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Providing expert support for collaborative problem formulation

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Abstract

In this paper, I describe how collaborative problem formulation can be facilitated by the language used to describe the problem and by a tool that eases use of that language. The situations that constitute urban design problems are extremely complex, and formulating these problems is usually an intractable task. As a procedurally rational response to this intractability, scholars and practitioners have prescribed ways in which such complex problems can be systematically formulated. Some of these are tools for representing problem information, others are procedures for systematically manipulating the information. Whatever the approach, applying these tools and procedures requires a high level of expertise and effort, and this represents a serious disincentive for using them in everyday design endeavors. Problem formulation methods could be made more accessible and useful through computer-based tools that encode the expertise necessary to implement the methods. One such tool is SmartDRAW, which provides expert support for creating FAST diagrams of problematic situations. The FAST diagram is a diagrammatic vehicle for representing the different parts of a view of a problem and the relationships among the parts. First, I describe the FAST diagram and discuss why it is suited to formulating complex problems. Then, I describe how SmartDRAW provides expert support in constructing FAST diagrams, and discuss how this could be done more effectively for groups.

1. Introduction

Urban design schemes are the result of collective decisions made in a turbulent decision environment. Consequently, they are prey to "errors of the third kind:" solving the wrong problem.[2] These errors arise when formulating, from available information about the situation, the problem being encountered. Problem formulation involves identifying why a particular situation is problematic; or, to put it differently, constructing a representation of the problem to be solved. In what way is the situation unsatisfactory or threatening? How are the different facets of the problem interconnected? If these questions are not correctly answered--if the problem is wrongly represented--then attempts at remedying the situation will most likely be ineffective. For example, improvements are made in an aging central commercial area, but the businesses located there respond to market pressures and move to a suburban location.

The problematic situations that urban designers encounter are complex, and most often cannot be represented as unitary problems, or systems of tractable problems, with well-specified solution conditions (Ackoff 1974, Churchman 1967). As a result, such "messy" and "wicked" situations can be represented in a number of ways, not all of which will result in satisfactory solutions. A representation of a problem could be incorrect because it does not recognize any of the facets of the problematic situation (urban blight is caused by bad weather); it could be incomplete because it misses some of the facets (urban blight is caused by poor maintenance); or, it could be inappropriate because it ignores facets considered important by those who contribute to or are affected by the situation (blighted areas have no redeeming qualities whatsoever). If planning problems are wrongly formulated, it is usually because they are incomplete or inappropriate, and not because they are incorrect.

As a procedurally rational response to this intractability, scholars and practitioners have prescribed ways in which such complex problems can be systematically formulated. (See George 1990 for a review of different procedures and tools for problem formulation.) Some are tools for representing problem information, others are procedures for systematically manipulating the information. These procedures and tools allow the creation and manipulation of an external, tangible, representation of the problem. The purpose of using a procedure or a tool is not to identify a single correct formulation of a problem, but rather to provide the means for representing a problem explicitly and examining it more thoroughly. By inspecting this external representation, a group can identify errors and shortcomings of a particular formulation of a problem. The external representation could also be the basis for identifying, discussing, and resolving group differences.

In this paper, I describe how collaborative problem formulation can be facilitated by the language used to describe the problem and by a tool that eases use of that language. The Function Analysis System Technique (FAST) diagram is a problem formulation tool, a diagrammatic vehicle for representing the different parts of a view of a problem and the relationships among the parts. Unfortunately, learning to use tools such as the FAST diagram, and applying them, requires a high level of expertise and effort; this is a serious disincentive for using them in everyday design endeavors. These problem formulation methods could be made more accessible and useful through computer-based tools that encode the expertise necessary to implement the methods. One such tool is SmartDRAW, which provides expert support for creating FAST diagrams of problematic situations. First, I describe the FAST diagram and discuss why it is suited to formulating complex problems. Then, I describe how SmartDRAW provides expert support in constructing FAST diagrams, and discuss how this could be done more effectively for groups.

The collaboration that is envisaged in this paper is characterized by immediate, face-to-face interactions; participation in problem formulation is not distributed either over space or time. The group formulating a problem are all in one place, possibly lead by a facilitator; the lively clash of ideas that a face-to-face setting produces is often vital to successful problem formulation. This is not say that problem formulation cannot be distributed over space: advances in teleconferencing technology make it possible for intense discussions to be held over long distances.

Using procedures and tools to formulate problems does not guarantee either that the problems will be correctly formulated or that implementing solutions to problems thus formulated will mitigate the problematic situation. Errors in problem formulation may sometimes be intentional: a wrong formulation may be the most pragmatic, the most desirable, or even the only option available. For example, inner-city blight may be incompletely represented as a problem of low capital investment in order to qualify for special assistance. Even if the problem is correctly formulated, the solution that is devised may not address the problem as represented, and, hence, may not remedy the problem. In short, there are no ironclad guarantees that using these procedures and tools will make planning more effective. What they do provide, however, is the means for realizing a desire to better formulate a problem, and, because of the need for accountability and fairness that goes with public decisions, the means for making explicit the basis for these decisions.

2. Problem Formulation and The FAST Diagram

One means of creating an external representation of a problem is the FAST diagram. The FAST diagram has been developed by value analysts, who use it to represent the problematic situations they encounter (Snodgrass and Gill 1982; Tufty 1983; Jarboe and Ferguson 1977). Value analysis, sometimes also called value engineering, originated in U.S. industry during World War II and was a response to the material shortages and high demand that existed at that time (Tufty 1983). Over the years it has been used widely in industry and government all over the world, resulting in an impressive record of savings made in the cost and the effectiveness of projects.[3]

With a few modifications the FAST diagram can also be used to represent urban design problems (George 1992). Essentially, the diagram displays the different policy objectives that must be realized if the problematic situation is to be addressed, together with the relationships among them. Policy objectives are represented by labelled boxes, and the relationships among them by lines linking the boxes. Boxes are linked together in a manner very similar to a flow chart, except that they are in causal rather than chronological sequence. Two boxes are linked together not because one follows the other, but because one makes the other necessary, or is made necessary by the other.

In any diagrammatic representation of information, the syntax of the diagram (the way parts of the diagram are laid out and connected) is crucial to constructing and understanding the diagram. In Figure 1, the syntax for FAST diagrams, as modified for urban design applications, is illustrated. Figure 2 illustrates a FAST diagram representing the problem in a historic but deteriorating inner-city neighborhood adjacent to a soon-to-be built indoor stadium. There are three main features of the diagram syntax: the way policy objectives are described, and the way objectives are linked horizontally and vertically. Policy objectives (improve economy, enhance social stability) must be described succinctly using an action descriptor (a verb: improve) followed by an object descriptor (a noun or a noun phrase: economy or social stability) that describes the object of the action. Describing policy objectives in this way, called two-word abridgement, necessitates confronting the exact nature of group or individual intentions in a particular situation, and encourages clarity of purpose.

A horizontal link in the diagram connects two objectives, one at each side of the link. The objective at the left-hand side of a link is why the objective at the right-hand side is to be performed: for example, in Figure 2, maintain social ties is the reason why it is necessary to prevent displacement. Complementarily, the function at the right-hand side of a link is how the objective at the left-hand side is attained: by preventing displacement, social ties can be maintained. This why-how relationship represents one-way causality: one objective causes a second objective, which in turn is the effect of the first.

The vertical links in the diagram allow the diagram to better represent urban design problems. In urban situations, it is sometimes hard to distinguish between cause and effect. For example, in Figure 2, it can be argued that if the economy is to be improved, then social stability will have to be improved. It can also be argued that efforts to enhance social stability are useless unless economic conditions are supportive of such efforts. Such relationships cannot be portrayed adequately using horizontal links only; to do so would require links that loop back. Vertical links can be used to describe such relationships. Each objective in a chain linked vertically would be a cause and an effect of all the others in the chain; they would be together with each other, they would be both how and why all the

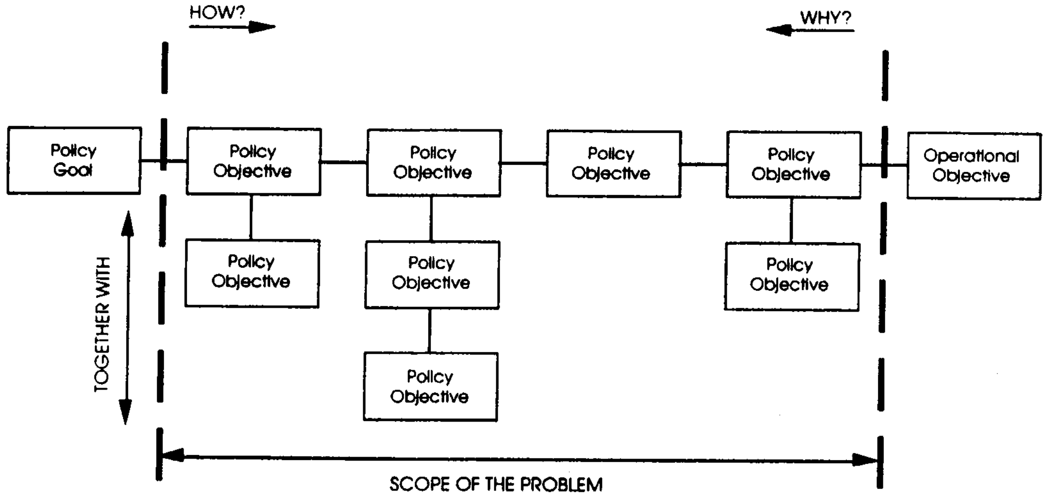

Figure 1: FAST diagram syntax

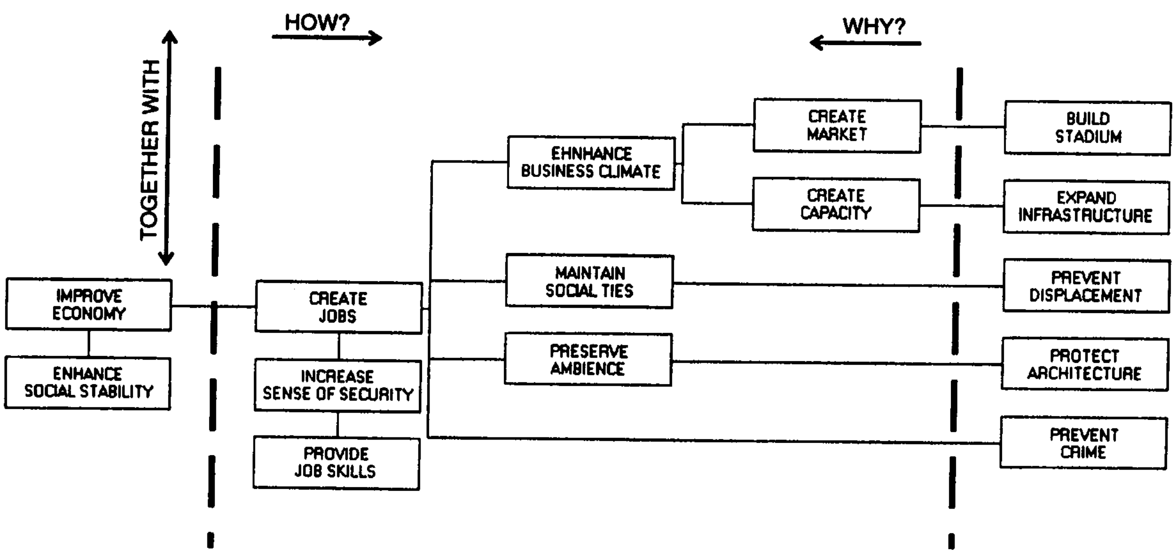

Figure 2: FAST diagram of an inner-city problem

other objectives must be attained.[4] A together with relationship represents mutual causality. For example, in Figure 2, the objectives create jobs, provide job skills, and increase sense of security illustrate the together with relationship.

The FAST diagram is constructed by iterating through three steps: listing the policy objectives to be attained, identifying other objectives that are how or why each objective must be attained, and constructing a diagram to represent this information. (A detailed description of how a FAST diagram is constructed can be found in George 1992.) The first two steps are carried out simultaneously using a worksheet; a fragment of a worksheet is illustrated in Table 1. A policy objective is listed in the middle column of a three-column table. Other objectives, those that are why this objective must be attained, are listed in the column to the left of it; objectives that are how this objective is attained are listed in the column to the right. As new objectives are identified, they are added to the ones already listed in the middle column. This process continues until the situation has been comprehensively covered. As a result, objectives, and relationships among objectives, that may not have been salient before this exercise was conducted, are often brought to light.

Table I: Worksheet for developing FAST diagrams

WHY?	FUNCTION	HOW?
Improve Economy		Enhance Business
Enhance Social Stability	Create Jobs	

The next step involves constructing the diagram itself. Boxes are laid out and connected by horizontal and vertical links in a manner that best represents the relationships among the objectives listed in the worksheet. The diagram resulting from objectives and relationships listed in Table 1 is illustrated in Figure 3. Diagram construction is itself an iterative process that requires many passes before all the objectives and all the relationships can be adequately represented. Boxes must be rearranged, and links made and broken, until the diagram is satisfactory. As the diagram is being constructed, new objectives and relationships may become apparent, or those already identified may be changed, and the diagram revised to reflect these changes and additions.

A FAST diagram is never complete or finished, it is constantly evolving; there is also no single, correct diagram of a situation. Rather, at any given point in time, the diagram is a record of the current formulation of the problem. The ability to view and evaluate an external representation of mental constructs is an important feature of the FAST diagram. There are primarily two potential benefits to formulating problems by constructing FAST diagrams. Incomplete formulation of problems may be avoided because diagram construction encourages a systematic and thorough examination of a problematic situation. Inappropriate formulations of problems may be avoided if, using the FAST diagram, individuals critically examine their own understanding of the situation, and if group members critique the collective formulation of the problem.

Under some circumstances diagrams are extremely powerful tools for reasoning and analysis. As Larkin and Simon (1987) state in the title of their article, "a picture is (sometimes) worth ten thousand words." In addition to taking advantage of the human facility for perceptual reasoning, Larkin and Simon point out that diagrammatic representations support reasoning through the geometric and topological relations by which they are characterized. Since information in a diagram is distributed across two-dimensional space, inferences can often be made directly from the way bits of information are grouped without expending much effort in searching for, recognizing, and matching the elements crucial to making those inferences. Koedinger (1992) suggests that, in addition, constructing a diagram to depict a situation can cause certain properties of the situation to emerge that were not part of the

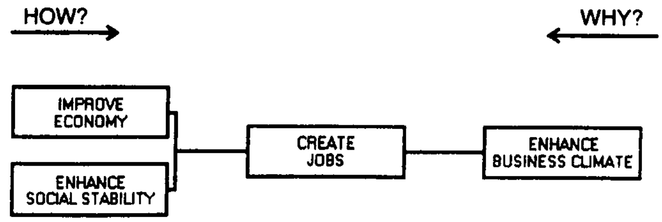

Figure 3: FAST diagram of objectives and relationships in Table I

original understanding of the situation. These emergent properties can reduce the indirect processing that other forms of representation would make necessary. Stenning and Oberlander (1992) argue that diagrams also reduce the number of ways in which information can be interpreted, and in doing so make the information easier to process. Abstraction and simplification is a crucial characteristic of diagrams.

3. SmartDRAW: Expert Support for FAST Diagramming

Unfortunately, constructing the FAST diagram is a cumbersome process and requires considerable expertise. This includes the ability to construct and manipulate diagrams, as well as knowledge of diagram syntax. The diagram has to be sketched and redrawn many times before it is satisfactory. Parts of the diagram have to be rearranged to accommodate the desired correction, any changes will have to conform with the diagram syntax, and boxes may have to be rearranged so that the diagram appears orderly and links between boxes do not cross. Apart from requiring graphic skill, this can also be extremely tedious. For a novice, this could be a daunting task and it may not appear worth spending time and other valuable resources to acquire the necessary expertise.

To make the FAST diagram more accessible, I have developed a computer-based tool, called SmartDRAW, that provides expert support in diagram construction.[5] SmartDRAW can interactively construct FAST diagrams for users in a way that makes few demands on their diagramming skills. With minimal training and expertise, by merely responding to a series of queries, users can diagram their perceptions of problems. SmartDRAW eliminates the distinction between the worksheet and diagram, and moves seamlessly between two tasks: identifying objectives and relationships, and constructing the diagram. A more expert user, however, can choose to construct the diagram directly and not interactively. SmartDRAW supports direct manipulation of diagrams by users: diagrams are constructed and edited using natural and intuitive gestures. Furthermore, one change in a diagram could require that other changes be made; if desired, SmartDRAW effects these changes automatically. Therefore, for both expert and novice user, the cognitive burden is less than in manual diagramming, and users can expend time and energy more usefully on substantive issues.

SmartDRAW is able to construct diagrams for users because of the expert feature built into it. Users can activate and deactivate this feature. Once the expert feature is activated, users' actions are monitored. If the diagram is being manipulated, then SmartDRAW does nothing. If not, then, depending on the current state of the diagram, a dialog between users and the system ensues, and, based on this dialog, the diagramming process is advanced. SmartDRAW also intervenes similarly in the diagramming process if users seek help directly.

I refer often to "users" of SmartDRAW, but only one person actually operates the system at any given moment. In collaborative problem formulation, this means that members of the group have to take turns modifying the diagram to express their views. This is not very feasible in even slightly large groups. More likely in the context of an urban design problem, one member of the group takes on the role of facilitator or moderator and makes the necessary additions and alterations to the diagram to reflect the group formulation of the problem as it evolves.

A comprehensive and detailed description of SmartDRAW is beyond the scope of this paper. (For a detailed description see George 1992, Chapter 3.) To provide a general sense of how SmartDRAW functions, I will describe how users typically interact with the system. To begin with, SmartDRAW interactively constructs a diagram for users. Then, users take control and manipulate the diagram until it is satisfactory.

In constructing a FAST diagram interactively, SmartDRAW first asks users to list some of the policy objectives that would help address the situation. Each objective is typed in two parts, the action and object descriptors, in accordance with the two-word abridgement syntactic constraint mentioned earlier. As objectives are entered, they are added to a list of objectives that are displayed. Unless users terminate this earlier, up to five objectives can be entered before SmartDRAW moves directly on to the next task.

Now that certain policy objectives have been identified, users must identify relationships among these objectives. SmartDRAW proceeds directly to ascertain these from the user via a dialog box. For each objective, users select from one list of objectives those that are how, and from another those that are why, that objective must be attained. An objective can be both how and why another objective is attained. As the relationships for each objective are established, SmartDRAW displays a diagram that reflects these relationships as well as those established earlier. To do this, the system creates lists of objectives that are already and newly identified as being how or why the concerned objective must be attained. Then, by eliminating redundancies and conflicts, the system produces three lists: objectives that are directly how, why, and together with the objective under consideration. In the diagram, appropriate links are drawn to boxes representing objectives in the three lists, and redundant links are erased. The diagram is redrawn, the boxes are arranged so that they are evenly laid out, the links among them do not cross, and they are correctly positioned relative to one another. This is done for each of the objectives identified by users.

Once relationships among all objectives have been identified and the resulting diagram drawn, SmartDRAW returns control to the user. Users can, at this point, directly edit and manipulate the diagram constructed by the system. If after a while a user has not attempted to do this, SmartDRAW intervenes and tries to help the user explore new objectives. This happens whenever SmartDRAW intervenes and finds a partially constructed diagram.

To help users identify new objectives, SmartDRAW queries them about the means by which an objective is to be accomplished, or the ends that objective is intended to serve. A candidate objective is selected, from among those already identified, using a strategy that encourages an exploration of the situation that is comprehensive in breadth and in depth. SmartDRAW alternates between exploring more abstract objectives, "Why must the candidate objective be accomplished?" and more concrete objectives, "How can the candidate objective be accomplished?" As an example, given the diagram in Figure 3, SmartDRAW will ask, "How would you enhance business climate?" This encourages users to explore the problem in greater depth. To encourage greater breadth of analysis, SmartDRAW will ask, "Why else would you create jobs?" That is, other than to improve the economy, and to enhance social stability.

If one or more new objectives have been identified, then SmartDRAW has users identify relationships among these objectives and those already identified. This is done in exactly the same way as for the initial set of objectives, via the same kind of dialog box. If new objectives and relationships have been identified, SmartDRAW revises and redraws the diagram to incorporate the necessary additions and alterations. When SmartDRAW queries users, relationships between some objectives may already be established and represented in the diagram. Repeatedly identifying these relationships can be both tedious for users and prone to error. Therefore, SmartDRAW selects for users any relationships that can be surmised from the current diagram. Users can change this selection if they so desire.

If users cannot identify new objectives when queried about a certain objective, then this objective is not selected again. If this happens for all objectives already identified, then this is taken as a sign that further efforts at diagram construction may not be fruitful. Users can at this point choose to terminate the diagramming process or start exploring new objectives all over again. In the former case, SmartDRAW deactivates the expert feature and returns control to users. Otherwise, all objectives are made eligible for selection as candidates, and SmartDRAW once again proceeds to query users about these objectives.

As described so far, SmartDRAW incrementally constructs a diagram by intermittently assuming control over the diagramming process, either of its own accord or when users request its help. By eliciting information from users, SmartDRAW adds to and alters the diagram. When SmartDRAW is not controlling the diagramming process, users can directly edit and manipulate the diagram. Whenever possible, users must play an active role and control the diagramming process. Otherwise, it is easy to simply accept the diagram drawn by SmartDRAW and not examine it critically.

In directly editing and manipulating the diagram, users can add a box, edit a descriptor, add a link between two boxes, delete boxes and links, and move boxes around. To perform each of these five operations, users select a mode of operation, and use natural, intuitive gestures to carry out the operation. For example, to draw a box when in the box-drawing mode, users point to the location at which the box is to be centered. To draw a link between two boxes, users point at one box and move the pointing device to the other box. To delete a box, users point to the box to be deleted, and issue the delete command.

Merely being able to use intuitive gestures to construct a diagram does not make diagramming much easier. Additions and alterations to a diagram can cause a number of violations of diagram syntax, and rectifying these violations can be tedious and burdensome. Altering one part of a diagram might change the meaning of the entire diagram and necessitate tedious alterations to other parts of the diagram. Such alterations can render the diagram hard to read because of haphazard arrangement of elements, and require further alterations. Therefore, after each editing operation, SmartDRAW is designed to intervene in a number of ways, and, thus, make diagramming less burdensome: it checks for syntax violations and either warns users of the violation or, if possible, remedies the violation; it makes the necessary changes to a diagram to preserve the meaning of the diagram; if desired, it can also rearrange diagrams so that they are more readable.

SmartDRAW detects or rectifies violations in diagram syntax. If, for example, users attempt to add a box such that it would overlap another, a warning message is displayed and the box is not drawn. If users attempt to create a box on a link, and there is enough space to draw a box at that location, then the link is split and the box located in between, and linked to, the two boxes the link originally connected. If users edit a descriptor and leave it blank, then they are warned that the descriptor is not valid. Since descriptors are alphabetic, any other character is not accepted (no warning message is displayed). If users attempt to link two boxes that are already connected, either directly or indirectly, then a message is displayed informing the user of this.

SmartDRAW can also help users preserve the meaning of a diagram. In deleting a box, users can choose to maintain or not maintain diagram continuity. In the first case, the box is removed and boxes prior and succeeding it are connected. Otherwise, the box and all its links are simply removed from the diagram. Many checks and changes are made when a box is moved. First of all, all related links and text are automatically moved with the box, eliminating the tedium involved in redrawing links to and rewriting text at the new location. Then, since the box has changed its position with respect to other boxes in the diagram, its relationship changes with other boxes to which it is connected. SmartDRAW redraws links to reflect these changes.

Finally, SmartDRAW helps users construct orderly, readable diagrams. For example, all boxes drawn are of the same size, the largest necessary to contain the longest descriptor. Also, when manipulating the diagram, often the resulting diagram has links that cross each other or boxes that are laid out haphazardly. This makes the diagram hard to read, and, consequently, not of much use. If this is the case, then SmartDRAW can rearrange the diagram so that link crossings are minimized, if not eliminated, and boxes are arranged in an orderly fashion. This operation is carried out if users desire it.

In these ways, SmartDRAW provides intelligent support for constructing FAST diagrams. This reduces the cognitive burden involved both in learning to construct FAST diagrams, and in actually constructing and manipulating diagrams. However, there are limits to the extent to which SmartDRAW can support problem formulation: it does not provide users with support based on domain knowledge; it cannot, in a substantive sense, judge the quality of a formulation.

There are indications that individuals find SmartDRAW a useful tool in problem formulation (George 1992). After a thirty-minute demonstration, persons are able to use SmartDRAW with virtually no assistance. It has been described as straightforward, and user-friendly. Individuals with stronger graphic cognitive abilities tend to find SmartDRAW more useful than those with stronger verbal cognitive abilities. Few people can, however, use SmartDRAW without a demonstration. Users have to be familiar with the diagram syntax, and the way in which the program operates. SmartDRAW achieves much of the accessibility that was intended, but there is still a learning curve associated with it. However, this learning curve is much flatter than that associated with learning and implementing the FAST diagram without SmartDRAW.

4. SmartDRAW and Collaborative Problem Formulation

While SmartDRAW may help individuals, its usefulness in collaborative problem formulation is less clear. Using a diagram as the basis for group discussion does appear to provide the group process with greater structure and better communication. Unfortunately, since in the case of SmartDRAW only one individual works directly with the diagram, there is not as strong a sense of ownership of the problem as there might be if everyone in the group could manipulate the diagram. Effective support of collaborative problem formulation must allow greater access to the diagram.

When SmartDRAW is used in a group situation--for instance, when I demonstrate its use to a group--the potential for facilitating dialogue and problem formulation becomes apparent. Diagram construction sparks off discussions of the best way to describe policy objectives, and of the appropriate relationships between objectives. Description of an objective often prompts discussion and clarification of the implications of describing the objective in that manner, and alternative descriptions are sometimes proposed and debated. As the various boxes in the diagram are moved around, and lines drawn and redrawn among the boxes, the discussion centers around the logic of the relationships being depicted. The diagram on the screen is a tangible and explicit basis for discussion, and, as a result, individual biases and differences of opinion are better articulated.

Greater improvements to the group process would result if individuals could participate more actively and directly in the diagramming process. With access to the diagram restricted the way it is currently, the individual performing the role of facilitator bears responsibility for giving all participants a sense of ownership over the problem. The facilitator has to ensure that each participant has access to the diagram, even if it is indirect, and is given the opportunity to participate in making additions and alterations. This has to be accomplished in addition to resolving various technical issues such as confusion over diagram syntax, and contributing to the substantive discussion. Taken together, this is an onerous burden on the facilitator.

Individuals can participate more actively by diagramming on a shared electronic drawing surface, either by manipulating one diagram or by manipulating individual diagrams that are all displayed on one screen. Each member of a group would work on a hand-held, pen-based computer linked to a central unit that would manage the shared drawing surface, the technology for which exists today (Bly and Minneman 1990). Group manipulation of a single diagram brings with it complicated issues of access control and priority, and the resolution of conflicts. If more than one participant wishes to make changes to the same part of the diagram at the same time, how are these change to be made? The preferred alternative, in many ways, may be separate diagrams together with a system-generated aggregate diagram. Each participant can view and compare the alternative representations, rather than just the group's representation; the similarities and differences within the group would be more starkly portrayed. Individual participation can be monitored, and equitable representation of different views can be encouraged by targeting the more reticent participants. Just as the expertise required for supporting individual problem formulation has been encoded in SmartDRAW, encoded expertise in facilitating productive and equitable group processes will support collaborative problem formulation.

5. Conclusion

Problem formulation tools, such as the FAST diagram, provide the means for representing the problematic situation being encountered. In the case of complex situations, this could result in more complete and appropriate formulations of the problem. Computer-based tools, such as SmartDRAW, that encode the expertise necessary to implement problem formulation methods, make the methods more accessible and reduce the cognitive burden required in implementing them. While this may be true of individual problem formulation, collaborative efforts require more extensive support. Participants in collaborative problem formulation must be involved actively and directly in the diagramming process. Besides the technology for facilitating this, there needs be encoded the expertise required to enable and enhance group processes.

Endnotes

1. I presented a version of this paper at the 34th Annual Meeting of the Association of Collegiate Schools of Planning held in Columbus, Ohio, in October 1992. The work presented in this paper has benefited greatly from discussions I have had with Steve Gordon, Lew Hopkins, Jack Nasar, and Ken Pearlman.

2. This error has been discussed by Mitroff and Featheringham (1974). It is also referred to as the Type III error by Dunn (1988) and Smith (1989), among others.

3. See Dell'Isola 1989 for an overview of the past performance and future potential of value analysis.

4. Another advantage in using vertical links is that only the topmost node need be connected to prior and succeeding nodes in the causal succession, the other relationships are implied. This would lead to diagrams with much fewer links that are much more easily comprehended.

5. SmartDRAW runs on PC-compatible microcomputers in the Windows graphic operating environment, version 3.0 or higher. PC is the registered trademark of International Business Machines; Windows is the registered trademark of Microsoft Corporation.

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