FURTHER DEVELOPMENT AND APPLICATION OF COMPUTER-ASSISTED CREATIVITY TO RURAL ROAD RESOURCES MANAGEMENT PROJECTS

by

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(ABSTRACT)

Artificial Intelligence (AI) is the part of computer science concerned with designing computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior--understanding language, learning, reasoning, solving problems, and so on. Many believe that insights into the nature of the mind can be gained by studying the operation of such programs. The AI concept has formed the basis for developing the computer-assisted creativity techniques called The Computer Consultant (TCC), and The Idea Machine (TIM).

TIM has, so far, been applied to topics in the engineering and "hard sciences" fields. In this study these techniques are presented/reviewed in detail and the research concentrated on the expansion/development of a methodology for computer-assisted creativity. This research will help in further evolution of TIM into a richer process for idea generation and general problem solving, and in enhancing the application capabilities. This is done by: (1) expanding the conceptual and ideas data bases from which analogies can

be drawn; (2) conducting comprehensive trials with TIM to establish its strengths and limitations; and (3) doing research on techniques for the screening and packaging of ideas techniques.

Rural road projects are an important part of rural development programs in the Third World countries. For some years the construction of such road projects, funded in part by international donor agencies, has been a subject of some controversy. Most policy makers in the developing or underdeveloped countries support the practice of expanding the rural dirt (unpaved) roads rather than spending limited resources on maintenance. Some donor agencies are now inclined to only support maintenance-biased road projects.

A similar situation arose in Pakistan where the U.S. Agency for International Development (USAID) proposed to fund a road resources development project in the Sind Province. This real life situation is selected as a basis for developing a road resources management model, and generating ideas using TIM. These ideas are screened and packaged to be used in revising the model for further trials.

The application of TIM to this problem from the civil engineering field results in some useful outputs. This study provides a good basis for further enhancing TIM capabilities.

DEDICATION

I wish to dedicate this study to

My late father

(a dedicated teacher for forty years)

My late mother-in-law

and

my late sister

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CHAPTER I

INTRODUCTION

1.1 Concept of Computer-Assisted Creativity

For many years prior to the advent of the modern computer, men and women of vision have foreseen the incorporation of human-like intelligence into machines. The machine, being an inanimate object, caused this intelligence to be viewed as artificial. This has led to the identification of a new and exciting field of Artificial Intelligence (AI). Today, in the presence of modern computational systems, it is possible and practical to make some of those early visions materialize [51].

The AI field includes many areas like Natural Language Processing, Robotics, and Knowledge-Based Expert System. The AI field as an area of actual development is sufficiently new and is still very fluid. While it is still relatively small, it is growing and taking shape very rapidly [51].

The area of Knowledge-Based Expert Systems is aimed at providing computer programs that imitate the behavior of humans in solving problems normally thought to require experts, or specialists, for their resolution. An expert system consists of two parts--a knowledge base and an inference engine. The knowledge base is a repository of information made up of facts about the subject, definitions,

formal rules to describe relationships, and control information to focus on a specific problem solution. An important aspect of the knowledge base is the representation of the expert's heuristic reasoning. This knowledge represents the expert's rules-of-thumb, rules of good guessing, or rules of good judgment and truly captures the application's expertise [51].

The inference engine is a generalized reasoning and dialogue manager. It contains the strategies used to solve problems, acquire knowledge, interface with other systems, and provide explanations for the reasoning process. Each combination of the inference engine with a knowledge base becomes a unique application, or expert system. Together, they act as a model of the expertise for the specific domain [51].

Since one goal of computer-assisted creativity is to make computers more useful, computer scientists, planners, and engineers need to know how computer-assisted creativity can help them solve difficult problems. The above AI concepts have formed the basis for developing the computer-assisted creativity techniques called The Computer Consultant (TCC), and The Idea Machine (TIM).

TCC (an Expert System "Shell") program has been developed to define a problem to a point where it can be most effectively addressed by TIM. TCC allows the user to identify a series of statements/conditions which describe a

problem situation; assign weights to the statements, which express probabilities of occurrence or non-occurrence; show how these statements are interrelated; and indicate how they affect the probability of achieving a particular goal(s). Of special interest in this process is discovering which factor(s), as embodied by the statements, have the greatest impact on the goal(s). TCC can, if desired, provide not only a logical conclusion from a set of statements, but also the chance that the conclusion will be true. TCC therefore is capable of highlighting the risks and uncertainties associated with impacts from many decisions.

The above-mentioned routines help the user in the establishment of a Computer Consultant System (CCS) which, in some sense, really is a model and will be referred to as a "system" in this research.

TIM is a program designed to help the user or "client" generate possible creative solutions to virtually any problem through the process of analogy. In order to begin the search for creative solutions, however, the problem must be structured beforehand (which is done with TCC).

The research which follows demonstrates the application of TIM (which includes TCC) to a "real life" problem-solving situation. This case study concerns a Rural Road Management Project (RRM) in the Sind Province of Pakistan. This project has been funded by the United States Agency for International Development (USAID) as part of an economic

development package for Pakistan.

The "client" in this study is assumed to be USAID and we, as experts, use TIM (including TCC) to generate ideas and establish the resultant effect(s) on the final goal of increasing accessibility in the twelve project districts of the Sind Province. During the course of this study I shall act as an "expert" and will refer to myself as a "consultant."

1.2 Aims of the Research

The overall objective of this research is to review and test the computer-assisted creativity techniques, expand their capabilities, and develop a rural road resources management model for the testing process. The aims of this research are:

(1) Review the concepts and methodologies of TCC and TIM techniques in their existing forms.

(2) Explore/develop some concepts and techniques which can be used to screen and package the ideas generated through TIM and also form the basis to develop a suitable computer consultant system.

(3) Conduct a detailed literature review and prepare a bibliography on the subject.

(4) Build a computer consultant system (CCS) based on the Rural Road Resources Management Project (RRM) for the Sind Province of Pakistan. Test TCC techniques using the

RRM system and generate ideas through TIM.

(5) Develop an "ideas data base" and "concepts data base" on road construction, maintenance, and management with a view to expanding the conceptual data bases of TIM from which analogies can be drawn. This will significantly enhance the capabilities of TIM.

(6) Carry out a comprehensive critique of the process and suggest ideas/topics for future research.

The suggested procedure to achieve these aims is explained in the next section.

1.3 Organization of this Study

Chapter One discusses the concept of computer-assisted creativity and discloses the purposes of the research.

Chapter Two includes a discussion on the computer-assisted creativity techniques (TIM and TCC) employed. This includes the presentation of the concept, methodology, and process of each of these techniques. These are then elaborated by an illustrative example discussed in Chapter Three.

Chapter Four presents a survey of relevant literature. This includes a brief review of associated concepts such as creativity, logic, data base management, decision-making, computer-assisted creativity, expert systems, and idea generation/ screening/packaging, which are used to develop the computer-assisted creativity techniques (TCC and TIM).

In Chapter Five a real life situation is selected for the case study. The rural road resources management project being funded by USAID in Pakistan has been selected as a model to build the system needed to apply and test TIM (including TCC).

Chapter Six covers the application of TIM to the system built in the previous chapter. In Chapter Seven the system is revised in light of the generated ideas and further tests are carried out using TIM.

Chapter Eight includes a discussion of some thoughts on the creation of an "ideas data base" and a "concepts data base" on road construction/maintenance/management. The critique of the research process is in Chapter Nine. This includes the findings of the trials on RRM system and a critique of the research approach including the strengths and limitations of TCC and TIM. This chapter concludes with some ideas on the future research. The last chapter (nine) is followed by a bibliography on the subject. A glossary of terms and definitions is at Appendix D.

CHAPTER II

THE COMPUTER-ASSISTED CREATIVITY TECHNIQUES

2.1 Introduction

The computer-assisted creativity techniques (TCC, TIM) were introduced in the first chapter. In this chapter they will be presented in detail.

The presentation on TCC will include the concept and methodology, building of the Computer Consultant System (CCS), and the areas in which the technique has been usefully applied. In the next chapter TCC application will be elaborated by a brief example from the road resources management project.

The review of TIM will include the concept and methodology, the six-step process, and the application areas. This review will also include a discussion of concepts on screening and packaging of ideas, the last step in the process, since this will be a major section of the study undertaken here. In the next chapter the technique is elaborated through an example application.

2.2 The Computer Consultant (TCC)

This section describes the main elements of TCC to highlight the characteristics and use of a complex CCS generating tool.

2.2.1 The Concept

TCC is a tool for helping to develop an Expert System, which we prefer to call a "Computer Consultant System" (CCS). This is defined as "an artificial intelligence whose knowledge base is constructed for a specific domain" [29].

TCC was conceived with the idea that many situations being analyzed involve logical and likely relations too numerous for most people to handle consciously at one time. In such situations it is all too easy to make mistakes or simply forget an important factor. A CCS thus can be developed with TCC and employed to replicate the logical chain of thought of an expert (or experts) in a particular field. CCS's also can be utilized to capture the relative likelihoods that the expert assigns to certain occurrences so that both logical and likely conclusions can be drawn [29].

The potential uses for such expert systems are quite wide. In fact, TCC already has been employed on such diverse topics as contracting, housing co-ops, airport security, finance, and street maintenance operation. In this research TCC will be employed on a topic from the engineering field--road resources management.

2.2.2 Methodology

The concept and the methodology are best explained by

an illustrative example which centers on decisions to be made by a consultant in the United States Agency for International Development (USAID) at Islamabad, Pakistan. The goal is to have the relevant agencies (district councils--i.e., local governments of the project districts) implement a proposed road maintenance plan. The first and simplest CCS has a freestanding decision by the consultant to propose the plan (or not).

As an elaboration of this example, suppose that the consultant in the USAID office is thinking about proposing a plan that his organization has developed to design a USAID-funded road maintenance program for rural roads in some selected districts of the Sind Province in Pakistan. In assessing the likelihood of implementation of that plan, he might have to consider the reactions of the provincial government, the federal government, and the district legislative council of each district. He also might have to take into account the workload and transience (or not) of the district council engineering office as well as budgets assigned to those other agencies (district councils) needed to implement the plan (which is the goal to be achieved). The logical sequence might look like:

IF: The consultant proposes the plan

THEN: The provincial government will approve the plan.

IF: The consultant proposes the plan

AND IF: The provincial government approves the plan

THEN: The district legislative council approves the plan.

IF: The district legislative council approves the plan

AND IF: The federal government approves the plan

THEN: The district council engineering office will develop the technical specifications and contract clauses.

IF: The district council engineering office prepares technical specifications and contract clauses

AND IF: All the districts included in the project are given sufficient budget

THEN: The district councils will implement the road maintenance plan.

Note that the outcome of one set of statements can be part of the input to another. This leads to a network of interconnected statements leading to the conclusion of "the district councils will implement the plan." This network is shown in Figure 1.

TCC can be utilized to analyze the impacts of various inputs to this sequence. Will the plan be implemented, for example, if the federal government does NOT approve the plan and the districts are NOT given sufficient budgets? Different positive-negative combinations of the conditions

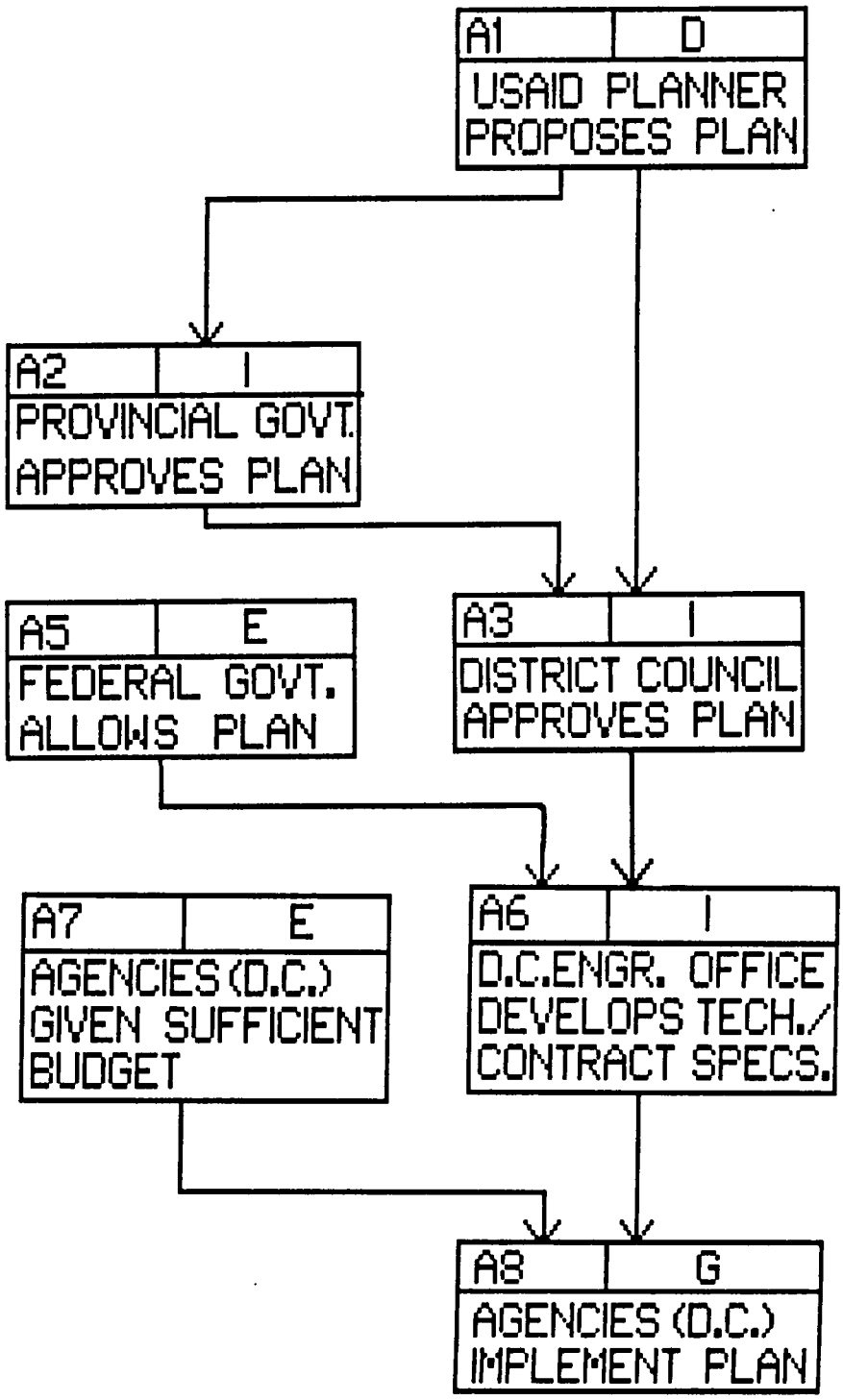


Figure 1: Example Network of Interconnected Conditions

(Rural Road Resources Project)

in the statements leading up to "the district councils will implement the plan" could produce a different outcome.

TCC can be employed simply to set up and interrelate statements like those above. But it can be taken a step further. We all realize that very little is absolutely certain in this world. Determining if the federal government will approve the plan, for instance, is a highly judgmental and risky endeavor. This can be recognized in TCC by assigning "confidences" or "likelihoods" to each condition. To illustrate, the consultant might estimate either from past experience or from talks with a "real" consultant, the likelihood that the federal government will approve the plan. If that likelihood is high, there naturally also should be a high likelihood that the plan will be implemented. TCC thus can, if desired, provide not only a logical conclusion from a set of statements, but also the chance that the conclusion will be true. TCC therefore is capable of highlighting the risks and uncertainties associated with many decisions. Application of TCC is given in the next chapter.

2.3 The Idea Machine

2.3.1 Concept and Methodology

Work has progressed over the last four years in a technique of creativity enhancement known as The Idea

Machine (TIM). The notion of TIM first came to light from a survey of the literature on creativity and on computer stimulation of such. Almost all the sources generally talk about a four-step process involving (1) Preparation; (2) Incubation; (3) Insight; and (4) Verification. They then focus on the use of metaphor and analogy in this process and on the building of one idea on another, as in brainstorming. TIM generally follows these steps, employing analogies with concepts taken from such diverse fields as engineering, sociology, religion, biology, management, and science fiction. The basic objective in TIM is to specify in detail the study condition for which an idea (or ideas) is needed and then use that statement to develop, via analogy, a series of broad strategies from which the user can select one that appears most appropriate.

Computer scientists, particularly those in Artificial Intelligence (AI), have given relatively little attention to the subject. Those that have addressed anything similar have centered on mathematics as a topical domain and have tried to automate the entire discovery process. TIM tries to bridge the gap between the completely automated and completely unautomated approach. It elaborates on a much larger and broader framework for the four-step process but, at the same time, it leaves room for human hunch, intuition, and experience to play important roles in the creative process.

2.3.2 The Process

The main steps in the process are diagrammed in Figure 2. First, a specific client for any forthcoming ideas is identified. Next, the aim to be achieved is set out in a sentence or two. At that point a small group of words (base words) is selected to describe the essence of the aim. These words are taken from a set provided by TIM [27].

In step 4 a matching process takes place by which the selected words are compared to those associated with the concepts stored in the diverse TIM data bases. Matching concepts may be presented in written, audio, visual, and even aromatic forms. The user then is asked to draw ideas from any relevant analogies (step 5). Finally, in step 6, the best resultant ideas would be selected (screened) and then put in "packages" for implementation [27].

One of the advantages of TIM is that concepts can come from a variety of sources other than the written word (step 4). Some of the sources can be: (1) particular word files; (2) synonyms/examples; (3) the Electronic Encyclopedia; (4) proverbs; (5) music; (6) aromas; (7) video disks; (8) slides or pictures; (9) non-electronic encyclopedia; and (10) user knowledge/experience [27].

The process is better understood by an example application of TIM. An illustrative example on rural roads is presented in Chapter Three. In its present form TIM is functionally complete up to and including step five of the

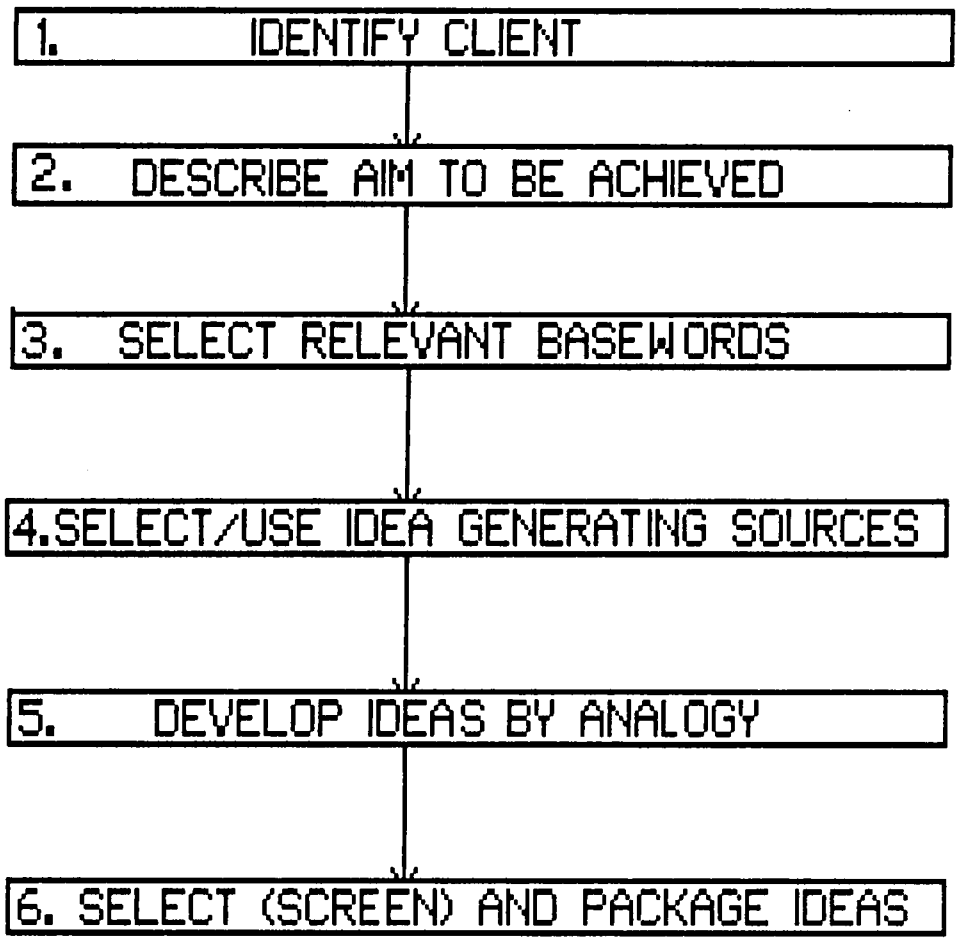


Figure 2: Six Stages in The Idea Machine Process

process, but it is deficient in its last step. So, the program needs to be developed further to include screening and packaging capability. Hence, the screening and packaging of ideas is briefly discussed here, while additional concepts are presented in Chapter Four (Review of Literature).

2.3.3 Screening and Packaging of Ideas

2.3.3.1 General Description

Screening (Selection) and Packaging is the sixth stage in The Idea Machine Process (Figure 1). Diverse ideas generated by use of TIM need to be culled and grouped for further use. "Screening" is a review of the many generated ideas to select the most relevant ones. In "packaging", two or more ideas are combined into a strategy for solving a particular problem or set of problems. In the case of a model or system in which a number of factors comprising a problem are identified, ideas may be packaged which address the same and/or different factors.

Screening and packaging can be done manually or through computer programs. Many studies on analogy have been done, but not much is available on specific techniques to screen and package the resultant ideas. In this research we shall suggest some manual and conceptual research approaches to screen and package the ideas. These concepts eventually

form the basis for building the mathematical models and the computer programs.

2.3.3.2 Rationale

Some of the rationale for the selection and packaging of ideas is given below:

(1) Ideas may holistically complement one another, resulting in an impact on the final goal (or problem statement) which is more than merely the sum of the impacts of the individual ideas.

(2) Ideas may come from quite different directions and so increase the chance of successfully reaching the goal or solving the problem. This is similar to the concept of "triangulation," as it is borrowed from the field of surveying and applied to social science research. In triangulation, different methods of collection are employed in order to gather data which address the same question, e.g., archival research and direct observation may both be used in an attempt to gauge employees' use of an organizational library.

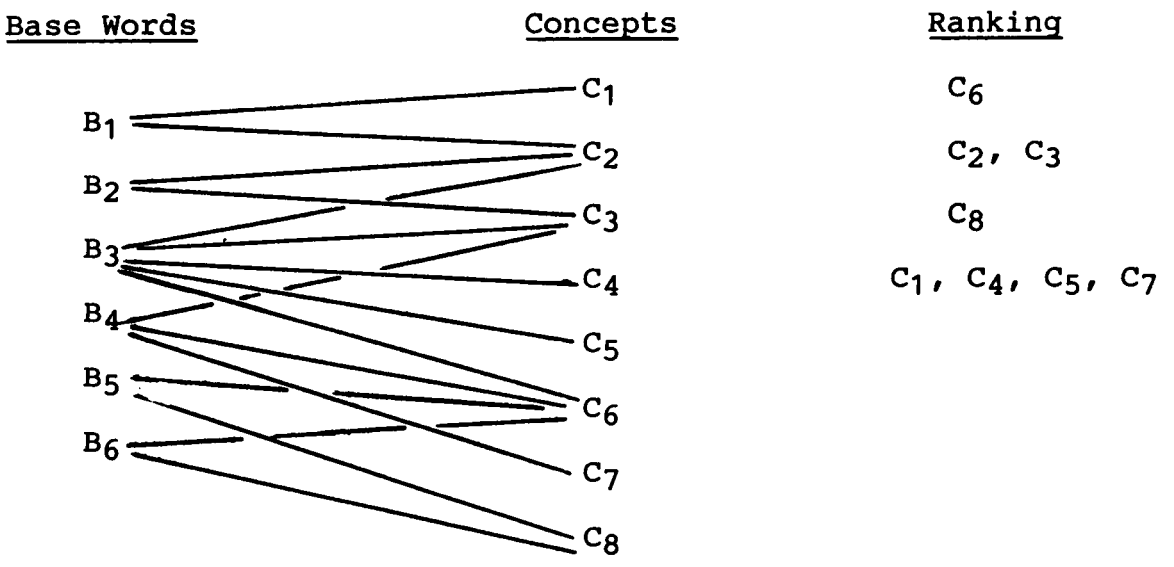
(3) Ideas may be packaged for political purposes. Particularly in an instance in which there are a number of stakeholders, ideas may be selected and combined which reflect the varying preferences of individuals or groups. In this way the overall idea package may gain widespread support. For instance, if Group A supports

idea #1 and Group B supports idea #2, then the use of both ideas (assuming that they are not disparately opposed) might gain the support of both groups. This is obviously important, as the greatest solution to a problem will be ineffective if it receives inadequate support from a major group or is sabotaged.

2.3.3.3 Screening

Several techniques for screening of ideas are discussed under "Review of Literature" in Chapter IV. One is suggested and discussed here. This is predicated on the number of base words supporting a concept. While applying TIM, an expert picks a few relevant base words (from the list in the program) to generate ideas. A base word will instigate the computer to search and display known concepts. These concepts instigate the expert's mind to think of related idea(s). A particular concept may be displayed against more than one base word. Keeping track of the concepts (used to generate ideas) and counting the number of base words from the selected list which support each of the concepts will result in a relative ranking, which also implies a ranking of the generated ideas. This can help in picking the top one for further use.

For example, suppose an expert picks six base words, starts using TIM, and comes up with eight concepts:



The same thing can be shown in a table:

	CONCEPT							
BASE WORD	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
1	X	X						
2		X	X					
3		X	X	X	X	X		
4			X			X	X	
5						X		X
6						X		X
Total	1	3	3	1	1	4	1	2

In this example any generated ideas based on concept C_6 are taken as most important. The accuracy of the results is

related to the range and authority of the information data base of TIM. It appears feasible to modify the existing TIM program to include this technique, i.e., develop a routine to implement this method.

2.3.3.4 Packaging

Some packaging concepts and methodologies are reviewed as follows:

(1) Packaging is required to find out how the screened ideas fit together. A package can have ideas which are in a sequence and are used in that order. Another package may have ideas which may not necessarily be considered in a particular sequence, but instead belong to one group or category. These two types are explained in Figure 3. For example, in Package A the client is first asked to do idea 1 then look at idea number 2, followed by idea number 3. In Package B the three ideas fit together as one package as they concern the availability of funds for the project. (2) Establishing a sequence of use of ideas in a package is important. The PERT technique may be useful in setting up the requisite package. "Think Tank", an "idea processor" program, can be utilized to help in outlining, ordering, and packaging idea chains in preparation for evaluation. In fact, a variety of commonly available software packages can be employed in and with TIM. This makes TIM (including TCC) a highly flexible and beneficial tool for idea generation

Package A: Ideas to be considered in a sequence [27]

1. Collect and analyze information on labor for tasks

THEN:

2. Look at four types of "reducible waste" (e.g., any transportation)

AND THEN:

3. Reduce time available to do the work (so that more useful work is done)

Package B: Ideas to be considered in a category or group

1. Increase revenue as a result of additional taxes/tolls

2. Obtain additional allocation of funds from the federal government

3. Obtain funds from an international donor agency

Figure 3: An Example Package of Screened Ideas

and analysis [6].

(2) Development of an Ideas Record Frame

The expert prepares a record "key" (or "frame") related to the subject on which ideas are generated. The key below, for instance, involves factors such as finance, economy, and climate.

Idea #	Fin-ance	Econ-omy	Manage-ment	Con-struct-tion	Main-ten ance	De-sign	Equip-ment	Train-ing	Cli-mate/ Envir

Using this key the expert enters an idea "weight," on a scale from 0 to 1, (indicating the "strength" of the idea vis-a-vis the related factor). We can go a step further and make a sub-record key for each of the components in the record key. This packaging technique is further elaborated during the example application of TIM in the next chapter.

2.3.4 TIM Applications to Date

Some of the specific applications to date are [25]:

- Stabilizing retail businesses in a low income neighborhood.
- Improving traffic circulation in a small community.
- Development of procedures for inexpensively checking VSLI chips to see if fault free.
- Improving employability of the handicapped.

- Contractor avoidance of building inspection costs.
- Identifying the relationship between ATP and membrane permeability.
- Determining the cause of microscopic crack formation in certain materials.
- Responses to international terrorism.

Many of the results have proven to be interesting and beyond what the individual client would have generated without TIM.

2.4 A Suggested Approach for Application of the Computer-Assisted Creativity Techniques (TCC and TIM)

TCC and TIM have been described separately but their application to a problem-solving process link them together. In fact, TIM includes TCC, and this will be highlighted when these are applied to a case study depicting a real-life situation in Chapter Five.

The proposed approach to apply TIM (including TCC) to the selected problem in this research is shown in Figure 4. After the problem is identified and described, the expert needs to know the client's decision. The expert builds a CCS based on his education and experience and conducts tests with TCC to compute likelihoods and elasticities of the conditions. Based on these tests, rank lists of intermediate and external conditions are prepared. After discussion with the client, the expert applies TIM to all or selected conditions and generates ideas. These are then

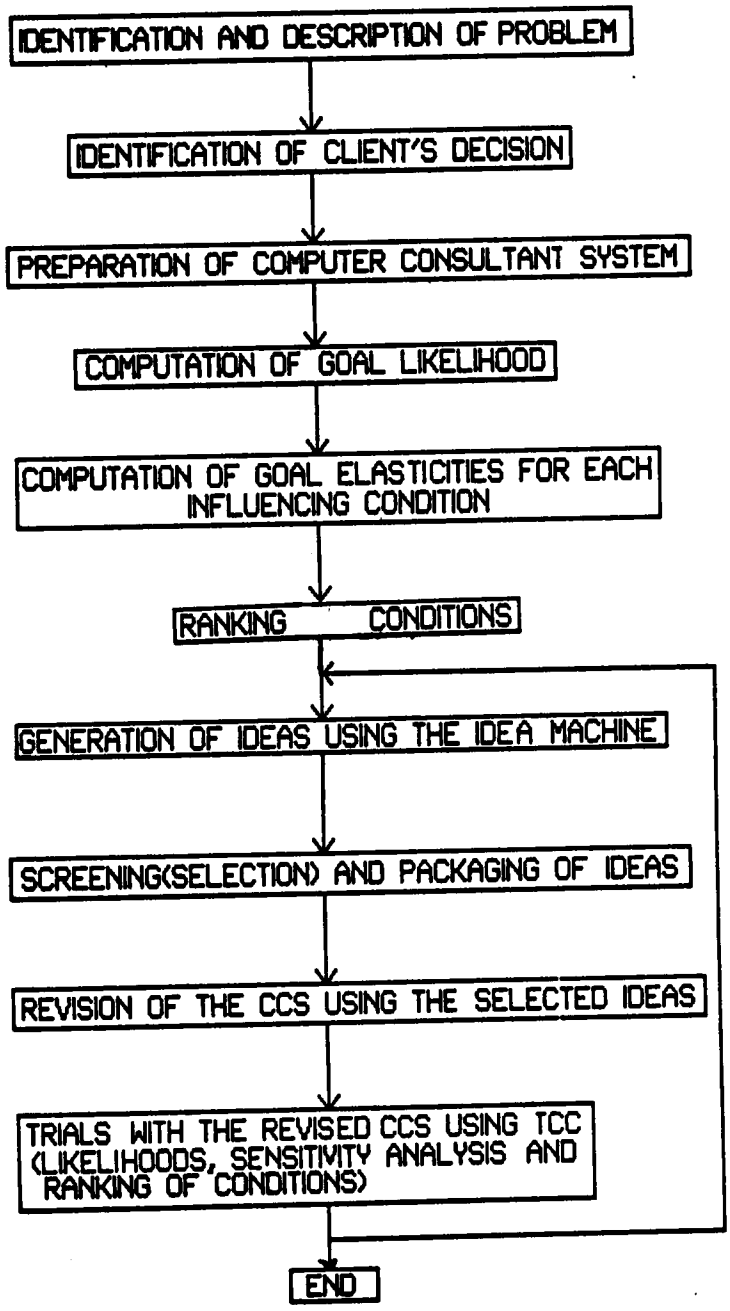


Figure 4: A Suggested Approach for Application of the Computer-Assisted Creativity Techniques

screened and packaged for further use in revising the CCS and to carry out further trials. Here the expert consults the client and decides to go back and generate more ideas by using TIM, or he completes the report. This approach will be employed in this study.

CHAPTER III

EXAMPLE APPLICATION OF TCC AND TIM

3.1 Introduction

In this chapter the concepts and methodology of TCC and TIM are elaborated by application to a problem. The example application is based on the model (Figure 4) built in the previous chapter.

3.2 Example Application of TCC

This section shows how TCC can be employed to:

a. Build or modify a CCS.

b. Inspect the resultant CCS in a variety of ways.

c. Use TCC to compute likelihoods of each intermediate and goal condition.

d. Use the CCS to compute the likelihood of certain conditions given decisions on others as well as external conditions.

e. Use the CCS to conduct the sensitivity analysis to find the elasticity of a particular condition to the goal condition.

Figures 5, 6, and 7 show some of the inputs to TCC. The first step in creating the PLAN-IMP CCS is to list all the conditions in the CCS. These are divided into four

```
==========================================================
 CCS: plan_imp          DATE: 03-08-1987        TIME: 20:27:14
==========================================================
            ID CODE, SUBJECT, AND ACTION/STATUS
==========================================================
                      CLIENT DECISION CONDITIONS
----------------------------------------------------------
* 2* a1 USAID Consultant proposes rd. maint. plan
----------------------------------------------------------
                      EXTERNAL CONDITIONS
----------------------------------------------------------
* 1* a5 Fed. Govt. allows changes in rd. policy
* 1* a7 Agencies(Districts) given sufficient funds
----------------------------------------------------------
                      INTERMEDIATE CONDITIONS
----------------------------------------------------------
* 1* a2 Provincial Govt. approves plan
        a1 USAID Consultant proposes rd. maint. plan
* 1* a3 Dist. Legis. Council approves plan
        a1 USAID Consultant proposes rd. maint. plan
        a2 Provincial Govt. approves plan
* 1* a6 D.C. Eng. Office prepares contract documents
        a5 Fed. Govt. allows changes in rd. policy
        a3 Dist. Legis. Council approves plan
----------------------------------------------------------
                      GOAL CONDITIONS
----------------------------------------------------------
    a8 D.Councils implement rd. maint. plan
        a6 D.C. Eng. Office prepares contract documents
        a7 Agencies(Districts) given sufficient funds
==========================================================
The Quantity Between the Asterisks is the Number of Condi-
   tions Directly Influenced By That Non-Goal Condition.
```

Figure 5: List of Conditions Along with Influences

```
==========================================================
CCS: plan_imp RUN:          DATE: 03-08-1987
==========================================================
a1 USAID Consultant proposes rd. maint. plan          1
a5 Fed. Govt. allows changes in rd. policy            .6
a7 Agencies(Districts) given sufficient funds         .75
==========================================================
```

Figure 6: Decision and External Condition Likelihoods

CCS: plan_imp RUN: DATE: 03-08-1987

CONDITION	COMBINATION OF INFLUENCES		CONFIDENCE
a2	na1		.2
a2	a1		.65
a3	na1	na2	0
a3	a1	na2	.7
a3	na1	a2	.6
a3	a1	a2	.95
a6	na5	na3	0
a6	a5	na3	.9
a6	na5	a3	.88
a6	a5	a3	1
a8	na6	na7	0
a8	a6	na7	.45
a8	na6	a7	0
a8	a6	a7	.95

A `n' BEFORE THE INFLUENCING CONDITION MEANS `NOT'

Figure 7: List of All Confidences

categories:

Client decision: A major choice to be made by the client.

External: A factor assured beyond the control of the client and uninfluenced by any other condition.

Intermediate: A condition that both influences and is influenced by other conditions.

Goal: A final condition that represents the last step or end point and thus does not influence any others.

In Figure 5 the quantity between the asterisks is the number of other conditions that particular one influences (or to which it is a direct predecessor). The conditions shown indented are those that influence the one above it.

Figure 6 shows that each decision (in this CCS there is only one--designated by the ID CODE of "A1") has a corresponding "yes" (1) or "no" (0). Similarly each external condition, A5 and A7, is assigned an initial likelihood (0.6 and 0.75 respectively).

A third set of inputs, displayed in Figure 7, is the "confidences." These show the probabilities associated with each logical combination of directly influencing conditions. As an example, since A1 and A2 influence A3, there are four logical combinations of influences (see second set in chart). Thus, for instance, if A1 does not occur (designated by "nA1") and, likewise for A2 ("nA2"), then the confidence (or probability) that A3 occurs is zero.

As a generality, the confidences are supplied by

experts, through generalization of their experiences, or are based on statistical cross-classification. The likelihoods and decisions, however, are based on the "local" situation and data.

Figures 8 and 9 highlight two ways of displaying the CCS "graphically." The former shows all the conditions on the most direct paths from any non-goal condition to a goal (in this case A1 to A8). The latter chart is derived in the same way, but gives the full description of the conditions instead of just the ID CODES.

There are several ways in which TCC can be employed. One that has a fairly direct analogy with traditional systems analysis involves taking the inputs in Figures 6 and 7 and calculating, through Bayes Equation [24], the likelihoods of each intermediate and goal condition. This is portrayed in Figure 10, where the likelihood of A8 Districts Implement Plan, comes out to be about 0.74.

Another useful type of output from TCC is the sensitivity analysis portrayed in Figure 11. A particular external condition or decision is selected (in this case A5) along with a goal (the only one here being A8). The initial value of the former had been set at 0.6. This is arbitrarily reduced by 0.1 to 0.5. The likelihood of the goal, A8, then is calculated for both these cases. These turn out to be 0.739 and 0.720 respectively. The elasticity of A5 with A8 subsequently can be computed (0.141). This

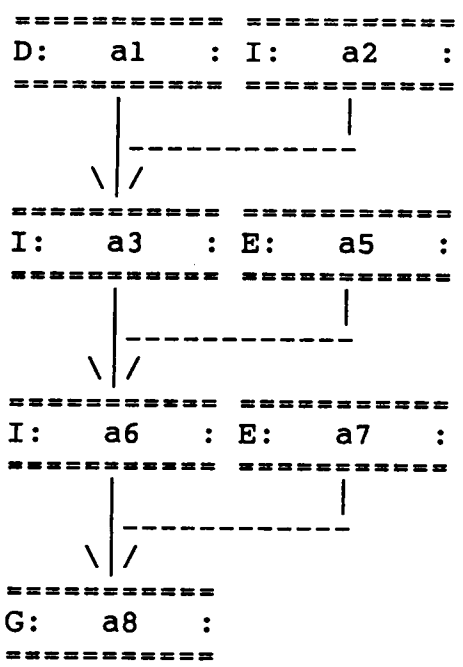


Figure 8: CCS Displayed "Graphically"
(Direct Influence Paths)

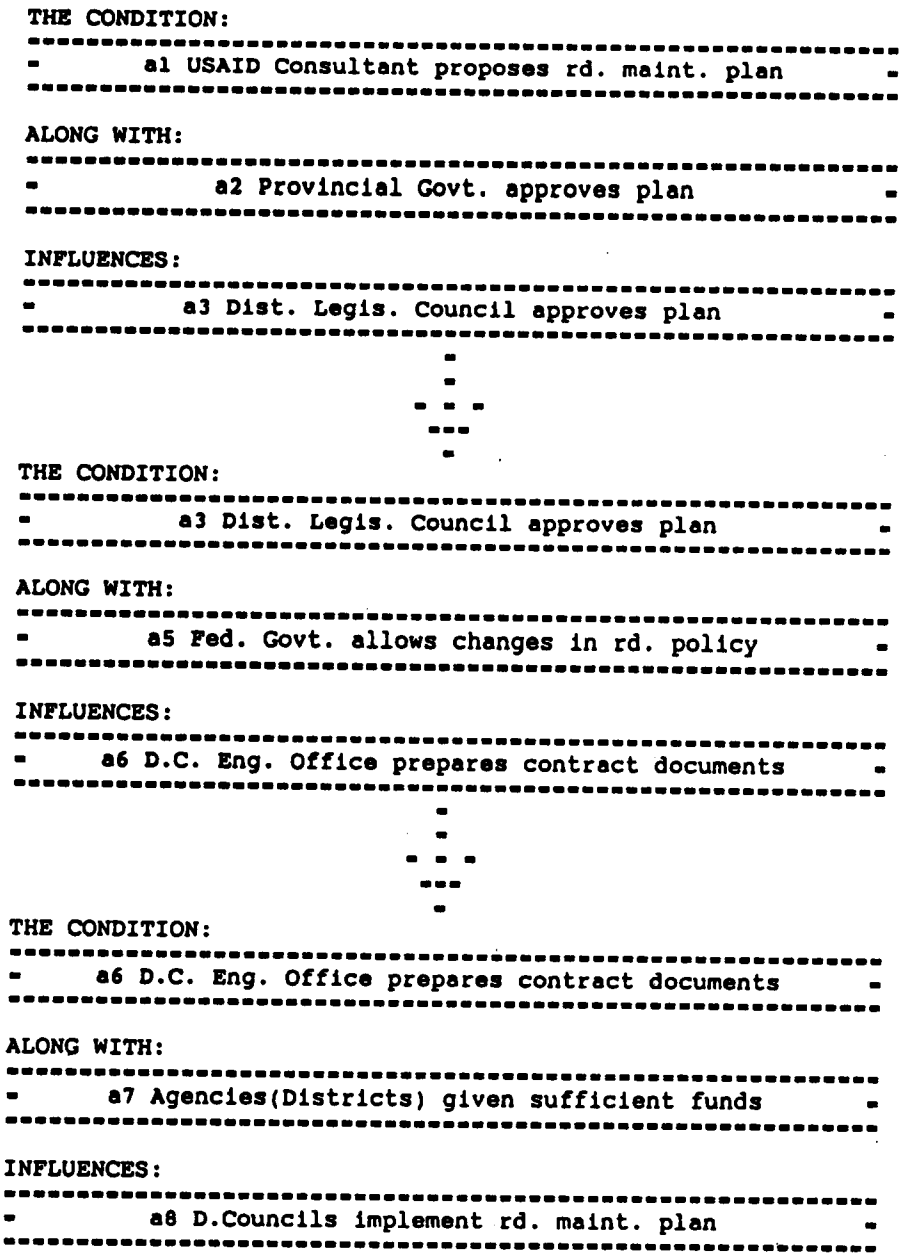


Figure 9: CCS Displayed "Graphically" (Full Description)

```
============================================================
CCS: plan_imp RUN:          DATE: 03-08-1987
============================================================

------------------------------------------------------------
a2 Provincial Govt. approves plan
                . . . . . IS PROBABLE  ( .65)
------------------------------------------------------------

------------------------------------------------------------
a3 Dist. Legis. Council approves plan
                . . . . . IS PROBABLE  ( .862)
------------------------------------------------------------

------------------------------------------------------------
a6 D.C. Eng. Office prepares contract documents
                . . . . . IS PROBABLE  ( .895)
------------------------------------------------------------

------------------------------------------------------------
a8 D.Councils implement rd. maint. plan
                . . . . . IS PROBABLE  ( .738)
------------------------------------------------------------
============================================================
```

Figure 10: Resulting Likelihoods

FOR THE:

CCS: plan_imp RUN: DATE: 03-08-1987

THE SENSITIVITY OF END (GOAL OR FINAL DECISION) CONDITION:
a8 D.Councils implement rd. maint. plan
TO CHANGES IN THE DECISION/EXTERNAL (INFL) CONDITION:

	INFL COND LK/DEC 1	INFL COND LK/DEC 2	END COND LKHOOD 1	END COND LKHOOD 2	ELASTICITY
a1 USAID Consultant proposes rd. maint. plan	1	0	0.739	0.486	0.206
a5 Fed. Govt. allows changes in rd. policy	0.600	0.500	0.739	0.720	0.141
a7 Agencies(Districts) given sufficient funds	0.750	0.650	0.739	0.694	0.437

Figure 11: Sensitivity Analysis

shows that a 1% increase in the likelihood of A5, all other factors being held constant, leads to a 0.141% increase in the likelihood of A8. Such elasticity figures can help the analyst and client determine which conditions generally are having the greatest unit influence on the goal(s).[1]

3.3 Application of TIM

The application of TIM is illustrated by a very simple and brief problem selected from the example already discussed under TCC application (Figure 1). The client in this example is the USAID Office. It wants to plan, design, and fund a rural road maintenance project for a few districts in the Sind Province of Pakistan.

While there are several problems with the planning and completion of the road project under study, the most crucial one is that of availability of sufficient budget for each of the project districts. USAID will finance the project; yet due to neglect in the past, the roads are in very bad shape and additional funding resources need to be explored to maintain and upgrade the maximum number of roads in each district. So the client asks the consultant to generate ideas, through TIM, on the condition of "Agencies given sufficient funds" (Figure 1). The aim (step 2, seen in the middle of Figure 12), thus is to "generate sufficient funds

---

[1]Some of the phrasing in Section 3.1 came from the "brochures" on TCC by John W. Dickey.

Client:	USAID
Aim:	Generate sufficient funds to complete maintenance of roads in each of the project districts.

Base words for a possible search:

Finance, Money

Numerous<>Scarce, Wealthy<>Poor

Figure 12: Identification of Client, Aim, and Base Words

to complete the maintenance of roads in each of the project districts."

In step 3 (bottom of Figure 12) four base words are selected from a TIM list to represent the preceding aim. These are represented by two nouns (Finance, Money) and two adjective pairs (Numerous<>Scarce, Wealthy<>Poor).

Step 4 in the TIM process involves a search for relevant concepts. As noted earlier, these can come from quite diverse sources (from engineering to art). This step in the process involves matching. To illustrate, generation of sufficient funds is always an important issue during planning and execution of road projects. So "Anxiety about Finances" might be a useful concept and TIM selected it (Figure 14) because of matches on the words "finance" and "wealthy."

As in step 4 of the process the concepts are generated based on the principle of analogy, so it is logical to briefly explain the application of analog distance. Part of the process TIM uses in creating idea chains involves matching base words. The words do not have to be exactly the same, however. Suppose the originally selected base word had been "money." The first closest word could be "wealth," which might be used in its place. Or, the second closest of "quality," or the tenth closest of "peer group" might also be employed. This is shown below:

Base Word:	5610 Money
First Closest Word:	5930 Wealth
Second Closest Word:	5700 Quality
.	
.	
.	
.	
Tenth Closest Word:	1600 Peer Group

The advantage of using words at a greater "analog distance" is that they may lead to more novel and unique concepts being selected by TIM. On the other hand, the selected concepts may be difficult to use in analogy generation. TIM thus offers the user a choice of analog distances in making a tradeoff [25].

Step 4 in the process involves matching. To illustrate, let us apply TIM to our example (Figure 13) and generate concepts using the selected base words. Results are shown in Figure 14.

In step 5, TIM asks the user how the concept can be applied to generate an idea for the aim under study. This usually requires that the user specify an instigator, action, and impact for the proposed idea. In this case, the user feels that a good idea would be for a consultant to collect and analyze information on revenue generation sources of each district included in the project. While this certainly is not a new idea, it still may be worthwhile in this case.

In TIM step 6, the generated ideas first are screened to select the most relevant ones. Then, some or all of

CAN YOU THINK OF A GOOD WAY TO INCREASE THE AMOUNT OR LIKELIHOOD OF: Revenue generating sources

TO: Generate sufficient funds to complete maintenance of roads in each of the project districts

TO DESCRIBE YOUR IDEA, FILL OUT THE CHART BELOW

WHO OR WHAT IS THE INSTIGATOR? Consultant

ACTION VERB? Collects and Analyzes

Collects and Analyzes WHOM OR WHAT (OR BLANK)? Information

PREPOSITION (OR BLANK)? on

WHO OR WHAT IS IMPACTED MOST BY Consultant? Revenue Generating Sources

CONDITION OF Revenue Generating Sources AFTER THIS IDEA IMPLEMENTED? Known

MATCHING WORDS: Finance, Money, Numerous<>Scarce, Wealthy<>Poor

---

Figure 13: Example of User Entry of an Idea Based on the Suggested Concept

C_1 RELATIONAL CONCEPT: Anxiety about finances
(Match: Finance, Wealthy)
IDEA 1: Plan next year's development budget and development projects in time.
IDEA 2: Review and revise the toll rates to generate sufficient funds for road maintenance.

C_2 RELATIONAL CONCEPT: Perceived control of income
(Match: Money)
IDEA 2: Tighten budget control to reduce wastage.

C_3 RELATIONAL CONCEPT: Things people value are scarce
(Match: Scarce)
IDEA 3: Finance road projects with district council revenue as well as the international donations.

C_4 GENERAL IDEA: Somebody "extend credit" to something
(Match: Money)
IDEA 4: Loans and matching funds from the provincial government should be added to the money available for road projects.

C_5 DEFINITIONAL CONCEPT: All dwelling units privately owned
(Match: Wealthy)
IDEA 5: Involvement of private sector in road construction/maintenance projects should be encouraged to reduce the government burden.

C_6 SPECIFIC IDEA: Public Manager delivers honest work for other agencies and individuals
(Match: Institution)
IDEA 6: District Council Chairman should insure that the Council distributes the district revenue fairly to all the areas.

Figure 14: Sample of Ideas Generated with TIM

these screened ideas can be combined into "packages" for implementation. In the first part, the concepts from Figure 14 are compared according to base word usage. Figure 15 shows the concepts generated by use of five base words.

C_1 is the only concept which is supported by two base words, while each of the other concepts is supported by only one base word. So the ideas generated as a result of C_1 concept are considered most important. The remaining ones are equally, if less important, so let us suppose that numbers 4 and 5 are selected in addition.

Next is the "packaging" process. The expert classifies the screened ideas and allots weights, as illustrated in Table 1. All four ideas pertain to finance. Ideas #1 and 2 also concern management. Idea #4 concerns funds from the district council revenue and the international donations. The former source is used for maintenance only, while the latter could be used for design, construction of new roads, purchase of equipment and for training of staff and contractors. Idea #5 concerns the matching funds and allocations from the provincial government. This is normally allowed to be used for construction of new roads and purchase of equipment. So the expert, while allotting weights, keeps these aspects in mind. As a result of this classification the obvious packages can be:

Package #1: Ideas #1, 2, 4, 5 (Finance)

Package #2: Ideas #1, 2 (Management)

Base Words	Concepts					
	C_1	C_2	C_3	C_4	C_5	C_6
Money		X		X		
Finance	X					
Wealthy	X				X	
Scarce			X			
Institution						X
Total	2	1	1	1	1	1

Figure 15: Screening of Ideas

Table 1: Record on Ideas: Illustrative Example
(Weights within Brackets)

Idea #	Factors								
	Finance	Economy	Management	Construction	Maintenance	Design	Equipment	Training	Climate/ Envir
1	(.7)		(.8)						
2	(.6)		(.5)						
4	(.8)				(.7)	(.6)	(.5)	(.4)	
5	(.5)					(.5)	(.4)		

Package #3:	Idea #4	(Maintenance)
Package #4:	Ideas #4, 5	(Design, Construction)
Package #5:	Ideas #4, 5	(Equipment)
Package #6:	Idea #4	(Training)

The weights within each package show the relative strength and importance of each idea.

Now, the consultant selects one of the six packages and links to the appropriate condition in the existing CCS (Figure 1). For example, the consultant selects package #2 and introduces external conditions influencing A7 (agencies given sufficient budget) and applies TCC to find the new goal likelihoods. The revised CCS is shown in Figure 16. The new goal likelihood is .805 as against .738 (old likelihood). The increase means that the goal likelihood becomes more probable to succeed with the two additional conditions concerning the management of finance ideas. Good financial management means more funds available to the agencies (D.C.) for the implementation of the development plan.

The goal likelihood in the CCS ("PLAN-IMP") is 0.738. The two ideas are then entered as external conditions influencing A7, which becomes an intermediate condition. The goal likelihood then comes out to be 0.805. Let us assume that the client agrees to both the ideas. Thus we introduce the two corresponding decision conditions into the

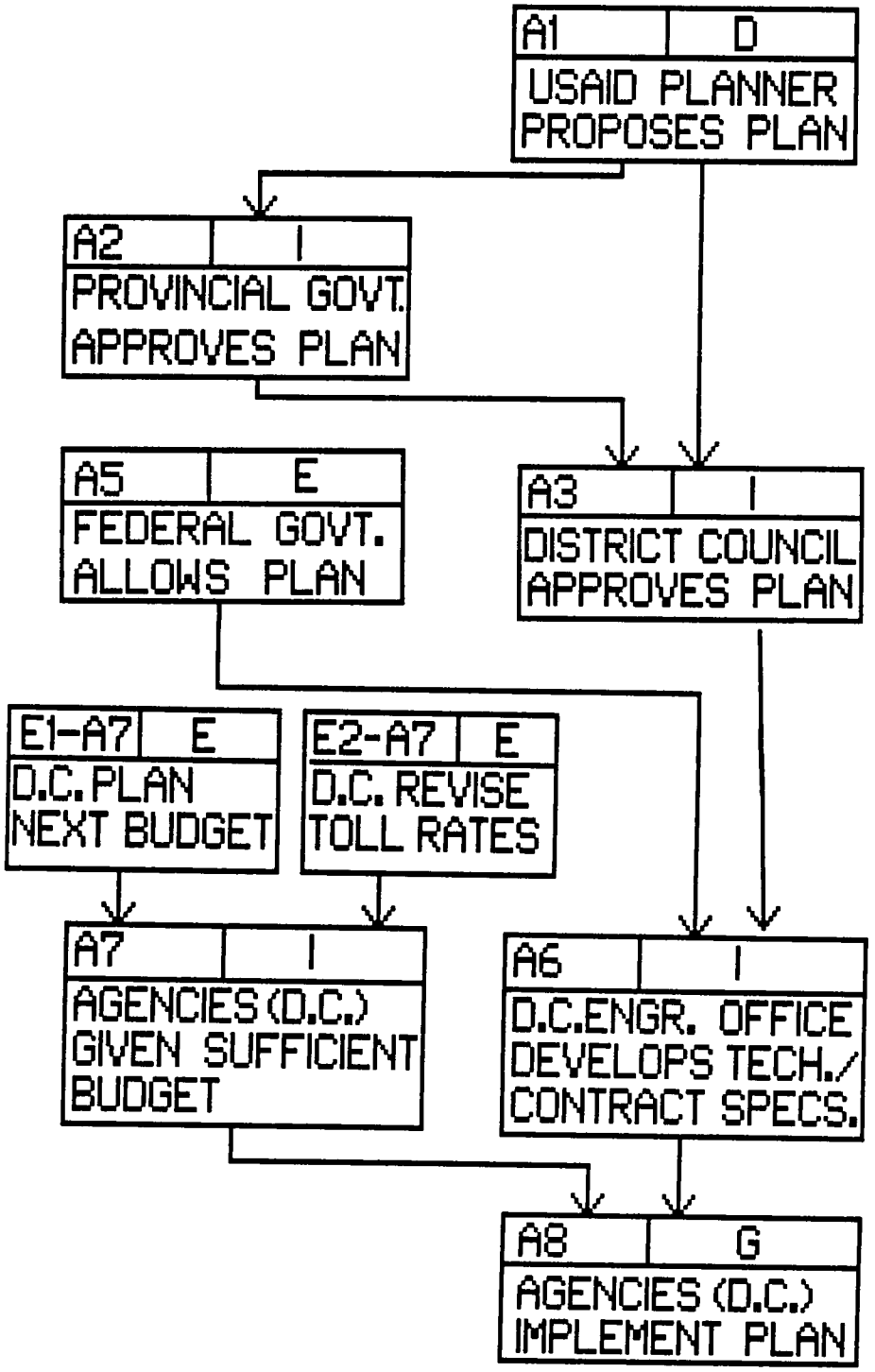


Figure 16: Revised Example Network of Interconnected Conditions

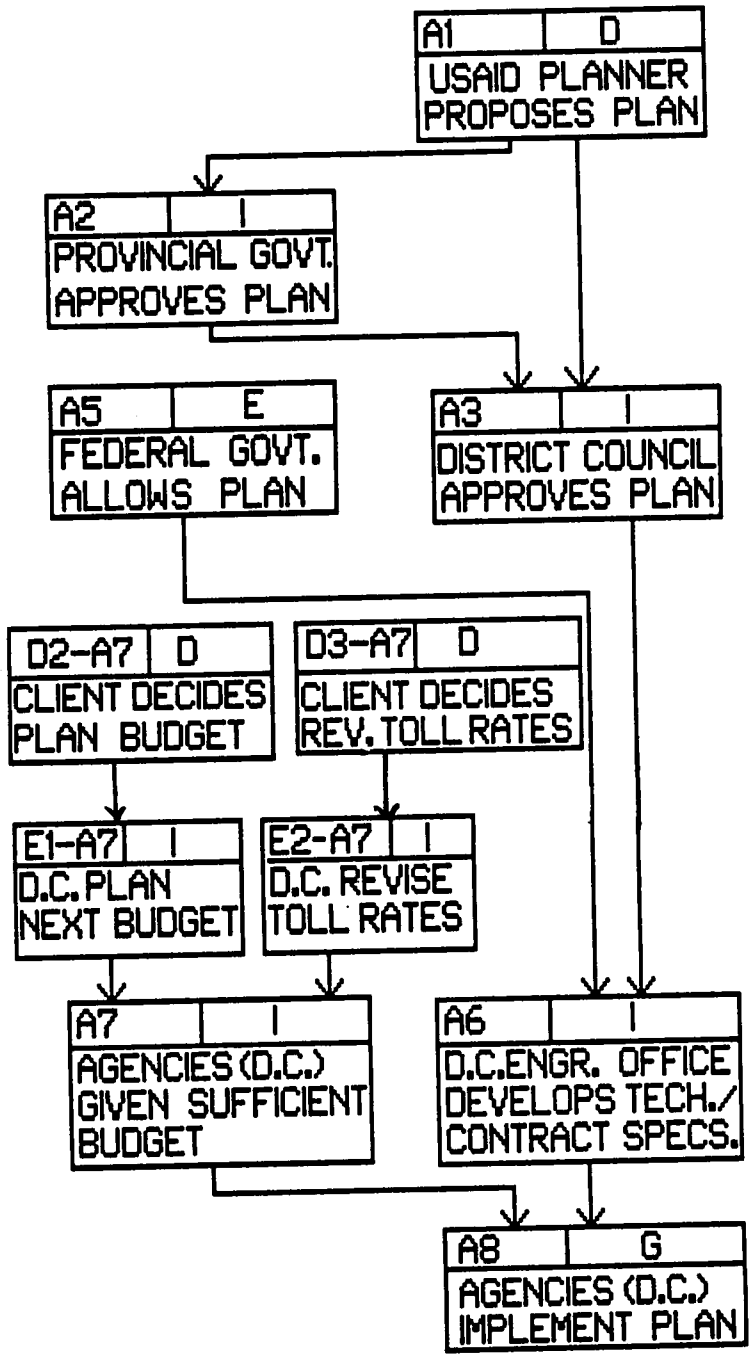


Figure 17: Example Network of Interconnected Conditions with Decision Conditions

CCS (Figure 17). The goal likelihood with D2-A7 decision condition active turns out to be 0.819, while with D3-A7 it is 0.817. With both the decision conditions the goal likelihood is 0.828. A summary of the results is shown below:

	System (CCS)	Goal Likelihood
1.	PLAN-IMP CCS	0.738
2.	With two external conditions (E1-A7, E2-A7)	0.805
3.	With one decision condition (D2-A7)	0.819
4.	With second decision condition (D3-A7)	0.817
5.	With both decision conditions (D2-A7, D3-A7)	0.828

We thus conclude that introduction of generated ideas into the system does increase the goal likelihood, but it is after acceptance of those ideas as decisions by the client that we get the maximum increase.

CHAPTER IV

REVIEW OF LITERATURE

Some of the basic concepts and methodologies which form the basis for the computer-assisted creativity techniques include:

(1) Creativity

(2) Logic

(3) Decision-making

(4) Analogy

(5) Brainstorming

(6) Metaphor

(7) Data base management system

(8) Evaluation

(9) Screening and packaging of ideas

(10) Pointer

In this chapter, a very small portion of literature on the above-mentioned concepts and methodologies is given a cursory review so as to facilitate the understanding of these computer-assisted techniques. Obviously these are very broad areas, each in itself having a vast literature; thus we will only skim the surface. More emphasis is put on screening/packaging, but we do not intend to be comprehensive, merely to show the broad connections to computer-assisted creativity.

Creativity

Many people, perhaps most, think that ideas fall from heaven like manna. However, creativity does not have to work that way. Ideas can happen as if by divine revelation. More often, though, they are the end product of arduous and well-organized intellectual activity. The final thought, referred to here as the "idea," is the result (Baker, 1979, p. 2).

Once we are willing to concede that creativity is not just a haphazard occurrence but a purposeful exercise, things fall into line with surprising ease. Logic encourages, "not" discourages, inspiration. To illustrate our point, we can choose as a symbol one of man's most extraordinary achievements, the pyramid. This structure rests on a wide base. Reaching for the sky, it tapers upwards until it comes to a point. In that, it bears a close resemblance to systematic problem solving. The foundation of the pyramid is the beginning of the creative thought process, the gathering of information. Without it, the structure would have no more solidity than a house of cards. The middle part represents the next phase, "analysis," which includes a wide variety of activities. Fortunately, the human brain is eminently flexible. It can stretch, dissect, combine, compare, backtrack, and juggle thought components with amazing facility. When it comes to reasoning, the brain surpasses even the largest computers

which admittedly can ingest several billion bits of information, but, unless told what to do with all that fodder, produce nothing of value. The third part is the culmination of all the effort, the "idea" (Baker, 1979, p. 2).

It is important and reassuring to know that the ability to create something tangible (a book, a picture) is hardly the sole criterion of being creative. Such an accomplishment merely suggests the presence of certain "talent"; it qualifies the individual as an expert in a field. However, it is possible to be creative, yet not to profess technical virtuosity in any one area. The hallmark of creative persons is their ability to initiate projects. If they lack the particular talent or training needed to implement their ideas, as is often the case, they know how to find someone who has it (Adiekes, 1981, p. 3).

It is amazing how easy it is to turn noncreative minds into creative ones by gentle prodding. Courses given in creativity are a case in point. When Dr. S.J. Parnes and Dr. A. Meadow offered a course in creativity, emphasizing goal-oriented thinking and utilization of knowledge, they found that within a semester their students became more creative (Baker, 1979, p. 4).

Decision-making

Decision-making is the act of selecting one from among

a set of feasible courses of action. A plan represents a set or sequence of decisions, each related to the others. Decision-making involves action. If decision-making does not lead to action, it is a futile exercise. Next, the courses of action must be feasible. They must be within the power of the decision maker to carry out. Also, there must be a set of courses of action. The decision maker needs to pick one of these courses. Decision-making is an art. This means that the choice among courses of action must not be passive or done by default. Some other aspects of decision-making are optimality, need for information, and the element of uncertainty (Martino, 1972, pp. 337-339).

The concept of forecast is used as decision information. Forecasting is an important step in a five-step cycle of organizational activity (other steps are plan, program, implement, and evaluate) (Martino, 1972, p. 14).

Within the context of organizational activity, decision-making is the process by which courses of action are chosen (from among alternatives) in pursuit of organizational goals. To be acceptable, a course of action must satisfy a whole set of requirements or constraints. The choice of one constraint over another generates an elaborate goal-action interplay, and in this context, the decision-making process itself is thought to involve at least three major phases:

(1) Analytic Phase. In this phase, situations that

affect goals (problems and opportunities) are perceived and information about them is gathered.

(2) Design Phase. In this phase, courses of action (options) are crystallized to deal with the problem situation.

(3) Choice Phase. In this phase alternatives proposed in one design phase are evaluated, and some are selected for implementation.

In addition, several analysts include the threshold phase (pre-analysis) of self evaluation as an important last phase. Although decision-making can be viewed as a process divided into three or four phases, the process is not goal free; that is, the circumstances in which decisions are made complicate the process. John Steinbruner refers to these circumstances as "complex situations" (Murray, 1986, pp. 10-11).

Analogy

The concept of analogy is used in the computer-assisted creativity techniques. These techniques are an interaction between the human mind and the computer. The human mind can think in horizontal and lateral directions and work serially and in parallel, while a computer can not think. The Idea Machine (TIM) makes use of the analogy principle in generating ideas (step 5 of the process).

Koestler (Weisberg, 1986) believes that everything is

possible in dreams and other related states of human mind; that any thought can be connected to any other thought. Scientists must rely on this sort of thinking, just as poets do, because they try to create analogies between seemingly nonanalogous things. Pliny's creation of analogy between the phases of the moon and the tides is such an example. Furthermore, the mental act of discovery, or the creation of a new analogy, is not based on facts--one does not know that the analogy will be useful until after it is proposed. The initial proposal of the analogy, therefore, is a leap into the unknown. Koestler believes this leap is based on emotional factors; that the analogy first strikes a chord in the unconscious and then we become aware of having thought of it. This is very similar to Poincare's theory of aesthetic judgments in the evaluation of ideas (Weisberg, 1986, p. 23).

George Prince, in his book The Practice of Creativity, urges the substitution of synectics methods for the traditional methods of committee work. He sees the synectics methods as having two key approaches: fostering normal means of speculating, and disciplining responses to speculation so that it is not choked off. Prince offers well-reasoned suggestions to leaders in realizing creativity of the participants. Chief among his recommendations is the extended use of "analogies" (Scheidel & Crowell, 1979, p. 312).

Idea Generation/Idea Development

Specific approaches may involve concepts of analogy, brainstorming, and lateral thinking, etc. (Scheidel & Crowell, 1979, pp. 27, 37, 38):

(1) Brainstorming. Osborn's plan: a freewheeling group suggests items for a listing with all criticism held back and with strong support for the production of "many" ideas and "different" ideas. Another panel (or the same one) later evaluates the list for the most promising; these few selected ideas are sharpened and heightened by modification and combination.

(2) Lateral thinking. Edward de Bono suggests lateral thinking as an alternative to the usual "vertical" thinking used in problem solving. He suggests the usefulness of looking at problems in new and different ways. A group may attempt "metaphorical" thinking to achieve imaginative solutions. The members may use (1) "direct analogies" and look at parallel relationships in nature, (2) "personal analogies" and imagine themselves directly involved in the problem, or (3) "fantasy analogies" and think of excellent but "farfetched" solutions. The group may strive for innovation (improvement) in contrast to creation (invention) in listing possible solution plans.

(3) Synetics. William Gordon suggests ways of promoting creativity in developing solutions by thinking in analogies "to make the strange familiar" and, by looking at things from new view points "to make the familiar strange."

(4) Using analogies for tests of inference and idea development.

(a) Are figurative analogies used for proof? Are the two cases compared from similar domains (as if comparing two cities and thereby using a "literal" analogy) or from different domains (as if comparing a city to a heart and thereby using a "figurative" analogy)? Are figurative analogies used appropriately for clarity and illustration or are they used to establish proof for the idea development.

(b) Is literal analogy adequate? If a literal analogy is drawn, do the "significant" items of similarity far outweigh any differences?

Logic

(1) Logic of priorities. Our minds have a limited capacity to assimilate and retain large amounts of information even for short periods of time. Because of such limitations, and because in many situations data are not available, we must base our decisions on the information at

hand and on the experiences we have accumulated over the years. No wonder individuals and even public and private enterprises often make decisions based on subjective knowledge rather than on thorough and complete logical resolution of issues--if that ever is a possibility. In addition, complex decisions are usually characterized by a large number of interacting factors. The problem is how to properly assess the importance of these factors in order to make tradeoffs among them; how to derive a system of priorities that can guide us to make good decisions by choosing a best alternative. To answer this problem of decision-making in the face of risk, uncertainty, diversity of factors, and varying opinions and judgments, an approach developed by Thomas Saaty (called the "Analytical Hierarchy Process") has proven quite useful (Saaty, 1982, p. 3).

(2) Logic Elements. Some of the logic elements are the AND, INCLUSIVE OR, and EXCLUSIVE OR elements. These are depicted in Figure 18.

The logic elements can be added to the intent structure near the end of its formulation when they will make more sense and be better understood. The logic-free intent structure is sometimes called an "objective graph." When an objective graph is in the form of a tree, it is called an "objective tree." The objective tree facilitates visual perception of the structure of the entire problem (Sage, 1977, p. 26).

Data Base Management Systems

Any automated information system is based on a collection of stored items (a "data base") that needs to be accessed. Thus data base management systems might simply be systems designed to manipulate and maintain control of any data base. In actual practice, data base management systems are concerned with the storage, maintenance, and retrieval of data facts available in the system in explicit form. That is, the information does not appear as natural language text, but is available instead in the form of specific data elements stored in tables. In a data base environment each item, or "record," is thus separated into several fields, and each field contains the value for a specific characteristic or attribute identifying the corresponding record. The characteristics used to identify a set of personnel records might be the names of individuals involved, the addresses of the various people, as well as their social security numbers, and the job classification. Specific values of these characteristics are used as identifiers for the individual records (Salton, 1983, p. 8).

Evaluation

Evaluation may be defined as a process that attempts to determine as systematically and objectively as possible the relevance, effectiveness and impact of activities in the light of their objectives. It is an important training and

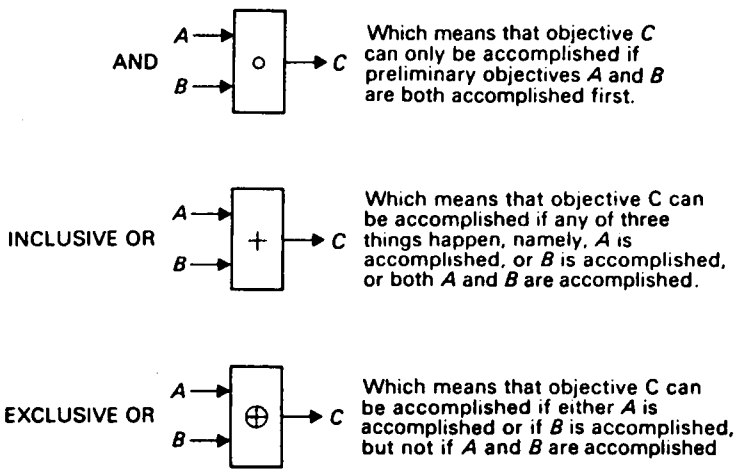


Figure 18: Logic Elements

action-oriented management tool and an organizational process for improving both activities still in progress and future planning, programming and decision-making. The contribution evaluation can make to improving both the planning and the execution of programs and projects is being more and more widely recognized. However, there is no single method or technique of evaluation that can serve all purposes and types of evaluation. Evaluation methods have to be elaborated or adapted to suit the particular need of each program and project, taking into account the availability of information, overall socio-cultural contexts and the purpose of evaluation (UNESCO, 1977, p.3).

It is important to assess the suitability of evaluation methods and procedures to the particular needs of programs and projects implemented in countries considered. It is essential to assess the adequacy of the evaluation methods and techniques and in so doing to identify where there is a need to develop new evaluation designs, methods and techniques. Future research is needed to develop new methods that can be easily adapted to different situations in different developing/developed countries. There is also a need to review the existing evaluation methods for their suitability of application to other techniques like ideas generated in the field of artificial intelligence--for example, The Idea Machine (TIM) concept/method developed by John Dickey at Virginia Tech. Let us identify the key areas

where progress could be made in the project evaluation field itself. First, greater attention must be given to organizational problems, if evaluation techniques are to be improved. A second area is the understanding of the uses of evaluation results and user needs and in developing both theory and policy of choice as to which evaluations should be made and which methods used given limited resources and a variety of sometimes conflicting goals. A third area of possible improvement lies in the methods and techniques themselves and evaluating/reviewing/modifying these techniques to make them applicable to other fields, like to the ideas generated through TIM.

There are many versions/approaches of the project appraisal process advocated by the experts. Dickey, (Dickey & Miller, 1984), suggests a seven-step project appraisal process and evaluation is the last step of this format. The most common techniques used in overall economic evaluation are cost-benefit analysis, internal rate of return, payback period, etc.

Pointer Technique

Variables are static and dynamic. The form and size of static variables is predetermined and they exist throughout the entire execution of the block in which they are declared. Programs, however, frequently need the use of a data structure which varies in form and size during

execution. Dynamic variables serve this purpose as they are generated as the need arises and may be discarded after use.

Such dynamic variables are not declared in an explicit variable declaration like static variables, and they cannot be referenced directly by identifiers. Instead, a special variable is used to point to the variable. This special variable is called a "pointer variable" (Dale & Orshalick, 1983).

Screening of Ideas

Screening (selection) and packaging of ideas generated through TIM is the last step (step 6) in the TIM process. An expert generates many ideas using TIM and not all the ideas are relevant. So a screening process is essential to pick the relevant ideas and also to rank them as per their importance, i.e., the goal condition may be more sensitive to certain ideas as compared to others. Some basic concepts and techniques are reviewed here.

(1) Base word supporting the number of ideas (already presented in Chapter II).

(2) Giving weights to the base words.

The expert, using TIM, selects some relevant base words and generates ideas based on the concepts displayed by the computer. For example, the expert might use eight base words in various combinations, thus using them eight times:

Base Word #	Concepts
1 3 5	(4)
2 4 5	(4)
5 6	(3)

$B_i = N_i/T$ where B_i = weight of base word

N_i = number of times base word is used

T = total number of times base words used

Weight of:

$B_1 = 1/8$

$B_2 = 1/8$

$B_3 = 1/8$

$B_4 = 1/8$

$B_5 = 3/8$

$B_6 = 1/8$

$B_7 = 0$

$B_8 = 0$

Total = 1

The base words used, but generating no relevant concept, have zero weight, e.g., B_7, B_8. Once the weight of each base word is found, generate ideas:

Concepts	Base Words	Weights	Total
C_1	B_1	1/8	
	B_3	1/8	
	B_5	3/8	5/8
C_2	B_2	1/8	
	B_4	1/8	
	B_5	3/8	5/8
C_3	B_5	3/8	
	B_6	1/8	4/8
C_4	B_5	3/8	
	B_7	0	
	B_8	0	3/8

So the ideas generated using concepts C_1 and C_2 are more important than by C_3 and then C_4. Thus the ideas generated using the concept(s) related to a base word with higher weight are more important. This suggested technique can be incorporated in the TIM program, i.e., to enhance TIM capability whereby the computer could calculate the weight

each concept used by an expert to generate new idea.

(3) Ranking (White, Agee & Case, 1977)

If a decision maker (expert) is capable of stating preferences among ideas, then these ideas/objectives may be ranked in terms of relative importance. A technique to assist the decision maker in making consistent preference statements is the method of paired comparisons. To illustrate the method, we assume that four ideas (objectives/goals) are relevant: G_1, G_2, G_3, and G_4. The method of paired comparisons enumerates all possible pairs [n(n-1)/2], makes preference statements, and deduces a ranking for each goal. In this example, the possible pairs are:

G_1 versus (vs.) G_2	G_2 vs. G_3	G_3 vs. G_4
G_1 vs. G_3	G_2 vs. G_4	
G_1 vs. G_4		

If the symbol $>$ represents "preferred to" and the symbol $<$ represents "not preferred to," suppose the results of the decision about the pairs were:

$G_1 > G_2$	$G_2 < G_3$	$G_3 > G_4$
$G_1 < G_3$	$G_2 > G_4$	
$G_1 > G_4$		

Rewriting so that all comparisons are of the "preferred to" variety yields:

$G_3 > G_1$ $G_1 > G_2$ $G_2 > G_4$

$G_3 > G_2$ $G_1 > G_4$

$G_3 > G_4$

It can then be concluded that G_3 is preferred to all others., G_1 is preferred to two others, G_2 is preferred to one other, and G_4 is preferred to zero others, and the following ranks should be assigned: G_3 = I, G_1 = II, G_2 = III, and G_4 = IV.

If, in the above procedure, the preference statement had been $G_1 > G_2$, $G_2 > G_4$, and $G_1 < G_4$, the decision maker should reconsider the inconsistent judgments. The results are "intransitive" in a mathematical sense.

This ranking method is certainly useful, but it has some obvious deficiencies as well. For instance, the ranks do not indicate the "extent" to which one idea is preferred over another. Furthermore, because rankings are an ordinal scale of measurement, the mathematical operations of addition, subtraction, multiplication, division, and so forth, cannot be performed. Therefore, a higher-order scale of measurement (interval or ratio scale) is generally required to determine choices among alternatives under conditions of risk and uncertainty. Unfortunately, accepted methods for measuring objectives on a ratio scale do not currently exist.

(4) Weighting Ideas (Objectives) (White, Agee, & Case,

1977).

This method uses the concepts given in techniques 1 and 2 above. Here the expert assigns weights to ideas by judgment. That is, in the case of four ideas (G_1, G_2, G_3, G_4) the decision maker may reason that G_3 is twice as important as G_1, three times as important as G_2, and five times as important as G_4. Assigning a weighting value of 1.00 to G_3, it can be reasoned that the set of weighting values is:

For G_3: $w_3 = 1.000$

For G_1: $w_1 = 0.500$

For G_2: $w_2 = 0.333$

For G_4: $w_4 = 0.200$

These weights may be transformed to a scale from 0 to 1 or "normalized," by dividing each weight by the sum of all weights: that is:

$w'_3 = 1.000/2.033 = 0.4918$

$w'_1 = 0.500/2.033 = 0.2459$

$w'_2 = 0.333/2.033 = 0.1639$

$w'_4 = 0.200/2.033 = 0.0984$

Another method of assigning weights to ideas by judgment, but still keeping consistency is explained by an example:

Step 1: Assume that it is desired to determine weight

values for four ideas where these have been made in order of importance such that G_1 is most important and G_4 is the least important.

Step 2: The objectives are tentatively assigned the weights: $w_1 = 1.00$, $w_2 = 0.80$, $w_3 = 0.50$, and $w_4 = 0.20$.

Step 3: Assume that G_1 is preferred to the linear combination of the other objectives. That is, $G_1 > (G_2 + G_3 + G_4)$. Since $w_1 > (w_2 + w_3 + w_4)$, it is necessary to adjust w_1 to be greater than the sum of 1.50--say $w_1 = 1.75$. Then proceed to Step 4.

Step 4: Comparing G_2 versus $(G_3 + G_4)$, assume that $G_2 < (G_3 + G_4)$, and the step 3 procedure is repeated. Since the weighting values do not reflect this [i.e., $w_2 = 0.80$ is not less than $(0.50 + 0.20)$], w_2 is adjusted to be 0.65. [The adjustment to decrease w_2 does not violate the previous preference of $G_1 > (G_2 + G_3 + G_4)$ with the new value of $w_1 = 1.75$ to reflect this preference.] Since, in this example of only four ideas/objectives, the comparison of G_{m-2} versus $(G_{m-1} + G_m)$ or G_2 versus $(G_3 + G_4)$ has been completed at this point, step 5 of the procedure has been done.

Step 5: Continue until the comparison of G_{m-2} versus $(G_{m-1}$

+ G_m) is completed.

Step 6: If desired, convert each w_k into normalized value dividing w_k by the sum $\sum_{k=1}^{m} w_k$.

If it is desired to normalize the results, new weighting values are calculated as:

$$w_1' = 1.75/(1.75 + 0.65 + 0.50 + 0.20) = 0.5645$$

$$w_2' = 0.90/3.10 = 0.2097$$

$$w_3' = 0.50/2.10 = 0.1613$$

$$w_4' = 0.20/3.10 = \underline{0.0645}$$

$$\text{Total} = 1.0000$$

For a small number of ideas, this method is relatively easy to use, but becomes cumbersome as the number of ideas increases. However, it is believed that many real-world problems reduce to a few primary objectives. It is emphasized that this method still depends on the decision maker's judgment in assigning the weights.

(5) Linear Programming

We can use linear programming to compare the generated ideas and thus establish a ranking. This can help in screening and packaging of generated ideas. This concept may be easier and more realistic to apply to a few ideas (say, three or four) after these have been narrowed down/ranked by one or more of the above mentioned concepts.

This concept could be best explained by an example of road maintenance by the district council:

Total money available per year = $K

Number of times the job needs to be done per year = N

Takes "H" hours to do the job

Capital = K/N, Z = Capital - Labor Cost - Equipment Cost

Maximize $Z = K/N - (A_1X_1 + A_2X_2 + A_3X_3\text{---}) - (B_1Y_1 = B_2Y_2 + B_3Y_3)$

A_1, A_2, A_3------ = Rates for type 1, 2, 3-----workers

X_1, X_2, X_3------ = Hours worked by 1, 2, 3----workers

B_1, B_2, B_3------ = Hourly expenditure for equipment type 1, 2, 3

Y_1, Y_2, Y_3------ = Hours, equipment 1, 2, 3----is used

Number of days (D) * $(X_1 + X_2 + X_3\text{-------}) = H$

Availability (say):

$2 \leq X_1 \leq 4$

$? \leq X_2 \leq ?$

$? \leq X_3 \leq ?$

.

.

$X_1 = Y_1$

Z is the function

if $Z \geq 0$ ok

if $Z < 0$ not good (must increase K or decrease N)

(6) Screening by an Expert

The expert alone or with other experts and the client reviews the generated ideas, one by one, and based on the past observations and knowledge, classifies them, i.e., allocates status to each idea. A suggested status key can be:

- Infeasible
- Successful
- Unsuccessful (probably was tried earlier)
- Incomplete
- None given
- More information needed
- Has potential
- Implement

This screening procedure can be automated by developing a computer program to work with TIM. Each idea is displayed on the screen and the expert(s) reviews it (as mentioned above) and the idea is either selected or not. Thus, the selected ideas are ready for packaging and subsequent use.

Packaging

Some useful concepts/methodologies have already been presented in Chapter Two. A method based on the "classification" concept has been explained with an illustrative example.

CHAPTER V

RURAL ROAD RESOURCES MANAGEMENT PROJECT

5.1 Introduction

Construction and upgrading of roads add to the development of the region and increase accessibility to various facilities. Construction and upgrading or even improved maintenance can set off a chain of events related to the development of a rural area where accessibility usually is unequally distributed.

A Rural Roads Project for Pakistan is selected as a model to build the system and apply TIM. In this chapter a Background Scenario, including relevant information on Pakistan, will be presented while the system build-up and TIM application are discussed in the next chapter.

5.2 Pakistan (see Figure 19)

Geographically Pakistan's location enjoys a strategic position in its region, and the developments in Afghanistan in 1979 have made this Country the focus of international politics. It became all the more important that Pakistan should grow economically. As a result of these new developments in international politics, the Government of Pakistan, as well as the western powers, took steps to make economic development plans for the Country. The United

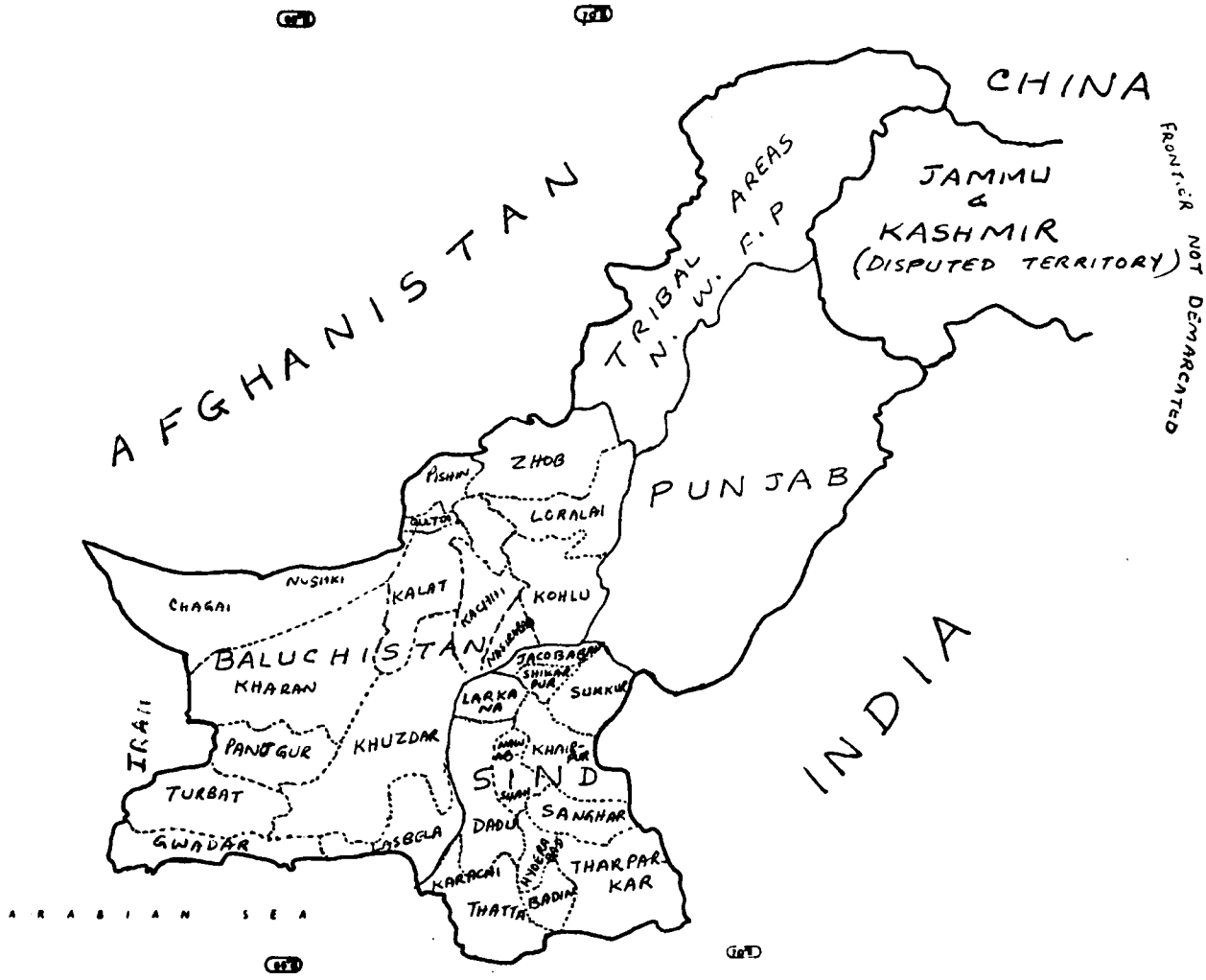


Figure 19: Map of Pakistan--Divisions and Districts

States agreed to fund many development projects in Pakistan under its economic assistance program. One of the projects planned under this program for the Sind Province, includes construction and maintenance of rural roads, and hence was named the "Road Resources Management (RRM)" project.

Administratively, Pakistan is divided into four provinces, and each of them into divisions (administered by a Divisional Commissioner), and each of these into two to four districts (each district administered by a Deputy Commissioner). Each district has a local government run by a District Council (D.C.). Elected representatives constitute the governing body, while the district council staff (executive, engineering, and accounts), permanent and temporary, is employed under a service structure. The District Council is responsible for planning and executing rural development projects. Elected representatives elect the D.C. Chairman and the Vice Chairman. Each D.C. prepares an Annual Development Plan (also called RDP). At the federal level the Local Government and Rural Development (LGRD) Ministry is responsible for rural development. The Federal Rural Roads and Engineering Cell (FRREC) coordinates rural development activities on behalf of LGRD ministry. At the provincial level there is an LGRD department to coordinate the rural development activities.

5.3 Background Scenario and the Problem

While efforts are underway in Pakistan to build up rail transport, particularly for bulk freight, the existing pattern of increasing dependence on roads, particularly in rural areas, is expected to continue. The road network is regarded by the Country's government as seriously inadequate, and this huge deficiency can be made good only through a long-term construction and maintenance program stretched over many national plan periods. The large amount of funding needed to make up the deficiency cannot be allocated from her own budget. Hence Pakistan needs international assistance and credit loans to develop the road system, particularly in rural areas [19].

The United States Agency for International Development (USAID) has done several feasibility studies on rural roads projects and has concluded that:

> At present, road resources are not well managed in this country. At all levels--national, provincial, and district--there is need and a demand for more and better roads. However, very little expansion of the rural road system or real upgrading of the highway system is taking place. The construction practices used in the past and the absence of routine and periodic maintenance combine to cause rapid deterioration of the existing roads. Implementing agencies use nearly

> all their resources mainly to keep the existing system operational. Remaining funds are allocated primarily to upgrading existing roads. Since upgrading typically is not done to acceptable standards, the national road system is rapidly deteriorating [19].

USAID advises the adoption of a maintenance-biased rural road policy at the local government, provincial, and national levels. USAID lays major emphasis on the maintenance and upgrading of existing roads rather than on funding new ones. This approach generally is not in agreement with the thinking of policy-makers in Pakistan. USAID will agree to fund a model rural road project in the twelve districts of the Sind Province only if the above policy changes concerning road construction and maintenance are undertaken.

In this case study we have assumed a scenario in which USAID is our "client." The "client" approaches the consultant to prepare a road resources management model and apply TIM to evaluate the disputed policies and generate more ideas to improve the planning, design and execution of the said road resources management project (RRM).

CHAPTER VI

APPLICATION AND TRIALS ON THE RRM SYSTEM USING TIM

6.1 Introduction

In the previous chapters we have explained the concepts and methodologies of the computer-assisted creativity techniques (TCC and TIM), and selected a rural road resources management project (RRM) for the Sind Province of Pakistan to be used for a case study. In this chapter the application and trials using TIM will follow the approach suggested in Chapter Two (Figure 1). A CCS on RRM will be described and trials will be done using TCC. This will be followed by TIM application. The ideas generated through TIM will be screened and packaged, and the CCS will be revised using selected ideas. Finally, trials will be conducted on the revised CCS using TCC.

6.2 Building the CCS

After a hypothetical discussion with the client, we identify and describe the problem and the client's decision possibilities. Based on our knowledge and experience, we then prepare a comprehensive (CCS) system (Figure 20). Trials then are undertaken to establish ranking and likelihoods of all the conditions. The client asks us to select from the model any number of these conditions (two or

three or more) and apply TIM to generate ideas. Generated ideas are screened and packaged by the expert, and important and relevant packages are entered into the original CCS. TCC is applied again to the CCS revised in the light of the idea package to compute their effects, i.e., changes in the goal likelihoods and the elasticities for each influencing condition. At this stage a final report can be prepared for the client.

Using the above described approach, we have identified the sequence of interactive conditions (Figure 20) which will be used to develop a CCS. The conditions are divided into eight levels and are listed below along with their respective ID Codes. Location of the conditions in the CCS system are decided by the expert based on his knowledge and experience. Another expert may come up with different locations. For example, J7 (local contractors trained) is shown at the same level with construction of roads (J8), whereas it could be linked before the latter; i.e., the contractors could be trained first, and then they could do road projects, otherwise both the activities would start at the same time.

(1) Decision Making Level (D,A)

- International Donor Agency (IDA, i.e., USAID in this case) asks for policy changes in Road Construction and Maintenance Policy of the Host Country (H.C.)(D)

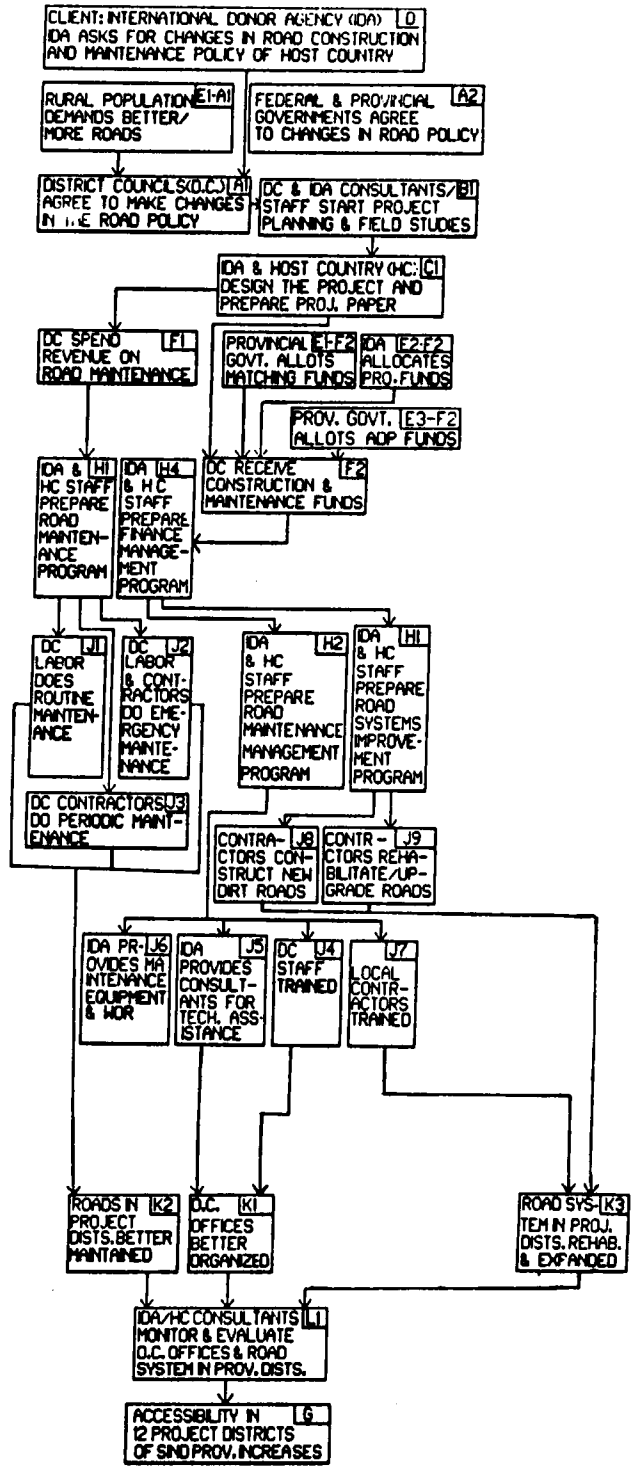


Figure 20: Road Resources Management Project (RRM)--

Network of Interconnected Statements

- District Councils (D.C.), i.e., local governments of the project-districts, agree to make the changes in the road policy (A1)
- Federal/Provincial governments agree to the changes in the road policy (A2)

(2) Strategic Planning Level (B,C)

- D.C. staff and USAID consultants start project planning and the field studies (B1)
- IDA and Host Country (H.C.) design the project, prepare project paper, and sign an agreement (C1)

(3) Finance and Management Level (F)

- D.C. manage and spend the road budget (revenue) on maintenance of rural roads (F1)
- D.C. receives funds for the construction (upgrading and new dirt roads) and maintenance of the roads from sources other than own revenue (F2)
- Provincial government allocates matching funds for construction (E1 - F2)
- IDA allocates funds for the project (E2 - F2)
- The Provincial government allocates funds (Annual Development Plan--ADP) for construction (E3 - F2)

(4) Operational Planning Level (detailed phases) (H)

- D.C. staff, under advice of IDA consultants, prepare the Road Maintenance Program (D.C. funds) (H1)

- USAID/H.C. consultants/staff prepare Road Maintenance Management Program (H2)
- USAID/H.C. consultants/staff prepare Road System Improvement Program (upgrading and construction) (H3)
- IDA and H.C. staff/consultants prepare the financial management program for the project period (H4)

(5) Execution Level (implementation phases) (J)

- D.C. labor gangs do routine maintenance (J1)
- D.C. labor/contractors do emergency/routine maintenance (J2)
- D.C. contractors do periodic maintenance (J3)
- Training (on-the-job, rural academy, abroad) of D.C. staff (J4)
- Consultants deputed to provide technical assistance to each D.C. (J5)
- IDA provides new machinery and tools for road maintenance and establishment of workshop facilities under the project (J6)
- IDA organizes training of D.C. contractors on maintenance/construction techniques and contract procedures (J7)
- Contractors construct new dirt (unpaved) roads planned under the project (J8)
- Contractors do road rehabilitation/upgrading of

roads planned under the project (J9)

(6) Output Level (outcome) (K)

- D.C. roads are brought to maintainable standards (K2)

- D.C. offices are better organized and the staff efficiency increases (K1)

- D.C. roads are upgraded/expanded as a result of completion of the project (K3)

(7) Evaluation Level (L)

- IDA and H.C. consultants complete monitoring and evaluation of D.C. roads and offices (L1)

(8) Goal Level (G)

- Accessibility in the twelve project districts of the Sind Province increases (G)

6.3 Application and Trials

TCC routines are applied to the problem as follows:

(1) The consultant (expert) enters the CCS (RRM) and allots confidences, between 0 and 1, to all combinations of influences (Appendix A, Figure 30). These confidences are as realistic as possible.

(2) The influence path can be determined (Appendix A, Figures 31 and 32).

(3) The resulting likelihoods of all intermediate and goal conditions are computed. Results can be found in Figure 21.

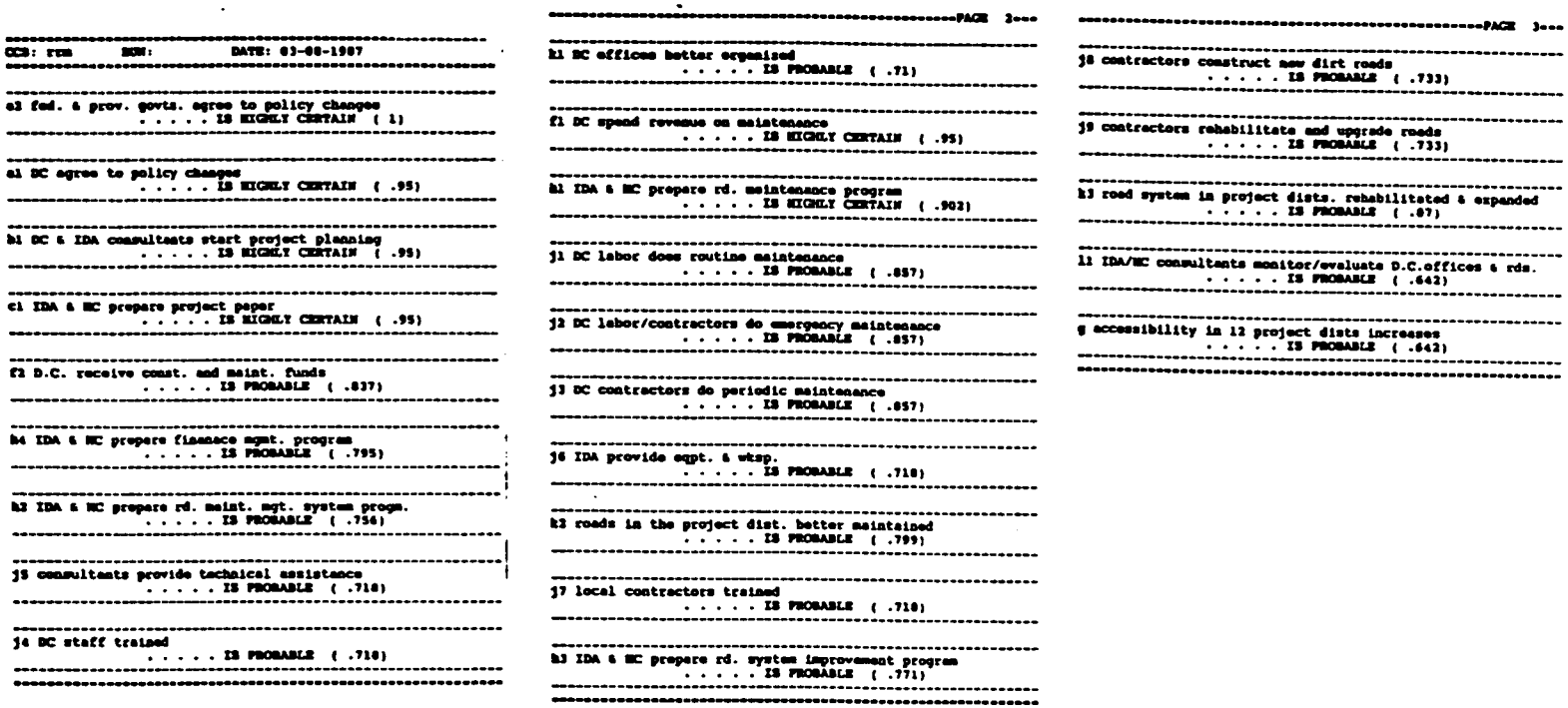


Figure 21: Resulting Likelihoods (RRM)

FOR THE:

CCS: rrm RUN: DATE: 03-08-1987

THE SENSITIVITY OF END (GOAL OR FINAL DECISION) CONDITION:
g accessibility in 12 project dists increases
TO CHANGES IN THE DECISION/EXTERNAL (INFL) CONDITION:

	INFL COND LK/DEC 1	INFL COND LK/DEC 2	END COND LKHOOD 1	END COND LKHOOD 2	ELASTICITY
d IDA asks for changes in rd. policy	1	0	0.643	0.050	0.856
e1-a1 rural population demands better and more rds.	0.500	0.400	0.643	0.637	0.040
e1-f2 Provincial Govt. allots matching funds	0.500	0.400	0.643	0.641	0.014
e2-f2 IDA allocates project funds	0.800	0.700	0.643	0.640	0.030
e3-f2 prov. govt. allots ADP funds	0.550	0.450	0.643	0.639	0.027

Figure 22: Sensitivity Analysis (RRM)

(4) The sensitivity of one goal or end condition to changes in the decision/external conditions is computed (Figure 22).

(5) The status of each intermediate condition is changed temporarily to an external condition (one by one) and TCC is applied to get the sensitivity of the goal condition to these temporarily designated external conditions. During the process, when TCC asks for the likelihood (from 0 to 1) of this external condition, we type in the figure from Figure 20. For example, we change F1 intermediate condition to external status by removing the influence of the C1 condition; i.e., F1 is no more influenced by any other condition. In the computation, the likelihood of 0.95 is used. The resulting elasticity for F1 comes out to be .283 (Table 2). So we start with F1 and complete the trial with each intermediate condition in the CCS.

(6) The likelihoods of all other intermediate conditions are computed during the above trial (step 5 above). There is no change in the likelihoods from the original results, e.g., before we change F1 to an external condition, the goal condition likelihood remains 0.643 and those of other intermediate conditions remain the same.

(7) Based on the resultant elasticities a ranked list (Table 2) of the eighteen intermediate conditions is prepared. The rankings are also shown on Figure 23 (in

Table 2: Rank List of Conditions: RRM Model

RANK	CHANGED TO EXT-ERNAL COND	INFL COND LK/DEC 1	INFL COND LK/DEC 2	END COND LKHOOD 1	END COND LKHOOD 2	ELAS-TICITY
1	H4	0.795	0.695	0.643	0.598	0.537
2	F2	0.837	0.737	0.643	0.600	0.537
3	K2	0.799	0.699	0.643	0.603	0.472
4	K3	0.870	0.770	0.643	0.613	0.391
5	H2	0.756	0.656	0.643	0.613	0.335
6	F1	0.950	0.850	0.643	0.623	0.283
7	H1	0.902	0.802	0.643	0.622	0.282
8	K1	0.710	0.610	0.643	0.617	0.273
9	H3	0.771	0.671	0.643	0.626	0.195
10	J4	0.718	0.618	0.643	0.631	0.123
11	J1	0.857	0.757	0.643	0.634	0.111
12	J5	0.718	0.618	0.643	0.632	0.109
13	J9	0.733	0.633	0.643	0.633	0.103
14	J6	0.718	0.618	0.643	0.635	0.087
15	J3	0.857	0.757	0.643	0.636	0.085
16	J2	0.857	0.757	0.643	0.636	0.082
17	J8	0.733	0.633	0.643	0.636	0.071
18	J7	0.718	0.618	0.643	0.642	0.012

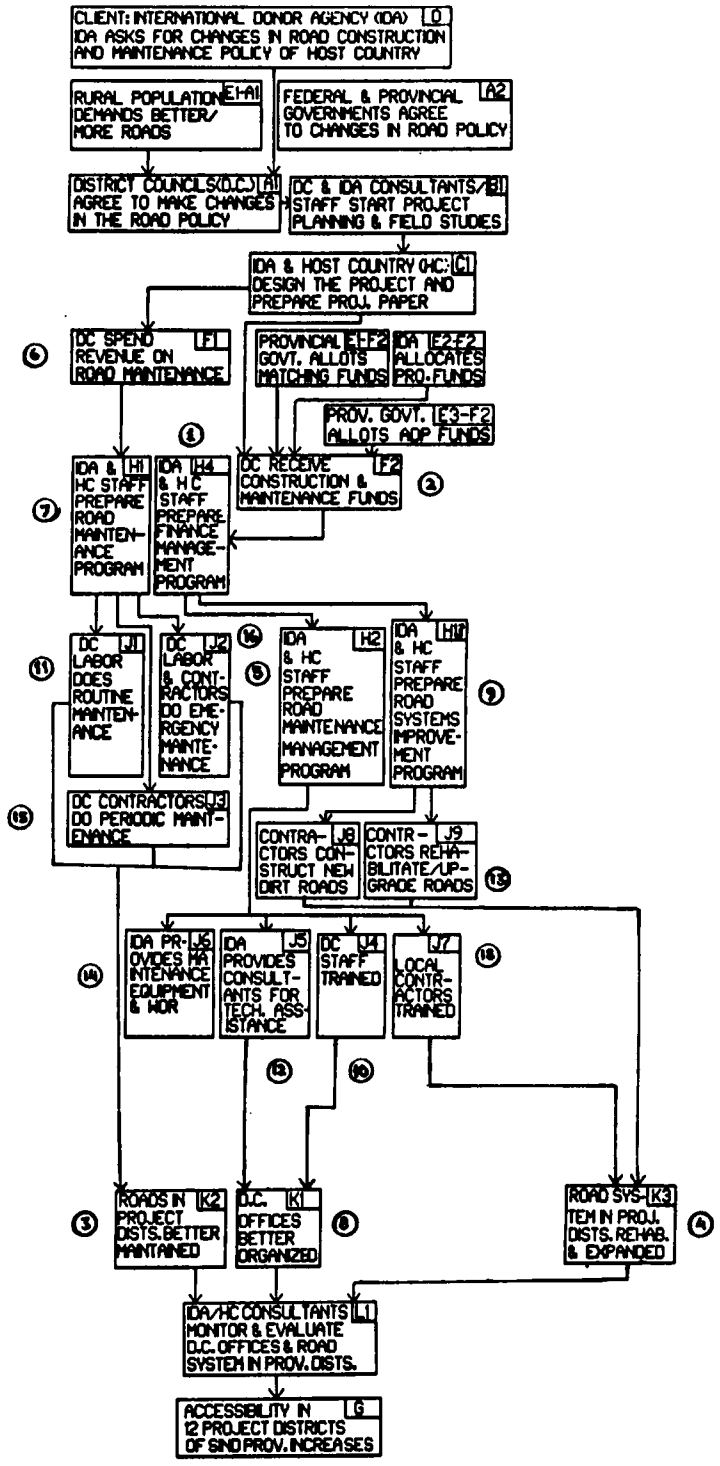


Figure 23: Road Resource Management Project (RRM) CCS

Showing Ranking of Conditions

circles).

6.4 Results and Comments on the Trials

(1) The likelihood of each condition indicates, under the given circumstances, the probability of that factor happening.

(2) TCC application, having a fairly direct analogy with traditional system analysis, takes the confidences of all the conditions as inputs and calculates the likelihoods of each of the intermediate and goal conditions (Figure 21). Here the likelihood of "Accessibility Increases in the Twelve Project Districts of the Sind Province" (G), comes out to be 0.642.

(3) From the elasticities of the four external conditions (Figure 21), we can assess the relative importance of each. So the four external conditions are ranked as follows: (1) (E1 - A1) (Rural population demands better and more roads); (2) (E2 - F2) (IDA allocates project funds); (3) (E3 - F2) (Provincial government allots ADP funds); and (4) (E1 - F2) (Provincial government allots matching funds for construction and upgrading of roads).

(4) The ranked list of intermediate conditions (tested after changing each to external status--see Table 2) indicates the relative importance of each. Finance Management Program (H-4) and Construction and Maintenance Funds (F2) top the list, while Traning of Local Contractors

(J7) is last on the list.

(5) During the trial to establish rankings, depending upon the layout of the CCS, we could not test each and every intermediate condition. For example, we could not change the B1 condition to external status because it would have cut off the decision condition. It is not so important to test the factors at decision-making and strategic planning levels. Hence we tried the conditions at the F, H, J, and K levels (Figure 22).

(6) Based on the overall rankings, we can compare conditions within each level (independent of other levels). For example, at the outcome level (K), well-maintained roads (K2) came out to be more important than either rehabilitation and expansion (K3), or office improvements (K1). At the H level, the top of the list, the financial management program (H4) is followed by the maintenance management system program (H2), then the maintenance program at D.C. (H1), and, last, the road system improvement program (H3), involving the upgrading and construction of new dirt (soil) roads.

(7) The client, with the expert's advice, may decide on a threshold likelihood of the conditions above which he would consider planning/implementing those conditions. In our study if our client fixes a .75 limit, then on computing the likelihoods we find that the J4, J5, J6, J7 conditions do not pass the test, i.e., they drop out of consideration.

That means the provision of road equipment, consultants, and training of D.C. staff and contractors are not included in the project. The client has to decide if this is acceptable or not. Let us assume that the client decides to keep them in the CCS and agrees to review his decision. So the client lowers the threshold limit to .70. Then J4, J5, J6, J7 stay in the system, i.e., all the intermediate conditions in the CCS pass the test and meet the threshold limit.

(8) The above results lead to an important deduction regarding choice of the conditions from the ranked list (Table 2) for further consideration, i.e., generating ideas through TIM. The client may decide to ask the expert to generate ideas about the top one or two factors, or a few selected ones, but a situation may arise where it is decided that ideas need to be generated on the problem as a whole, i.e., on all the conditions.

For example, in the CCS under consideration, the client (USAID) lays emphasis on the maintenance aspect of the road project. The client advises the district councils to spend the road budget on maintenance and upgrading only, so that the roads are brought up to a maintainable standard before any new rural roads are constructed. The client then may want ideas generated only for those conditions in the CCS related to road maintenance activities.

The decision regarding the selection of the conditions will also influence the expenses involved. More conditions

mean more expense in terms of time and money, i.e., time of the consultant to revise the CCS, apply TIM, and retest with TCC.

In this study we assume that the client wants the consultant to generate ideas concerning the road construction and maintenance problems as a whole, i.e., covering all or most of the conditions in the CCS.

The application of TIM to generate ideas and selection of conditions to revise the CCS are described in the next section. The CCS is revised and tested with TCC in Chapter VII.

6.5 Ideas Generation with TIM

At this stage of the study, the client and the aim (steps 1 and 2--Figure 13) have already been identified. The next step is to select the relevant base words from the list in the TIM data base. Selected base words are given in Table 3. The consultant uses these base words to access the relevant concepts (TIM data base) which instigate his mind to generate ideas on road construction and maintenance. The list of thirty-five ideas is in Appendix B. An example of idea generation is given in Figure 24.

Next, relevant key words are selected (Table 4) for generating ideas using the Electronic Encyclopedia [47]. Nine sample ideas are in Appendix B. Some of the key words are also used to generate six sample ideas using relevant

Table 3:

Selection of Base Words from TIM Data Base

accessible	new
climate	numerous
communication system	perfection
concept	price
control	production facility
development	quality
distance	quantity
effect	relation
event	safe
finance	scarce
government	spatial
government facility	state
hazardous	structural support
imagination	taxation
institution	thought
level	transportation system
management	value
mechanics	wealthy
money	

Base word entered: Management

One of the concepts which appeared on the computer screen: "Public Manager relates well with powerful legislatures."

Idea which came to the consultant's mind: The District Council Chairman should establish good relations with the Provincial Legislatures to get more funding for the development projects in his district.

Comments: The provincial annual development programs are discussed and approved in the provincial legislature (assembly) body. So personal relations could help in getting funding under ADP and matching schemes.

Figure 24: Example of Idea Generation

Table 4

Sample Key Words for Literature Search and Electronic Encyclopedia [47]

administration	materials
agencies	motivation
alternatives	needs
attitude	physical resources
benefits	plan
budget	policy
budget control	poverty
completion	priority
coordination	private sector
cost	procedure
creativity	procurement
criteria	project management
data	protection
deterioration	public participation
disaster	reforms
distribution	responsibility
economic life	revenue
environment	road system
equipment	roads
evaluation	rural
experience	self-help
feasibility	short-term
financial management	standards
financial resources	strategy
foreign policy	taxes
funds	technical
highway	techniques
incentive	traffic
inflation	training
inventory	travel
investment	toll
labor	user costs
labor intensive	work
local government	work schedule
local resources	world economy
long-term	
maintenance	

literature (Appendix B).

The consultant could generate many more ideas with TIM, but in this study a total of fifty ideas is considered appropriate (Appendix B). This takes the consultant through step 5 of the TIM process.

6.6 Screening of Ideas

Step 6 is the screening (selection) of the generated ideas and packaging the selected ideas for attachment to the Relational Network (CCS under study) for further tests with TCC.

Under "Review of Literature" (Chapter Four) we have reviewed many concepts to screen and package the ideas. Here, only those methods described in Chapter Two will be used to screen the ideas:

(1) All fifty ideas (Appendix B) can be used to build a new CCS or can be introduced into the existing CCS. Then, the consultant can apply TCC (as was done in this chapter to build Table 1) to get a new ranking list. This ranking list will help the consultant/client in screening the ideas. This method is not applied here.

(2) The consultant (or better, a panel of experts) is an expert in the field, so he reviews the generated ideas and discusses them with the client to accomplish the screening on the merit of each idea. The method has been explained in Chapter Three.

(3) The screening concept based on the number of base words supporting a concept (based on which an idea was generated) has already been explained in Chapter Two. The base words supporting each idea have been listed in front of each of the thirty-five ideas (Appendix B). This is a simple example. Each of these ideas may be supported by more base words in the TIM data base, so the search could be made more comprehensive by selecting and using more base words. In case the TIM program is modified to enhance its capability to list the number of base words supporting each concept automatically, then screening will be complete, comprehensive, and easier.

For now, this simple example should explain this concept adequately. Idea #31 is supported by four base words; ideas #9, 12, 22, 25, 30, 34 by three base words; ideas #7, 14, 16, 17, 19, 20, 24, 28, 35 by two base words; and the rest of the nineteen ideas by only one base word. This, importance-wise, divides the thirty-five ideas into four categories.

For screening the ideas (36 to 50) generated by use of the Electronic Encyclopedia and the literature, the consultant has to do the screening (method 2 above).

6.7 Selection of Conditions for Revision of the CCS

The topmost idea happens to be #35, i.e., "new and better roads should result in better administration and

government control." This is an idea but looks more like a general form. The consultant could not think of a specific way to link and package it for use in the existing CCS. So this idea was not selected for further use.

After discussion with the client, the consultant decided to select the following five ideas from those supported by three base words:

Idea #	Idea
9	District Council and provincial government should encourage self-help and incentive schemes for road projects.
12	D.C. should plan ahead to generate more financial resources by revising tax/toll rates annually.
16	Create a pool of road equipment at district/division level and rent it to the contractors involved in road construction/maintenance jobs.
22	Corrupt and inefficient staff should be fired/retired early.
34	Involvement of the private sector in the road projects will reduce burden on the local government.

Idea #48 has been selected from the list of ideas generated through the literature ("Each new construction project should include funds for maintenance after completion").

6.8 Packaging of Selected Ideas

6.8.1 As explained earlier in Chapter 2, packaging could be based on a sequence or according to the categories. The

consultant examines the six ideas selected and finds that these can be called one package and need not be introduced into the existing CCS in a particular sequence. Instead each one fits in with a particular condition already in the CCS. For example, idea #34 means availability of private construction and maintenance funds for the district council, so this idea is packaged with the existing conditions influencing F-2. Similarly idea #48 will be best linked with H-1 condition. Accordingly all the six selected ideas forming a package (call it #1) are linked into the existing CCS (Figure 25).

6.8.2 Another concept/methodology to package ideas has already been discussed and elaborated by a hypothetical example in Chapter 2. Using this method, we shall now construct "records" of the six ideas screened from the list of fifty ideas (Appendix B) and also for the data base (file) constructed on road construction, maintenance, and management (Chapter 8). The "record" of the six ideas is shown in Table 5. As stated above, the first package is formed by all the six screened ideas. Five more packages formed from Table 5 are shown below:

(1) Ideas	(2) Ideas	(3) Ideas	(4) Ideas	(5) Ideas	(6) Idea
# 9	# 12	# 12	# 16	# 9	# 16
12	34	22	34	12	
16	48			16	
22				34	
34				48	
48					

Table 5: Packaging of Ideas on RRM (see Appendix B)

	Factors								
Idea #	Finance/ Budget	Management	Economy	Construction	Maintenance	Design	Equipment	Training	Climatic/ Environment
9					(0.5)				
12	(0.8)	(0.7)			(0.9)				
16				(0.7)	(0.3)		(0.8)		
22		(0.6)							
34	(0.5)			(0.6)	(0.4)				
48	(0.6)				(0.5)				

These packages can be used to build or enhance a CCS. At this stage the consultant discusses the situation with the client and has a choice to introduce one of these six packages into the existing CCS as external or intermediate conditions. Package 2 can go with condition H_4 (finance management program), 3 with H_1 (road maintenance program), 4 with J_8 (new road construction), 5 with H_2 (road maintenance management program), and 6 with J_6 (maintenance equipment). Or, the consultant can treat each of the six selected ideas individually and connect each with a relevant condition in the existing CCS. In this study the consultant (expert), after discussion with the client, decides, say, to link these six ideas (as external conditions) to the existing CCS as follows:

Idea # 9 is linked to J1 condition.

Idea #12 is linked to F1 condition.

Idea #16 is linked to J3 and J8 conditions.

Idea #22 is linked to K1 condition.

Idea #34 is linked to F2 condition.

Idea #48 is linked to H1 condition.

In the next chapter these six ideas are used (as package #1) to revise the CCS and conduct tests with TCC to see the effect of the first package on the goal likelihood and ranking of the conditions. Then the other five packages are used (one at a time) to compute the goal likelihoods.

CHAPTER VII

REVISION OF RRM SYSTEM

7.1 Revision of the Computer Consultant System (CCS)

As explained in the last chapter, the six new statements based on the selected ideas are entered in the CCS under study (Figure 25) as external conditions. At this stage the consultant is not sure of the success (or otherwise) of each of the six ideas used to revise the CCS, so he allots 0.5 confidence to each of these. Some or all selected conditions can be built-in as intermediate or external conditions, but in this study the consultant feels that these ideas best fit as external conditions. Another expert may think it best to introduce the ideas as intermediate conditions, or may introduce some as external and others as intermediate.

7.2 Tests with Revised CCS

7.2.1 Using Package #1

The revised CCS is tested with TCC and the trials are carried out in the same way as done in Chapter 6 (section 6.3). Now instead of four, there are a total of eleven external conditions. The list of conditions and influencing conditions and list of confidences are shown in Figures 34

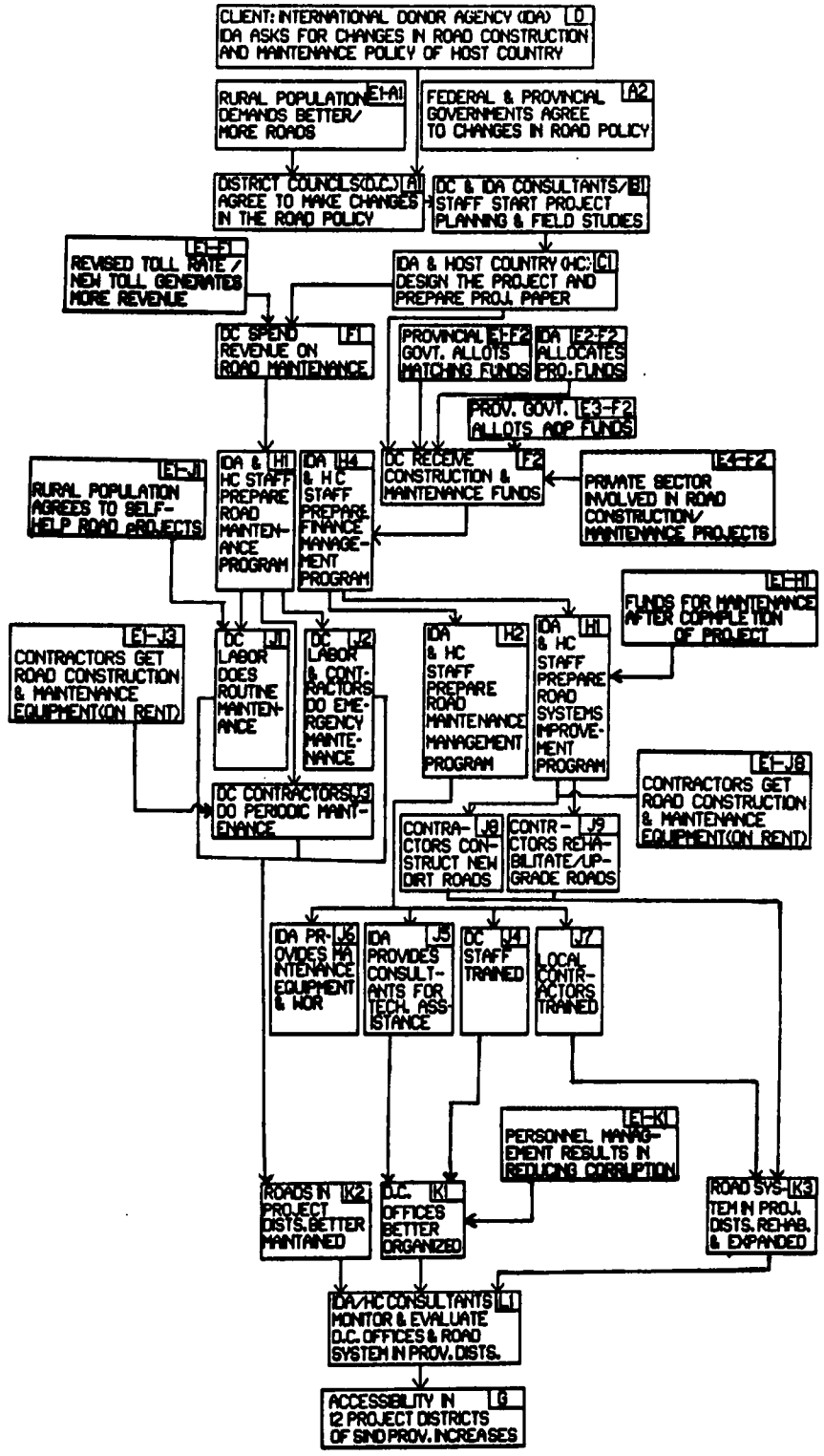


Figure 25: Road Resources Management Project (RRMREV)

Revised Network of Conditions

and 35 (Appendix C) respectively. The following are computed during TCC tests:

(1) Sensitivity of end condition (goal) to change in a decision/external condition (Figure 33, Appendix C). The elasticity figures helped in ranking the ten external conditions and thus indicate their importance in planning and execution of the RRM project.

(2) Resulting likelihoods of each of the intermediate conditions and the goal condition (Figure 26). The comparison between the two likelihoods (CCS and revised CCS) indicate the overall increase in the likelihood of each condition except F1, which decreased by .015. The likelihood of the goal condition increased from 0.643 to 0.719, i.e., by about .08.

(3) Each intermediate condition is changed (one at a time) to be an external condition and the sensitivity of the goal condition computed. As a result of this trial, the eighteen intermediate conditions are ranked (Table 6), i.e., the same procedure is adopted as for Table 2. The consultant compared the two tables (6 and 2) and found changes in the ranking of some of the conditions.

(4) Suppose the client accepts one or more of the six suggested ideas. The accepted idea(s) is introduced along with a decision condition influencing it, and the goal likelihood is computed. Here, the consultant selects ideas (E1-H1 and E4-F2) and conducts the test

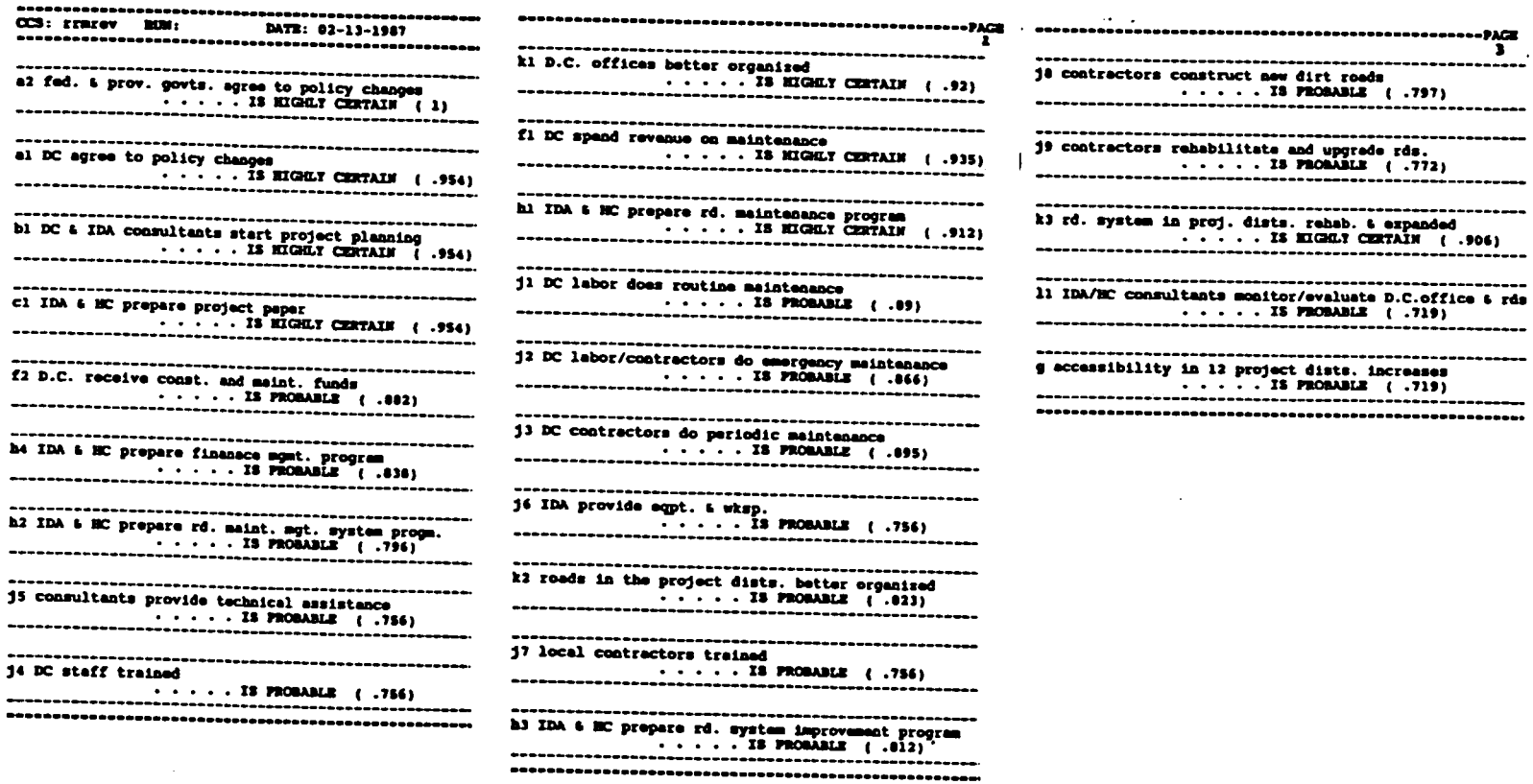


Figure 26: Resulting Likelihoods (RRMREV)

TABLE 6

Rank List of Conditions - Revised RRM Model (RRMREV)

RANK-ING	CHANGED TO EXT-ERNAL COND	INFL COND LK/DEC A	INFL COND LK/DEC 2	END COND LKHOOD 1	END COND LKHOOD 2	ELAS-TICITY
1	K2	0.823	0.723	0.719	0.676	0.471
2	H4	0.838	0.738	0.719	0.677	0.441
3	F2	0.882	0.782	0.719	0.682	0.440
4	K3	0.906	0.806	0.719	0.687	0.387
5	K1	0.920	0.820	0.719	0.692	0.329
6	H1	0.912	0.812	0.719	0.695	0.286
7	F1	0.935	0.835	0.719	0.696	0.286
8	H2	0.796	0.696	0.719	0.695	0.255
9	H3	0.812	0.712	0.719	0.702	0.183
10	J1	0.890	0.790	0.719	0.709	0.113
11	J9	0.772	0.672	0.719	0.710	0.094
12	J6	0.756	0.656	0.719	0.710	0.092
13	J3	0.895	0.795	0.719	0.712	0.087
14	J2	0.866	0.766	0.719	0.712	0.083
15	J8	0.797	0.697	0.719	0.712	0.069
16	J4	0.756	0.656	0.719	0.712	0.068
17	J5	0.756	0.656	0.719	0.713	0.058
18	J7	0.756	0.656	0.719	0.718	0.015

(one decision condition at a time). With E1-H1 the goal likelihood increases to .725, and with E4-F2 to .732. The original goal likelihood, without any addition of a decision condition, is 0.719. This shows that changing the status of an idea from an external condition to a decision condition increases the goal likelihood and thus the chance of success.

7.2.2 Using the Six Packages

The CCS is revised using the six packages, one at a time, and goal likelihoods are computed. All the packages above have been put through the comprehensive trials, but only the first one has been elaborated here. The comparative goal likelihoods computed as a result of using all six packages show the importance of each. The goal likelihood of the existing CCS before introduction of these packages is .643. The new goal likelihoods are:

Package #	Idea #	Goal Likelihood
1	9,12,16,22,34,48	.719
2	12,34,48	.709
3	12,22	.694
4	16,34	.701
5	9,12,16,34,48	.715
6	16	.687

CHAPTER VIII

DEVELOPMENT OF IDEAS AND CONCEPTS DATA BASE ON ROADS

A comprehensive ideas and concepts data base has been prepared to include ideas and concepts covering road construction, upgrading, maintenance, and pavement management systems. These data base files are linked with the existing information data base of TIM and have enhanced its application range and capability of generating concepts which instigate an expert to generate ideas.

Illustrative examples from the "Ideas Data Base" and "Concepts Data Base" are shown in Figures 27 and 28.

Also, based on the idea packaging method explained in Chapter Two, records are prepared for the ideas in the "ideas data base."

The "ideas data base" has been added to the section called "Previous Ideas" in the TIM program where all the ideas from the previous exercises are stored. These idea files are indexed by using a software package called "Zy Index" [140]. When we index a data file (as on road ideas) this package makes a map of the words in the ideas. This helps in search of the ideas during TIM use. So, a person using this "ideas data base" can use the key words to search ideas in the file or can use an index prepared through the "Zy Index" package.

The "concept file" has definitional concepts on road

Idea # 1	
Description	Compare investment alternatives at both the network and project levels, coordinating design, construction, maintenance and evaluation activities, and making efficient use of existing methods and knowledge.
Comments	This constitutes Pavement Management System which exists to achieve the best value possible for the available funds.
Keywords	Management, Investment, Funds, Pavement
Idea # 2	
Description	Ensure that future traffic requirements are met and roads are maintained as far as possible at a required level of service by complying with the minimum standard for road surface quality.
Comments	This will prevent the deterioration of structural characteristics of the pavement.
Keywords	Traffic, Requirements, Quality, Deterioration Pavement

Figure 27: Ideas Data Base: Illustrative Example

Concept #1: Shoving

Shoving is a permanent, longitudinal displacement of a localized area of the pavement surface cause by traffic loading. When traffic pushes against the pavement, it produces a short, abrupt wave in the pavement surface. This distress normally occurs only in unstable liquid asphalt mix (cutback or emulsion) pavements. Shoves also occur where asphalt pavements abut PCC pavements; the PCC pavements increase in length and push the asphalt pavement, causing the shoving.

Reference: Shahin, M., & Starr, K. (1979). Development of a pavement condition rating procedure for roads, streets, and parking lots (Vol. 1): Condition rating procedure. Champaign, IL: U.S. Army, Construction Engineering Research Laboratory, p. 56.

Concept #2: Flexible pavement, full depth

Where asphalt mixes are employed for full courses above the subgrade.

Reference: Road and Transportation Association of Canada. (1977). Pavement management. Ottawa, Canada, p. 1.10.

Figure 28: Concepts Data Base: Illustrative Example

construction, maintenance, and management. This file goes under the "Definitional Concepts" section of the TIM program. Definitional concepts are terms with defined properties or characteristics. A definitional concept will normally be shown in the file almost exactly as it would be in a book or encyclopedia. The user of TIM can access these concepts through the index prepared by the "Zy Index" package. The user boots the TIM program and from the main menu he enters the command for search of ideas or concepts from the respective files. The word(s) are entered into the "Zy Index" file which knows where these words are in the road idea/concept file. So the "Index" file makes the access to the related ideas/concepts entering the key words very fast.

CHAPTER IX

SUMMARY AND CONCLUSIONS

This chapter is presented in three major sections. It begins with a presentation of the summary and findings of the study. This is followed by a critique of the techniques used. This chapter concludes with a presentation of some topics for future research.

9.1 Summary and Findings

The consultant builds the Computer Consultant System (CCS) in a real life situation in a Third World country; i.e., The Road Resources Management project (RRM). The CCS has a decision condition, four external, twenty-three intermediate, and one goal condition. The client (USAID) is of the view that the rural roads in Pakistan need to be brought up to maintainable standards, and that the district councils should spend their resources mostly on maintenance rather than on construction of new dirt roads. This view is in conflict with some of the policy makers in federal, provincial, and local governments.

TIM (including TCC), a computer-assisted creativity technique, has been used to develop the CCS and carry out comprehensive trials to compute the sensitivity of the goal condition to the external and the intermediate ones in the CCS and thus establish a ranking list.

These trials indicate that, overall, the maintenance of rural roads is the most important part of this development project. Rehabilitation/upgrading and construction of new roads is next in importance, followed by improving the office organization and training of staff. Some of the intermediate conditions in the CCS are listed below in order of importance:

(1) Finance management program

(2) Availability of funds for road construction and maintenance

(3) Preparation of road maintenance management program

(4) Preparation of road maintenance program for the district roads

(5) Spending district council road revenue on maintenance

(6) Road improvement (rehabilitation/upgrading and construction) program

.
.
.

(14) Construction of new dirt roads

Ideas on road construction and maintenance are then generated through TIM using the computer program, the Electronic Encyclopedia, and relevant literature as the sources. Out of fifty sample ideas generated, six are screened (selected) and then packaged for subsequent use.

The resulting six packages are introduced into the existing CCS (RRM), which is put through trials with TCC.

The introduction of the package with all six ideas into the CCS increases the likelihood of the goal condition's success by about .08 from 0.64. Each of the other five packages has a lesser number of ideas and the increase of the goal likelihood falls within the .08 range; i.e., between 0.64 and 0.72.

Among the six ideas introduced into the CCS, "involvement of the private sector" and "availability of maintenance funds after project completion" proved to be most important. It was found that the increase in goal likelihood depended on the number of ideas in a package and also their location in the revised CCS.

For revision of the CCS, each of the six ideas was linked as an external condition to a related intermediate condition. At that stage the expert was not sure of the success of the idea. So, two ideas were picked and it was assumed that the client accepted those. Hence, the two decision conditions were introduced, influencing those two external conditions (one at a time and then both together). The trials indicated that the goal likelihood increased from 0.719 to 0.738.

9.2 Critique of the Computer-Assisted Creativity Techniques

In this section some of the inherent strengths and

limitations of the techniques used in this research are briefly discussed.

9.2.1 The Computer Consultant (TCC)

TCC is a good tool for helping develop an Expert System, which we prefer to call a "Computer Consultant System" (CCS). TCC is simple to learn and apply to various problems in the fields of "hard sciences," and engineering. TCC menu instructions are elaborate and lead the user through the step-by-step procedures. Assignment of "confidences" or "likelihoods" to each condition helps the user in recognizing the elements of risk and judgment connected with the problem under review. Another useful aspect of this technique is that the expert, based on his expertise, can decide on a threshold likelihood figure to compare the likelihood of the goal and other conditions. Those below the threshold limit may be discarded, not being useful ideas. A model used to build the CCS may have one or more client decisions and goal conditions. It is very easy to add or remove conditions from a CCS during trials. This makes TCC a flexible and very useful technique.

Another advantage of TCC is that the variables used are nominal scale; i.e., many should not be quantified (and perhaps cannot be) at this point in the process.

Basically, the strength of TCC lies in the knowledge of the expert using it because he needs to allot realistic

confidences and likelihoods to the conditions in the CCS. So the output quality is strongly dependent on the expertise of the user. Two experts, working independently, will allot somewhat different confidences and likelihoods to the conditions, but the relevant trials can still be useful in establishing relative importance and effectiveness of the conditions and the likelihoods of the goal(s). Location of a condition in the CCS network is important. A condition closer to the goal condition is likely to affect the latter more than the other conditions. This may appear to be a disadvantage or weakness, but that is probably true for most other techniques also.

TCC, being a linear model, has the usual inherent advantages and disadvantages (strengths and weaknesses) associated with the linearity concept. TCC assumes a linear relationship among the variables, which may not be there; i.e., the relationship may be of some other shape. TCC does not have any feedback loops; i.e., there is no self regulation through negative and/or positive feedback loops.

9.2.2 The Idea Machine (TIM)

TIM tries to bridge the gap between the completely automated (centered on mathematics) and completely unautomated approach of the creativity process. TIM contains an extremely large and diverse data base of concepts and ideas which come from diverse fields ("hard

sciences," engineering, etc.). TIM also provides a means to help establish analogies from these concepts. The expert identifies ideas, many of which can be employed to address the problem at hand. These ideas usually represent better solutions than the user alone could produce. In order to begin the search for creative solutions, however, the problem needs to be structured beforehand.

TIM is flexible and is based on an interaction between the human brain and the computer. TIM has been successfully applied to the problems in the fields of social sciences and engineering. In social sciences we need to have a quantifying level for the variables in a model built to solve a problem. But in TIM application there is no need to quantify the variables.

A big question about TIM is whether the real "meaning" of an aim can be captured. Some qualities of a certain aim may be captured in four base words, and even if the four words match with the concepts, what type of relationship is described? We may assume two meanings of a word, but the computer may be using slightly different logic. What will happen if instead of using logic, the computer does the search for ideas at random? Will the random operation be as good as the present approach based on logic? The real value of TIM is in taking a concept and bringing it to proximity, which forces us to think how our aim is related to the concept. These are some of the questions which need

additional thinking.

The quality of ideas generated through TIM depends on the range and authority of the built-in information data base as well as the theoretical and practical knowledge of the expert using TIM.

The last step (#6) in the TIM process concerns the screening (selecting) and packaging of the generated ideas. A user of TIM generates many ideas, but not all are relevant or needed to solve the problem under review. So it is very important to perform the screening process and come up with those ideas which appear to have potential, or have not been unsuccessfully used earlier, or do not clash with the interests of the client or some strong groups (e.g., politicians) in the country. After screening it is essential to package these ideas for further use. This capability of TIM (step #6 of the process) is very important for solving problems, and hence is an inherent strength of the program.

In this research we discussed many concepts and techniques to screen and package ideas and applied one of them to screening, and a second to packaging. Here we present a critical review of each of these (using the base word concept for screening, and "records" for packaging).

These techniques are relatively easy to understand and simple to apply. It appears that these two methods correlate roughly to what happens and may form some sort of

basis for building some additional concepts/programs to use with TIM. But, in their present form, these appear to have some limitations too.

As mentioned earlier, the quality of the screening of ideas depends on the range and authenticity of the data base in TIM. We base the screening on the number of base words supporting each concept. That depends upon the way a data base has been built initially. A second data base built by another expert may give different results. Depending on the data base, a one-line concept may come out as a result of, say, eight base words, while a long concept may be supported by four base words.

Another limitation is that building a comprehensive data base is a time-consuming job. The expert building a data base can make it fairly authentic by selecting the concepts based on the citation concept; i.e., the concepts mentioned the maximum number of times in the literature would be linked to the maximum base words. Another limitation of the screening method is that we initially rank the concepts and not the ideas. A concept ranked at the top of the list may not instigate an expert to generate an idea or a generated idea may not be particularly important in that situation. On the other hand, another concept may be supported for a lesser number of base words, but may help generate more and better ideas. The factor of the unknown can be another limitation. For example, we do not know what is in the Electronic Encyclopedia.

In the packaging technique we prepare a "Record of Ideas" and classify them according to their categories (factors). One idea may come under one or more categories, and a potential problem can occur when all screened ideas fall under all factors. Then the allotment of weights will differ from one expert to another. Also, the process is implicit in nature whereby we look at the weight table and group the ideas into packages. This appears less scientific. There are other techniques (multi-variate techniques) such as "Factor Analysis," which have potential for grouping ideas into packages. Perhaps other researchers could explore this in the future.

As far as the mechanics of TIM use is concerned, it is a simple and interesting technique which has great potential. Though in its present form it is very useful, further research on TIM is expected to make the program more versatile and comprehensive.

9.3 Concluding Remarks on the Study

Overall, we are satisfied with the approach and methodologies used to achieve the aims of this research. The enhancement and application of TCC and TIM proved quite useful in helping provide insight that will actually aid in solving a typical road resources management (RRM) problem based on a real-life situation in Pakistan. Our conclusions are substantiated by the following facts:

(1) Application of TCC aided in the development of a computer consultant system (CCS) on the road resources management model.

(2) Comprehensive trials with TCC (using the above CCS) brought out many useful results and exposed its strengths and weaknesses.

(3) Step-wise detailed application of TIM to the RRM brought to light the flexibility and usefulness of the technique.

(4) Review of the sixth step of TIM (screening and packaging of generated ideas), and injection of some additional thoughts into the study, enhanced the application capability and also established the importance of this step.

(5) Development of the concepts and ideas data bases on road construction, maintenance, and management added to TIM's existing data base on many other fields.

(6) A fairly detailed literature review adds to the usefulness of this study.

(7) This study, along with other research work in this field, may prove helpful in future research and studies.

(8) The results of this study (particularly sensitivity of the goal condition to the other conditions in the CCS on the Road Resources Management project) can be used as one of many project planning tools.

9.4 Future Research

No critique of a research study is complete without some thoughts on topics for future research. Some suggested ideas are as follows:

1. Expand the RRM revised CCS (RRMREV), to include conditions related to other rural development activities in the fields of education, health, social services, etc., which, along with road construction and maintenance, increase the overall accessibility in the region. Application of TIM to this model should provide some interesting and useful results on accessibility in the rural areas of developing countries.

2. Apply TIM to some purely technical aspects of road construction and maintenance, e.g., Distress Analysis of pavements.

3. Expand the TIM data base further to enhance its capabilities to include application to a wider range of engineering problems/topics.

4. Based on the concepts and methodologies on idea screening and packaging (step 6 of TIM process) presented in this study, develop a computer program to enhance the scope of the existing TIM program.

5. In this study, the RRM CCS has been built following one approach (Figure 3) in which TCC is applied, then ideas are generated using TIM program, followed by trials with TCC again. Another approach would be first to

generate ideas using TIM and then build a model for CCS construction and test with TCC. The comparison between the two approaches may result in some interesting and useful findings.

6. In this study, the packaging of the six screened ideas resulted in six packages which are introduced as external conditions to revise the CCS and conduct fresh trials with TCC. Another expert may come up with different ideas and different packages. It should be interesting and useful to see the differential in goal likelihoods and ranking of the conditions.

7. In our RRM model, we have one client decision and one goal condition. In real life a problem model may have more than one decision and goal condition (e.g., political and/or economic goals). It appears useful to apply TCC and TIM to such situations.

8. Should a person using TIM use concepts from his own field or from a broader range of fields? This hypothesis can be investigated by potential researchers.

9. The evaluation concept has been briefly explained under the "Review of Literature." After ideas have been screened, a manageable number may need to be evaluated for their cost effectiveness. Further research on the existing economic evaluation techniques may result in the development of some methods to evaluate the ideas as alternatives.

10. The screening and packaging process needs to be

explicit and not implicit, as it is now. We may have great ideas, but we should be able to see explicitly what a client can do; i.e., what decisions a client can make or can not make.

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APPLICATION OF TCC TO THE MODELS: TEST/TRIAL RESULTS

I. RRM - The Original Computer Consultant System (CCS) (Appendix A)
   1. List of conditions along with influences.
   2. List of all confidences.
   3. Display of influence paths.
   4. Description of influence path.

II. Example Ideas Generated Through TIM (Appendix B)

III. RRMREV - Revised CCS (Appendix C)
   1. Sensitivity of end (goal) condition to 1% change in the decision and each of the external conditions.
   2. List of conditions along with influences.
   3. List of all confidences.

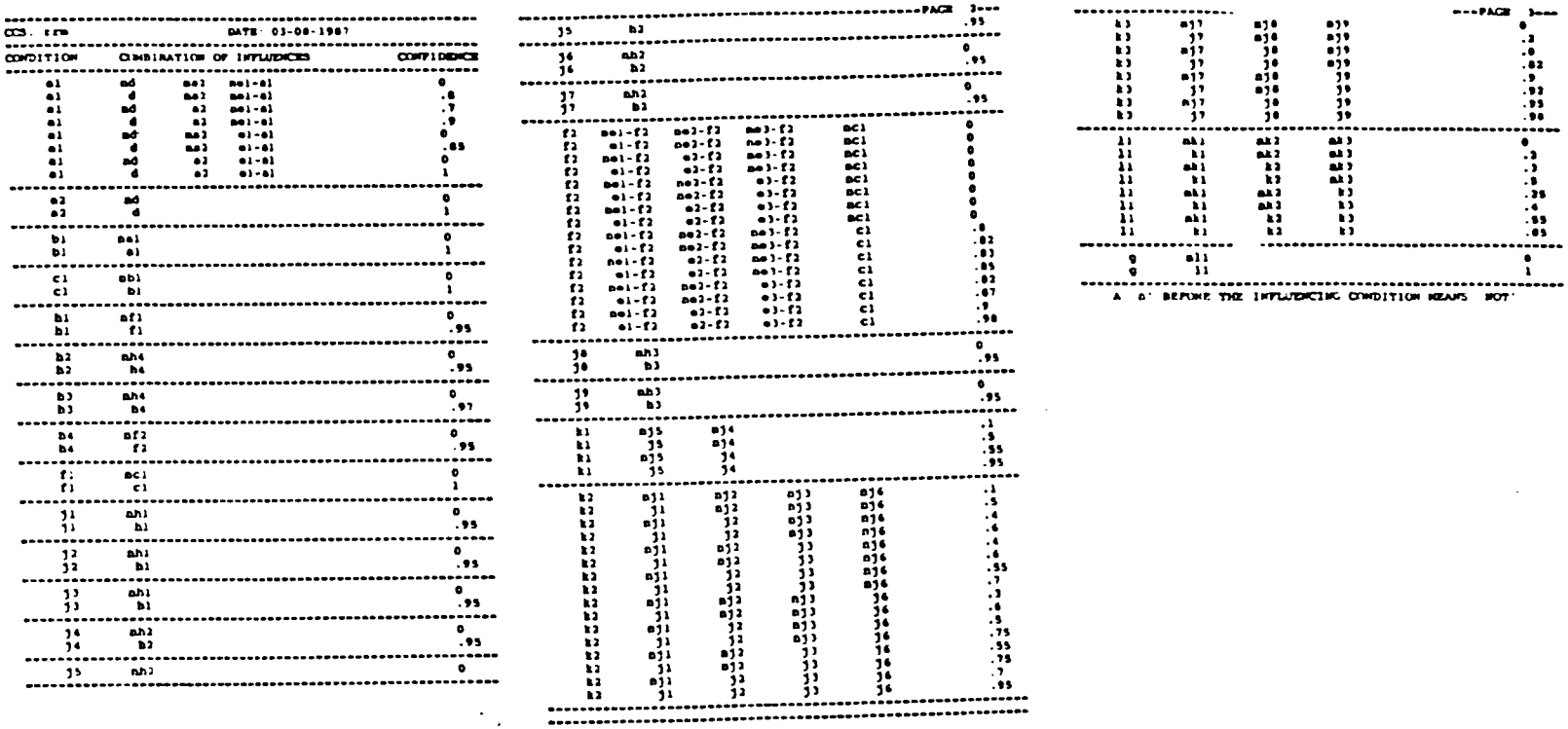
IV. Glossary of Terms/Definitions (Appendix D)

APPENDIX A

Print Outs: RRM--Computer Consultant System

```
CCB: rrm          DATE: 03-08-1987          TIME: 19:28:53
          ID CODE, SUBJECT, AND ACTION/STATUS
                  CLIENT DECISION CONDITIONS
* 2* d IDA asks for changes in rd. policy
                  EXTERNAL CONDITIONS
* 1* e1-a1 rural population demands better and more rds.
* 1* e1-f2 Provincial Govt. allots matching funds
* 1* e2-f2 IDA allocates project funds
* 1* e3-f2 prov. govt. allots ADP funds
                  INTERMEDIATE CONDITIONS
* 1* a1 DC agree to policy changes
        d IDA asks for changes in rd. policy
        a2 fed. & prov. govts. agree to policy changes
        e1-a1 rural population demands better and more rds.
* 1* a2 fed. & prov. govts. agree to policy changes
        d IDA asks for changes in rd. policy
* 1* b1 DC & IDA consultants start project planning
        a1 DC agree to policy changes
* 2* c1 IDA & HC prepare project paper
        b1 DC & IDA consultants start project planning
* 3* h1 IDA & HC prepare rd. maintenance program
        f1 DC spend revenue on maintenance
* 4* h2 IDA & HC prepare rd. maint. mgt. system progm.
        h4 IDA & HC prepare finanace mgmt. program
* 2* h3 IDA & HC prepare rd. system improvement program
        h4 IDA & HC prepare finanace mgmt. program
* 2* h4 IDA & HC prepare finanace mgmt. program
        f2 D.C. receive const. and maint. funds
* 1* f1 DC spend revenue on maintenance
        c1 IDA & HC prepare project paper
* 1* j1 DC labor does routine maintenance
        h1 IDA & HC prepare rd. maintenance program
* 1* j2 DC labor/contractors do emergency maintenance
        h1 IDA & HC prepare rd. maintenance program
* 1* j3 DC contractors do periodic maintenance
        h1 IDA & HC prepare rd. maintenance program
* 1* j4 DC staff trained
        h2 IDA & HC prepare rd. maint. mgt. system progm.
* 1* j5 consultants provide technical assistance
        h2 IDA & HC prepare rd. maint. mgt. system progm.
* 1* j6 IDA provide eqpt. & wksp.
        h2 IDA & HC prepare rd. maint. mgt. system progm.
* 1* j7 local contractors trained
        h2 IDA & HC prepare rd. maint. mgt. system progm.
-------------------------------------------------------------
* 1* f2 D.C. receive const. and maint. funds
        e1-f2 Provincial Govt. allots matching funds
        e2-f2 IDA allocates project funds
        e3-f2 prov. govt. allots ADP funds
        c1 IDA & HC prepare project paper
* 1* j8 contractors construct new dirt roads
        h3 IDA & HC prepare rd. system improvement program
* 1* j9 contractors rehabilitate and upgrade roads
        h3 IDA & HC prepare rd. system improvement program
* 1* k1 DC offices better organized
        j5 consultants provide technical assistance
        j4 DC staff trained
* 1* k2 roads in the project dist. better maintained
        j1 DC labor does routine maintenance
        j2 DC labor/contractors do emergency maintenance
        j3 DC contractors do periodic maintenance
        j6 IDA provide eqpt. & wksp.
* 1* k3 road system in project dists. rehabilitated & expanded
        j7 local contractors trained
        j8 contractors construct new dirt roads
        j9 contractors rehabilitate and upgrade roads
* 1* l1 IDA/HC consultants monitor/evaluate D.C.offices & rds.
        k1 DC offices better organized
        k2 roads in the project dist. better maintained
        k3 road system in project dists. rehabilitated & expanded
                  GOAL CONDITIONS
    g accessibility in 12 project dists increases
        l1 IDA/HC consultants monitor/evaluate D.C.offices & rds.
-------------------------------------------------------------
The Quantity Between the Asterisks is the Number of Condi-
   tions Directly Influenced By That Non-Goal Condition.
```

Figure 29: List of Conditions Along with Influences (RRM)



CCS. crm DATE: 03-08-1987

CONDITION	COMBINATION OF INFLUENCES			CONFIDENCE
a1	ad	aa2	aa1-a1	0
a1	d	aa2	aa1-a1	.6
a1	ad	a2	aa1-a1	.7
a1	d	a2	aa1-a1	.9
a1	ad	aa3	a1-a1	0
a1	d	aa3	a1-a1	.85
a1	ad	a2	a1-a1	0
a1	d	a2	a1-a1	1
a2	ad			0
a2	d			1
b1	aa1			0
b1	a1			1
c1	ab1			0
c1	b1			1
b1	af1			0
b1	f1			.95
b2	ah4			0
b2	h4			.95
b3	ah4			0
b3	h4			.97
b4	af2			0
b4	f2			.95
f1	ac1			0
f1	c1			1
j1	ah1			0
j1	h1			.95
j2	ah1			0
j2	h1			.95
j3	ah1			0
j3	h1			.95
j4	ah2			0
j4	h2			.95
j5	ah2			0

---PAGE 2---

j5	h2				.95
j6	ah2				0
j6	h2				.95
j7	ah2				0
j7	h2				.95
f2	ae1-f2	ae2-f2	ae3-f2	ac1	0
f2	a1-f2	ae2-f2	ae3-f2	ac1	0
f2	ae1-f2	a2-f2	ae3-f2	ac1	0
f2	a1-f2	a2-f2	ae3-f2	ac1	0
f2	ae1-f2	ae2-f2	a3-f2	ac1	0
f2	a1-f2	ae2-f2	a3-f2	ac1	0
f2	ae1-f2	a2-f2	a3-f2	ac1	0
f2	a1-f2	a2-f2	a3-f2	ac1	0
f2	ae1-f2	ae2-f2	ae3-f2	c1	.8
f2	a1-f2	ae2-f2	ae3-f2	c1	.82
f2	ae1-f2	a2-f2	ae3-f2	c1	.83
f2	a1-f2	a2-f2	ae3-f2	c1	.85
f2	ae1-f2	ae2-f2	a3-f2	c1	.82
f2	a1-f2	ae2-f2	a3-f2	c1	.87
f2	ae1-f2	a2-f2	a3-f2	c1	.9
f2	a1-f2	a2-f2	a3-f2	c1	.98
j8	ah3				0
j8	h3				.95
j9	ah3				0
j9	h3				.95
k1	aj5	aj4			.1
k1	j5	aj4			.5
k1	aj5	j4			.55
k1	j5	j4			.95
k2	aj1	aj2	aj3	aj6	.1
k2	j1	aj2	aj3	aj6	.5
k2	aj1	j2	aj3	aj6	.4
k2	j1	j2	aj3	aj6	.6
k2	aj1	aj2	j3	aj6	.4
k2	j1	aj2	j3	aj6	.6
k2	aj1	j2	j3	aj6	.55
k2	j1	j2	j3	aj6	.7
k2	aj1	aj2	aj3	j6	.3
k2	j1	aj2	aj3	j6	.6
k2	aj1	j2	aj3	j6	.5
k2	j1	j2	aj3	j6	.75
k2	aj1	aj2	j3	j6	.55
k2	j1	aj2	j3	j6	.75
k2	aj1	j2	j3	j6	.7
k2	j1	j2	j3	j6	.95

---PAGE 3---

k3	aj7	aj6	aj9	0
k3	j7	aj6	aj9	.2
k3	aj7	j6	aj9	.6
k3	j7	j6	aj9	.82
k3	aj7	aj6	j9	.9
k3	j7	aj6	j9	.92
k3	aj7	j6	j9	.95
k3	j7	j6	j9	.98
l1	ak1	ak2	ak3	0
l1	k1	ak2	ak3	.2
l1	ak1	k2	ak3	.3
l1	k1	k2	ak3	.9
l1	ak1	ak2	k3	.35
l1	k1	ak2	k3	.4
l1	ak1	k2	k3	.55
l1	k1	k2	k3	.85
q	all			0
q	j1			1

A 0 BEFORE THE INFLUENCING CONDITION MEANS NOT

Figure 30: List of All Confidences (RRM)

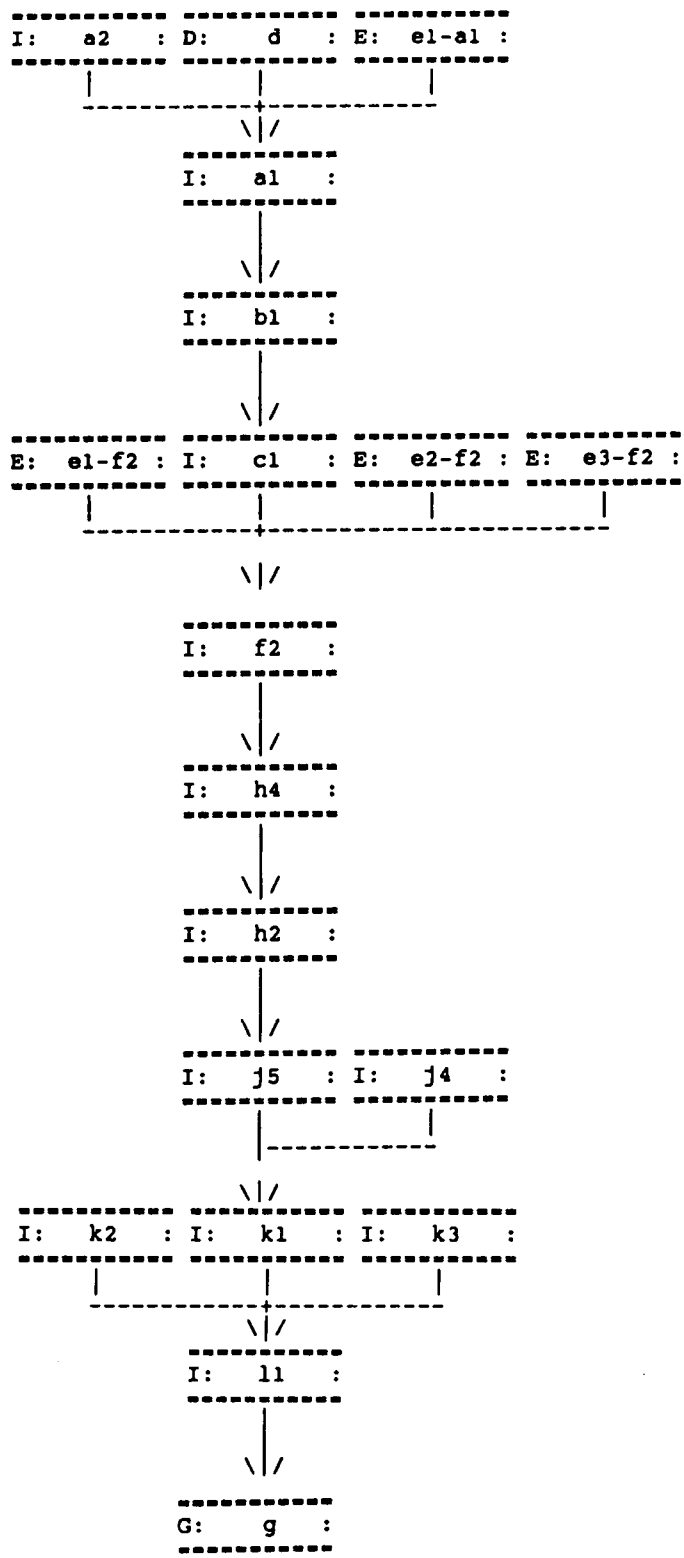


Figure 31: Direct Influence Path (RRM)

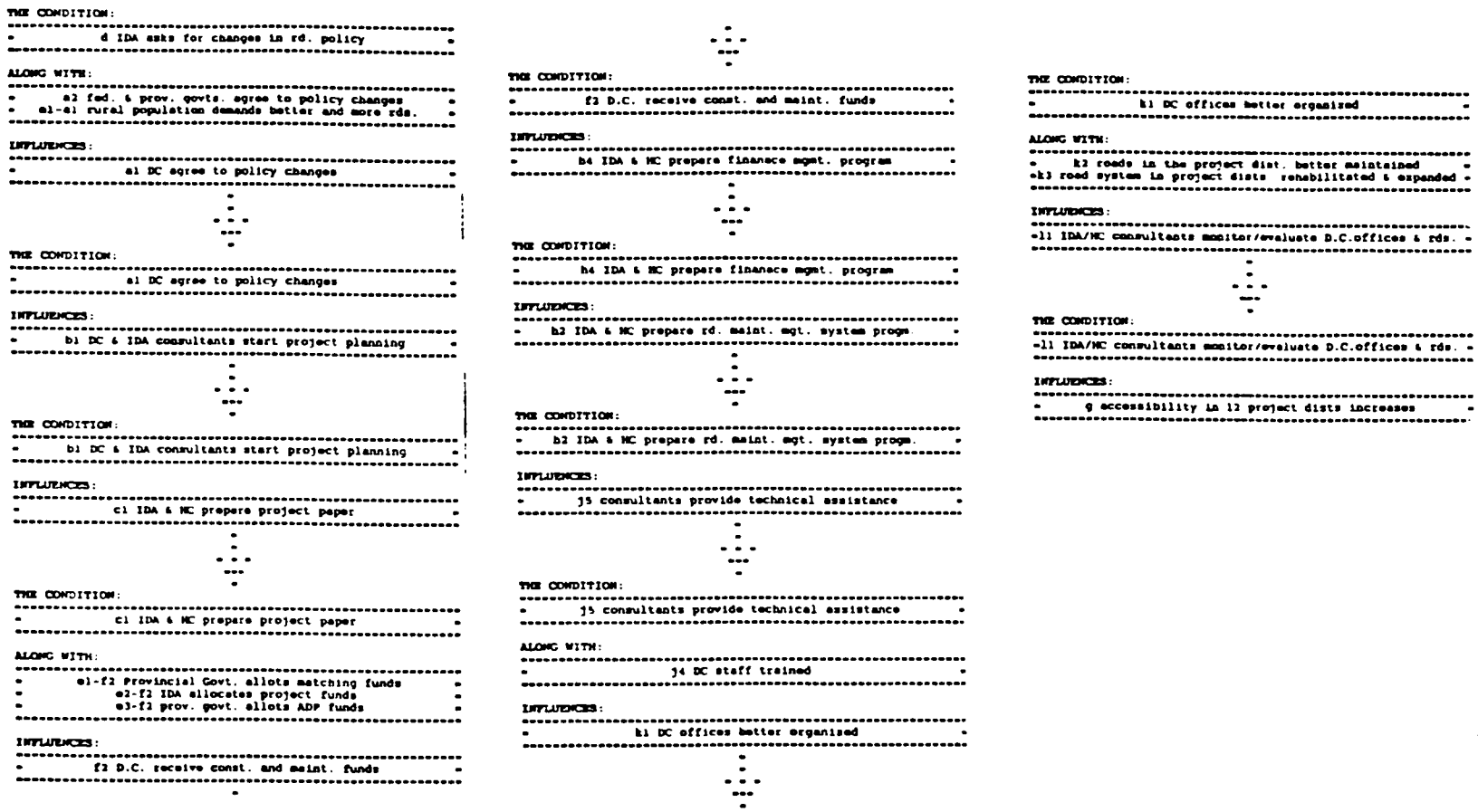


Figure 32: Description of Influence Path (RRM)

APPENDIX B

Example Ideas Generated through TIM

APPENDIX B

EXAMPLE IDEAS GENERATED THROUGH TIM USING RRM-CCS

I. TIM Program

Idea No. 1

Concept: "Public Manager relates well with powerful legislators."

Description: The district council chairman should establish good relations with the provincial legislatures to get maximum matching and ADP funds for the development projects.

Comments: The development plans come up before the provincial assembly (legislative body) for approval.

Base/Key Words: Management

Idea No. 2

Concept: "Public Manager gives information about his project."

Description: The D.C. staff should provide complete and up-to-date information on already finished and in-progress road projects to the consultants engaged in feasibility and planning studies.

Comments: It is important to keep the office record and road inventory complete and up-to-date at all times.

Base/Key Words: Management

Idea No. 3

Concept: "Public Manager has good personal relationships."

Description: The D.C. staff should have good relations with the community of the district and their counterparts in the neighboring districts.

Comments: This is very useful in planning and execution of the development projects.

Base/Key Words: Management

Idea No. 4

Concept: "Public Manager knows and understands rules on personnel, budgeting, and procurement."

Description: The D.C. staff--the district engineer, accounts officer, executive officer--should be well trained in engineering jobs, budgeting, and financial management.

Comments: This will be a help in good planning and completion of projects.

Base/Key Words: Management

Idea No. 5

Concept: "Public Manager utilizes power and effort."

Description: Adequate rules/standards/regulations should be formulated to run the office, plan the schemes and execute road construction/maintenance projects.

Comments: Formulation of adequate rules/regulations and their implementation is a cornerstone for office management.

Base/Key Words: Management

Idea No. 6

Concept: "Public Manager delivers effective projects."

Description: The project plans should conform to the correct technical specifications and standards.

Comments: If the roads are not maintained and constructed properly, they will deteriorate quickly. This results in loss of funds and public dissatisfaction.

Base/Key Words: Management

Idea No. 7

Concept: "Public Manager chooses experienced people to work."

Description: Qualified and experienced people should be selected for employment in D.C. offices and they should be paid adequately.

Comments: This will raise the office efficiency and minimize corrupt practices.

Base/Key Words: Management, Institution

Idea No. 8

Concept: "Public Manager delivers honest work."

Description: Staff should be motivated at all levels of administration.

Comments: This will raise the efficiency/output.

Base/Key Words: Management

Idea No. 9

Concept: "Collectivism."

Description: District Council and provincial government should encourage self-help and incentive schemes for road projects.

Comments: Public participation at project planning stage gains people's confidence who then get a sense of achievement.

Base/Key Words: Government, Management, Development

Idea No. 10

Concept: "Public Manager is fair and honest."

Description: D.C. chairman and members of the district council should set an example in fair dealings.

Comments: Resources/funds are always short. Honest efforts by the councillors will help all undeveloped areas in a district to get share of development projects.

Base/Key Words: Management

Idea No. 11

Concept: "Public Manager keeps boss well-informed on his past and present actions and his plans."

Description: D.C. offices should send accurate information to provincial/federal governments when requested.

Comments: This will help the provincial/federal government to plan good development plans.

Base/Key Words: Management

Idea No. 12

Concept: "Anxiety about finances."

Description: D.C. should plan ahead to generate more financial resources by revising tax/toll rates annually.

Comments: More revenue is needed to meet the rising costs of development schemes. Budget management will save wastage of revenues.

Base/Key Words: Finance, Climate, Money

Idea No. 13

Concept: "A person's management excellence."

Description: Cash incentives and out of turn promotions should act as a good way to encourage D.C. staff to work hard.

Comments: This means timely completion of development projects at reasonable cost.

Base/Key Words: Management

Idea No. 14

Concept: "Overmanagement."

Description: Overmanagement is to be avoided.

Comments: Overmanagement results in centralizing the control at top levels of administration. This kills initiative at lower levels.

Base/Key Words: Management, Quantity

Idea No. 15

Concept: "Overall resources available."

Description: Information/data on the overall resources available in a district (its own and from outside) should be collected and stored for easy access when needed.

Comments: This will help in doing a realistic assessment of revenue resources before deciding on new taxes/tolls, etc.

Base/Key Words: Numerous

Idea No. 16

Concept: "The firm leasing the equipment to the public agency."

Description: Create a pool of road equipment at district/division level and rent it to the contractors involved in construction and maintenance jobs.

Comments: Most of the contractors do not own road building equipment.

Base/Key Words: Numerous, Value

Idea No. 17

Concept: "Firm passing some savings on to public agency."

Description: Avoid spending the budget savings on unimportant projects near the close of the fiscal year.

Comments: The projects must be evenly spread over the year. Correct planning and controls over execution of projects should not result in such a situation.

Base/Key Words: Money, Management

Idea No. 18

Concept: "A statement establishing the structure and purpose of the organization."

Description: The development plan should clearly define the objectives and procedures involved in successful completion.

Base/Key Words: Management

Idea No. 19

Concept: "A political party."

Description: Political parties and community social groups should motivate the population to participate in the district development schemes.

Comments: This will lead to self-help concept and idea of cooperation amongst people/villages.

Base/Key Words: Government, Management

Idea No. 20

Concept: "Movement to the area of low concentration."

Description: Rural road projects should form part of a plan including development projects in education/health/industrial sectors.

Comments: Overall development of rural areas could reduce outmigration of general population to urban areas.

Base/Key Words: Numerous, Scarce

Idea No. 21

Concept: "Government neglect of Emission Regulations."

Description: An environmental impact analysis should be carried out as part of every new road project.

Comments: This will help control the land erosion/waste and other health hazards.

Base/Key Words: Government

Idea No. 22

Concept: "The speed of exit of a civil servant."

Description: Corrupt and inefficient staff should be fired/retired early.

Comments: This should increase efficiency.

Base/Key Words: Government, Management, Corrupt

Idea No. 23

Concept: "Traffic generated at local complexes."

Description: Plan road improvements in time as the new roads and better maintenance will generate more traffic.

Comments: Allow for increased traffic in future plans.

Base/Key Words: New

Idea No. 24

Concept: "Challenge provided."

Description: Provincial government should introduce ways to inculcate inter-district competitive spirit in planning and completion of road projects in time, at low cost, and meeting technical standards.

Comments: Incentive can be in the shape of more matching funds and/or reduction in provincial taxes for the people in the winning district.

Base/Key Words: Relation, Value

Idea No. 25

Concept: "Job sharing."

Description: Job sharing should help in meeting shortage in certain categories of skilled labor.

Comments: For example, a road roller or a dozer mechanic may be good enough to do the jobs in two neighboring districts.

Base/Key Words: Taxation, Control, Relation

Idea No. 26

Concept: "Somebody use a new art style...something."

Description: Use the latest technology in road construction, maintenance, and financial management.

Comments: These roads will not deteriorate fast.

Base/Key Words: Mechanics

Idea No. 27

Concept: "Somebody make a substitute...something."

Description: Planners/engineers in D.C./provincial government should keep thinking of innovative ideas in road project planning, management, and execution.

Comments: For example, use of suitable material available locally may give good results at a cheaper cost.

Base/Key Words: Development

Idea No. 28

Concept: "A data base management system."

Description: Train D.C. staff in the use of microcomputers.

Comments: This will help in storage of data.

Base/Key Words: New, Accessible

Idea No. 29

Concept: "Easy updating of records/files, etc."

Description: Each district council office should conduct a complete road inventory and keep it up-to-date.

Comments: In most of the districts the road inventories are known to be incomplete. This inaccurate/incomplete data results in problems during preparation of annual development road plans.

Base/Key Words: Management

Idea No. 30

Concept: "Somebody raise the price of something."

Description: New concepts/methods to generate more revenue through additional tolls/taxation at local level should be sought.

Comments: Increased revenue will help meet the ever-increasing demand for project funds.

Base/Key Words: Development, Climate, Thought

Idea No. 31

Concept: "Imperialism: policy of one country or people (usually 'developed') extending control or influence...over other areas, (usually 'underdeveloped'). Justification given is...backward areas advanced technologically, economically and culturally."

Description: New and better roads should result in better administration and government control (e.g., tribal areas and interior of the province).

Comments: This will help maintain law and order situation.

Base/Key Words: Quality, Effect, Control, Wealthy

Idea No. 32

Concept: "Monopoly."

Description: The development plan should aim at equal distribution of the road projects over the whole district.

Comments: The rural areas and district councils are under the control of landlords with big land holdings. They try to develop/improve the roads in their own areas which is an unfair practice.

Base/Key Words: Relation

Idea No. 33

Concept: "Somebody add human interest."

Description: Successful projects by a D.C. should make the provincial/federal governments and International Aid agencies interested in funding road projects in that area.

Comments: Projects yielding good results will act as a model in that district and for other districts in the province.

Idea No. 34

Concept: "Control of economic activity by the community or government."

Description: Involvement of private sector in road projects will reduce burden on the local government.

Comments: A private party can be allowed to collect toll in return for building and maintaining a road.

Base/Key Words: Control, Government, Thought

Idea No. 35

Concept: "Autonomy given when performing the job."

Description: Federal/provincial government should provide overall advice but otherwise should let district councils plan their development schemes.

Comments: The people and their elected councillors will have a sense of participation.

Base/Key Words: Management, Quantity

II. Through Electronic Encyclopedia [47]

Idea No. 36

Concept: "The greatest road builders of the ancient world were the Romans. As they developed from a city-state by conquering other small states, they built roads into the conquered regions to help consolidate their gains."

Description: Increased accessibility in the border areas should help in the development as well as in the defense of the country against foreign aggression and smuggling.

Idea No. 37

Concept: "The revolutionary feature of the Appian Way was that it was paved, partly with stone and partly with lava. After that time road-building formed an important function of Roman government."

Description: Construction and maintenance of roads in rural areas is an important government function and should be adequately covered in the national development plans.

Comments: Adequate allocation to road sector is required to be made in the annual budget of the nation (provincial and federal levels).

Idea No. 38

Concept: "Posting stations where horses could be changed and attended to were placed about every 10 miles along the road for government use."

Description: Maintenance gang huts and stations to park and maintain road equipment must be planned as part of a road project.

Comments: These facilities should be located at intervals along the roads.

Idea No. 39

Concept: "The barbarian tribes which...Western Empire...and finally destroyed it, were not concerned with centralized power; rather,...they disliked cities...and avoided Roman roads, which gradually decayed."

Description: Officials at federal/provincial/D.C. levels should give more importance to maintenance of roads.

Comments: Mostly the emphasis has been on new dirt roads.

Idea No. 40

Concept: "John Metcalf (1717-1810), a blind engineer, worked in England and devised a method of carrying roads across marshy ground on rafts of ling or heather tied in bundles."

Description: Road designs and practices for construction and maintenance works should avoid use of imported materials.

Comments: This will increase the project cost tremendously.

Idea No. 41

Concept: "...Turnpike Commission, which, by the sale of bonds plus a direct state loan, raised enough money to build 159 miles of motorway between Harrisburg and Pittsburgh."

Description: Sale of government bonds by the district councils should raise revenue for road projects.

Comments: This should be a controlled practice because people will lose confidence in bonds if they are not properly managed.

Idea No. 42

Concept: "Initially, Roman authorities constructed roads to accommodate military movements and transport...communication between towns and camps being an essential precondition of control...but roads were also used by merchants (who paid duty on goods), couriers, or ordinary citizens."

Description: Roads across the border should boost the trade with a neighboring country.

Comments: Tolls, etc. can raise value of revenue for the provincial/local governments.

Idea No. 43

Concept: "Programming of improvements is the matching of proposed projects with available long- and short-range goals. Programming is definitely a planning function and both may be visualized as an aspect of each other.

Description: Road projects at local government level should integrate into the overall short- and long-term national development plans.

Comments: This will result in a coordinated development.

Idea No. 44

Concept: "Today's traffic, plus that forecasted for the next few years, will play an important role in the selection of priority projects."

Description: Traffic counts and studies should be done annually by each district council.

Comments: Traffic data is very important and at present districts do not do it regularly and realistically.

III. Through Relevant Literature [19]

Idea No. 45

Concept: "At present, road resources are not well managed in this country...absence of routine and periodic maintenance combine to cause rapid deterioration of existing roads."

Description: The district councils should change their approach/policy towards allocation of revenue for road projects and start spending more funds on maintenance.

Comments: Lack of glamour in maintenance is prevalent in all the developing countries as well as in the developed countries, but good maintenance is economically essential.

Idea No. 46

Concept: "The current low standard of road construction...makes cost-effective maintenance impossible..."

Description: The district councils should first bring roads to maintainable standards by undertaking rehabilitation work.

Comments: Most of the rural roads are not maintainable in their present condition. District Engineer uses a few laborers with hand tools or runs a grader over the road which turns the road into a channel.

Idea No. 47

Concept: "However, the current systems...and supervising the work do not promote completion of road works to the necessary standards."

Description: Equipment for a field testing laboratory should be made available to each district engineer to exercise quality control during road construction projects.

Comments: Very little quality control of road construction or maintenance is performed by the D.C.'s, either for contractual work or for that done by force account.

Idea No. 48

Concept: "Institutionalization, maintenance management policies..requires a long-term commitment by..."

Description: Each new construction project should include funds for maintenance after (say five years) the project has been completed.

Comments: Construction costs generally are the most extensive, yet maintenance costs can be substantial in the long run.

Idea No. 49

Concept: "The current mix of labor and machinery is highly labor-intensive and thus in general appropriate to Pakistan's needs."

Description: Construction and maintenance of road projects should be planned to use the needed machinery, but enough labor should be used too.

Comments: Improved road technology may not necessarily involve more and more machinery and/or materials at the expense of labor. Otherwise it could result in higher unemployment in the rural areas.

Idea No. 50

Concept: "..., but maintenance of such equipment continues to be a problem, particularly where a system of public sector ownership and private sector rental is followed."

Description: Field and workshop repair facilities should be made available to take care of the road machinery being used by the district councils and local contractors.

Comments: Normally the users are not conscious of the fact that each piece of equipment is very expensive, and no maintenance or lack of maintenance will reduce its life and performance.

APPENDIX C

Print Outs: Revised CCS (RRMREV)

FOR THE:

CCS: rrmrev RUN: DATE: 03-14-1987

THE SENSITIVITY OF END (GOAL OR FINAL DECISION) CONDITION:
g accessibility in 12 project dists. increases
TO CHANGES IN THE DECISION/EXTERNAL (INFL) CONDITION:

	INFL COND LK/DEC 1	INFL COND LK/DEC 2	END COND LKHOOD 1	END COND LKHOOD 2	ELASTICITY
d IDA asks for changes in rd. policy	1	0	0.717	0.143	0.668
e1-a1 rural population demands better and more roads	0.500	0.400	0.717	0.712	0.030
e1-f2 provincial govt. allots matching funds	0.500	0.400	0.717	0.716	0.008
e2-f2 IDA allocates project funds	0.800	0.700	0.717	0.715	0.021
e3-f2 prov. govt. allots ADP funds	0.550	0.450	0.717	0.715	0.015
e1-f1 revised toll rate/new toll generates more revenue	0.600	0.500	0.717	0.716	0.008
e4-f2 private sector involved	0.500	0.400	0.717	0.714	0.017
e1-h1 funds for maint. after proj. completion allocated	0.500	0.400	0.717	0.716	0.007
e1-j1 rural population agrees to self help projects	0.520	0.420	0.717	0.717	0.003
e1-k1 pers. mgt. results in reducing corruption	0.500	0.400	0.717	0.716	0.004
e1-j3 contractors get rd. const./maint. equipment	0.000	0.100	0.717	0.717	0.000
e1-j8 contractors get rd. const./maint. equipment	0.620	0.520	0.717	0.717	0.002

Figure 33: Sensitivity Analysis (RRMREV)

LIST OF CONDITIONS ALONG WITH INFLUENCES

CCS: rrmrev DATE: 03-14-1987 TIME: 11:34:46

ID CODE, SUBJECT, AND ACTION/STATUS

CLIENT DECISION CONDITIONS

* 2* d IDA asks for changes in rd. policy

EXTERNAL CONDITIONS

* 1* e1-a1 rural population demands better and more roads
* 1* e1-f2 provincial govt. allots matching funds
* 1* e2-f2 IDA allocates project funds
* 1* e3-f2 prov. govt. allots ADP funds
* 1* e1-f1 revised toll rate/new toll generates more revenue
* 1* e4-f2 private sector involved
* 1* e1-h1 funds for maint. after proj. completion allocated
* 1* e1-j1 rural population agrees to self help projects
* 1* e1-k1 pers. mgt. results in reducing corruption
* 1* e1-j3 contractors get rd. const./maint. equipment
* 1* e1-j8 contractors get rd. const./maint. equipment

INTERMEDIATE CONDITIONS

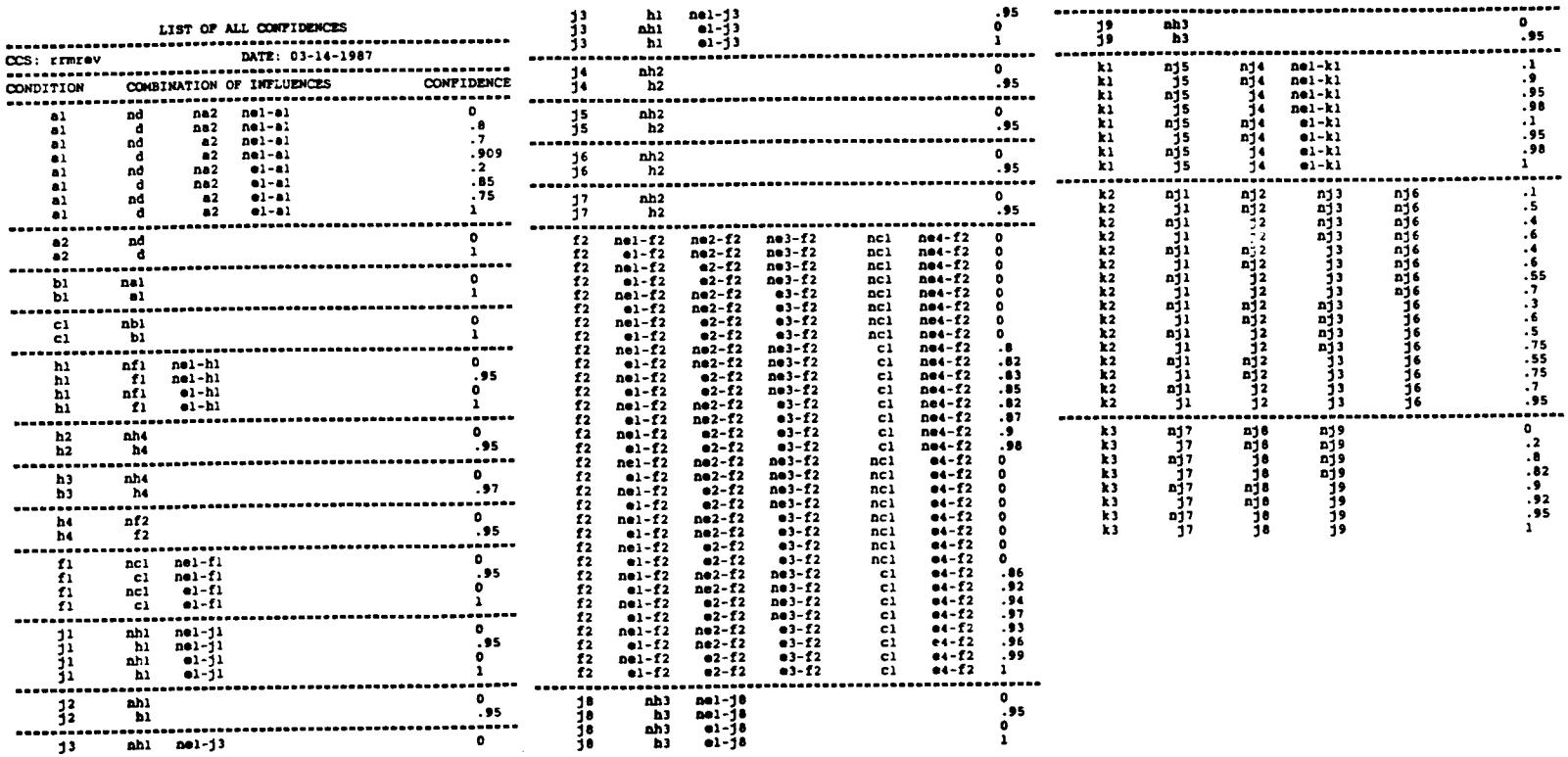
* 1* a1 DC agree to policy changes
d IDA asks for changes in rd. policy
a2 fed. & prov. govts. agree to policy changes
e1-a1 rural population demands better and more roads
* 1* a2 fed. & prov. govts. agree to policy changes
d IDA asks for changes in rd. policy
* 1* b1 DC & IDA consultants start project planning
a1 DC agree to policy changes
* 2* c1 IDA & HC prepare project paper
b1 DC & IDA consultants start project planning
* 3* h1 IDA & HC prepare rd. maintenance program
f1 DC spend revenue on maintenance
e1-h1 funds for maint. after proj. completion allocated
* 4* h2 IDA & HC prepare rd. maint. mgt. system progm.
h4 IDA & HC prepare finanace mgmt. program
* 2* h3 IDA & HC prepare rd. system improvement program
h4 IDA & HC prepare finanace mgmt. program
* 2* h4 IDA & HC prepare finanace mgmt. program
f2 D.C. receive const. and maint. funds
* 1* f1 DC spend revenue on maintenance
c1 IDA & HC prepare project paper
e1-f1 revised toll rate/new toll generates more revenue
* 1* j1 DC labor does routine maintenance
h1 IDA & HC prepare rd. maintenance program
e1-j1 rural population agrees to self help projects
* 1* j2 DC labor/contractors do emergency maintenance
h1 IDA & HC prepare rd. maintenance program
* 1* j3 DC contractors do periodic maintenance
h1 IDA & HC prepare rd. maintenance program
e1-j3 contractors get rd. const./maint. equipment
* 1* j4 DC staff trained
h2 IDA & HC prepare rd. maint. mgt. system progm.
* 1* j5 consultants provide technical assistance
h2 IDA & HC prepare rd. maint. mgt. system progm.
* 1* j6 IDA provide eqpt. & wksp.
h2 IDA & HC prepare rd. maint. mgt. system progm.
* 1* j7 local contractors trained
h2 IDA & HC prepare rd. maint. mgt. system progm.
* 1* f2 D.C. receive const. and maint. funds
e1-f2 provincial govt. allots matching funds
e2-f2 IDA allocates project funds
e3-f2 prov. govt. allots ADP funds
c1 IDA & HC prepare project paper
e4-f2 private sector involved
* 1* j8 contractors construct new dirt roads
h3 IDA & HC prepare rd. system improvement program
e1-j8 contractors get rd. const./maint. equipment
* 1* j9 contractors rehabilitate and upgrade rds.
h3 IDA & HC prepare rd. system improvement program
* 1* k1 DC offices better organized
j5 consultants provide technical assistance
j4 DC staff trained
e1-k1 pers. mgt. results in reducing corruption
* 1* k2 roads in the project dists. better maintained
j1 DC labor does routine maintenance
j2 DC labor/contractors do emergency maintenance
j3 DC contractors do periodic maintenance
j6 IDA provide eqpt. & wksp.
* 1* k3 road system in the project dists. rehabilitated & expanded
j7 local contractors trained
j8 contractors construct new dirt roads
j9 contractors rehabilitate and upgrade rds.
* 1* l1 IDA/HC consultants monitor/evaluate D.C.office & rds.
k1 DC offices better organized
k2 roads in the project dists. better maintained
k3 road system in the project dists. rehabilitated & expanded

GOAL CONDITIONS

g accessibility in 12 project dists. increases
l1 IDA/HC consultants monitor/evaluate D.C.office & rds.

The Quantity Between the Asterisks is the Number of Conditions Directly Influenced By That Non-Goal Condition.

Figure 34: List of Conditions Along with Influences (RRMREV)



LIST OF ALL CONFIDENCES

CCS: rrmrev DATE: 03-14-1987

CONDITION	COMBINATION OF INFLUENCES			CONFIDENCE
a1	nd	na2	ne1-a1	0
a1	d	na2	ne1-a1	.8
a1	nd	a2	ne1-a1	.7
a1	d	a2	ne1-a1	.909
a1	nd	na2	e1-a1	.2
a1	d	na2	e1-a1	.85
a1	nd	a2	e1-a1	.75
a1	d	a2	e1-a1	1
a2	nd			0
a2	d			1
b1	nb1			0
b1	b1			1
c1	nb1			0
c1	b1			1
h1	nf1	ne1-h1		0
h1	f1	ne1-h1		.95
h1	nf1	e1-h1		0
h1	f1	e1-h1		1
h2	nh4			0
h2	h4			.95
h3	nh4			0
h3	h4			.97
h4	nf2			0
h4	f2			.95
f1	nc1	ne1-f1		0
f1	c1	ne1-f1		.95
f1	nc1	e1-f1		0
f1	c1	e1-f1		1
j1	nh1	ne1-j1		0
j1	h1	ne1-j1		.95
j1	nh1	e1-j1		0
j1	h1	e1-j1		1
j2	nh1			0
j2	h1			.95
j3	nh1	ne1-j3		0
j3	h1	ne1-j3		.95
j3	nh1	e1-j3		0
j3	h1	e1-j3		1
j4	nh2			0
j4	h2			.95
j5	nh2			0
j5	h2			.95
j6	nh2			0
j6	h2			.95
j7	nh2			0
j7	h2			.95

f2	ne1-f2	ne2-f2	ne3-f2	nc1	ne4-f2	0
f2	e1-f2	ne2-f2	ne3-f2	nc1	ne4-f2	0
f2	ne1-f2	e2-f2	ne3-f2	nc1	ne4-f2	0
f2	e1-f2	e2-f2	ne3-f2	nc1	ne4-f2	0
f2	ne1-f2	ne2-f2	e3-f2	nc1	ne4-f2	0
f2	e1-f2	ne2-f2	e3-f2	nc1	ne4-f2	0
f2	ne1-f2	e2-f2	e3-f2	nc1	ne4-f2	0
f2	e1-f2	e2-f2	e3-f2	nc1	ne4-f2	0
f2	ne1-f2	ne2-f2	ne3-f2	c1	ne4-f2	.8
f2	e1-f2	ne2-f2	ne3-f2	c1	ne4-f2	.82
f2	ne1-f2	e2-f2	ne3-f2	c1	ne4-f2	.83
f2	e1-f2	e2-f2	ne3-f2	c1	ne4-f2	.85
f2	ne1-f2	ne2-f2	e3-f2	c1	ne4-f2	.82
f2	e1-f2	ne2-f2	e3-f2	c1	ne4-f2	.87
f2	ne1-f2	e2-f2	e3-f2	c1	ne4-f2	.9
f2	e1-f2	e2-f2	e3-f2	c1	ne4-f2	.98
f2	ne1-f2	ne2-f2	ne3-f2	nc1	e4-f2	0
f2	e1-f2	ne2-f2	ne3-f2	nc1	e4-f2	0
f2	ne1-f2	e2-f2	ne3-f2	nc1	e4-f2	0
f2	e1-f2	e2-f2	ne3-f2	nc1	e4-f2	0
f2	ne1-f2	ne2-f2	e3-f2	nc1	e4-f2	0
f2	e1-f2	ne2-f2	e3-f2	nc1	e4-f2	0
f2	ne1-f2	e2-f2	e3-f2	nc1	e4-f2	0
f2	e1-f2	e2-f2	e3-f2	nc1	e4-f2	0
f2	ne1-f2	ne2-f2	ne3-f2	c1	e4-f2	.86
f2	e1-f2	ne2-f2	ne3-f2	c1	e4-f2	.92
f2	ne1-f2	e2-f2	ne3-f2	c1	e4-f2	.94
f2	e1-f2	e2-f2	ne3-f2	c1	e4-f2	.97
f2	ne1-f2	ne2-f2	e3-f2	c1	e4-f2	.93
f2	e1-f2	ne2-f2	e3-f2	c1	e4-f2	.96
f2	ne1-f2	e2-f2	e3-f2	c1	e4-f2	.99
f2	e1-f2	e2-f2	e3-f2	c1	e4-f2	1

j8	nh3	ne1-j8	0
j8	h3	ne1-j8	.95
j8	nh3	e1-j8	0
j8	h3	e1-j8	1
j9	nh3		0
j9	h3		.95

k1	nj5	nj4	ne1-k1		.1
k1	j5	nj4	ne1-k1		.9
k1	nj5	j4	ne1-k1		.95
k1	j5	j4	ne1-k1		.98
k1	nj5	nj4	e1-k1		.1
k1	j5	nj4	e1-k1		.95
k1	nj5	j4	e1-k1		.98
k1	j5	j4	e1-k1		1
k2	nj1	nj2	nj3	nj6	.1
k2	j1	nj2	nj3	nj6	.5
k2	nj1	j2	nj3	nj6	.4
k2	j1	j2	nj3	nj6	.6
k2	nj1	nj2	j3	nj6	.4
k2	j1	nj2	j3	nj6	.6
k2	nj1	j2	j3	nj6	.55
k2	j1	j2	j3	nj6	.7
k2	nj1	nj2	nj3	j6	.3
k2	j1	nj2	nj3	j6	.6
k2	nj1	j2	nj3	j6	.5
k2	j1	j2	nj3	j6	.75
k2	nj1	nj2	j3	j6	.55
k2	j1	nj2	j3	j6	.75
k2	nj1	j2	j3	j6	.7
k2	j1	j2	j3	j6	.95
k3	nj7	nj8	nj9		0
k3	j7	nj8	nj9		.2
k3	nj7	j8	nj9		.8
k3	j7	j8	nj9		.82
k3	nj7	nj8	j9		.9
k3	j7	nj8	j9		.92
k3	nj7	j8	j9		.95
k3	j7	j8	j9		1

Figure 35: List of All Confidences (RRMREV)

APPENDIX D

Glossary of Terms and Definitions

GLOSSARY OF TERMS/DEFINITIONS

Accessibility: Ability of people to reach various functions/facilities.

Action/Status: The event or level produced by a subject which helps define a "condition."

ADP: Annual Development Plan: Prepared before start of the fiscal year at federal and provincial levels.

AI: Artificial Intelligence

Analogy: Resemblance or correspondence in relations between different objects.

Brainstorming: A brainstorm is a sudden burst of inspiration. The term is used in the concepts related to idea generation by a group or an individual.

C & W: Communication and Works

CCS: Computer Consultant System: A particular (situation-specific) set of logical rules and associated likelihoods and confidences.

Client: The person/organization for whom CCS has been developed to apply TCC.

Client Decision Condition: One that represents a choice to be made by the client for whom the CCS has been developed. Its value is set at either 0 (decide against) or 1 (decide for). Freestanding decision conditions can not be influenced by any other conditions.

Commissioner: Government official (bureaucrat) in charge of administrating a division in a province in Pakistan.

Computer Consultant System (CCS): A particular (situation-specific) set of logical rules and associated likelihoods and confidences.

Conclusion Statement (or, simply, conclusion): The THEN condition associated with an IF-THEN rule that represents the result of examining all the influencing conditions.

Condition Statement (or, simply, condition or statement): A discrete event or decision that involves a subject (or subjects); an action or status of the subject; and a classification as either external, decision, intermediate,

or goal. The statement can be no longer than 50 characters (including spaces).

Confidence Value: A value associated with a rule. It ranges from 0 to 1, and represents the strength of the relationship between a particular combination of influencing conditions and the conclusion statement of the rule.

A suggested confidence range is [24]:

0.91 - 1.00 -- The condition is highly certain

0.61 - 0.90 -- The condition is probable

0.51 - 0.60 -- The condition is slightly probable

0.41 - 0.50 -- The condition is slightly improbable

0.11 - 0.40 -- The condition is improbable

0.00 - 0.10 -- The condition is highly uncertain

Consultant: Here referred to as an expert.

Councillor: Elected representative of people.

Creativity: It has sometimes been called the combination of seemingly disparate parts into a functioning and useful whole.

D.C.: District Council: Functions as a local government for each district (excluding cities/towns) and is comprised of councillors.

Decision-Making: The conclusion arrived at by the client and/or the expert.

Definitional Concept: Term with defined properties or characteristics.

Deputy Commissioner: Government official administering a district in a division of a province in Pakistan.

Directive: An order given to the user, depending on the likelihood of the precedent condition compared to the threshold. A directive is binding on the user and is carried out automatically.

Dirt Road: Rural road (unpaved earth road).

Discretion: Free, individual judgment.

District: Pakistan consists of four provinces. Each province is divided into divisions and each division into districts.

Division: See "district."

"Dummy" Condition: An intermediate condition set up in those situations where there are more than five conditions influencing another.

Elasticity: Percentage change in a particular end condition likelihood for a 1% change in an associated external or decision condition likelihood. The changes are calculated at the respective means.

Evaluation: To compare costs and benefits of alternatives. Evaluation can be "economic and overall."

Expert: One who has special knowledge of a subject or special skill in a field of action.

External Condition: One that influences but is uninfluenced by (or at least assumed to be) another condition.

Federal: Applying to the Central Government at Islamabad, Pakistan.

Final Decision: An influenced decision which does not influence any other condition. In other words, it occurs at the end or bottom of a CCS network.

Fiscal Year (FY): GOP FY is from July 1 to June 30 each year; e.g., 1986-87.

Freestanding Decision: A client decision which is not seen as influenced by any other condition.

FRREC: Federal Rural Roads and Engineering Cell: The technical organization of the Ministry of Local Government and Rural Development responsible for rural roads, water supply and allied matters.

Functions: Refers to facilities like a post office, bus station, police station, market, etc., which increase the accessibility in the area.

General Idea: Broad-based phrases involving action.

Goal Condition: One that represents the ultimate intent or goal sought by the user. A goal condition cannot influence any other.

GOP: Government of Pakistan (Federal).

Heuristics: An approach to problem-solving in which a formally unjustifiable solution is assumed as an aid in exploring the implications of the problem.

Identification (ID) Code: A small unique set of characters (no more than 7 numbers and/or letters) given to each condition by the user.

Influence Path: A series of IF THEN statements where the conclusion (THEN statement) can be the influencing condition (IF statement) for the next.

Influenced Conditions: Intermediate, goal, and influenced decision conditions.

Influenced Decision: A client decision condition which is not freestanding. It is seen as being affected by another condition. It usually has, but does not necessarily have to have, an associated recommendation or directive.

Influencing Condition: One that affects another, as specified in the "IF" part of a rule.

Intermediate Condition: One that is not a client decision, external, or goal condition but influences as well as is influenced by other conditions.

Katcha Road: See dirt road.

Knowledge Base: For example, knowledge-based expert system is aimed at providing computer programs that imitate human behavior in problem-solving.

Legislature: Refers to the provincial elected body.

LGRD: Local Government and Rural Development: A ministry in federal government and also used for a department in each provincial government.

Local Government: Same as district council.

Likelihood Value (or likelihood): A value from 0 to 1 associated with external conditions. It indicates the degree to which the external condition statement is either true or false. The likelihood for a decision condition is either 0 or 1. Likelihoods are also the output for each intermediate and goal condition.

M.C.: Municipal Committee: Local government of a city.

Metalled Road: Paved road (also called "pacca").

Metaphor: It is understanding and experiencing one kind of thing in terms of another.

Matching Funds: Provincial/federal government allotments to D.C. with the condition that the D.C. will match that amount.

Monitoring: To watch/evaluate the impacts of a project after completion.

Packaging of Ideas: This is putting the screened ideas into different packages for subsequent use.

Pakistan: A country in the Third World, located at the Indian Ocean with China/Russia to the north.

Paved Road: See metalled road.

Precedent Condition: The single condition which leads directly to an influenced decision.

Province: Pakistan is divided into four provinces--Sind, Punjab, Baluchistan, and Frontier Province.

RDP: Rural Development Program: Prepared by each district council for the district and includes projects in road, health, education, etc. sectors.

Recommendation: A decision suggested to the user, depending on the likelihood of the precedent condition compared to the threshold. A recommendation is not binding on the user.

Relational Concept: Relationship between a conclusion and one or more premises.

RRM: "Road Resources Management" Project.

Rule: A set of directly influencing conditions on one concluding condition, set in an "IF-THEN" format.

Screening of Ideas: Selection of relevant ideas generated by use of The Idea Machine.

SDO: Sub-divisional Officer: Each district engineer has 2/3 SDOs--one each for a Tehsil (i.e., sub-division of district).

Sensitivity: The change in one condition brought about by a change in another.

Sequential Process: Procedure for computation of the likelihoods of influenced conditions in which the inputs (decisions and external condition likelihoods) are requested from the user in order.

Specific Idea: Relatively standard solution which already has been tried elsewhere.

Statement: See condition statement.

Subject: The person, group, or object which produces an event or level, which helps define a "condition."

System: Term used for CCS and a model.

Tax: Normally levied by federal and provincial governments.

TCC: The Computer Consultant: A computer-assisted creativity technique.

Tehsil: See SDO.

Threshold: The level of the likelihood of a precedent condition for a decision above or below which a particular recommendation or directive is given.

TIM: The Idea Machine: A computer-assisted creativity technique for generating ideas.

Tolls: Levied by the district council on roads to generate revenue.

USAID: United States Agency for International Development.

User: Term used for an expert who is applying TCC and TIM to solve a problem.

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