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Invited Review

Cognitive mapping

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It is appropriate to start a review with a few allusions to the history of its development within an Operational Research context. Although the term cognitive mapping was supposedly first used by Tolman in 1948 for a psychology paper entitled "Cognitive Maps in Mice and Men" it was not until the last decade that the ideas had expanded into use by social and behavioural scientists. Even so the developments in the field of Operational Research occurred independently of these activities, and for markedly different reasons.

Self preservation

I had completed a degree in Engineering and a higher degree in Operational Research, specialising in production scheduling problems. Alongside the research degree I was beginning to be established as an Operational Researcher in the engineering industry, and after some years laid claim to the position of OR Manager of a small but active group of four people. During my time as somebody with the label ORer attached to my name I struggled to use the body of mathematical techniques that seemed the very essence of OR text books of the day—books such as Ackoff and Sasieni (1968). However it must be admitted that they rarely seemed to play an important role in the projects that my clients regarded as successful. This could of course be the result of incompetence. But even computer simulation and dynamic programming (of which I regarded myself as something of an expert—they were very central to my research) never had a substantial impact on organizational life. And yet... a majority of the projects I undertook were taken to be successful and useful by my clients... these were, without exception, those where the modelling technique was simple and consequently transparent to the client, and seemed to help organise his/their thinking rather than suggest a course of action. Thus Critical Path Analysis with PERT overtones worked not because of the analysis but because it prompted the consultant to ask sensible questions. What has this to do with the development of cognitive mapping?

In my late twenties I left the engineering industry to become a 'management consultant' with a small consulting company. Within two years I had worked on marketing, production, personnel, and any other problem area whether or not it had anything to do with OR. At the end of which I left for a one year temporary appointment with the University of Bath, ostensibly to take a sabbatical year pondering upon what characterised his successful work in comparison with less successful work (no failures?!). Many years later I am still in the University sector and still pondering. Nevertheless out of the first few years of pondering grew *cognitive mapping* as the first strands of a reflective OR practice.

The basis of this development was, to me then, a profound (sic!) discovery that managers think and work for most of their lives with language and ideas not with numbers and mathematical sym-

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bols. Therefore OR should be making a model building contribution to the way managers work with ideas. If OR models of any sort were going to have a real impact on the decisions they made then they must gently shift the way in which the manager sees his decision making world. This point seemed so powerfully captured by Thomas and Thomas (1928) when they said "if men define situations as real, they are real in their consequences"—on the one hand a trivial point but on the other a powerful explanation of where to search for theories and ideas that might inform my practice.

Building practice out of theory

In one brief step I moved into the world of "subjectivism"—I puzzled over Existentialism because this seem most obviously appropriate but I did not find that it informed by understanding of organizations. I enjoyed and benefitted from reading Wittgenstein (1969). But finally I stepped away from the traditional philosophers and discovered, within a search for some help from psychology, a body of theory that I take as a philosophy and a psychology together. A Theory of Personal Constructs (Kelly, 1955) seemed to provide a way of understanding personal and organizational problem solving, it also provided a way of understanding itself. A *reflexive?* theory that 'earned it's living' as a way of helping me understand important parts of my consulting practice must be significant discovery. In addition Kelly had enough respect for his own theory that, based on the theory, he designed a technique that would influence his own professional practice as a psychotherapist. There are few theorists who manage to match their theories to their practice, and those that do command my respect (within the OR world Ackoff and Checkland have worked hard to relate coherent theory to their own consulting practice). Kelly devised the technique known as the Repertory Grid. It is as a result of using the Repertory Grid technique as an interactive modelling method for problem construction and having to face its inadequacies in the field of Operational Research (Armstrong and Eden 1979; Eden and Jones, 1984) that a 'Kelly based' version of cognitive mapping was developed.

The essence of Kelly's theory argues that man is continually striving to "make sense of his world". It is built to around a single "fundamental postulate" and eleven corollaries that elaborate the postulate. The postulate implies that a person continually checks the sense he makes of his world by using it to anticipate—reach out for the future. Basic to our making sense of our world is the detection of repeated themes and the construal of them using a *construct system* which has a finite number of constructs, each of which has a pole of affirmation and a negative pole, rather than their being categories of a unipolar type ("construction" corollary and "dichotomy" corollary). However the key corollaries for helping thinking about working with individuals and teams in organisations are the "individuality" corollary, "sociality" corollary, and "commonality" corollary. That is "persons differ from each other in their construction of events" (individuality) because they see/perceive different things in what might be regarded as the same situation by a third person, and more importantly because they construe the "things" differently by explaining its occurrence and what matters about it through the use of different construction systems. "To the extent that one person construes the construction processes of another, he may play a role in a social process involving the other person" (sociality)—which means that effective interaction between members of a problem solving team depends upon the extent to which they can each understand how the other interprets the situation. "To the extent that one person employs a construction of experience which is similar to those of the other person" (commonality) argues that, in attempting to create a consensus and commitment to action in a team, members of the team will need to develop a common way of construing future events.

Repertory Grids were devised to help elicit the system of *constructs* that a person uses to make sense of a repertoire of *elements* in a situation. In an OR context those elements might be options, people, products, design dimensions, and so on within a problem situation. By seeking to uncover the psychological attributes that identify similarities and contrasts between elements the constructs would be elicited. Asking a client to signify how the elicited constructs would be used with respect to each element provides data which can be statistically analysed to identify the *system* of constructs and elements used by the client to describe the problem situation.

For example, when provided with the following three elements: Soft Systems Methodology, Strategic Choice methodology, and Cognitive Mapping; I might differentiate them by arguing that *cognitive mapping* and *SSM* are similar because they both "involve some backroom work analysing data away from the client group" whereas Strategic Choice is always "done completely on the hoof in collaboration with the client group". I would then score each element, including the three that were used for construct elicitation, against the construct "involves backroom work... all on the hoof". After several random selections of three elements from a repertoire of different 'soft' OR approaches (or alternatively, a repertoire of OR consultants) I would have generated a list of constructs that should say something about the way in which I think about soft methodologies. The elements and constructs can then be evaluated against one another (in the form of a grid) by noting the extent to which each element is described by either one pole or the other of each construct. The outcome of this exercise can be analysed in a variety of ways which are designed to suggest which constructs have similar, or opposite, meanings and which elements are evaluated as similar or different. (Used alongside "Analytical Hierarchy Process" (Saaty and Kearus, 1985) the outcome of the grid can be used to help with choice (see also Wilcox, 1972).

The technique is, in principle, helpful and proved so to be in many OR projects. However it is not in my view a good enough reflection of the theory Kelly elucidated, in as much as the theory might apply to OR practice (see Eden and Jones, 1984) for an explanation of some of the difficulties in the theoretically sound use of Repertory Grids). It is clumsy to use in a consultant–client relationship, in a way which probably does not apply to doctor–patient relationships. Few clients are prepared to enter into such a structured 'interview'. The statistical output from exploring the grid is rarely helpful to the consultant, let alone the client, in a problem solving rather than diagnostic environment. We have found this to be the case when simple statistical techniques are used to analyse grids, such as 'simple linkage clustering' (Gower and Ross, 1969) as well as more sophisticated analysis such as 'principle component analysis'. A Grid is constraining in the degree of richness that can be captured—a grid much larger than 12×12 becomes unwieldly to elicit and even more confusing to analyse—and yet a single client will talk about a problem with more richness than could ever be captured by such a grid. A client team will generate ideas, explanations, and ways of making sense of the situation that will certainly run in several hundred constructs. Some disciplines of Kelly, within the field of psychology, have argued that the skilled use of grids can manage such demands; indeed they will argue that the grid itself is a powerful method for reducing unnecessary complexity. Unfortunately such assertions did not match my own experience of using grids or, more importantly, my reflections on my own successful practice. I had concluded that a managerial team had acted as a result of my intervention in those circumstances when I had transparently accounted for the detailed subtleties and richness of the way in which each team member had seen the problem. I had also experienced the power of a model as a 'negotiative device', providing it contained enough of each persons construction of reality for them to enter the negotiation. By the term 'negotiative device' I mean a model that can be used directly by the clients, under the guidance of a 'facilitator', to help members of a client team negotiate their view of the problem and more effectively negotiate a consensus for action.

Thus the next step was to encompass more richness into the model created by a grid. The first attempt was to stay within the literature relating to Kelly, and so we turned to 'Implication Grids' (Hinkle, 1965). Our experience suggested that the combination of Repertory and Implication Grids helped us in situations that were aimed more at team development and less at addressing substantive issues (Armstrong and Eden 1979). This conclusion is not surprising for the addition of an 'implication grid' did not add to the richness of constructs but simply added to the richness of the system of linkage between constructs. And so cognitive mapping from the perspective of Kelly was created...

Modelling cognition?

Cognitive mapping in the style of Kelly builds on three key assertions of the theory. Firstly, man makes sense of his world through contrast and

similarity, that is *meaning* in the context of action derives from relativism. Secondly, man seeks to explain his world—why it is as it is, what made it so. And thirdly, man seeks to understand the significance of his world by organising concepts hierarchically so that some constructs are superordinate to others. Within a problem finding/solving context this last assertion argues that man values some outcomes over others, sees some outcome as contributing to others, and some beliefs about the situation he faces as means to an end. This foundation for mapping is inevitably interpretative of Kelly as he does not address the role of values or the nature of problem construction in a direct manner.

Let me consider the last but one paragraph above, in which I set out some worries about the usefulness of grids as a problem construction modelling technique, as an example of constructing a cognitive map. A first draft of the system of constructs results in the map shown by Figure 1.

The map reads as follows: each block of text represents a "construct" which has two parts to it —the first part is the "presented pole" of the

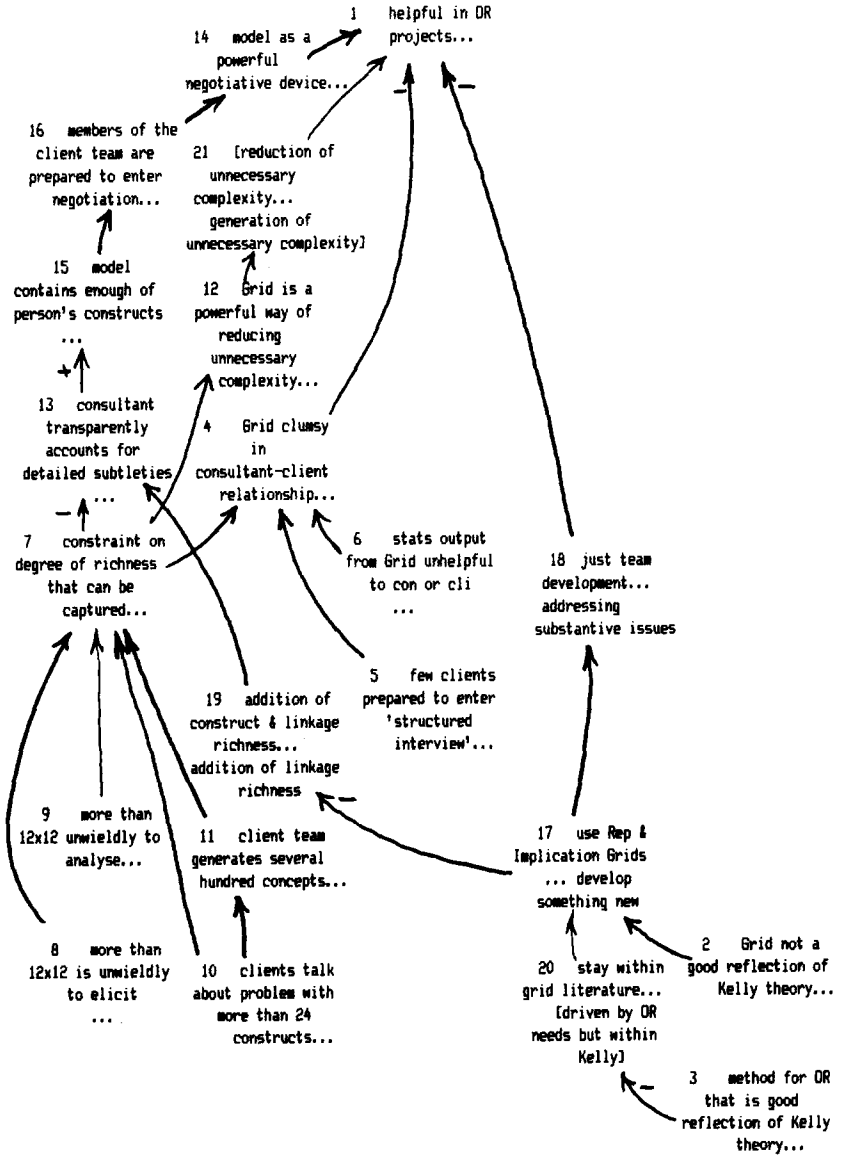

Figure 1. A cognitive map of the author's view on grids

construct and the second pole (separated by "..." which is read as "rather than") is the contrast or psychological opposite. The linkage between constructs represents the meaning of the construct in terms of the explanations and consequences—these links are not taken to be causal in a precise way. The link is in the form of an arrow to show the nature of the linkage—an arrow out of a construct shows a consequence and an arrow into a construct an explanation, each arrow therefore gives explanatory meaning to one construct and consequential meaning to another. A negative sign on the 'head' of an arrow implies that the first pole of the explanatory construct implies the second pole of the consequential construct.

Thus, in the above map "helpful in OR projects" is believed to be influenced by "addressing substantive issues" rather than "team development". Similarly "developing something new" rather than "using Repertory and Implication Grids" might lead to "addressing substantive issues". The map is hierarchical in form and suggests that an important goal in my thinking (as it was expressed in written form) is to find something that will be "helpful in OR projects". *But* how might this map of my thinking be helpful to me as a client?

Let me reflect upon the process of building the map and the outcome, let me also compare the map as model with a Grid that might have been developed for the same purpose. The purpose of building it is to demonstrate how it reveals the options open to us in moving from Grids towards a Kelly based modelling technique. Starting at the top of the hierarchy my goal is to find something that will be "helpful in OR projects" rather than a contrasting pole which was not specified. If Kelly is right then there will exist a psychological contrast which gives meaning to the first pole *with respect to this particular problem*; and it will also be helpful for me to make this contrast explicit in order to better *understand, predict and control* the problem I face. In the context of OR practice it will begin to provide a clue to the nature of the solution strategy. The contrast is discoverable by reference to earlier parts of this paper—"helpful in psychotherapy"—and so the solution strategy should *probably* not explore psychotherapeutic methods (this implication is not assertive or prescriptive but a clue to a developing picture). What options are open for attaining this goal?—constructs 14, 21, 4, and 18. I might consider a method that will provide "a powerful negotiative device" (construct 14) rather than "?" or now I reflect upon it the contrast that comes to mind is "be a model independent of the social dynamics of the client group". I might consider a method that "reduces" rather than "generates unnecessary complexity" (construct 21). I might look for a method that is not "clumsy in a consultant-client relationship" (construct 4) but rather "?"—"helps develop the consultant–client relationship". I should consider a method that will "address substantive issues" rather than "just team development" (construct 18). As consultant I now ask myself, as client, what other means come to mind for attaining the end of being "helpful in OR projects", other than the four already noted in the map? My experience as a general consultant led me to believe that the opportunity to "broaden the issue" beyond the problem label attached to the initial entry always substantially changed the nature of the project in a direction that was beneficial to client and consultant, it also enabled me to identify a wider range of uses for my OR skills than would have otherwise been the case. The modelling approach should therefore broaden the issue but also manage the complexity so created by identifying the network of interrelated problems that make up the client defined issue. My personal style of consultancy has always been better suited to the practical issues of making things happen rather than conducting 'proper' research and analysis. I have also argued above that the method must be transparent to the client, and that it should not be prescriptive but suggestive of action. All of which usefully elaborates the map by the addition of the constructs and links shown by Figure 2.

The sort of elaboration of a cognitive map that occurred to produce Figure 2 is typical of a consultant-client interaction. The consultant has constructed a model of the situation by listening carefully to the language used by the client and the assertions made about why the situation has occurred, the model may be a correct or incorrect representation depending upon the listening skills of the consultant. Nevertheless the primary purpose of the model at this stage is not its use as a problem solving tool but rather as a reflective device. The client is invited to correct the impressions gained by the consultant, and by so doing

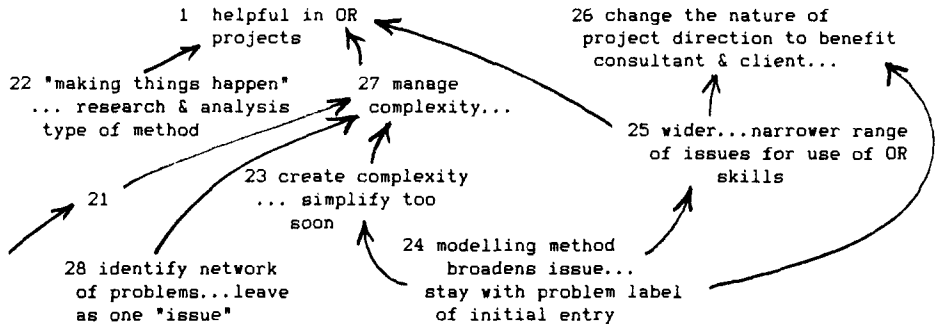

Figure 2. Elaboration of a cognitive map

reflect upon the implications of the model as presented. Thus the client is often tempted to say "I realise I devoted most of the interview to telling you about... but now I see this map I realise that I should have told you about role of values in defining the situation, by inviting the client to say more about why a concept with no proferred consequences (and therefore the most hierarchically superior) matters, in other words inviting the insertion of higher order goals/values, the goal system will be explored. Finally, the client may be invited to consider how some of the subordinate concepts may be made to come about. Each of these forms of elaboration occurred in my reflecting on the map produced in Figure 1. The 'consultant with model' is inviting reflective negotiation about the nature of the problem in an investigative, analytical, and scientific manner.

Reflective problem solving

Early research and consultancy with cognitive maps focussed upon problem solving with individuals. The approach to working with clients on their problems was tantamount to a psychotherapeutic/counselling paradigm. The aim was to build a model that was emphatic with the view of the problem as seen by the client, and to subsequently reflect this back to the client in the manner discussed above. The work reported in "Thinking in Organisations" (Eden et al., 1979) was clearly set against a backdrop of extensive experience of working with senior managers on messy intractable problems by encouraging problem solving through sensitive reflective modelling.

Although some of the maps constructed were large (over forty constructs) most were capable of being represented as one map on one sheet of paper. Indeed it was, and is, usual for the consultant to construct the map "on-the-hoof" and declare it to the client *during* the interview. Usually first draft maps constructed in "real time" would be very untidy and I felt embarrassed about showing them to the client in such a messy form; however I gradually came to realise that if the map *was* emphatic to the view of the world as seen by the client then the client would be uncaring of the untidiness. These experiences were not trivial for they reinforced our intellectually held belief that model ownership was the key to a successful consultant–client relationship. Clients would "play" with the model as a structured visualisation of the beliefs that define the problem.

Cognitive maps and team maps

Work in this decade has moved away from working with an individual towards working with small teams of six to ten people. The consultancy approach has been more specifically designed to help these teams negotiate a consensus and commitment to a portfolio of actions. Indeed the approach has now become known as SODA (Strategic Options Development and Analysis), which encompasses a particular consulting *style*, with a *process* for working with teams, the *technique* of cognitive mapping, and computer software called COPE for the *management of complexity*.

Within the context of working on messy problems with teams cognitive maps are used as a part the first stage of a project. That is the reflective style reported above is used to establish the views held by each individual team member. In this way individuality is exploited by deliberately seeking

to collect the particular view of the situation that is the consequence of each team member having different experience, a different role in the organisation, and different expertise. By spending time building a model with each team member they are each given considerably more "air time" for contributing to the problem construction stage than can ever be the case during a team meeting. In this way it is possible to decrease the probability of "group-think" (Janis, 1972) but also develop an interest in the contribution modelling can make to working on messy problems and a curiosity about the views of others.

In the practical setting of working with a team of busy managers cognitive maping is a tool for building interest from all team members in the problem solving activity. It is often difficult to gain adequate time investment from team members—many of them believe that the issues are obvious and are not prepared to take an interest in the views of others or to regard consensus and commitment as important outcomes of working on the problem. The consultant needs a device for gradually taking team members through the early stages so that interest in the wisdom of others is increased. Cognitive maps based on initial short conversations are a powerful vehicle for doing this. Our experiences, and the experience of other consultants, suggest that it is usual for an initial forty-five minute introductory conversation to turn into one of ninety minutes when maps are used as the device for reflecting the views of the team member. The client also becomes increasingly interested in the maps created by other team members and in further work on their own cognitive map. The shift from working with individual senior managers to work with teams lead to the development of a way of working that was aimed at facilitating negotiation amongst several individuals so that creative solution strategies could be built within the context of a model amenable to analysis. Thus whereas many consultants focused their professional activities of work with teams on messy issues (for example Kepner and Tregoe, 1965) they did not draw upon the Operational Research view that a model is useful because it is amenable to formal analysis, can become a routine part of the organisational memory, and so provide a framework for future monitoring and control. My continuiing interest in attempting to bring together the skills of the Organisational Development consultant with those of the Operational Researcher (Eden, 1978, 1986) lead to development of a process that saw individually owned *cognitive* maps as the "grounded" data for the construction of an aggregated map which could act as a model amenable to analysis which is more importantly a device for facilitating negotiation.

Other OR and Systems consultants see this facilitative device in terms of creating a "dialectic" (a creative tension between two views) by encouraging the client to envision an "idealised scenario" (for example Ackoff (1970), and Checkland (1981) through his "conceptual model" based on "root definitions"), or inverting current assumptions about the situation (Mason and Mitroff, 1981), or by building mathematical/simulation models that force "counterintuitive" outcomes (multiattribute analysis used for "Decision Conferencing" Phillips (1987), System Dynamics models using *Stella* Richmond (1987) based on Forrester (1961)). Because I had been involved in work with individuals it became clear that if each member of a team were given time to contribute to building a model of their own views about a situation then the differences between the situation as it was seen by each team member was so significant that this "*cross*-subjectivity" was a *natural* dialectic. This dialectic was importantly grounded in the team itself rather than being created by the consulting method, and so there was a greater chance of ownership and interest in the dialectic.

An aggregated model constructed by combining each of the individual cognitive maps produces a "team map" that is no longer a representation of the cognition/thinking of anyone and does not belong to anyone. The team map is a facilitative device where each team member will recognise concepts that belong to them but will not necessarily recognise the meaning attributed to them because the concepts that explain and the concepts that are consequential will belong to others in the group as well as the individual viewing the team map.

"Making sense" of problems in teams

Although this paper is a review of *cognitive* mapping it would be inappropriate to close at the point where cognitive mapping becomes the basis for work in a team. The primary aim of the early

work with cognitive maps was to guide careful problem construction whereby each member of the team can gently 'change their mind' and do so creatively. By seeing others concepts in the context of their own concepts the meaning of them changes, this process coupled with sensitively managed social dynamics leads to new insights (team elaboration) created by the synergy stimulated by the team map. (The process is fully declared by Kelly through the sociality, individuality and commonality corollaries outlined earlier).

Each person will now see their own concepts set in the wider context of concepts that derive from other team members. By seeing their own ideas in this form of visualisation they are being encouraged to "change their mind" in a way that does not demand the development of face-saving strategies. During a team meeting they can feel certain that their own views have been faithfully retained and they are free to acknowledge ownership of their own ideas or simply leave them for others to evaluate within the broader context.

The cycle of *problem construction, making sense, defining the problem*, and declaring a *portfolio of solutions*, which I have discussed elsewhere (Eden, 1982) is the framework that guides the process of working with teams. Thus building and working with the cognitive maps of each individual is primarily aimed at helping each team member reflectively 'construct' and 'make sense' of the situation they believe the team is facing. The teams map is initially designed as a device to facilitate the team in their negotiation towards a 'reconstruction' of the situation, and subsequently to their making joint 'sense' of the situation. However, *strategic options development and analysis* follows from the particular action orientation of the coding method used to construct the team map. This process is aimed at helping the team 'define' the nature of the issue—that is, identify key issues within the problem and their relationship one to another, and establish the nature of the goal *system* within which the issues are defined.

Within the above cycle the act of defining the problem precedes a designed exploration of the subordinate concepts in the map in order to 'declare a portfolio of solutions'—thus each interrelated issue is given an action focus by considering the 'tails' of the map (those concepts with no explanations) that are subordinate to the key concepts that label the issue being considered. These tails are the most detailed portfolio of options that have an impact on the most superordinate concepts in the map that defines the particular issue.

If we treat the map formed by the combination of Figures 1 and 2 as a microteam map (team maps are usually made up of several hundred concepts) then visual inspection reveals six clusters of concepts that might be seen as interacting issues. These clusters are identified in Figure 3 and, while they are smaller than would generally be the case, they each have a superordinate concept which is the goal for the issue but also a tail or option for the superordinate issue. Concept 7 defines an issue to do with "degree of richness that can be captured" and which includes concepts 8, 9, 10 and 11, with concepts 8, 9, and 10 as tails. But concept 7 also acts as a tail, alongside concept 19, within an issue defined by concepts 14 and 21 which are in their own turn immediately subordinate to concept 1, which alongside concept 26, define the goals of the overall problem.

SODA as an approach to working with the messy problems of small teams thus embodies cognitive mapping and team mapping as the technique to support the method. The overriding objective of the approach has been built on a bedrock psychology to help work with an individual in his organization, and the social psychology of organizing to understand the process of negotiation in groups and the facilitation of teams. These frameworks inform a practice because they are then set within a perspective on the nature of organizations. However at the core of SODA lies operational research as model building and the analysis of the content and structure of the model, within a *social* setting. Cognitive mapping as an OR technique depends upon the application of coding principles that relate to hierarchies (Simon, 1962), to directed graphs (Harary, Norman and Cartwright, 1965), to the mathematics of cluster analysis (Aldenderfer and Blashfield, 1984) and to computer science for the recent developments we have made in software to manage and present cognitive maps.

Cognitive maps and the role of computers

As I intimated above, some of the power of mapping comes from the ability to retain owner-

ship by holding onto richness. Richness comes at the cost of complexity, most team maps reach in excess of 500 concepts and 700 links after aggregation for the first team meeting. And yet the ability to analyse the structure and content of maps is a major contribution to "defining the issues" and

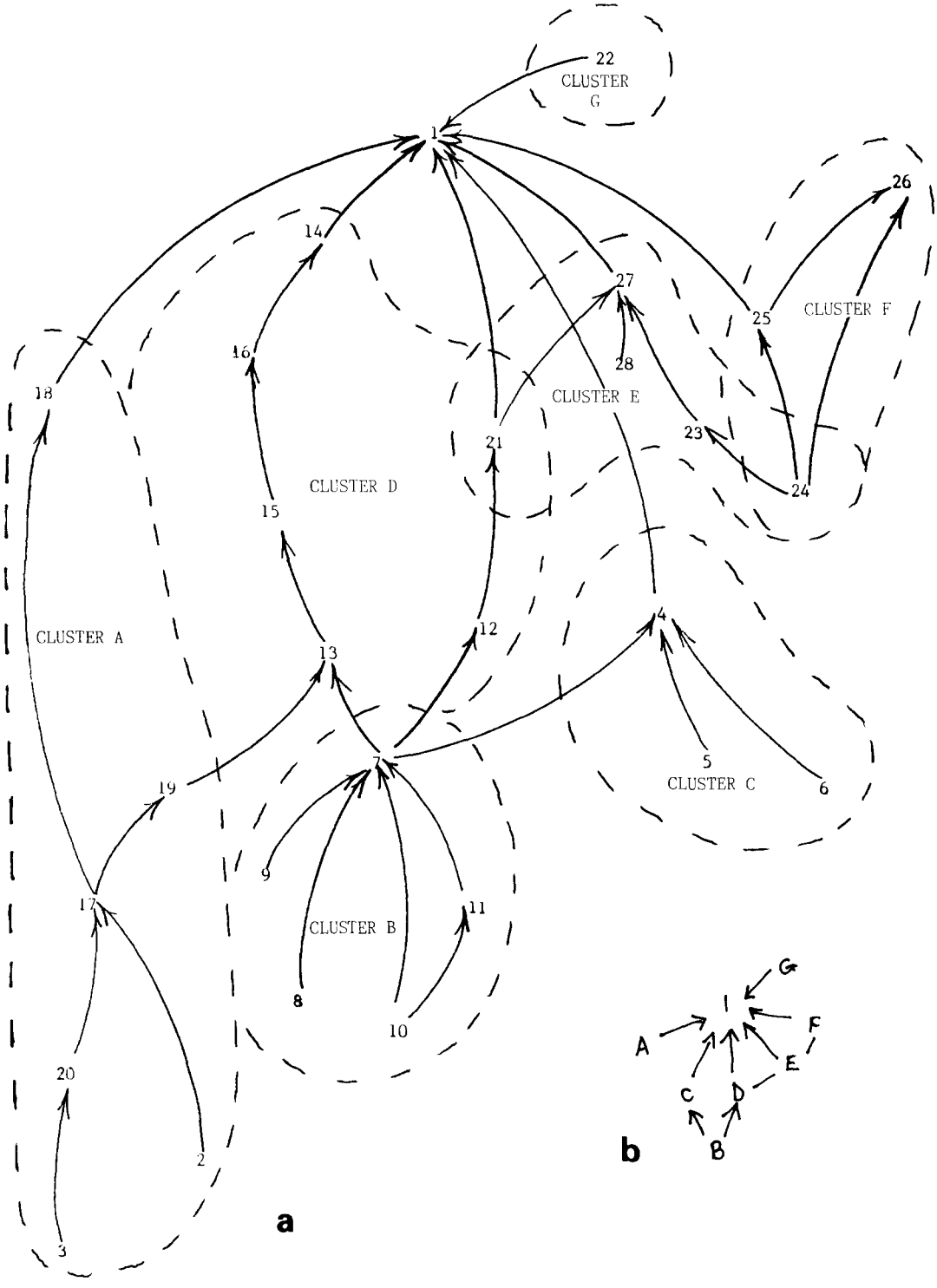

Figure 3. (a) An example of clustering; (b) Relationship between clusters

identifying "portfolios of options". It was within this context that we have been continuously developing computer software (called COPE) to record, represent, and analyse maps. The software is passive in operation and acts as an aid to a good consultant by enabling him to *manage complexity* in many different ways in response to his own judgement about the particularities of the project.

The software has its own 'fourth generation language' that enables users to define menu screens, design output formats, construct special purpose analysis routines, devise interactive question-answer sessions, and make full use of the special facilities of particular hardware configurations. In many circumstances the software is used during initial interviews, this has become more common since the advent of portable, but powerful, desk top computers such as the Toshiba 3100.

The software has been designed to accept two forms of input: firstly, the direct input of concepts with each concept automatically numbered and links between them entered by a simple command ('54 + 65 − 188' representing an arrow from concept 54 to 65 and also to 188 with a negative sign); and secondly through a controlled dialogue. The mapping principles make no demands for consistency or non-conflictual argumentation: a conflicting line of argumentation can be entered in the same way as, and alongside, the alternative view.

From the basic database of concepts and links it is possible to recover aspects of the map in a variety of ways. The most obvious facilities enable the user to search for text, list ranges of concepts, and play back parts of the argumentation. A frequently used display allows the user to place any concept in the centre of a VDU screen and see the adjacent concepts. In workshops that are aimed at agreeing a portfolio of strategic options this command is used to focus attention on a sequence of concepts that may be strategic interventions. As each option is displayed a group of managers are able to explore concepts at the periphery of the screen in order to gain further meaning, elaboration and consequences for action. The command clears the screen quickly and replaced it with the new concept in the middle and yet in the same position relative to the previous concept. In this style of operation the software is a part of what is now referred to as a *Group Decision Support System* or GDSS (Huber, 1982; DeSanctis and Gallupe, forthcoming).

There are many other forms of output and some of these depend upon having conducted some analysis to focus upon a particular sub-system of concepts. The software currently offers a number of different ways in which a large map can be analysed. A useful approach for large maps is to attempt to 'slice' the complete model into clusters. The clusters are formed through an algorithm which uses the link structure to determine the similarity of one concept to another, based upon calculating a modified Jaccard coefficient as the measure of similarity (Everitt, 1974). The overall aim is to split the model into groups which have a minimum number of inter-group links. Naturally there is a trade off between the 'exhaustiveness' of this process and its speed, and between the coarseness of the original data and the arbitrariness of pure distinctions between membership and non-membership of a cluster. Nonetheless experience shows that each cluster is likely to result in the identification of a 'strategic issue'. Within each cluster there will be 'heads' (those concepts at the end of the chains of argument) that represent the goals to be attained within this particular strategic issue. The preferred size of a cluster can be chosen so that each issue is 'manageable'—a typical cluster will contain 25–30 concepts. Once clusters have been formed they are stored in 'groups'. Groups can be created using the clustering algorithm and by storing any other subset of concepts such as all concepts that relate to a particular division of the organization.

When a model has been structured by forming groups, any of the groups can be printed as a map. Deciding upon the best layout for a map is non-trivial and involves calculating the optimal position for each concept to as to reduce the number of crossing arrows, and to provide natural 'flow lines' along chains of concepts. The software uses a combination of 'principal co-ordinate analysis' (Gower, 1966) and series of complex heuristics. The heuristics used in the algorithm attempt to allow for the amount of text in each concept and convert the co-ordinates into two dimensions laid out on A4 size sheets. The module that has been designed for this task is specific to the problem faced in managing cognitive maps, but also has many general applications for the layout of any network structure with nodes and links. The mapping facility also allows the user to redraw the draft produced by the algorithm so that any spe-

cial requirements can be allowed for and the 'errors' made by the heuristics can be corrected.

A strategic database of this sort attributes equal importance to each concept in the first instance. Often a managerial group needs an overview of the major issues so that the interdependency between issues can be fully appreciated. The software provides two ways of establishing an overview. The first enables the clusters/groups to be given a title to describe the content of the group and each title may then be treated as a concept which is connected to others; thus the software is able to treat the network of clusters as a map in its own right so that any of the usual output facilities can be used. The second analysis permits the user to identify key concepts and 'collapse' the model into a smaller model containing only the key concepts that are related to one another according to the paths of other less important concepts that exist between them. This collapse facility also enables new models to be created which have screened out particular aspects of the overall model that should remain confidential.

A management team often demands an analysis of the data to help them identify 'the nub of the issue'. Such an analysis is always dependent upon the specific judgements that are made of the content of the data; however, analysis of the structure of the data usually provides some powerful help in identifying the core elements of issues. The methods of analysis that are available using the software focus upon a variety of different measures of the relative density of concepts in parts of the map. Thus, the software will compute the 'centrality' of each concept by (i) simply calculating the number of concepts immediately related to it; (ii) calculating the number of paths of argumentation that support and are consequential to the concept; (iii) calculating the extent to which these paths of argumentation are well elaborated; and (iv) calculating the density of concepts surrounding the concept by weighting those closest higher than those further away on an exponentially reducing basis. Inspection of each of these relative measures provides an insight into which might be 'core concepts'.

The software enables the user to define subsystems of different parts of the map. Each of eight subsystems acts as a reservoir for concepts. The subsystems are designed to enable the user to ask logic questions of the contents; thus one subsystem may contain all the data relating to 'financial' issues, another contain data that relates to 'short term' issues, another contain data that relates to the 'business systems division'. It is then possible to request an analysis that shows which short term issues are financial in nature but do not impact on the business systems division. Specifically the analysis possibilities are (i) show what is not in a subsystem, (ii) show what is in one subsystem and not in another, (iii) show what is in two subsystems. Because the results of each test can be placed in another subsystem the logic tests can isolate highly specific needs.

The future for qualitative modelling

The current thrust of work with cognitive mapping and SODA lies within the field of Group Decision Support Systems (GDSS). The experience we have gained within our research unit at Bath has enabled us to work in a computerized group decision support environment with the senior management teams in many organizations and over long periods of time. This experience has provided us with a future direction which fits closely with the views of Rohrbaugh (1987) about the way such facilities need to develop in the context of "top management". He has argued that "decision makers at the very highest organisational levels are unwilling to accept that they have no agency whatever over the states of nature" in decision trees and other decision analysis models. Consequently he argues that the use of computers with such groups is more likely to move to "information free" models based on beliefs, judgement and wisdom rather than on data—"such models have exhausted empiricism and placed no bounds on rationality".

As Huber (1984) has argued, a GDSS is "a set of software, hardware, and language components and procedures that support a group of people engaged in a decision-related meeting". Within this context we see the role of COPE as an interactive real-time modelling system becoming the core procedure for creating a powerful vehicle for using cognitive mapping as the "negotiative device" to facilitate thinking and decision making in small teams (Ackermann and Eden, 1987) and within the context of messy issues with a strategic significance for the organisation.

The practical aims of SODA and cognitive mapping remain as:

- providing a tool to enable a group to negotiate a definition of the problem that is visualised in the form of a model amenable to further elaboration and to the analysis of complexity;
- providing a method for designing more efficient problem solving meetings by allowing considerably more "air time" for each team member and thus surfacing the expertise and wisdom of team members rather than working with dominant views, or overview statements;
- an approach to problem construction that leaves open the techniques that will be most appropriately used to tackle each of the interrelated problems within the issue. Procedural uncertainty (Humphreys, 1984) is managed by reference to the contingent nature of the problem as it is captured through the modelling of 'natural' language;
- attaining an appropriate and powerful link between the qualitative aspects of a problem definition and the role of quantitative analysis (Eden et al., 1986).

Cognitive Mapping stands or falls not by its method or technique, but rather by its aims or intentions. This is not to say there is no technique, for there is much of it—indeed some argue there is too much, but its role is to support the intelligent handling of messy problems in a team setting.

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