Cognitive Maps of Product Development:

An object-based approach

(P-P528)

John R. Callahan

School of Business and

Department of Systems and Computer Engineering

Carleton University

1125 Colonel By Drive

Ottawa, Canada K1S 5B6

tel: (613) 788-2372, fax: (613) 749-7960

email: john_callahan@carleton.ca

Abstract

The cognitive maps of design managers in a large development project are captured using coordination structure. These maps are related to the roles and responsibilities of managers, and demonstrate the lack of a shared view of project structure that is possible among managers even within the same functional area.

Introduction

The cognitive maps of design managers in a large development project are captured using coordination structure. These maps are related to the roles and responsibilities of managers, and demonstrate the lack of a shared view of project structure that is possible among managers even within the same functional area.

The research builds on the work of Dougherty (1992) who found that the individuals within a functional department of a company generally have an intrinsically harmonious perspective on product development which does not overlap extensively with those held by other functional departments, and that of Krackhardt and his colleagues (Krackhardt (1990), Krackhardt and Hanson (1993), and Kilduff and Krackhardt (1994)) who used social networks to model the informal structure of organizations and came to the conclusion that what matters is that these "networks are in sync with company goals" (Krackhardt and Hanson 1993).

Using Coordination Structure for Cognitive Mapping

A coordination structure is a configuration of actors (individuals or groups of individuals -- units in an organizational situation) who have interdependent responsibilities to create, modify and use an array of shared work objects. In the product design domain, typical shared work objects would be customer requirements, designs and test results. Associations between an actor and a set of shared work objects specify the actor's responsibilities. The responsibilities of actors are interdependent if the actors have associations with one or more of the same shared work objects.

Coordination structure has been used to model descriptively technology based alliances (Bailetti and Callahan 1993), the standards interactions of product development organizations (Bailetti and Callahan 1995a) and the integration of a firm's core competences with market requirements (Bailetti and Callahan 1995b). Coordination structure has also been used in a normative way as a tool for the management of complex projects in uncertain environments (Bailetti, Callahan and DiPietro 1994), and as a basis for the gathering and analysis of data on temporal changes in responsibility structure of projects (Bailetti, Callahan and McCluskey 1998).

Using this approach, a respondent can be asked to draw a diagram composed of the relevant actors in a development project, the work objects that they share, and the associations between the actors and shared work objects. This diagram captures the respondent's view as to how the development project is structured. The diagrams produced by respondents are cognitive maps (Weick and Bougon 1986).

To date, most management research on cognitive mapping has used cause maps (Axelrod 1976, Bougon, Weick and Binkhorst 1977, Eden, Jones, Sims and Smithin 1981, Eden, Jones and Sims 1983, Hall 1984, Dunn and Ginsberg 1986, Walsh and Fahey 1986, Weick and Bougon 1986, Bazerman and Carroll 1987, Roos and Hall 1990, Walsh 1990, Eden 1992, Fiol and Huff 1992, Simons 1993). A cause map is a directed graph consisting of concepts linked by arrows representing a causal link between concepts of the form "concept A has consequences for or can be explained by concept B". The social networks used by Kilduff and Krackhardt (1994), Krackhardt (1990), and Krackhardt and Hanson (1993) are also a form of cognitive map.

Multiple Views in a Large Development Project

<u>Collecting the data</u>

At the time the research was carried out, design and development had been underway for twelve months. The project was at the midpoint of its expected duration. The objective of the project was to develop a major software based telecommunications application for a large international supplier of telecommunications products. The project included market researchers, product managers, human factor specialists and software designers. All members of the project were full time employees of the telecommunications equipment supplier and were dedicated to work full-time on the project. The manager responsible for the project as a whole reported to the general manager of a business unit which developed and deployed new services in service-provider networks. The more than 100 designers in the design function represented a large percentage of the people working on the project. The design function and the business unit were located in different cities. The manager responsible for the design function of the project was a member of a centralized corporate R&D laboratory and as such did not report directly to the business unit's general manager.

The formal structure of the design function of the project was as follows. There were ten design and development teams in all: six chunk teams responsible for the development of specific components of the product design; a team responsible for design verification; a team responsible for design tool provision and support; an architecture team responsible for maintaining the integrity of the product architecture and for coordination around it; and a product team responsible for coordination between the design function and the business unit, customers and standards organizations such as Bellcore. Each of these teams was led by a team manager who was an engineer or computer scientist. Each of three senior managers oversaw the work of three or four of the team managers. The three senior managers reported to the manager of the design function of the project.

Data were gathered in two rounds of personal interviews with each of ten design managers: four chunk team managers; the managers of the design verification, design tool, architecture and product teams; and two senior managers. In the first interview each respondent identified actors, shared work objects and associations in response to the request "to develop an object-based diagram which captures the structure of the project". During the first round of interviews, respondents were also asked three specific questions: "when you look into the future, what uncertainties do you see for the project?", "what aspects of the project do you consider most critical?", and "what is the objective of the project?". These three questions were derived from the themes that Dougherty (1992) used to differentiate among "thought worlds".

During the second interview, each manager in the sample was asked to performed three tasks. Managers were first asked to check the computer drawn version of their original hand drawn diagrams and then to examine all of the diagrams from the first interviews. They were not provided with the identities of the respondents who had developed the diagrams in the round one interviews.

Second, managers were asked to rate each of the 10 diagrams on the extent to which it addressed the different aspects of project structure. Scope data were gathered from the managers as responses to the following question: “how completely does this diagram represent the various aspects of project structure?” Responses were on a five-point Likert scale, with end points 1=only one aspect is represented and 5=all aspects are represented. An aspect was defined as being either a particular concern in the project (e.g. testing, prototype development, planning) or a connection with actors outside the project team (e.g., connection with product management, connection with the team building the operating system base that would support the application being built). Managers’ responses to the question above were named scope scores. A scope score was then a measure of how complete a manager felt a particular diagram was in representing the various aspects of project structure. A diagram with a scope of five was complete in the sense that the respondent could not think of aspects of the project not considered.

As the third task, managers were asked to make adjustments to their original diagrams using as input the first round diagrams from the other nine respondents.

Results

The answers of the respondents to the first thought world question ("when you look into the future, what uncertainties do you see for the project?") focused on three major uncertainties: 1. the ability of the development organization to use the new product and development process technology so that its potential benefits were captured and still meet very demanding project schedule milestones; 2. the ability of the organization to hire and train sufficient new people to meet its milestones; and 3. the suitability of the structure of the development organization for coordinating design development and for incorporating customer requirements into the design.

The answers of the respondents to the second thought world question ("what aspects of the project do you consider most critical?") focused on two critical aspects: 1. the success of the simultaneous effort within the firm to develop both the software platform upon which the sample project's product application would depend and the product application itself, and 2. the development of a robust product architecture which would serve as a platform for future product development. These aspects were identified by eight and five of the ten respondents respectively.

Responding to the third thought world question ("what is the objective of the project?"), all of the respondents specified the meeting of customer commitments on time as the primary objective of the project. The "customer commitments" referred to by the respondents were specific commitments (specific product releases to specific lead customers at specific times agreed to by the lead customers and the firm) not general unspecified commitments to non-specific customers. One senior manager included making a profit for the firm as an objective in addition to the objective of meeting customer commitments on time.

For each of the second round diagrams of project structure, Table 1 provides: i. average and standard deviations for the scope scores, ii. measures of comprehensiveness, connectedness and complexity, and iii. judgments of the principal types of actors and the level of object aggregation.

Comprehensiveness, connectedness and complexity were measures used by Calori, Johnson and Sarnin (1994). Comprehensiveness of a manager's diagram of project structure was measured by the total number of actors and work objects in the diagram. Comprehensiveness indicates the extent to which the respondent was able to differentiate several elements in the project. Connectedness of a manager's diagram of project structure was measured by the number of links between the actors and the work objects divided by the total number of actors and work objects in the diagram. Connectedness indicates the extent to which the respondent was able to integrate the differentiated elements in the project. Complexity was measured as the total number of links in the diagram. It equals the product of comprehensiveness times connectedness.

The average scope scores for the ten diagrams ranged from 1.7 to 4.3. The Cronbach alpha of the scope scores for the ten diagrams was 0.75 indicating internal consistency reliability for the scope measure itself. Comprehensiveness (total number of actors and objects in a diagram) ranged from 19 to 74; Connectedness (the number of links per element) from 1.47 to 2.62; and Complexity (the total number of links) from 28 to 152.

The diagrams of project structure of the same four respondents scored the highest in average scope, comprehensiveness and complexity. These four respondents were: the two senior managers, the manager of the product team, and the manager of chunk team one. The

Table 1. Significant Characteristics of the Second Round Coordination Structure Diagrams

Respondents and role in project	Average scope (stand dev)	Comprehensiveness: No. of elements (actors and objects)	Complexity: No. of links	Connectedness: No. of links per element	Principal type of actors chosen	Level of object aggregation
1. Senior manager one	4.2 (0.57)	40	95	2.38	managers	High
2. Senior manager two	4.3 (0.62)	74	152	2.05	teams	Medium
3. Manager product team	4.0 (0.85)	57	115	2.01	teams	Medium
4. Manager architecture team	3.0 (0.60)	31	69	2.23	teams	Medium
5. Manager design verification	1.9 (0.90)	37	60	1.62	teams	Low
6. Manager design tools	1.7 (0.75)	32	49	1.53	teams	Low
7. Manager chunk team one	4.1 (0.51)	72	151	2.09	teams	Medium
8. Manager chunk team two	3.3 (0.75)	35	92	2.62	teams	Medium
9. Manager chunk team three	3.2 (0.83)	21	47	2.23	teams	Medium
10. Manager chunk team four	1.8 (0.57)	19	28	1.47	teams	Low

manager of chunk team one had assumed a special responsibility for process improvement in the project based on his interest and experience.

Measures of connectedness for the diagrams developed by the manager of design verification, manager of design tools and manager of chunk team four (respondents 5, 6 and 10 respectively) were the lowest in the sample; they ranged from 1.47 to 1.62. The measures of connectedness of the other seven respondents ranged from 2.01 to 2.62.

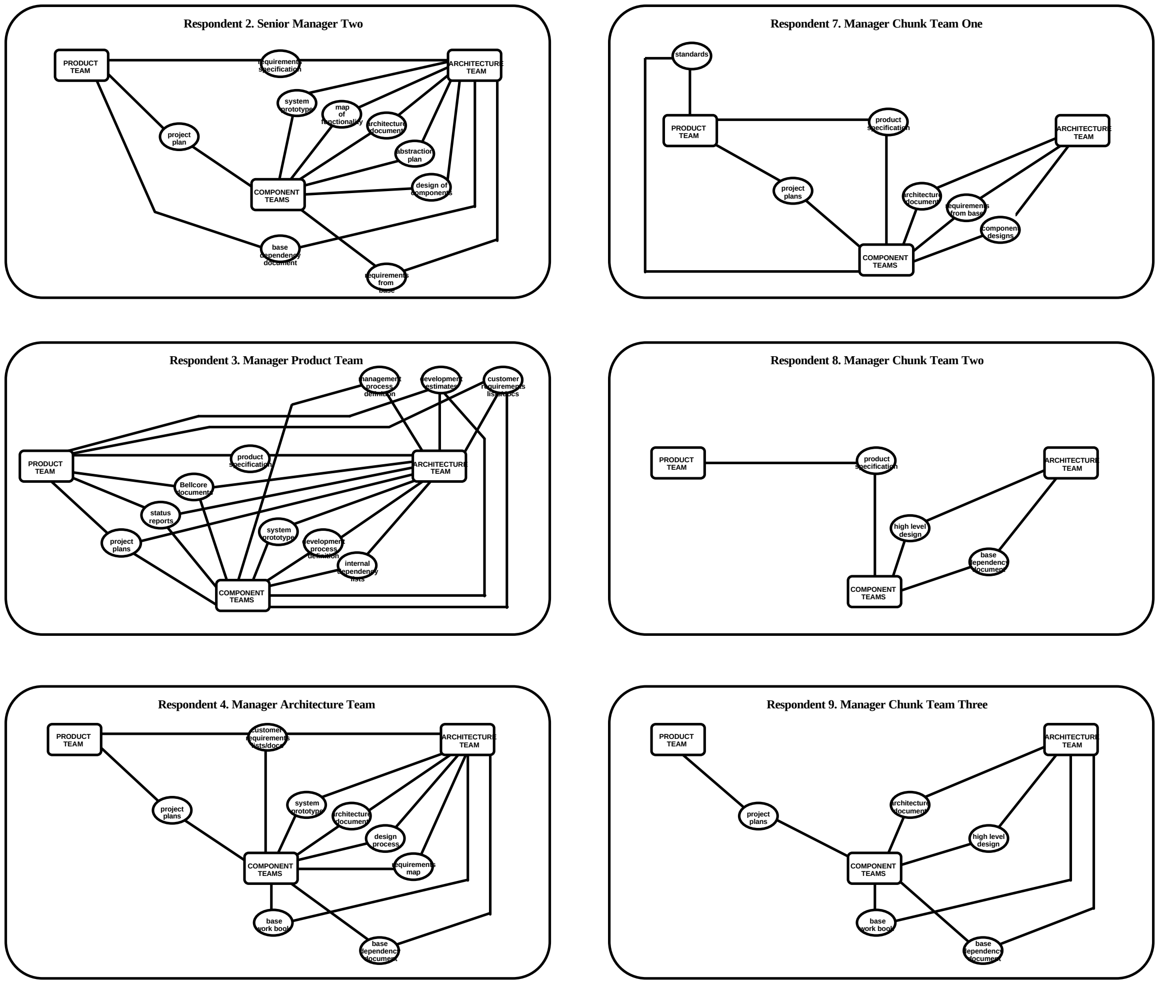
Six respondents developed object-based diagrams using actors and shared work objects of the same level of aggregation. They modeled actors using the teams specified in the formal hierarchical organization structure of the project. The shared work objects that they used were of a medium level of aggregation, pertaining for the most part to design, design requirement and schedule aspects relevant to the project as a whole. As a result, the six diagrams developed by these six respondents were directly comparable in spite of having different average scope, comprehensiveness, connectedness and complexity scores.

Figure 1 provides subsets of these diagrams showing the views of internal integration of the project of the six respondents. They are anchored on three key actors in the project: Product Team, Architecture Team and Component Teams. The actor, Component Teams, encapsulates all of six of the chunk teams. Figure 2 provides diagrams derived in the same way showing the views of the same six respondents concerning external integration of the project anchored around three actors external to the project: Bellcore, Customers and Product Management; and the three key actors in the internal integration diagrams.

<u>Discussion of the results</u>

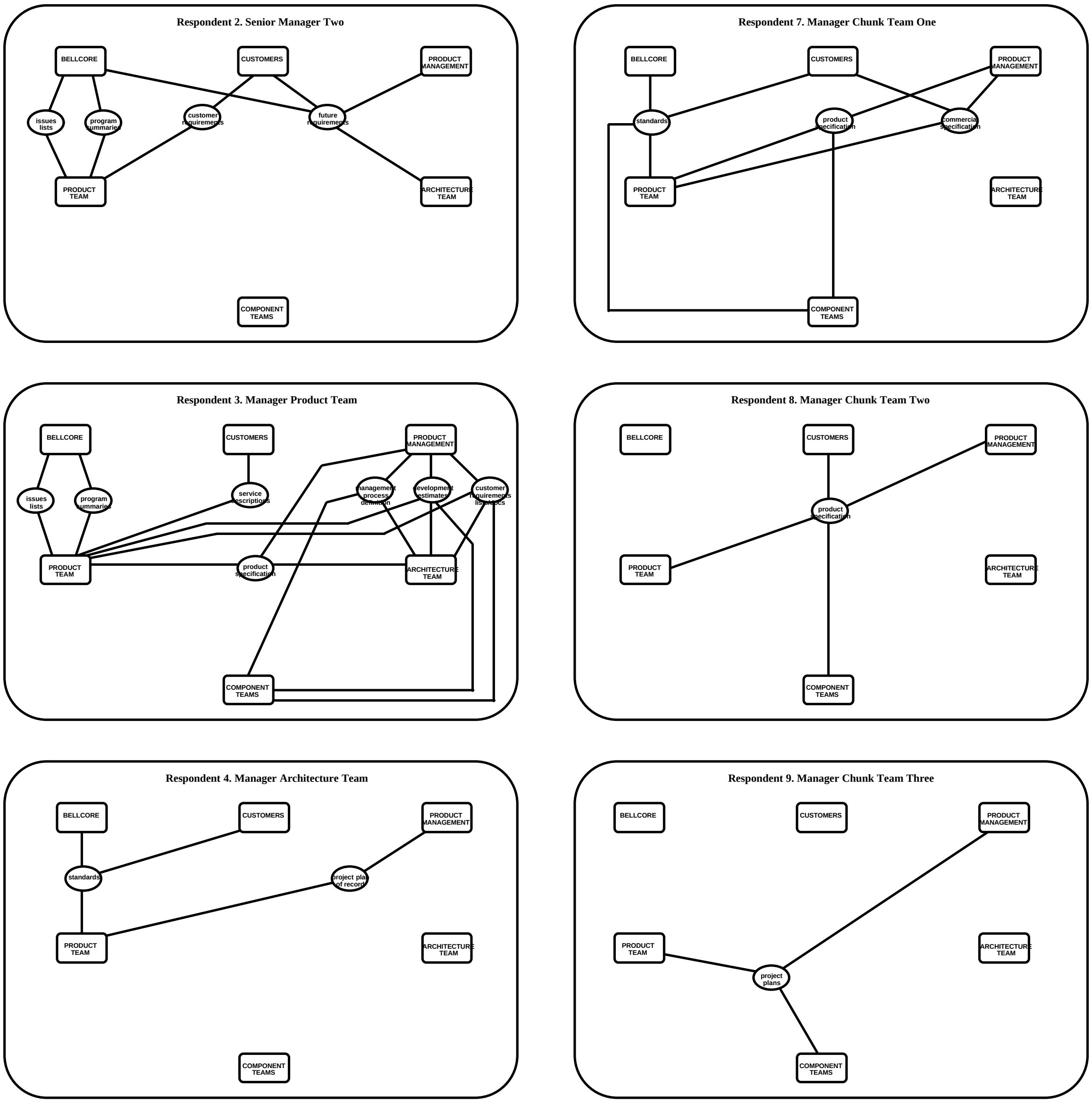
The responses to the three thought world questions were similar. The results suggest that the sample respondents are from one thought world with the exception, perhaps, of senior manager one who was the only respondent to identify profit for the firm as a project

Figure 1. Views of Internal Integration Among Key Actors in the Project



objective. The results support Dougherty's finding that the individuals within a functional department of a company generally have an intrinsically harmonious perspective on product development. However, the thought world identified in the sample is not identical to "technical people", the most similar thought world identified by Dougherty (1992). She found that "technical people" view the product as something that has physical presence and is "neat", the market as being defined by what the product does, the development task as a hands-on tactile activity, and the uncertainty of the project as finding out what the parameters of the design should be.

Figure 2. Views of External Integration Between Key Actors in the Project and External Actors



The product in the sample project was software based. This may explain the difference between these results and those in Dougherty's study. Software does not have a "physical presence", nor is it "tactile". Nor would the respondents maintain that the product is "neat". It is too big and too complex to be "neat". The project structure diagrams with the highest scores for average scope, comprehensiveness and complexity were developed by managers with responsibility for integration with the environment external to the project and for design process improvement.

Nine of the ten respondents chose teams as the actors in the diagrams. Respondents, however, did not use the same level of abstraction in their representations of shared work objects. In general, the higher the level in the hierarchy of the respondent, the higher the level of shared work object abstraction they use. Senior managers used more objects that were managerial in nature.

There was little evidence of a shared view of internal integration. The diagrams in Figure 1 show that respondents 8 and 9 (managers of chunk teams two and three) modeled fewer interdependencies among the key internal actors than did the other respondents. The internal integration diagrams of respondents 8 and 9 have the lowest connectedness and complexity measures of those shown in Table 1. Respondents 8 and 9 were managers of two of the six chunk teams. They did not have coordination responsibilities for the project as a whole. On the other hand, respondents 2, 3, and 4 had project wide coordination responsibilities and respondent 7 had process improvement responsibilities.

The internal integration diagram of the manager of the architecture team had relatively high scores in the connectedness and complexity measures, however, the scores on these same measures in this individual's external integration diagram were relatively low. This result is consistent with the focus of the architect team's efforts on integrating the work of teams within the project rather than on integrating the project with its environment.

The three diagrams with the highest average scope also have the highest scores for comprehensiveness, connectedness and complexity in the external integration diagrams. They were developed by senior manager two and the manager of product team (both of whom had responsibilities for integrating the project with the external environment) and by the manager of chunk team one (who was responsible for process improvement as well as for the design of a specific component of the system).

The results of the study suggest that the perspectives on project structure held by senior managers and those managers responsible for product integration, process improvement and architecture are central to the attainment of consistency between project structure and project objectives.

Conclusions

Using an object-based approach the views of structure of a large development project held by a sample of project managers were captured and made visible. Although managers' opinions concerning the important uncertainties, critical aspects and objectives of the sample project were similar enough to consider them as part of one 'thought world" (Dougherty 1992), their views of structure were different. The characteristics of their views of structure were also related to their roles and responsibilities in the project.

The results of the study demonstrate how views of organizational structure can be captured and made visible using object-based models of structure. They also show how the characteristics of these views can be measured and potentially used to identify those roles and responsibilities that can contribute the most to the internal and external integration of a large project.

An extensive literature tells managers that, to be effective at product development, they must align project objectives with project structure. Although the research is limited by its exploratory nature and the fact that the sample included only one project, the results suggest avenues for further research on what an alignment between project objectives and structure means and how it might be attained. Two specific research questions suggest themselves. The first is: under what circumstances are efforts to create a shared understanding of project structure from disparate perspectives held by members of the same function just as important as efforts to create shared understandings from disparate perspectives held by members of different functions? The second is: should efforts to create a shared view of development project structure within a function focus on the perspectives held by the senior managers of the function and by those managers responsible for product integration, process improvement and architecture? The perspectives held by managers with other responsibilities, while still important, did not seem as central in the sample project to the attainment of internal and external integration.

A related question is whether or not, in considering the alignment of project objectives and project structure, researchers and managers need to identify whether what must be aligned with project objectives is a single view of project structure or a perspective that shows how possible multiple views of project structure are organized and relate to each other. Can multiple views of project structure be organized in such a way that what is shared by participants is the organization of the multiple views of project structure? The study highlights the need to better understand the dynamics involved in the aggregation of multiple views of project structure that lead to effective development organizations (Langfield-Smith 1992, Laukkanen 1994).

References

Bailetti, A.J., Callahan, J.R. and McCluskey, S., 1998. Coordination at Different Stages of the Product Design Process. R & D Management, 28(4):.

Bailetti, A.J. and Callahan, J.R., 1995a. Managing Consistency between Product Development and Public Standards Evolution. Research Policy, 24(6): 913-931.

Bailetti, A.J. and Callahan, J.R., 1995b. Specifying the Structure which Integrates a Firm's Skills with Market Needs. R & D Management, 25(2): 227-240.

Bailetti, A.J., Callahan, J.R. and DiPietro, P., 1994. A Coordination Structure Approach to the Management of Projects. IEEE Transactions on Engineering Management, 41(4): 394-403.

Bailetti, A.J. and Callahan, J.R., 1993 The Coordination Structure of International Collaborative Technology Arrangements. R&D Management, 23(2): 129-146.

Calori, R., Johnson, G. and Sarnin, P., 1994. CEO's Cognitive Maps and the Scope of the Organization. Strategic Management Journal, 15, 437-457.

Dougherty, D., 1992. Interpretive Barriers to Successful Product Innovation in Large Firms. Organization Science, 3(2): 179-202.

Eden, C., 1992. On the Nature of Cognitive Maps. Journal of Management Studies, 29(3): 261-263.

Fiol, C. M. and Huff, A.S., 1992. Maps for Managers: Where are we? Where do we go from here?. Journal of Management Studies, 29(3): 267-285.

Kilduff, M. and Krackhardt, D., 1994. Bringing the Individual Back In: A structural analysis of the internal market for reputation in organizations. Academy of Management Journal, 37(1): 87-108.

Krackhardt, D., 1990. Assessing the Political Landscape: Structure, cognition, and power in organizations. Administrative Science Quarterly, 35:342-369.

Krackhardt, D. and Hanson, J.R., 1993. Informal Networks: The company behind the chart. Harvard Business Review, July-August: 104-111.

Langfield-Smith, K., 1992. Exploring the Need for a Shared Cognitive Map. Journal of Management Studies, 29(3): 249-368.

Laukkanen, M., 1994. Comparative Cause Mapping of Organizational Cognitions. Organization Science, 5(3): 322-343.

Weick, K. and Bougon, M., 1986. Organizations as Cognitive Maps: Charting ways to success and failure. In: H.P. Sims, Jr., D.A. Gioia and Associates (Eds.) The Thinking Organization: Dynamics of organizational social cognition, Jossey-Bass, San Francisco, CA, 102-133.