Creative Problem Solving Processes

Innovation Case Study:

Application of Creative Problem Solving Processes to R&D Planning

A Case Study in Urban Roads Technology Research

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ABSTRACT

This paper describes the application of a Creative Problem Solving process to an R&D planning exercise. The challenge was to define the priorities of a laboratory specializing in urban road and pavement technology at the National Research Council of Canada. The Creative Problem Solving (CPS) process allows a group to collectively identify a problem they want to work on, to define that problem very precisely in all its dimensions, to generate possible solutions, and to plan for an effective implementation. In this instance, only some elements of the process were used leading to a precise definition of the R&D challenge.

The CPS process was used in three different sets of applications. In the first phase, it was used in the context of two one-day meetings with the Laboratory researchers. During these meetings, a wide range of possible research was identified in relation to some of the observed problems, and to the key challenges faced by the end-user community. The result was a detailed two-dimensional map, that showed graphically clear links between specific R&D areas and the key challenges faced by municipalities. The impact of generating such a map collectively enhanced the team building of the group. Subsequently the group used this map in the process of generating a business plan.

Another set of applications involved the end-user constituency (i.e. senior municipal road engineers), to determine with some precision what their priorities and needs were with respect to R&D. The next step in this process is underway involving meetings with the scientists to design actual R&D projects. While results from this step are still inconclusive, the results from the first two applications proved quite effective from a time-savings viewpoint, and in terms of achieving a consensus among stakeholders.

The R&D Context

The client for this exercise was a research laboratory in the Institute for Research In Construction, part of the federal National Research Council of Canada. A group of about fifteen scientists and technologists in that laboratory are dedicated to research relating to urban roads. Their challenge was to develop a business plan which would lead to funding approval for the next three years.

The need for increased research and development in urban roads at the federal level has been stimulated recently by a number of factors. In Canada, 64% of the 840,000 kilometer road network comes under the jurisdiction of cities, and recent legislative changes have shifted even more roads under their responsibilities. Municipalities are faced with escalating costs, limited experience and a complete lack of research capability to evaluate or develop technologies that are most cost effective. It is estimated that about $5 to $6 billion are spent annually in Canada on maintenance, repair and renovation of roads. Unfortunately, most research on roads focuses on highways, which are subject to a different set of conditions than urban roads.

According to need studies, municipalities, as the primary owners, lack expertise in maintaining, repairing, rehabilitating, upgrading or rebuilding the system. They have followed traditional methods for constructing and maintaining urban pavement systems. This situation has arisen because of tight budgets, the "low technology" approach of the industry and the lack of notable investment in R&D. A few university researchers and consulting firms are attempting to fill some of the technological gaps. There is still relatively little recognition that the technical problems and needs of municipalities are often significantly different compared to the traditional highway pavement problems. Hence, there is a great and urgent need, expressed by all road transportation agencies and associations across the country, to accelerate R&D in road design, construction and rehabilitation in order to contain the enormous costs currently required to maintain the Canadian urban road network.

To tackle this challenge, the Urban Roads group of the Infrastructure Laboratory undertook a strategic planning exercise to provide a focused vision and a needs analysis for investment of their publicly-funded R&D effort. A significant part of this exercise was a facilitated creative problem solving (CPS) process, which over a period of four days of intensive meetings, provided the research manager with critical data to contribute to development of a business plan for the Laboratory.

The SIMPLEX CPS Approach

This case study used the SIMPLEX™ creative problem solving (CPS) process which has been extensively documented in the management and creativity literature. The following is a brief practical synopsis of the steps used in this case study.

Simplex is a group process for finding and solving problems; identifying and overcoming challenges; and establishing and achieving goals. Use of Simplex allows individuals and organizations to be creative, innovative and to succeed in a world where fast-paced change is the order of the day. The Simplex process has been developed over a number of years by Dr. Min Basadur of McMaster University and founder of the Centre for Research in Applied Creativity, and is being used by many business and technological organizations in North America.

Most people work with only a limited and unconnected set of problem solving tools. By contrast, Simplex is a "complete" process of creative problem solving with three stages (finding problems, solving problems, implementing solutions) and eight discrete steps. The process provides a framework for using various tools. Simplex is represented as a wheel to reflect the circular, perennial nature of problem solving. Its eight steps include:

- problem finding,
- fact finding,
- problem defining,
- idea finding,
- evaluating and selecting,
- action planning,
- gaining acceptance, and
- taking action.

Note that in this particular case study, because the challenge was to plan an R&D program, emphasis was placed on the first three steps, leading to defining of the R&D problem.

Three skills are required for participants to use the creative problem solving process effectively: divergence – the ability to imaginatively list facts, ideas, solutions without evaluation, judgment or criticism, convergence – the skill as individuals and as a group to select the most important, insightful facts, idea or solution using judgment and evaluation, and the deferral of judgment – the ability to consciously separate the two steps.

Setting the Stage

A key objective of the process is to arrive at a definition of the full problem, as accurately and as meaningfully as possible, in all its dimensions. Before the application session itself, there is a pre-consultation meeting with the client, the individual who "owns" the problem. At that meeting, the agenda for the full application session is prepared, and the participants who will have valuable input into the discussion are identified. The discussion or application sessions in the case described in this article have been of varying lengths, from half a day, to two or three days. Participants numbered between eight and fifteen.

Step 1: Problem Finding

The process begins with an initial statement of the problem, which may not necessarily be the best possible or most accurate statement of the challenge. Generally, this problem statement is incomplete or ill-defined, and usually fairly complex. It is referred to as the "fuzzy situation". The "fuzzy situation" is usually selected by the client, the individual who owns the problem or is responsible for it, in the course of the pre-consultation meeting.

Step 2: Fact Finding

The bridge between finding a problem and clearly defining it is fact finding. Seven fact-finding strategies help to remove the "fuzziness" from a problem:

- divergently seeking possibly relevant facts;
- using several viewpoints;
- being aware of unconscious assumptions;
- avoiding a negative attitude toward "problems";
- sharing information;
- having the courage to say what you think; and
- looking for the truth rather than ways to boost your ego.

A number of useful questions are used to uncover important facts about a problem. These facts go beyond information generated from conventional techniques such as quality control histograms, process flow charts and market research questionnaires.

Some fact-finding prompting questions include:

- What do you know or think you know about the "fuzzy situation"?
- What don’t you know but would like to know?
- Why is this a problem for you?
- What would you that have you don’t have now if this problem were solved?
- What have you thought of or tried already?
- What assumptions are you making you should not be making?

Answers to fact-finding questions should be simple but precise in order to ensure effective fact-finding and, hence, an insightful problem definition.

As much as possible, judgment is avoided while gathering facts. The object is to aim for quantity and diversity. This is the "divergence" mode of thinking. Once a sufficient number of facts have been generated and recorded on flip charts, they are then posted on the wall. Participants in the meeting are then asked to "converge", that is to evaluate, prioritize, and narrow down the number of facts to a selected few that are considered important and provide new insights.

Step 3: Problem Defining

Problem defining is the connection between fact finding and solution finding. Creativity is required to identify the most fruitful challenges or problem definitions from the key facts.

How Might We (HMW)?

A key step in problem definition is to frame each problem as a challenge, by prefacing it with the words "How might We…". The phrase "How might we?" is probably the most important question in the creative problem solving process. It is a way around the roadblocks posed by the phrase " we can't because" (or variations thereof).

Figure 1: Mapping Using "Why- What's Stopping" Analysis

The "why-what's stopping" analysis is used to map out problem definitions. The method involves a three-step process:

1. asking "why" (or "what's stopping") of a challenge;
2. phrasing the answer in a simple, complete sentence; and
3. creating a new challenge based on the answer.

Asking these questions repeatedly further broadens or narrows the problem's scope.

Mapping the results of the "why-what's stopping" analysis yields a hierarchy of inter-related challenges. The hierarchy is limited in size: at some point, one has to decide that the problem definition is sufficiently complete and then proceed toward solutions. The Simplex process helps, and to a certain extent requires re-definition of problems before coming up with solutions. Innovation is used in defining problems as well as solving them.

The "why-what's stopping" analysis is a way to involve people throughout the organization in defining problems, to link strategic goals with operations, and to help people understand how their function fits into the bigger corporate picture. In the context of this Case Study, the generation of a problem map was considered to be the key result of the exercise, since the challenge was to define precisely an R&D program. In the course of the exercise, a number of such problem maps were generated.

The underlying logic of the map is illustrated by the following development sequence taken from the case study. In the normal process, the key starting challenge is written on a large 5" x6" card and placed on a wall. In the current Case Study, the initial challenge was stated as "How might we make roads last longer?"

Starting with the initial challenge statement, one asks the question "Why would you want to make roads last longer?"

The different answers provided by the group, in simple factual sentences, were "to provide a desired/required level of service, to optimize the use of money, to save dollars for the taxpayers", etc.

These were then transformed into new challenges, at a broader policy, public good level. For example, "HMW provide a desired/required level of service; HMW optimize the use of money; HMW save dollars for the taxpayers". These challenges were written on new cards and placed above the initial card, linked by an arrow (upper portion of figure 1). The validity the position of a card above or below another card is established if the cards below answer the question "what's stopping us?" and the cards above answer the question "why?"

The "why? - what's stopping us" analysis was continued by asking the question, "What is stopping us from making roads last longer?", and the answers generated were "We need to build a better road in the first place", and "We need to prevent road degradation"

These two statements were transformed into challenges: "HMW build a better road in the first place", and "HMW prevent road degradation", written on two new cards, placed below the original challenge, and linked with two arrows. Ultimately, over a period of two days, some eighty cards were filled out and placed in a logical sequence resulting in a map that covered an entire wall.

Steps 4 and 5: Ideation and Idea Selection
Once a problem is very clearly defined, a wide range of possible solutions can be generated, followed by the generation of criteria for the selection of the best ideas, and zeroing in on the most desirable solution. These steps were not used extensively in the current Case Study, since the aim was to define the problem, rather than solve it.

Step 6: Action Planning
Once a solution is found and selected, an action plan is generated, which consists of identifying what will be done, by whom, when, where and how.

Note that steps 7 and 8 were not used in these application sessions and were addressed elsewhere.

The Application

The application of the CPS process took place over three sets of sessions, which totaled seven meetings of about a day, each, with various participants. Each session followed the SIMPLEX CPS process, as described in the previous section.

1. ***Session with the Laboratory researchers to define overall R&D framework***

After meeting with the client, the manager of the research group, it was established that the "fuzzy situation" facing him was the creation of a business plan which would provide a justification for a research and development agenda for his group. The agenda for the first application session was stated simply as "How might we dramatically reduce the problems with urban roads in the Region of Ottawa-Carleton." This specific region of Canada is where the Laboratory happens to be located, and was selected to provide a concrete challenge, rather than an abstract generalization.

The first day, twelve Laboratory scientists and technical officers, the manager, and the director of research, together participated in the process of divergent thinking generated some fifty facts, and then converged and selected the following 11 key facts:

Figure 2: The 11 Key facts of the R&D framework

1. Technology transfer and acceptance is a major problem to be solved in putting ideas into practice
2. Rehabilitation is more important and will be increasingly so (total dollars, volume, distances) than new construction
3. Roads fail prematurely
4. Climate, harshness, salt, thermal cycles are unique to our environment
5. The present construction quality control/design practices are not adequate for the environment
6. Our recipes for designing roads (material mix) are not based on performance, but accumulated experience
7. We don't understand the performance of the construction of existing roads to the external loads/elements (traffic, thermal, mechanical, chemical, salt)
8. There is a lack of understanding of the interaction of the various components (aggregates, layers, backfills, utility pipes, manholes, catch basins, sluice boxes, shutoff valves...)
9. The will of the owner/operators to solve these problems is unknown
10. Roads are dug up too often without adequate co-ordination with utilities (sewers, water, gas, hydro ...)
11. Repair technology (roads requiring to be fixed 2nd,, 3d, 4th, ...time) is not good enough

Based on these facts, the group diverged again and generated 21 challenges, beginning with the phrase "How might we…?" or "HMW".

The challenge selected by group consensus was "How might we make roads last longer?" This challenge was used as the starting point for generating the "Why…? - What's Stopping…?" map. The logic of the map is simple and yet very effective in crystallizing the problem in all its dimensions.

The resulting map (which took a second day to complete) is shown in all its complexity in Figure 1. It illustrates graphically a powerful link with the narrow technical or R&D challenges at the bottom of the map (e.g. HMW produce thin overlay, HMW reduce deformation cracking, HMW improve drainage and prevent water ingress), with the broad end-user requirement "HMW make roads last longer" which is linked to even broader political concerns "HMW save dollars for the taxpayers". In effect, this map is an R&D framework for this area of technology.

2. *Session with end-user constituency to identify priorities*

These two sessions, each half-day meetings were held in two different geographical areas, with representatives from the end-user constituency, namely senior engineers responsible for the construction and maintenance of urban roads. The two regions were Ottawa-Carleton and the Greater Toronto Area.

Again, participants diverged and generated facts, converged on the key facts, diverged and generated challenges using the phrase "How Might We…?", and generated a "Why-What's stopping" map. This time, once the map was generated, participants were asked to allocate $500,000 of virtual R&D funds through the placing of five sticky dots on the map, each dot representing $100,000

Figure 2 shows the map that was generated by one group of municipal engineers from one of the urban regions, representing some five different cities. Table 1 shows the detailed analysis of the "Virtual dollar allocation" by challenge and by participant (P 1, P2, …) indicating very precisely the priority of each individual. This turned out to be more important than initially imagined, because different municipalities, depending on how many major arteries they have or own in their area, will place a different emphasis on certain traffic-load related problems, such as rutting.

Table 1: Virtual Dollar Allocation by Challenge and by Participant

HMW statements from map	P 1.	P 2.	P 3.	P 4.	P 5.	P 6.	P 7.	P 8.	P 9.	TOTAL
HMW minimize the effects of utility cuts on road deterioration	1	1	1	1	1	1	1		1	8
" improve the PMS framework to model performance	1	1	1			1	1	1	1	7
" minimize the effects of frost heave	1			1	1		1	1		5
"get better tools & info for cost/effective decisions /comparisons		1		1	1		1			4
" develop a managerial system to understand and optimize our infrastructure		1		1	1		1			4
" find out how we benchmark vs. Others										4
" minimize utility & non-homogeneous elements effects on pavement performance	1	1		1			1			4
" minimize reflective cracking	1					1		1	1	4
" minimize the effects of vibrations			1					1		2
" better predict the performance of roads	1									1
" get the analytical tools of the road conditions			1							1
" minimize thermal cracking								1		1
" minimize the effect of environmental aging						1				1
" reduce the effects of rutting						1				1

The end result of these two sessions was a precise measurement of the key interests of the client groups for the Laboratory, from a problem-driven R&D perspective.,

Based on these results, a combined map revealed that the clear common interest in the groups was in the challenge of "HMW minimize the effects of utility cuts on pavement performance". These are the trenches cut in the city road to allow for installation or repair of gas, hydro , water or sewer lines, and are seen by the client or end-user constituency as being the single most damaging factor in the life of the road.

The clearly documented priorities allowed the Laboratory manager to prepare and present to his management a convincing business plan including a comprehensive list of the overall R&D challenges in urban roads, together with a precise profile of client requirements. These two elements, taken into consideration with the capabilities of the laboratory, staff expertise and work done elsewhere, allowed the manager to select those areas where his team could work with the greatest impact.

3. ***Session to define research project***

This session consisted of three meetings which were held to develop a specific set of R&D projects which would address one of the key challenges identified by the end-user group in the municipalities – How might we reduce the impact of utility cuts on the life of the pavement.

Again, the researchers identified and generated facts, converged, generated challenges and developed a problem map.

Unfortunately, they were unable to converge on specific projects. Part of this was due to unclear guidelines at the outset of what would constitute an acceptable project. But part of this also stemmed from the fact that the scientists had insufficient data to make a considered judgment as to which R&D project would have maximum impact on the initial challenge.

So, a new project was designed which would create a filter or prioritization of the key R&D challenges, and would start with a literature review. Based on the identification of this project, a detailed action plan (see Table 2) was generated, which spelled out the major tasks necessary to develop a proposal for funding to be tabled at two major industrial conferences. (Note that S1, 2, 3… refer to individual scientists in the group).

Table 2: The Detailed Action Plan

WHAT	WHO	WHEN	HOW
1. Presentation /briefing by S2	S2	Feb.27	15-20 minute presentation
2. Literature search/REVIEW on construction, performance, damage to roads and related research	Led by S1	Start Feb.27, to early April	S1 to pass out topics, papers, YK :reliability, performance of roads OS: case studies JFM: surface distress SB: asphalt evaluation
3. (In Parallel) Identify key players for literature review, technical content, & sharing workload	S1 & S0	Feb.27	S1 gets together with S0 (1 hour ++) Skip Marketing Meeting?
4. Team meeting: Is proposal viable? should go/no go?	S1 and others with GF	Early April	Presentation by S1 & others of what we know, don't know, discuss potential partnerships
5. Prepare 2 page prospectus on proposal	S1, S0, S3, S4	Day after Client Meeting	Write it
6. Contact potential clients, present prospectus	S1 with help of S0, S3	1 week after client meeting	Telephone, Fax
7. Do Work Statement for full proposal	S1	15-Apr	In collaboration with S2, 3, 4, 5, 6, 7, and others
8. Prepare budget for proposal, milestones, project plan	S1, plus S2, contract & mark'tg office	Right after April 15	
9. Do proposal to develop "filter" for key industry conferences	S1 to lead	By May 1	In collaboration with all above
10. Sell proposal			For 2 major industry conferences
11. Identify research projects for ongoing work	All people in room today	Week of May 8	Identify other work emerging from literature search

Action Plan:

Write a proposal for funding agencies to identify & quantify the factors that affect performance of Utility Cuts.

The action plan was also generated using a converging/diverging approach, where identification of certain tasks pre-supposed the completion of previous tasks, and required a proper sequencing of these to form a coherent plan.

Conclusion

This is a case study of how a creative problem solving process was successfully applied to an R&D planning challenge. It was seen that through CPS, in very little time, a group of researchers was able not only to map out the key research areas and show how they were logically linked to the needs of the end-user, but also to get direct confirmation from the end user-constituency as to where exactly its priorities were. Furthermore, the process resulted in a consensus among the Laboratory personnel as to what work should be carried out. Reducing the impact of utility cuts was identified as a key challenge on everyone's list.

The CPS process was also used to start planning work on designing a specific research project. The difficulty in the efforts to converge on a specific project led to the creation of a new project, namely to design a filter or prioritizing framework which would allow the scientists to identify which challenge or R&D project will have the greatest impact on the utility cuts problem.

In addition to achieving consensus among the researchers, the process also generated very positive feedback and linkages with the end-user groups, who were consulted in the course of the planning exercise.

Lastly, this technique has proven to be particularly effective from a time savings aspect, since in the course of four sets of meetings, all the data required for the planning were collected and synthesized in a very transparent way, through the "why-what's stopping" maps.

The CPS technique is clearly valuable in the case of research planning. It is too early to tell in this particular case, whether the technique will also accelerate the research project design phase.

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