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The Roles of Creative Thinking and Decision-Making Tools for Building Knowledge Societies

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ABSTRACT

Specialists in practice express the need to complete up with other special insights in order to attain the requisite holism. Systems thinking has always helped people fight oversight. This paper emphasizes, therefore, the need for the appropriate knowledge about the basics of both systems theory and the applied computer supported methods that can help individuals or groups in researching important complex decision-making problems, which we consider necessary (but not sufficient) conditions for innovations. We demonstrate that the modern Operations Research / Management Science (OR/MS) methods can help managers much more than the traditional ones. Learning how to apply an appropriate knowledge of OR/MS in practice can support problem solving capacity. In attempts to increase the extent to which company strategies and operating practices are oriented toward innovation we emphasize the capacity of dialectical systems thinking as a precondition for requisite holism, and therefore for successful and efficient creating and decision-making.

Keywords: creativity, decision-making methods, knowledge society, system science

1. INTRODUCTION

Studying the values of the national innovative capacity index[1] (See: [1]) can let us report that the advanced OECD countries like USA, Japan, Austria and France are ranked in the first third, whereas e.g. Australia, S. Korea and some of new EU member countries (as of May 1st 2004) like Slovenia and Hungary are ranked in the second, and some of them like the Czech Republic in the last third among 36 OECD countries, EU member and candidate countries with available data in 2003.

Creation of inventions and making innovations from them requires consideration of a network of all essential and only essential viewpoints or factors; it is called a dialectical system [2, 3, 4, 5; etc]. It enables requisite holism in both individual and group thinking in order to define problems and produce creative and useful ideas by methods of creative thinking and networking in interdisciplinary co-operation (See: [6, 7, 8]; etc). In this paper we collected, generalized and edited main purposes of their applications, together with software products supportive of creativity. Still, decision makers in enterprises have to select viewpoints to be considered and networked, including relations in networks to be considered, and to develop, choose, and verify possible solutions in order to develop inventions into innovations, leading to improvements in e.g. quality and quantity of output, its cost, range offered and environment friendly, including their synergies (in a best-case scenario). They can do so by several methods, among which we emphasize, in this paper, the decision-making ones supported with appropriate computer programs. To help them, we completed up Belton and Stewart's [9] general multiple criteria decision analysis process (See: [10, 11, 12]). In this paper we demonstrate that the modern Operations Research methods can help managers much more than the traditional ones [13]. They can well support their requisite holism, i.e. diminish their danger of making oversights, and diminish their danger of being overwhelmed by data and thus of losing their focus.

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1 National Innovative Capacity is measured by the national innovative capacity index [1], composed of a sub-index of the availability of scientists and engineers (shares in total workforce), a sub-index of innovative policy (intellectual property protection, extent and availability of tax relief/subsidies for R & D activities, effectiveness of national regulation in the field of promoting long-term competitiveness), a sub-index of the entrepreneurial environment for innovation (clusters development, extent of competition and demand sophistication), a sub-index of connectedness in the field of innovation (the availability of specific research and education institutions, the availability of venture capital for innovative projects), and a sub-index of the innovative orientation of companies (level of a company's competitive abilities dependence from original products and services, level of marketing sophistication, and level of a company's income dependence on productivity) [1].

2. GENERATING AND DEVELOPING INNOVATIONS

Since common-practice statistical methods – nowadays very appreciated by some scientists – cannot satisfactorily support many complex decision-making processes, including developing creative ideas into innovations, entrepreneurs' effort to master *interdisciplinary co-operation* as a means of systems / systemic / holistic thinking (See: [14]) can be supported with multi-criteria decision-making (MCDM) methods.

When applying MCDM methods to several decision-making problems, we concluded that they should be approached step-by-step. We followed the phases of decision-making processes that are commonly acknowledged in literature (See: [9], p. 6): from identification of a problem, through problem structuring – model building, its use to inform and challenge thinking, to the creation and analysis of activities plan to solve a problem (e.g. to implement a specific choice, to suggest a recommendation, and to monitor performance), but we adapted and completed them up for the problem's type [10, 11, 12]. Now, we extend Belton and Stewart's [9] general multiple criteria decision analysis process to the process of generating ideas and developing them to innovations as we present in Figure 1 [15].

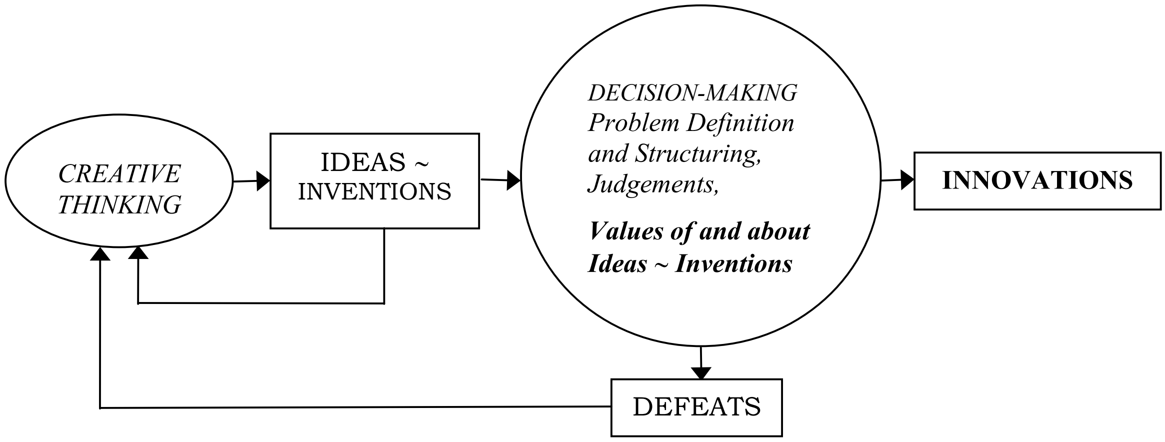

Figure 1: The Process of Generating and Developing Innovations

It has been assessed that two thirds of innovations are results of a demand-pull, whereas one third of them is a result of a discovery push (See: [16]). Newer theories mention five phases of innovation management theories (See: [17], pp. 23-25):

(1) Innovation derived from science (technology push).
(2) Innovation derived from market needs (market pull).
(3) Innovation derived from linkages between actors and markets, such as chain-link theories.
(4) Innovation derived from technological networks, such as "systems of innovation" on a national, regional or international basis, which cause synergies of ideas and information from both internal and external sources.
(5) Innovation derived from social networks, which enable a lot of exchange of information and make knowledge available very rapidly on a worldwide basis. The point is meeting the need for many kinds of knowledge and their convergence from a variety of actors.

Hence, the theory (5) is closest to (informal) dialectical systems thinking. (See: [18, 19]).

Of course, the idea is only the initial stage in the invention-innovation process. It has to pass the invention, suggestion, developmental, production etc., and commercial, phases before e.g. a product is innovated and diffused, massively produced and sold. Therefore, modern internationally advanced methods for strengthening creativity like Work Simplification, USOMID, 20 keys, ISO 9000, TQM, EQA (also enacted as Slovenian quality award), re-engineering of business performance, learning enterprise, knowledge management, Total Systems Intervention, project management, and other methods, supporting the innovation acceleration should be used to improve innovation capacity everywhere. Further, research and development, and unprofessional invention and innovation creation should be used to strengthen creativity in core invention-innovation activities.

3. TOOLS SUPPORTIVE OF CREATIVE THINKING

A wide variety of traditional methods for strengthening individual and group creativity are outlined in literature (See e.g.: [16, 20, 21, 22]). In practice it is enough to select the most appropriate one(s) according mainly to the problems' nature and their functions (see Table 1).

Table 1: Traditional methods for strengthening creativity.

FUNCTION	TECHNIQUES
PROBLEM/OPPORTUNITY DEFINITION	»Why«, mind mapping, fishbone diagrams, wishing, relevance trees, cognitive mapping
GENERATING IDEAS	Brainstorming, nominal group technique, provocation, forced relationships, brain-writing, attribute listing, morphological analysis, synectics, mind mapping, checklists
DECOMPOSING	Attribute listing, morphological analysis, mind mapping
ANALYSIS	Mind mapping, W
VERIFYING and SISTEMATIZATION	Checklists
FINDING SOLUTIONS	Synectics
RANGING IDEAS	Idea writing
CHOOSING IDEAS	Star rating matrices, the balance sheet method, paired comparison analysis, reverse brainstorming, nominal technique
DEFINING AND EVALUATION OF IDEAS	Nominal technique
SOLUTION IMPLEMENTATION	Balance sheet, stakeholder analysis, implementation checklist, critical path analysis

Numerous software products for creativity can be found on the Internet. They differ in prices, the offer of free-trial versions, applications, potential users (executives, entrepreneurs, journalists, farmers, college professor, writers – one or some of them), approaches, the number of participants (individual, group thinking, or virtual), the possibility of ranking each idea according to the thinkers' criteria, operating systems, forms (graphics, outline), and in the techniques used.

We focus on the tools that could help, mainly enterprises, in creative thinking and decision-making. Main fields of our interest include Product (and Service) design and development, Strategic Planning, Project Management, Re-engineering, Marketing planning and strategies, Total Quality Management, Business writing, Human Resource Planning. We collected, generalized and edited main purposes of applications, together with software products for creativity, and presented them in Table 2.

Table 2: Purposes of applications of available software products for creativity.

Purposes	Software products
Capturing, generating ideas	Inspiration, BrainStorm, BrainStormer, Idea Generator Plus, Brainstorming Toolbox, Idea Generator Plus, Sirius, Concept Draw MINDMAP®, Grouputer, IDEGEN++
Recording ideas	ACTA Advantage, CK Modeller, Visimap / InfoMap, MicMac, Microsoft Word – Outlining Feature
Visualizing ideas	Axon Idea Processor
Organizing ideas	ACTA Advantage, Axon Idea Processor, Inspiration
Manipulating ideas	CK Modeller
Drawing mind maps	Concept Draw MINDMAP®, MoonLite
Generating alternatives	Microsoft Word – Thesaurus Module
Team working	Grouputer, ThoughtPath
Virtual meetings	CM/1
Moonlighting	MoonLite
Solving problems	Brainstorming Toolbox, Idea Generator Plus, Sirius, Turbo Thought, Genius Handbook, Grouputer, IDEGEN++

Moreover, Brainstorming 1.0.1 is a program for helping frontline employees be more creative, innovative at work; IDEGEN++ is a program for creative problem solving and innovative thinking; The Creativity Machine facilitates a creative production. Some software packages support more functions. For example, Concept Draw MINDMAP® is software for creating Mind Maps® and diagrams, for facilitating the capturing, editing and presentation of ideas; Grouputer supports brainstorming, problem solving, team building, strategic planning and interactive learning, and ThoughtPath stimulates work teams and inspire break-through ideas.

Besides these functions, the upgrades of ThoughtPath software bring techniques and processes that enhance the user's natural creative abilities. Axon Idea Processor enables that idea processing is concerned with problems and solutions, questions and answers, unknowns and facts. Decision Explorer has applications not only in cognitive mapping, but also in many other areas including group decision support systems and knowledge modeling. By using Innovation Toolbox, a problem solving structure guides users through the different problem-solving processes to ensure that questions are answered and that all ideas are evaluated. By organizing information into hierarchies, TreePad makes an environment for organizing and creating new ideas.

It can be concluded that these computer programs can help decision makers define problems, generate ideas, together with recording and organizing, capturing, manipulating, editing and organizing them, and – to less extent – to solve problems. It can be up to the decision makers to decide if the idea is of value to them, and it may be their skill to develop the idea into a solution. However, decision-making methods can help choose and verify possible solutions.

4. NEW ROLES OF OPERATIONS RESEARCH

From the arguments of rare "philosophers of mathematics" (See: [23]) thirty-five years ago that overspecialization makes true inter-disciplinary work difficult [23], the emergence of complexity science has paralleled the embrace of new theories of knowing and knowledge among mathematics education researchers [24]. In parallel, Operations Research practitioners in enterprises express the need to (re)shape it following the needs of different management fields and to move from a posture of passive consultant to one of active leadership. McDonald [25] suggests; e.g.:

- Less emphasis on statistical hypothesis testing and significance levels;
- Less emphasis on measure theory and probability theory;
- Greater emphasis on visual analyses and interpretation;
- Greater emphasis on communication skills, on interdisciplinary studies and problem formation;
- Greater attention to organizational systems and processes rather than methodology for spatial problem solving;
- Further focusing decision theory on real decision-making in a business context.

Therefore, specialists in practice express the need to complete up with other special insights in order to attain the requisite holism (See: [26]). Mulej [26] concluded that it was systems thinking which has always helped people fight oversight. This paper emphasizes, therefore, the need for the appropriate knowledge about the basics of both systems theory and the applied computer supported methods that can help individuals or groups in researching important complex decision-making problems, which we consider necessary (but not sufficient) conditions for innovations. They should be used when intuitive decision-making is not enough for several reasons: e.g. conflicting criteria or disagreement between decision makers what criteria are relevant or more important, and what alternatives and preferences are acceptable. The following facts contribute to their applicability in solving complex problems:

- The MCDM methods do not replace intuitive judgement or experience and they do not oppress creative thinking; their role is to complement intuition, and to verify ideas and support problem solving.
- In MCDM we take into account multiple, more or less conflicting criteria, in order to aid decision-making.
- In this type of decision-making process we structure the problem.
- Users can compare different methods and assess their convenience in problem solving. The most useful approaches are conceptually simple, transparent and computer supported.
- The aim of MCDM is to help decision makers learn about the problem, express their judgements about the criteria importance and preferences concerning alternatives, confront other participants' judgment, understand the final alternatives' values, and use them in the problem solving activities.

Let us emphasize the main characteristics that distinguish single- from multi-criteria decision-making. The main goal of single-objective decision-making (and optimization) is to find the "best" solution, which corresponds to the minimum or maximum value of a single objective function. Single-objective models require that all design objectives must be measurable in terms of a single fitness function of same units (See: [27]). Single-objective approaches put the decision-making burden on analysts since single-objective optimization can detect one optimization solution in a single run, whereas decision makers must express preferences beforehand. When the role of supporting decisions and decision-making (or even decision-taking) is misunderstood, the responsibility for (wrong) decisions is much easier to place on analysts by using single-objective approaches. However, multi-objective approaches allow for one's responsibility for defining problem (goal, criteria and alternatives), its structuring, assigning the criteria's importance and expressing the preferences to alternatives, and even verifying the sensitivity of their judgements to be placed on decision maker. Although single-objective optimization identifies a single optimal alternative, it can be used within multi-objective framework [11], e.g. so that in the simulations obtained optimal values are included.

One of the most widely applied sets of multi-criteria methods is *multi-attribute value (or utility) theory* (MAVT or MAUT) (for a detailed description see [9]). From the late 1960's on, this set of methods has been developed not only by management scientists, mathematicians, psychologists, but also by practitioners in management, economic, environmental and public fields. The need to include different scientific, professional fields in the development of these methods results from the need to manage complexity. It has been improved to SMART (a simplified multi-attribute rating approach), and other approaches (for example SWING, SMARTER). They are supported by several computer programs, e.g. HIPRE 3+, Web-HIPRE and Logical Decisions® for Windows. One decade later Saaty (See: [28]) developed the *Analytic Hierarchy Process* (AHP) method, together with computer program Expert Choice. This method excels by wide applicability, too, and is distinguished by the scales used, the methods used to express judgements about the criteria importance and preferences concerning alternatives, and the manner of transforming these judgements into numerical values. A (relatively, perhaps requisitely) holistic approach (as the opposite of a linear and piecemeal approach) is used in this method in which all the problem criteria are structured in advance in a multilevel hierarchy. Furthermore, it is generalized for neural decision processing – the Neural Network Process (NNP). It is, in addition, completed with the interaction and dependence of higher-level elements on lower-level elements and relations in the form of feedback structure that looks like a network – the Analytic Network Process (ANP), which is supported by Super Decisions. It overcomes the traditional OR/MS approaches in the context of Systems Thinking because it allows us to include tangible and intangible factors and both interaction and feedback within clusters of elements (inner interdependence) and between clusters (outer interdependence).

The use of the discussed methods might lead to over-complexities: decision makers may not need all details of results they obtain with these methods. Namely, some decision problems do not require alternatives to be ranked with respect to their final values; often it is good enough to find out which of them is the most preferred. Therefore the so-called "outranking" approaches have been developed since 1970's. The most widely applied are ELECTRE in more variants and PROMETHEE (for details see [29]). Further, interactive methods as another set of multi-criteria approaches emphasize dialogues with the decision maker, who reacts to the first solution provided by the first computation step: he or she gives extra information about his/her preferences. These methods are especially applicable when a complete preference model is not constructed in advance and when alternatives need improvements (for details see [29]). An evolution from search-oriented to learning-oriented methods can be noticed.

Common-practice statistical methods – nowadays very appreciated by some scientists – cannot satisfactorily support many complex decision-making processes, including developing creative ideas into innovations. Hence, methods for the approximate specification of preferences are gaining power in enterprises. Moreover, theoretical work has been done to extend methods, such as AHP, and value tree analysis; the decision maker thus can express approximate preference statements through interval judgements. Preference programming (See: [30]) describes approaches (like PAIRS, PRIME and RICH) that can be helpful in group-decision making, too. Easy-to-use software has been developed to support the interval techniques: WINPRE supports preference programming, PAIRS and Interval SMART/SWING; PRIME Decisions is a software implementation of the PRIME method; RICH Decisions supports the RICH method.

However, the results of the multi-criteria decision-making should not be understood as the final ("right") answers in the problem solving process. Multi-criteria analysis cannot be justified within the optimization paradigm frequently adopted in traditional OR/MS (See: [9]). Appropriate ("objective" or, at least, requisitely holistic) analyses cannot relieve decision makers of the responsibility of making difficult judgements. It is an aid to decision-making, which seeks to integrate objective measurement with value judgement and to manage subjectivity. The last one is evident particularly in the choice of criteria and in determining of their weights.

Furthermore, representations of available decision analysis packages contain the information provided by the vendors and surveyed by the OR/MS researchers. Appropriate information can be easily found on www pages. It includes applications like tradeoffs among multiple objectives, analysis of uncertainty, analysis of probabilistic dependencies, risk aversion, sequential decision making, multiple stakeholders, and specific applications for which software is most widely used. Before buying such a decision support package, experts in enterprises can use trial-free versions of computer programs to find out whether a package offers enough possibilities for a convenient preparation of their decisions. However, when using results in answer and sensitivity reports, decision makers (e.g. in enterprises) must know the basics of the applied methods[2]. Furthermore, knowledge of OR/MS supports problem solving capacity, if decision-makers learn how to apply this knowledge in practice[3]. Especially in small and medium sized enterprises the sphere of action of one employee may combine a broader spectrum of working tasks than in large enterprises. There, each expert's knowledge base and ability to learn is of high importance when evaluating and verifying how useful are the creative ideas selected.

5. CONCLUDING REMARKS

To survive in the knowledge society, attributes of the modern innovative society must be strengthened (e.g. creativity, knowledge, entrepreneurship, total/excellent quality, learning, co-operation capacity, especially the interdisciplinary one) to face serious dangers (e.g. competition with no mercy) by responsible decision-making considering (in network) all dimensions of the so-called sustainable performance: economic, environmental, social, and ethical ones.

In innovative society (with information society, society of excellent quality, learning society, knowledge-based society, entrepreneurial society, … as its partial characteristics), successfulness depends on competitiveness, which depends in turn on requisitely holistic and creative thinking and decision-making – of individuals and organizations, from a family to all people. Therefore, creativity is at least as important as professionalism; its use is especially important in creating useful novelties, i.e. in innovating. And so is co-operation capacity and related methodological support for a dialectically systemic thinking by creative co-operation of different professionals.

In attempts to increase the extent to which e.g. company strategies and operating practices are oriented toward innovation we emphasize the capacity of dialectical systems thinking as a precondition for requisite holism, and therefore for successful and efficient creating and decision-making. For managers, the understanding of the economic role of creativity and relationship among central invention-innovations activities, the knowledge about traditional and modern methods supportive of activating and strengthening creativity, as well as the capacity to understand and use the selected quantitative methods that support creativity and decision-making, including adequate computer programs, is often necessary. Multi-criteria decision-making methods that have already turned out to be very applicable in business practice can be used

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[2] According to the opinion of European employers (See: [31]), the most important competencies for an employee's contribution to his or her firm's success are: capacity to learn, capacity for applying knowledge in practice, capacity for analysis and synthesis, capacity to adapt to new situations, and interpersonal skills. They are followed by capacity for generating new ideas, communication skills, and decision-making. According to the opinion of European academics, however, capacity for generating new ideas is ranked on the fourth place among seventeen considered competencies. – Dialectical systems thinking, enriched with OR method can support all of them in network, our experience says.

[3] The analysis of students' answers in the research carried out at the University's of Maribor Faculty of Economics and Business in 2003 and 2004 (See: [32]) shows that they had not sufficiently developed the capability to apply knowledge in practice. However, quantitative courses have gained very high marks from students.

to complement intuition, and to verify ideas, and support their development into innovations. They support requisite holism without talking the systems theory language. This makes them more acceptable. Methods for the approximate specification of preferences are coming into force in enterprises both because of their theoretical developments and because of failures in common-practice statistical methods. Hence, the point is in reaching the requisite holism with only requisite effort by applied systems thinking and innovation.

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