Towards a Comprehensive Systematic Innovation Model: A Literature review

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***Abstract*—The management of innovation would require a distinctive innovation process. There are indications that the innovation process is vaguely described, which means it will be difficult to manage it.**

Two streams of innovation processes are discussed and a generalisation of one of them to determine the extent of having a comprehensive systematic innovation process model. For the purpose of this paper a short definition of innovation is given. The innovation methods, systematic innovation, creative problem solving and TRIZ are briefly discussed. Methods to analyse problems is given as adequate definitions of problems are necessary for efficient finding of solutions. Idea creation techniques are discussed as well as the evaluation and implementation of ideas.

Systematic innovation for business and management and the influence of psychological factors, problem definition and solving is examined. The conclusion looks at the combination of the creative problem solving and TRIZ processes and tools as presented in the model for systematic innovation for business and management and provide an evaluation of it. The detected shortcomings towards being comprehensive are indicated.

***Index Terms*—Innovation, Innovation Management, Management**

I. Introduction

[1] stated that in 30 years he had met very few entrepreneurs who had the "entrepreneurial personality" that was supposed to be the common trait of entrepreneurs. Successful entrepreneurs rather have a common commitment to systematic innovation.

Successful entrepreneurial innovations in general, apart from a flash of genius, originate from a conscious and purposeful search for such opportunities. There are four internal situations where such opportunities exist:

1. Unexpected occurrences;
2. Incongruities;
3. Process needs; &
4. Industry and market changes.

External to an organisation in its social and intellectual environment there are three other issues:

1. Demographic changes;
2. Changes in perception; &
3. New knowledge

The sources overlap, have different risk, difficulty and complexity natures and could give rise to opportunities in more than one area at a time. According to [1] they account for the majority of opportunities for innovation.

A. Definition of Innovation

Innovation is defined in two ways. According to Miriam-Webster: "the introduction of something new" and "a new idea, method, or device — novelty"[2].

A related concept is renovation. The definitions of renovate are: "to restore to a former better state (as by cleaning, repairing, or rebuilding)" and "to restore to life, vigour, or activity" [3].

Innovation is also defined as [4]:

1. The generation of an idea or invention; and
2. The implementation or exploitation of it.

In [4] the following steps for the management of innovation to effectively use the resources of an organisation are provided:

1. Creating new knowledge
2. Generation of technical ideas based on the new knowledge aimed at new products, processes and services
3. Development of the new ideas into working prototypes
4. Transferring and transforming of the prototypes for manufacturing, marketing and utilisation.

It is reasoned that a causal link clearly exists between knowledge sourcing and an innovative business result. The strength and level of contribution of each of these activities varies and depends on the chosen innovation indicator [5].

The literature on innovation processes is impeded, because knowledge, innovation and ideation are used as synonyms. Knowledge is a resource used in innovation and a possible outcome of the process and ideation is part of the creative activities that enables innovation. Innovation involves change, but the reverse is not necessarily true [6].

B. Need for and benefits of innovation

Innovative products and services should result from the stimulation of persons' creativity and that leads to the generation of employment for others that participate in the establishment and implementation of the products and/or services [7], [8].

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C. Management of Innovation

It is not difficult to determine the contribution innovation can make to competitiveness. It is, however, difficult to correlate innovation and performance. This may be caused by the lack of systematic innovation and the resulting unpredictability [9].

Innovators achieve higher profit margins than their counterparts. Cyclical downturns affect innovating firms much less [9].

Studies of innovation management are in general normative and focused on the requirements of successful innovation. Formal management of innovation processes is not a common practice. Different approaches have been used inside a single organisation, because a contextual approach will in general render the best solutions [10].

Investment in R&D does not by itself create the organisational ability to be innovative. If it is assumed to render innovation, assumptions are made about the sequence and order of events occurring in the organisation — it is considered an input and cannot determine the output. Innovation is considered an output, but the fundamental mechanisms through which it is rendered has not been fully developed [6].

II. Purpose of this paper

The problem is that in the management model and like in [4] the detail of the innovation process is omitted. This paper will show some approaches to the innovation process itself with the focus on being systematic of nature and attempt to show the progress towards a comprehensive innovation process model. With a comprehensive process model it would be easier to implement systematic innovation and to manage the process efficiently.

III. Innovation Methods

A. Systematic Innovation

Many step-by-step innovation methods can be found in the literature, for instance [11] lists in excess of 190 methods and variations of them. In [12] and a subsequent publication more than 100 creative techniques are detailed. Each of these techniques have recommended steps to follow and could therefore be classified as systematic.

Analysis of the techniques will show that the majority of them are methods to find either new ideas or solutions concepts for problems. Some of these techniques will assist the user to use divergent thinking. Most of them use current knowledge and observations. This and the common approach to see what the boundaries of potential implementations are, leads to accepting compromises, which means that they could probably be innovative, but are limited by accepting the compromises as rules to all innovation, or as in [13]: "Old solutions to new problems".

B. Creative Problem Solving Methods

The existence of a problem or opportunity is a prerequisite for using Creative Problem Solving (CPS), else it would be a fruitless effort. A perceived gap could be detected as a problem, the perception being the main qualifier. The difference between the status quo and the desired is used to define the type of situation as follows [12]:

1. Anticipated opportunities exist when a change in goals would be required;
2. A threat to the goal would exist if the status changes;&
3. Opportunistic development such as totally new ideas might be possible if both states are changing.

1) Redefinitional Methods: Absence of an adequate definition of a problem is a major set back for the efficient solution of problems. Without it there exists a high probability that a solution will not be found. The initial perception of a problem in general will determine the approach taken to solve it [12].

The following methods are suggested to redefine a problem [12]:

1. Boundary Examinations;
2. Goal Orientation;
3. 5W1H: (Who? What? Where? When? Why? & How? as actions);
4. Progressive Abstractions; &
5. Why Method.

To analyse problems the following methods can be used [12]:

1. Decomposable Matrices;- Breaking problems down into subsystems that can be analysed;
2. Dimensional Analysis:- Take into account various dimensions of a problem;
3. Input-Output:- Consideration of various sequences of input and output;
4. Organised Random Search:- A less organised method, useful for less complex problems; &
5. Relevance Systems:- Consideration of the constraint of solutions.

2) Idea Creation Techniques: The following principles should enhance the creation of ideas [12]:

1. Postpone judgement:- Early criticism of ideas will reduce the amount of proposals given. Judgement should only be used during the evaluation and selection phases;
2. Quality through quantity:- This based on the assumption that if five out of hundred is good, then if a thousand is available then fifty good ideas can be expected;
3. Wilder ideas are better:- Wild ideas can, with modification, lead to breakthrough ideas;
4. Combine and Improve:- Many ideas on their own could be less worthwhile, but after they are combined with other and somewhat improved they could be very useful.
5. Do not ponder too long at a time:- Exhaustion reduces people's creativity, and it be could useful to move to another problem after some time has been spent on the current one.

The CPS techniques for the creation of ideas are typically divided whether they are more suitable for individuals or groups, but this categorisation is not always absolute. Some of them in either subclass could be modified and adapted to be used in the other. Another distinction can be applied to the items in each subclass:

1. Brainstorming and brainwriting, &
2. Free association or forced relationships [12].

Brainstorm refers to the verbal creation of ideas and brainwriting refers to creating ideas by means of writing. The former is typical group methods and the latter mostly used by individuals. Both of these are based on either free association, forced relationship or a combination of them. Free association is the creating of ideas without any specific stimulus, the ideas generated could serve as stimuli. In the case of forced relationships a specific stimulus serves as the source for creating ideas, it forces together related or unrelated concepts [12].

All the idea generation methods that are discussed in [12] are either brainstorming or brainwriting types. The latter ones use silent creation of ideas in writing, while the other ones are verbal of nature. He also states that the brainstorming definition is more generic than the technique called Classic Brainstorming. Brainwriting type of methods are in general used by individuals. Brainstorming is only useful in small groups and brainwriting is the recommended approach for large groups. Brainwriting can be conducted without a facilitator.

The idea generation methods have two dimensions: 1. The procedure dimension: Forced relationships or Free Association; & 2. The stimulus dimension: Related or Unrelated stimuli. Forced relationship is based on the forced combination of two or more concepts to produce ideas, whereas in free associations the creation is based on the current knowledge that includes experience and observation to create ideas. The relatedness of the stimuli determines the uniqueness of the ideas created. Both types of stimuli may be present in some techniques. Related stimuli are also useful and may be the best approach to some problems and groups [12].

3) Evaluating and Selecting Ideas: The next step in the CPS processes is to evaluate and select the most suitable ideas. The following classes of techniques are provided in for selecting an alternative between generated ideas:

1. Individual Techniques;
2. Group techniques with abundant time available; &
3. Group techniques with limited time available.

The evaluation methods are variants and combinations of considering the disadvantages against the advantages, simulation, voting, weighting alternatives and analysis of their effectiveness in achieving the goal [12].

4) Implementing Ideas: In [12] four techniques to implement ideas are given. Three of them are primarily used to implement moderate to complex solutions. The fourth is aimed at detecting the potential negative results of the possible solution alternatives, but it could also be used to assist in the selection of alternatives. The following methods are given [12]:

1. Consensus Mapping
   In this method consensus is reached through drawing of 'strawman' maps in which each subgroup depicts the sequence of activities and estimated time frames to implement an idea or a combination of ideas.
2. Potential Problem Analysis
   This method is a risk analysis method to determine the importance of risks and the abatement thereof.
3. Program Evaluation Review Technique
   This a standard project management technique that evaluates the critical path(s) of an implementation process.
4. Research Planning Diagram
   This is a process flow method with expected time values attached to each step of the process. If a process exceeds the associated time value the total process can either be re-planned or aborted if it seems that it will not be successful, depending on the progress at the specific hold point in the flow diagram.

The processes are all valid management tools for implementation, typically used in project management. They are, however, suggested as the direct follow-up of the selection of the most suited idea or set of ideas to solve a problem. In some cases, an idea might be merely implemented, but in general it would require development of the detail of the idea to be in a position to implement it and there is not a clear indication of this as a requirement in the approach depicted in [12].

Several other approaches could also be followed that would assist in the management of the implementation of ideas. It is also not clear how these selected techniques contribute specifically to the creative solving of problems or why other methods would not also suffice.

5) Eclectic and Miscellaneous Techniques: Fourteen methods have been classified as being either eclectic or miscellaneous. The eclectic methods combine two or more techniques and the miscellaneous ones combine stages of problem solving into one [12].

The techniques are:

A. Eclectic Techniques: 1.) Bobele-Buchanan, 2.) Coca-Cola, 3.) Creative Problem Solving, 4.) Lateral Thinking, 5.) Value Engineering,
B. Miscellaneous Techniques: 1.) Decision Seminar, 2.) Delphi, 3.) The Idea Generator, 4.) Idea Tracking, 5.) Kepner-Tregoe, 6.) Nominal Group Technique, 7.) Packcorp Scientific Approach, 8.) Phases of Integrated Problem Solving, 9.) Problem Centered Leadership,

C. TRIZ and its derivatives

An algorithm was developed for inventive problem solving (ARIZ) in which the aim is not to settle for the compromises, but to go beyond [14]. It was the result of analysing numerous patents to derive the generic steps followed (see also [15]). This was a method to combine the different tools developed as part of TRIZ ("Theory of the Solution of Inventive Problems" in Russian) [16], [14].

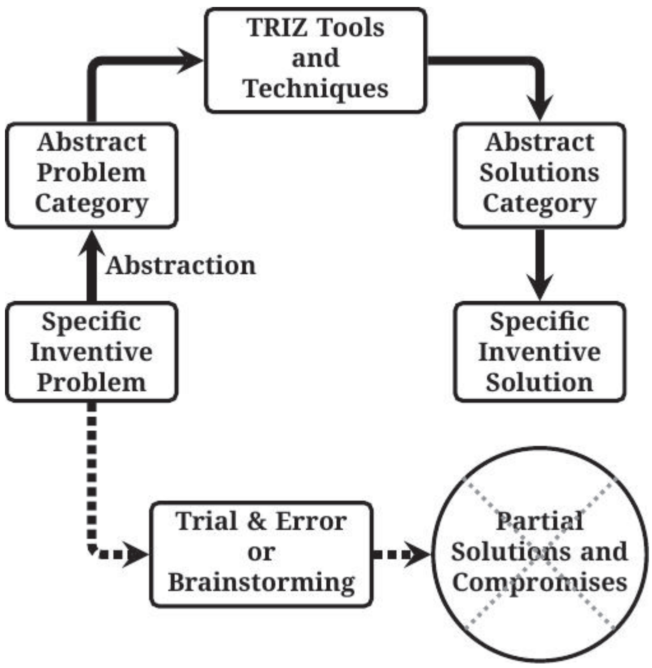

Figure 1. TRIZ solution process (adapted from [14], [16])

Direct derivatives of this algorithm like “SIT” [17] and “USIT” [18] aim to do the same but with less complexity. These methods start with a known problem and work to an ideal generic solution.

Further development of TRIZ was proposed, because the conclusion was reached that more people were starting to utilise the TRIZ methods and tools for problems outside the scope of engineering. It was called OSTM, from the Russian of General Theory of Powerful Thinking. During this development to the classical TRIZ approach two transformations were proposed [19]:

1. A more general approach for solving non-standard or creative problems; &
2. Attempts to enhance the powerfulness of thinking towards problem analysis and synthesis of a solution.

The developer of TRIZ was critical of the “Creative Problem Solving” methods. They were regarded to be actually very convergent instead of divergent as they are claimed to be. The problem indicated was that their primary handicap exists in that they make compromises when confronted with contradictory requirements [20]. The general approach of ARIZ/TRIZ is to determine a solution by abstraction. The specific problem is described as a more generic problem. By application of the tools and techniques a generic abstract solution is found, which is then made into a specific solution for the specific problem [16], [14], as depicted in Figure 1. It also shows the critique towards Trial-and-Error and Brainstorming

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The TRIZ/ARIZ methods are good enough on their own to develop system or product concepts, but need other processes to continue the development. They could be used again to solve technical problems that emanate during the

Table I
Levels of Innovation

Level	%	Knowledge environment
1	32	Apparent solution (local knowledge). Simple improvements with known knowledge
2	45	Minor Improvement (knowledge in industry). Adaptation of similar solutions from same industry
3	≈ 18	Major change (knowledge from other industries). Innovation is radical new application from other industry.
4	<4	New application or technology concept. Combined technologies for new solutions
5	<1	Scientific discovery. A complete new invention typically based on a new scientific discovery

concept development [21].

In [20] it is suggested to use the stages of the S-Curves to identify potential opportunities for innovation other than the innovative solving of existing problems. Another approach would be to look at the eight “Trends of Evolution” as they are considered valid for all technical systems [14]. The TRIZ tools are valuable in conjunction with the other methods as described in section III-B as they may provide more thorough analysis of requirements or selection of solutions [14].

An ideal solution is called the Ideal Final Result(IFR) and it can be expressed as [14], [22]:

$$\text{Ideality} = \frac{\sum \text{Benefits}}{\sum \text{Harmful effects}}$$

There are creativity triggers contained in TRIZ which can be applied to any or all stages of innovation [14]:

1. Define and seek a solution that will approximate the IFR relationship;
2. Imagining a solution to the problem;
3. Map the situation in terms of past, present and future for the system, subsystem(s) and supra-system;
4. Retain all ideas, even when they seem poor at the time;
5. Attempt the reverse;
6. Generalize the problem and determine if it has been solved (as in Figure 1);
7. Use ‘Smart Little People’ to solve the problem;
8. Exaggerating/downplaying in terms of Size, Time and Cost in either direction;
9. Rephrase the problem in simple language without technical terms;
10. Compare to Life and Death critical solutions;
11. Drill down to the concepts behind ideas;
12. Identify beneficial features instead of functions; &
13. Aggregate all benefits from various solutions.

Innovations can be classified in terms of their uniqueness and difficulty as is shown in Table I. TRIZ is especially useful to attain level 3, although also effective at levels 1 & 2 [14].

IV. Systematic Innovation for Business & Management

Based on twelve years of experience, according to [22], a generalisation to the TRIZ approach was developed and it was expanded with additional methods. This expands on the problem definition stages of TRIZ and it translated the physical characteristics of the tools to business and management.

A. Psychological Factors

The first part of this approach is to overcome Psychological Inertia. The aim is to avoid vertical or logical thinking, which typically occurs when a similar problem has been solved before and the solution is merely tailored to suit the problem at hand. It is a human trait to take the simplest approach, due to recognising a similar pattern and translating it to the current situation. It also manifests when the problem at hand is perceived as unsolvable and could reappear in later stages of Systematic Innovation [22], [14].

To overcome Psychological Inertia it is suggested that approaches like the 'lateral thinking' and the 'Six Hats' methods of De Bono and Mind-Mapping should be used. These methods will help to find more creative solutions [22].

Other countermeasures are [14]:

1. consider an ideal solution without regards for the constraints; &
2. apply elements of the TRIZ tool-kit.

A typical brainstorm session flattens out after 20 minutes, but by introducing one of the Inventive Principles at that stage, new vigour could be introduced and more ideas would be created [22].

B. Problem Definition

In order to comprehend the context of the current situation or any concept derived during systematic innovation the System Operator could be used. It is a mapping of a system in terms of its subsystems and super-systems against the past, present and future. Any of the 'axes' could also be expand. It could also be done with other attributes of the system like capabilities, perceived value, identity, physical characteristics. It could be done for different individuals and groups as well. This provides a definite approach to think in 'Time and Space' or other attributes and 'Space' to achieve segmentation of a problem. Each of the provided methods will be discussed in this section [22].

1) Exploring problems: To explore a problem the following steps are provided [22]:

1. Analyse the benefits and to whom they apply;
2. Determine the resources available, either directly or in the nearby environment;
3. Investigate and record the applicable constraints; &
4. Identify the impediments to solving the problem.

To identify hindrances to obtaining a solution actions are proposed to assist in achieving the aim. They are [22]:

1. Auditing of the current efficiency;
2. Utilisation of the 'Theory of Constraints' to investigate process issues of problems
3. Subversion analysis to determine potential failures;
4. Root Contradiction Analysis to determine what are the current fundamental limits or embedded compromises.

2) Analysis of functions and attributes: This is done by using a modified version of Function and Attribute Analysis [22]:

1. System element identification;
2. Determination of the positive tangible and intangible interrelations between elements; &
3. Determination of the negative tangible and intangible interrelations between elements.

The negative aspects are characterised as being absent, excessive, inadequate or adverse.

3) S-curve analysis: The use of the 'system maturity' curve to determine where a system is in its life-cycle. In this approach the curve is considered for ideality against time. In the different stages of the curve the types of problems will be different. During the initial stage it will be an improvement problem, whilst towards the end it will be where the system is reaching its perceived fundamental limits.

4) Ideality and the Ideal Final Result: Ideality is seen as the ratio of perceived benefits to drawbacks or undesired effects, in the business and management environment. The aim of innovation is to increase the Ideality towards what is called the Ideal Final Result (IFR), where the system will ideally only render benefits and no dis-benefits. This process is conducted by answering the following questions:

1. What is the final purpose of the system?
2. How would the IFR be described?
3. What is blocking the achievement of the IFR?
4. Why is it blocking the achievement?
5. How could the block be removed?
6. What resources can assist with the removal?
7. Has this been done before?

5) Mapping of perceptions: The first step is to record as many perceptions as desired about the problem. The next step is to determine 'flows' or 'cause' between all pairs of them. The contradictions or conflicts are then identified in the pairs. The last step involves the graphical mapping of the perceptions and their relationships. The result is considered a means to manage complexity in the solving of the problem.

C. Problem Solving

To solve the problem the first step is to determine the main characteristics of the problem. In [22] a table is provided to suggest the selection of the proposed tools to use to find a solution. The tools are ranked in terms of their preferred choice. The tools provided are as follows:

1. Elimination of conflicts or compromises in relation to Inventive Principles
   This tool is based on a generalisation of the Contradiction Matrix and Inventive Principles as contained in TRIZ. The identified contradictions of a problem are located on the rows and columns of the matrix. At the intersections ranked Inventive principles are proposed that could be used to solve the problem.
2. Removal of contradictions; To remove contradicitons four strategies are given:
   a. Separation in Space, move contradicting/conflicting items away from each other;
   b. Separation in Time, schedule conflicting items on different times;
   c. Separation on Condition, control the occurrences of events based on conditions; &
   d. Separation by Transition to an Alternative system, which also includes moving the function to a subsystem, super-system or inverse system.

   The realisation of the strategies can be achieved by means of the generalised Inventive Principles as provided in [22].
3. Problems of Measurement;
   In some problems it could be about measurements. The first part of solving this is to determine the requirements and purpose of the measurement. The issues to consider pertain to the need versus the expectation of it. After a clear definition of the requirements and purpose has been obtained, there are nine potential strategies contained in [22] to attempt to solve the problem.
4. Trends of System Evolution;
   A generalised set of trends of evolution is provided in [22]. The purpose of these is to see how far a system has evolved in terms of the provided trends. This enables one to see potential areas of evolving the system, taking ideality into account.
5. Consideration of local or nearby resources;
6. Search for additional and/or generic knowledge;
7. Refocus or re-frame the problem;
8. Elimination of unnecessary or redundant elements;
9. Seeking the Ideal Final Result by using Evolutionary Trends to accelerate the evolution of the system; &
10. Subversion Analysis to make the system more robust.

D. Evaluation of the derived Solutions

All the solutions derived by using the proposed methods are then evaluated in terms of them meeting the goal of the problem. Multi-criteria decision analysis is used to evaluate them in terms of qualitative and quantitative criteria. It is also recommended that they should be subjected to sensitivity and robustness analyses [22].

The best solution should be analysed to determine how many useful functions are performed per elements present. This ratio should be at least one. If not there are redundant elements present which should be eliminated. The system should also be scrutinised for unresolved contradictions, which can be solved in a subsequent cycle through the process. The selected solution should also be investigated to determine which of the potential resources are not used. If there are features that appear in one of the unselected solutions that are outstanding, it would good to try to add them to the chosen solution [22].

V. Conclusion

The original CPS set of processes can be combined to the TRIZ/ARIZ process and tools as indicated in [14] and to a lesser extent in [22]. The CPS processes are limited by the use of current concepts as solutions to new problems. The TRIZ processes are focussed on technical problems. In its original form it only indicated how to get the concept solution in principle. It does not make provision for the detail development of the solution [10].

The generalisation of the TRIZ tools and adding additional methods as in [22] is based on 12 years of experience as was determined in communication with the author. There are some observations about it:

1. Analysis of the parameters used to construct the contradiction matrix addresses only the following aspects of business: a. Customer b. Information c. Production d. Engineering e. Supply f. System
   There are also three parameters that do not fall into a specific category of business which are regarded as of mixed nature.
   Aspects like for example Finance, Strategy, Human Resources are not addressed, which means the generalisation can not easily be applied to the other areas of business and management.
2. The generalisation of the 40 Inventive Principles are close to the ones that were developed with the original TRIZ ones. For instance the concept of resonance is well understood by engineers and scientists, but it is not a common concept in business and management. This should therefore be further developed and maybe sets of the tools should be developed that are more applicable or easier understood by people in business and management.
   Other transformations of parts of TRIZ to specific business areas exist, but it appears that they have not been investigated and there is no clear evidence that they were subjected to the scientific method where they would have been peer reviewed.
   One fundamental difference between the original TRIZ approach and the generalisations is that the original was developed based on the investigation of patents, while patenting is rare if at all possible in business and management.

In the CPS set of methods amongst the miscellaneous techniques is one called Decision Seminar [12], which is aimed at solving social policy problems. It could be enhanced by combining it with the core of the TRIZ approach to solve conflicts and contradictions as it currently is not capable of resolving them.

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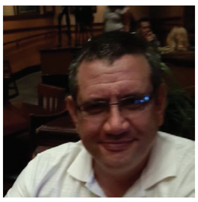

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