can also be produced for sale. **Services** are activities (work) for others with an economic value, usually performed on a commercial basis [16].

In addition to services, **information technology (IT)** must be considered in the context of digitization [3]. Within the framework of PSS, information and communication technologies enable many services and additional value creation. These are now accessible and affordable, and to a large extent it is possible for manufacturers to enhance their products with information technology [17].

The fourth dimension is the **business model (BM)**, in which PSS enables the manufacturer to offer a higher value that differentiates more easily from the competition. The goal of PSS logic is to use the knowledge of the designer/manufacturer to both increase value as output and reduce material and other costs as input to a system [18]. Thus, another feature of the PSS that affects the usual ways of making profits is the possibility of generating income and profits not through sales but through efficiency gains [19].

2.2. TRIZ

TRIZ is the Russian acronym for the Theory of Inventive Problem Solving. It is a set of methods for the structured and systematic development of products [20]. The knowledge underlying TRIZ is based on the analysis of several million patents. Characteristic for TRIZ is the thinking in contradictions. The purpose is to generate innovative solutions by resolving contradictions [21]. A typical contradiction is, for example, that the weight of a component is to be decreased but the strength must not be reduced. With a non-systematic solution search (e.g. Trial and Error) the probability of finding the best solution for complex problems is relatively small. TRIZ uses the mechanism of abstraction for this, because the analysis of the patents showed that a large number of different solutions are based on a relatively small number of generalized solution principles. For the solution, the concrete contradiction is translated into a generalized contradiction, which is then resolved by a generalized solution principle. The generalized solution principles originate from the patent analysis and are the so-called 40 Inventive Principles. The generalized contradiction, is formulated by two of 50 technical parameters [22]. In order to ensure a systematic approach, TRIZ offers the contradiction matrix as a tool to assign the correct Inventive Principles for the solution to the formulated contradiction. Since the number of Inventive Principles has remained constant over the last decades even after several updates (e.g. [22]), it can be assumed that new and previously unknown technologies will also be covered by them.

2.3. TRIZ-Reverse

According to Brockmöller et al. [5], the procedure of contradiction resolution can also be used to determine the potential of unknown technologies. Figure 2 shows the process of resolving a contradiction with TRIZ [23] compared to the TRIZ-Reverse process [5]. The lower part of Figure 2 shows that the procedure is performed in reverse order. The first step is to determine which of the 40 Inventive Principles offer a solution for the technology under investigation. Then all irrelevant principles are removed from the contradiction matrix. Now, only the technology-specific contradictions are present and the potential of the technology becomes visible. In the CRC 1153, TRIZ-Reverse is used to determine whether the use of the Tailored Forming technology is worthwhile for the components under investigation. Here TRIZ-Reverse is part of a computer-aided engineering environment and the first process step to design Tailored Forming components from scratch. Note that TRIZ-Reverse is not to be confused with “Reverse TRIZ”. This is an approach to detect failures of a system during early development stages, similar to the Failure Mode and Effects Analysis (FMEA) [24].

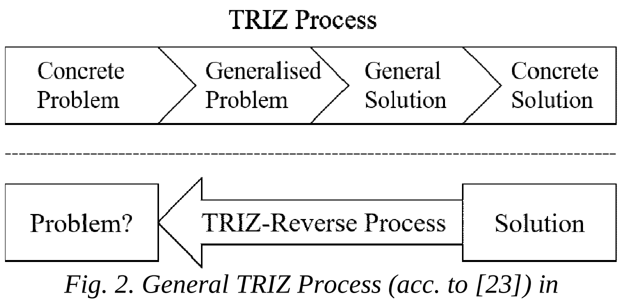

Fig. 2. General TRIZ Process (acc. to [23]) in comparison with TRIZ-Reverse Process (acc. to [5])

3. DEPLOYED RESEARCH METHODS

3.1. Systematic Literature Review (SLR)

For a systematic literature review a defined procedure is necessary, in which the research question to be treated and the methods for its implementation are named. These include a search strategy aimed at finding as much relevant literature as possible and its documentation [25]. The entire review process must be disclosed, including the selection of keywords and sources, the derivation of search phrases, the definition of evaluation criteria, etc [26, 27]. The result of the research is to describe the current state of research or knowledge available in the scientific literature and to base further work on it [28].

The procedure of the literature analysis is shown in Figure 3 and its steps are based on the findings of Thorpe and Hold [29] and Kitchenham [30]. It is divided into the following seven steps:

(1) Research question of the SLR, in which the underlying research questions are defined. (2) Selection of literature databases, in which a reasoned selection of the databases used for the research is made. (3) Definition of the search phrases used for the analysis and derived from the research questions. (4) Merging of the search results, in which the search hits are merged and duplicates are removed from the data set. (5) Application of the exclusion criteria, by which the search results are further narrowed down and reduced by the irrelevant hits. (6) Conduction of the review, in which the information is filtered out of the literature and prepared for further work steps. (7) Synthesis of the result, further use and processing of the results from the literature.

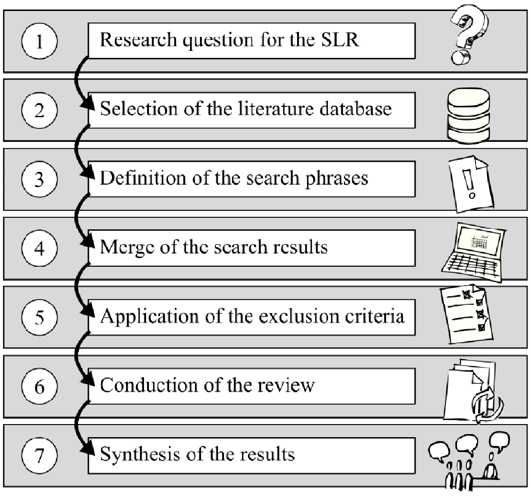

Fig. 3. *Phases of the SLR procedure*

The seventh step of the SLR in the context of this paper takes the form of a workshop. The workshop design is presented in Section 3.3.

3.2. Execution of the Literature Review

The literature analysis is carried out starting with step (1), in which the underlying research questions are derived from the motivation and the state of the art. The review is based on the following two questions:

- ***SLRQ 1:*** *to what extent is TRIZ applied in the PSS literature and is it used to determine potential?*
- ***SLRQ 2:*** *how were TRIZ principles interpreted in the literature for PSS or in relation to PSS?*

In the second step (2), Google Scholar and Scopus are selected as the considered databases. Google Scholar is chosen because of its variety of sources and its interdisciplinary overview of prior research including various studies and academic papers. It is extended by the search in the Scopus database, as it is an important database especially for leading journals and proceedings from publications on the PSS research area. For the advanced search in both databases, it is possible to define different keywords and their combination and merging by using search phrases. This is done in the third step (3) and is documented in Table 1.

Table 1. *Search phrase for Google Scholar and Scopus*

Google Scholar	(„Product Service System" OR „PSS" OR „IPSS" OR „Industrial Product Service System") AND („TRIZ" OR „Potential determination")
Scopus	(„Product AND Service AND System" OR „PSS" OR „IPSS" OR „Industrial AND Product AND Service AND System") AND („TRIZ" OR „Potential AND determination")

The result lists of the searches were sorted by relevance, and since a continuously decreasing relevance of the articles for our research purpose could be observed in the rear hits, only the first 10 pages of the results (N=100 articles) were considered, which could be assumed as a sufficiently large sample. In the next step (4) the results from the searches were merged and the duplicates removed from the lists, resulting in a sample of N=155 articles (see step I in Figure 4 of the SLR results).

This is followed by the application of the exclusion criteria (5), which is illustrated in Figure 4 by steps II and III. First the headlines and abstracts of the articles were read and the number was reduced to N=135 articles. After carrying out the review (6) for the remaining articles with focus on the use of Innovative Solution Principles with a reference to PSS or the determination of potentials of PSS, the selection could be narrowed down to N=10 relevant articles. The essential information from these articles was processed and analyzed in a workshop and the results were synthesized (7).

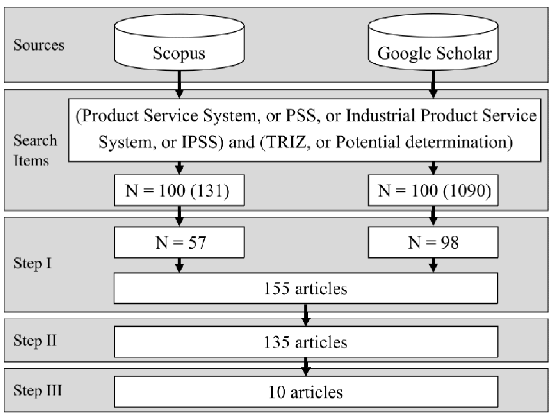

Fig. 4. *SLR Results*

3.3. Coding Workshop

In order to evaluate and classify the results of the SLR, a focus group workshop [31] was organized. This is a guided discussion among experts from the fields of product development, industrial engineering and information systems research. The aim of the workshop was to create a uniform basis for resolving contradictions in PSS from the results of the SLR. The workshop was planned in such a way that the interpretations of the principles were discussed one after the other in order to analyse the statements. The interpretations will be generalized and, if necessary, assigned to other principles. In addition, the focus group is intended to supplement missing aspects.

4. RESULTS OF THE STUDY

4.1. Results of the Literature Review

The result of the literatur research shows that definitions and interpretations of the basic innovative principles for PSS are available in the existing literature. However, these differ significantly in some cases. One reason is that very specific examples are used (e.g. Cosmetics [32]), or the description is very general and uses the same examples for different principles (e.g. [33]). Often the principles also refer to individual parts (products or services) of the PSS (e.g. [34]) and not to the overall system. With respect to the interdisciplinarity and holistic system view of the principles, the results of the SLR are synthesized in the coding workshop.

4.2. Findings of the Coding Workshop

The results of the SLR formed the basis for the discussions within the focus group by making the interpretations of the 40 Innventive Principles available to the workshop in a roughly pre-sorted form. The following are the issues that were discussed in the workshop.

One result of the SLR is that different authors assign the same interpretations to different principles. As a consequence, the focus group has re-sorted some of the interpretations so that the same interpretations are clearly assigned to a single principle. Furthermore, it has been recognized that in the PSS area some of the 40 inventive principles are subprinciples of other ones. Interpretations of these subprinciples have been assigned to the respective parent principles. In addition, some interpretations are formulated in such general terms that a concrete reference to a PSS is not possible. These have not been further considered. The same applies to purely product-related interpretations, since in this case the classical TRIZ can still be used. The result of the workshop is that not all 40 inventive principles of the classical TRIZ are used for a PSS. 28 of the original 40 innoventive principles remain for which a PSS can offer a solution. The principles P09, P10, P14, P29-P33 and P37-P40 are not suitable for PSS or are part of another principle. For example, Principles P09 (Preliminary counteraction) and P10 (Preliminary action) are almost entirely merged into Principle P11 (Beforehand cushioning). Finally, principles P18 and P28 have been renamed from a purely mechanical to a PSS context (P18 mechanical vibration to oscillation and P28 mechanical substitution to virtualization).

4.3. Elaborated PSS Principles

Table 2. shows the 28 PSS principles and their interpretations that were developed during the workshop. It also shows which authors used the same interpretation for the same principle (column "same") and - if available - in which other principles the interpretation was found in the literature (column "different"). In addition, Table 2. contains further interpretations (in italics) that were added by the focus group.

In order to be able to apply the PSS principles systematically in the sense of TRIZ, an assignment to parameter-based contradictions is also necessary here.

Table 2. PSS Principles

PSS-Principles	Same	Different
Principle 1: Segmentation		
• Segment the service (processes) into individual tasks, products into modules (experts, specialized machines or programs for certain subtasks)	[35], [36], [37], [40], [41]	
• Segment users/customers (e.g. needs, age, buying behaviour)	[34], [41]	[41]: P03
• *Segment the service according to local or regional differences*		
Principle 2: Taking out		
• Operate Outsourcing	[33], [40]	[34]: P24; [40]: P24
• *Clean up your value network to achieve more direct customer interaction (horizontal integration)*		
Principle 3: Local Quality		
• Adapt products/services to the needs of the customers/users (personalization)	[33], [34], [40], [41]	[34]: P35; [41]: P4, P31, P35
• Create a "feel-good atmosphere" in your branches	[41]	[41]: P6, P10, P32, P35
• *Adapt your stock keeping to the local conditions (customer orientation)*		
Principle 4: Asymetry		
• Destandardization (products/ processes), consciously providing with degrees of freedom	[34], [41]	
• *Provide Predictive Maintenence*		
Principle 5: Merging		
• Bring together products and/or services (bundle offer/operator business models)	[34], [41]	
• Bring products and services together in time and place (sequential)		[40]: P40

Principle 6: Universality		
• Have various services performed by one person, machine or program	[34], [40]	
• Use already existing components of products/services/places to use them additionally in another way		[40]: P05
• Provide sharing and leasing offers		[40]: P17
Principle 7: Nesting		
• Offer additional services during a service (parallel)	[34], [41]	[34]: P40; [39]: P05; [40]: P20; [41]: P40
• Connect different services and let them exchange information	[41]	
Principle 8: Anti-weight		
• Use a brand image to distract from poor quality		[34]. P22, [41]: P22, P29
• *Compensate insufficient product features through software or services and vice versa*		
Principle 11: Beforehand cushioning		
• Use condition-based maintenance, *sensor integration and monitoring*		[40]: P09, P25
• Offer the user or customer securities in advance (e.g. money-back guarantee)		[34]: P09, P10; [40]: P09
• Plan possibilities for updating or customer communication (e.g. software update)		[41]: P09
• Store and interpret usage data to monitor product behavior		[35]: P10, P26.
• Train users, customers or own personnel to improve the use or application / Provide instructions or advice		[40]: P10; [41]: P09, P10, P16, P19
• Provide total redundancies in the value network	[39], [40]	
Principle 12: Equipotentiality		
• Offer the same service at different locations	[34], [40], [41]	[41]: P10
• *Cooperate with others to compensate local market differences*		
Principle 13: Inversion		
• Reverse the type of responsibility	[40], [41]	
• Reverse the type of distribution	[41]	
• *Reverse the type of payment (performance in advance)*		
Principle 15: Dynamics		
• Use pricing models adapted to the conditions / use contracts flexibly	[34]	[34]: P11; [35]: P16; [37]. P12; [41]: P11
• Personalize products, services or programs / Plan service or system configurations and reconfigurations	[41]	[32]. P10
• Design products, services or programs flexibly (transient devices for temporary supply)	[40]	[34]: P13, P30 P34; [41]: P30
• Let the system make its own decisions		[35]: P25
• Set focus on small market to serve it more effectively or vice versa		[41]: P35
Principle 16: Partial or excessive action		
• *Overfulfill requirements to keep the number of variants small (level models in configuration or price, portfolio analysis)*		
Principle 17: Another Dimension		
• Use different product-service-combinations for the same results (e.g. street cleaning, telephone advice)		
• Use the Closed-loop life cycle/economy		[38]: P20; [33]: P20
Principle 18: Oscillation		
• Adjust supply and price to demand / Use demand peaks and adjust the PSS accordingly	[34], [41]	[34]: P19, P36; [41]: P15, P19, P36, P37
• Adapt innovation cycles to technological trends		[33]: P17; [41]: P35
Principle 19: Periodic action		
• Ask for regular customer and user feedback	[34], [40]	[41]: P14, P23 P31
• Periodically check the status of all systems and services	[40], [41]	
• *Adjust maintenance intervals*		
Principle 20: Continuity of useful action		
• Store learned knowledge in databases and use it	[35]	
• *Bring regular updates*		
Principle 21: Skipping		
• Reduce waiting time for customers and users/ Provide additional services to "seemingly" reduce waiting time for customers and users	[34], [41]	[34]: P16, P31; [41]: P31
• *Offer the PSS flexibly and skip unnecessary processes*		
• *Offer privileges to Reduce the waiting time of customers*		

Principle 22: Convert harm into benefit		
• Learn from mistakes/complaints and reclamations and improve the processes	[34], [41]	[34]: P23; [40]: P23; [41]: P23
• Use of waste materials	[33], [40]	
• Offer additional service in case of problems to strengthen customer loyalty	[41]	
• *Operate retrofit offers*		
Principle 23: Feedback		
• Regularly report sales and inventory back to enable inventory adjustments	[41]	
• *Adapt the product, service, processes and programs according to the feedback or usage data*		
Principle 24: Intermediary		
• Intermediate services and products	[41]	
• Use multi-level sales systems (direct to end customers, B2B sales, platform economy)		[32]: P28; [41]: P17
• *Integrate your own systems into systems of other suppliers (and vice versa)*		
Principle 25: Self service		
• Let users or customers run part of the PSS (co-design or prosumer models)	[33], [34], [38], [40], [41]	[41]: P38
• *Let the PSS supply itself with consumables*		
Principle 26: Copying		
• Use systems to replace/support the human	[35], [41]	
• Transfer processes and methods from foreign systems and Adapt them (cross innovation)	[34], [41]	[33]: P05; [41]: P05
• *Adapt Best Practice Examples*		
Principle 27: Cheap short-living objects		
• Used limited (test) versions	[34], [41]	
• "Sacrifice" products to fulfill services		[40]: P34; [41]: P34
• Match the product life cycle with the properties of the materials used (obsolescence)	[40], [41]	
Principle 28: Virtualization		
• Use the advantages of digitalization and virtualization (e.g. remote maintenance, servitization, ...)	[34], [41]	
• Automate processes and services		[41]: P02
Principle 34: Discard and recovering		
• Repair, replace or dispose products or components (install replacement part circuits)	[40]	
Principle 35: Parameter changes		
• Adapt the environmental conditions for your own operation		
Principle 36: Phase transition		
• Adapt the service to the product lifecycle	[40]	
• Adapt the PSS to the life phase and circumstances of customers and users	[40], [41]	

4.4. List of TRIZ Parameter for PSS

Even if the constancy of the number of parameters is not quite as strict as with the principles, they are also defined for TRIZ and are continuously updated. For this reason, the existing parameters are used here, but since these have an influence on different dimensions of a PSS, the parameters are assigned to the dimensions. The dimensions have already been presented in Section 2.1, the assignment of the parameters, which dimensions they concern, was done by the described focus group.

Subsequently, the matrix is checked for consistency with principles (Section 4.3.) and the parameters. This results in the list of parameters for PSS (Table 3).

During the assignment it is noticeable that usually the product dimension is marked, which is a consequence to the fact that TRIZ has its origin in product development. However, the focus shifts to the consideration of systems. Starting with parameter 30 (e.g. for 32-40 non-functional parameters) many already refer to systems or consequences of the system concept that is also necessary for the PSS view. All dimensions are often selected here.

Table 3. *TRIZ parameter for PSS*

Parameter	**Product**	**Service**	**IT**	**BM**
1. Weight of moving object	x	x		
2. Weight of Stationary Object	x			
3. Length/Angle of Moving Object	x	x		
4. Length/Angle of Stationary Object	x			
5. Area of Moving Object	x			x
6. Area of Stationary Object	x			x
7. Volume of Moving Object	x	x		
8. Volume of Stationary Object	x			
9. Shape	x	x		
10. Amount of Substance	x	x		
11. Amount of Information	x	x	x	x
12. Duration of Action of Moving Object	x	x	x	
13. Duration of Action of Stationary Object	x		x	
14. Speed	x	x	x	
15. Force/Torque	x			
16. Energy Used by Moving Object	x			x
17. Energy Used by Stationary Object	x			x
18. Power	x	x		
19. Stress/Pressure	x			
20. Strength	x			
21. Stability	x			
22. Temperature	x			

23. Illumination Intensity	x	x		
24. Function Efficiency	x	x	x	
25. Loss of Substance	x	x		x
26. Loss of Time		x	x	x
27. Loss of Energy	x			
28. Loss of Information		x	x	
29. Noise	x	x		
30. Harmful Emissions	x			
31. Other Harmful Effects Generated by System	x	x	x	x
32. Adaptability/Versatility	x	x	x	x
33. Compatibility/Connectability	x	x	x	
34. Trainability/Operability/Controllability	x	x	x	
35. Reliability/Robustness	x	x	x	x
36. Reparability	x	x		
37. Security	x	x	x	
38. Safety/Vulnerability	x	x	x	
39. Aesthetics/Appearance	x	x	x	
40. Other Harmful Effects Acting on System	x	x	x	x
41. Manufacturability	x	x		
42. Manufacture Precision/Consistency	x		x	x
43. Automation	x	x	x	
44. Productivity	x	x	x	
45. System Complexity	x	x	x	x
46. Control Complexity	x		x	x
47. Positive Intangible Factors		x	x	x
48. Negative Intangible Factors		x	x	x
49. Ability to Detect/Measure	x	x	x	
50. Measurement Precision	x	x	x	

4.5. Enter the Matrix

In order to create a tool that can be used to capture the potential of a PSS implementation, the TRIZ-Reverse method is used. The principles relevant for PSS have already been identified during the workshop.

Improving Parameter ↓ / Worsening Parameter →		…	34	35	36	37	38	…
		…	Trainability/Operability/Controllability	Reliability/Robustness	Repairability	Security	Safety/Vulnerability	…
…	…							
24	Function Efficiency		25 ~~10~~ 1 13	35 ~~30~~ ~~40~~ 28	2 27 17 1	28 2 1 24	~~31~~ ~~30~~ 2 24	
25	Loss of Substance		3 15 ~~32~~ 2	~~10~~ 12 35 24	2 ~~14~~ 35 4	2 17 12 28	24 19 ~~31~~ 5	
26	Loss of Time		~~10~~ 25 4 26	35 ~~10~~ 3 ~~14~~	17 24 ~~32~~ 1	2 28 26 ~~9~~	25 12 13 11	
27	Loss of Energy		13 1 35 25	35 ~~40~~ 17 11	1 19 ~~30~~ 2	28 3 2 26	19 4 35 ~~31~~	
28	Loss of Information		7 1 3 ~~10~~ 5	13 24 ~~10~~ 26	2 ~~10~~ 17 13	26 24 25 1	~~10~~ 28 24 7	
…	…							

Fig. 5. Extract from the PSS contradiction matrix

Subsequently, the TRIZ-Reverse matrix (in this case the updated Matrix 2010 by Mann is used [22]) is now reduced by removing the principles that are not relevant for PSS. A section of the resulting PSS matrix is shown in Figure 5. The PSS matrix now depicts for which parameter combinations and contradictions PSS offers a solution and for which not. The division into the four dimensions of a PSS illustrates the areas where potential for PSS development exists.

5. TRIZ-REVERSE FOR PSS POTENTIAL DETERMINATION

Two different ways of determining the potential can be selected: On the one hand, the procedure can be applied generally for PSS. However, this leads to a high amount of work and a very confusing matrix, since irrelevant contradictions are also mapped. On the other hand, certain partial solutions or concrete application scenarios can be considered. In this case, the PSS-specific matrix can be reduced accordingly in advance, so that only relevant contradictions are mapped and the potential becomes more visible. For this reason, the procedure for determining potential for a concrete application scenario is shown below and illustrated using an example.

5.1. Systematic Approach of the TRIZ-Reverse Process for PSS

To reduce the matrix, the procedure of TRIZ-Reverse is applied to a specific PSS solution. The systematic approach is shown in Figure 6.

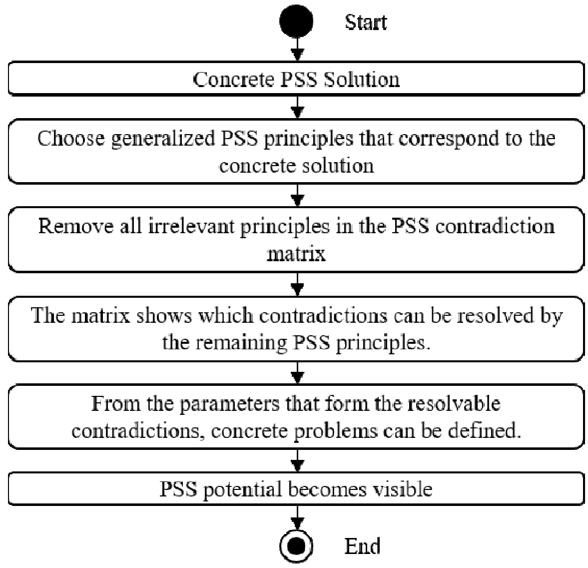

Fig. 6. TRIZ-Reverse process for PSS

In this way it can be analysed how different contradictions can be resolved with little effort. In addition, areas can be identified that are particularly suitable for the company, as capacities or expertise are already available for these cases. Furthermore, areas can be discovered which offer the corresponding potential, so that an investment to build up capacities or expertise is worthwhile. The reduced PSS matrix can be used in combination with the PSS principles analogous to the classical contradiction resolution process.

5.2. Potential Determination with TRIZ-Reverse for a PSS Application Example

For the potential determination and application of TRIZ-Reverse, a manufacturer of gastronomy coffee machines is considered who already offers an additional maintenance and cleaning service but wants to offer coffee to the customer in a results-oriented way and thus become a solution provider. For this purpose, he can integrate the existing services into the value proposition, but is facing the necessary expansion of his offer to include the supply of the machines with consumer goods.

TRIZ-Reverse is now used for the presented part of the PSS, so that the potential of consumer goods supply can be considered. In the first step, the PSS principles are reduced with respect to the existing **solution** (consumer goods supply). This results in an adapted list with the principles P01, P02, P03, P12, P13, P19 and P25. These can be regarded as the **generalized solutions**. In the next step, the PSS contradiction matrix with the parameters is also reduced by the deleted principles. In this way, the contradictory parameter combinations (as **generalized problems**) can now be deduced. Potentially **concrete problems** can be derived from these parameter combinations. From these existing parameter combinations, parameters relevant for the company or application are now determined.

For the example considered here, Figure 7 shows a section of the matrix for the parameters 24-28 (improvement) and 34-38 (deterioration), from which the relevant contradiction of the parameters 26 Loss of time (improvement) and 38 Safety (deterioration) is now considered. For a solution provider who sells coffee in a result-oriented manner, including the supply of consumables, a high time expenditure for delivery is problematic, as it becomes expensive due to personnel costs. It is therefore the aim to reduce this loss of time as far as possible. At the same time, the result-oriented supplier is responsible for the quality of the result and must therefore guarantee security against misuse or abuse in the process chain. He must therefore secure functions and processes in the system so that certain standards can be guaranteed in the result and are not endangered by time pressure.

When looking at the three deposited principles (P25, P12 and P13), however, potentials for resolving these contradictions become apparent. To this end, the dimensions of the parameters are first examined and the congruent ones identified. For parameters 26 and 38, these are the dimensions of service and information technology.

Based on the principle P25 "Self service (Let users or customers run part of the PSS)", the refill (controlled) by the customer can be derived for the service, which for IT means the implementation of a manual via the machine display or another device. With such a instruction, for example, it is possible to confirm that steps have been carried out (for quality assurance).

From Principle P12, "Equipotentiality (offer the same service on different locations/Cooperate with others to compensate local market differences)", it can be derived that the same bean quality is provided for the service, which can be achieved, for example, through licensed local roasting facilities. For IT, this results in the demand for a multi-sided platform for exchange and contact between roasting facility and machine or machine user.

From Principle P13 "Inversion (e.g. reverse the type of responsibility)" follows the approach of holding the customer responsible. For the service of consumer goods supply, this means that the user of the machine is obliged to comply with a minimum quality standard. For IT, this results in a platform or interface through which appropriately qualified critics can evaluate the coffee.

Worsening Parameter → / Improving Parameter ↓		…	34	35	36	37	38	…
		…	Trainability/Operability/ Controllability	Reliability/Robustness	Repairability	Security	Safety/Vulnerability	…
…	…							
24	Function Efficiency		25 1 13		2 1	2 1	2	
25	Loss of Substance		3 2	12	2	2 12	19	
26	Loss of Time		25	3	1	2	25 12 13	
27	Loss of Energy		13 1 25		1 19 2	3 2	19	
28	Loss of Information		1 3	13	2 13	25 1		
…	…							

Fig. 7. Extract from the "Consumer goods supply" contradiction matrix

6. CONCLUSION AND OUTLOOK

This paper shows how the TRIZ-Reverse method developed from TRIZ is used to determine potential for the use of PSS. For this it is necessary to interpret the inventive principles of TRIZ in a PSS specific context. In order to be able to use TRIZ-Reverse in a meaningful way, the number of principles must be reduced. So it is possible to concentrate on individual aspects of a PSS. Otherwise it results in a high amount of work and large scope and a focused illustration of the potentials is not possible. Using the example shown in this paper, which is limited to consumer goods supply, the number of principles to be considered was reduced from 28 to 7. In the PSS contradiction matrix, all other principles were subsequently removed. So the matrix indicates which contradictions can occur in consumer goods supply and how these can be resolved. By assigning the parameters to the four dimensions of a PSS, the potential of the technology and the areas in which it must be implemented become visible. The matrix can then be used like the classic TRIZ matrix.

Since a PSS-specific patent search is not feasible, a database set up analogous to Altschuller's patent search is not possible. Therefore the approach of reinterpreting the classic TRIZ principles was chosen. For this purpose the current state of TRIZ research and the use of TRIZ in the PSS field of research was analyzed. In the future it will be investigated whether the new interpretation of the PSS principles can cover the entire area of PSS. It must also be clarified whether the dependencies between the contradiction to be resolved and the assigned principle are retained in the PSS contradiction matrix. However, the principles are formulated in such a general way that they offer a wide scope for interpretation and yet potentials and solutions are found. To be able to evaluate these points nevertheless, further application examples are necessary. Ideally, the determination of potential is tested on a real application and compared with previous results.

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