IDEA GROUP PUBLISHING
701 E. Chocolate Avenue, Suite 200, Hershey PA 17033-1240, USA
Tel: 717/533-8845; Fax 717/533-8661; URL-http://www.idea-group.com
ITB12791

This paper appears in the book, *Emerging Trends and Challenges in Information Technology Management, Volume 1 and Volume 2* edited by Mehdi Khosrow-Pour © 2006, Idea Group Inc.

Meta-Matrix Modeling for Knowledge Management: An Introduction

Ronald Dattero, Department of Computer Information Systems, Missouri State University, 901 South National Avenue, Springfield, MO 65897, Phone: (417) 836-6357 (office), Fax: (417) 836-6907(fax), RonDattero@MissouriState.edu

Jing 'Jim' Quan, Department of Information and Decision Sciences, Perdue School of Business, Salisbury University, 1101 Camden Avenue, Salisbury, MD 21801, Phone: (410) 543-6514, jxquan@salisbury.edu

ABSTRACT

Knowledge management is a method for simplifying and improving the process of sharing, distributing, creating, and understanding organizational knowledge. The purpose of this paper is to introduce a new approach to model organizational knowledge management problems. Specifically, the modeling approach focuses on the (1) agents, (2) knowledge categories, (3) resources, and (4) processes or tasks. In addition, the relationships within and between the four classes are included in the model. The model is developed using the Meta-Matrix framework. The Meta-Matrix framework is a fairly new mathematical approach to model the various network relations of an organizational system. The Meta-Matrix framework represents the various network relations of an organizational system by integrating multiple and related network matrices into a single interrelated unit. Many other network based approaches focus only on the relations in a single matrix (such as personnel and the relations among them) so the Meta-Matrix framework is substantially more comprehensive.

INTRODUCTION

Many organizations now consider knowledge to be a strategic capital resource that must be properly managed if they are to achieve and sustain competitive advantage (Nunamaker et al. 2002; Argote and Ingram 2000; Brooking 1996; Ives et al. 1997). In fact, some researchers argue that knowledge is the dominant resource of the firm (Spender 1994; Spender 1996; Grant 1996a, Grant 1996b; Davenport and Prusak 1997) and a knowledge-based view of the firm is warranted. The knowledge-based view of the firm "…can yield insights beyond the production-function and resource-based theories of the firm by creating a new view of the firm as a dynamic, evolving, quasi-autonomous system of knowledge production and application" (Spender 1996). "Fundamental to a knowledge-based theory of the firm is the assumption that the critical input in production and primary source of value is knowledge" (Grant 1996b). Effective knowledge sharing (Nevis et al. 1995; Davenport and Prusak 1997; Chow et al. 2000; Lin and Lee 2004) is an important way to leverage core competencies and gain a competitive advantage (Gold et al. 2001).

Knowledge management is a method for simplifying and improving the process of sharing, distributing, creating, and understanding company knowledge (Nonaka and Konno 1998). Knowledge management can be defined as the "…conscious strategy of getting the right knowledge to the right people at the right time and helping people share and put information into action in ways that strive to improve organizational performance" (O'Dell and Grayson 1998).

Alavi and Leidner (2001) describe five perspectives on knowledge. The first perspective is that knowledge exists only in a human mind (Nonaka 1994), which is similar to the concept expressed by Churchman (1972) that "…knowledge resides in the user and not in the collection." The second perspective is that knowledge is an object which can be stored and manipulated (Zack 1999). The third perspective is a minor extension of the second perspective emphasizing how knowledge is organized so that it can be readily accessed and retrieved (McQueen 1998). Since knowledge is widespread and varied (in type) in an organization, knowledge maps can provide a graphical means of visualizing and categorizing the structure of the knowledge stored by the firm (Wexler 2001). The fourth perspective on knowledge is that knowledge is a process related to an application (McDermot 1999; Zack 1999; Bohn 1994) focusing on the more dynamic aspects of knowledge such as sharing, creating, adapting, learning, applying, and communicating (Allee 1997). The fifth perspective is that knowledge has the capability to influence future actions. Learning and experience are combined to interpret information, which is then used to make a decision (Watson 1999).

The purpose of this paper is to illustrate how to model an organization's knowledge taking into account these varied perspectives on knowledge. Specifically, the modeling approach discussed in this paper focuses on the (1) agents, (2) knowledge categories, (3) resources, and (4) processes or tasks. Agents refer to the organization's knowledge workers. From the first perspective on knowledge, it is essential to include agents in the analysis. In addition, from the knowledge-based view of the firm, it is important that the relationship between the agents needs to also be understood (Kogut and Zander 1996; Nahapiet and Ghosal, 1998; Cross and Parker 2004) because these relationships impact the efficiency and effectiveness of the creation and transfer of knowledge. From the second perspective on knowledge, resources represent the knowledge "objects". From the third perspective on knowledge, the relationship or mapping between different knowledge is an important factor to analyze. From the fourth perspective, the important processes need to be considered. The fifth perspective on knowledge as a capability to influence future action provides a strategic rationale for this analysis approach. In addition, this perspective provides a basis for analyzing the relationship within and between the four classes.

To model these relationships, the Meta-Matrix framework will be utilized. The Meta-Matrix framework is a fairly new mathematical approach to model the various network relations of an organizational system (Carley and Reminga 2004). In the Meta-Matrix framework, organizations can be defined by classes of entities (often referred to as nodes) such as personnel, knowledge, resources, tasks, and organizations or groups. Hence, the Meta-Matrix framework seems to be a promising modeling approach to analyze knowledge management issues.

In the next section, an overview of the Meta-Matrix framework will be presented. Then, the Meta-Matrix framework will be used to model a hypothetical software development firm. The paper concludes with some final remarks including an overview of the model measures and a discussion of some of the current limitations.

META-MATRIX FRAMEWORK

The Meta-Matrix framework represents the various network relations of an organizational system by integrating multiple and related network matrices into a single interrelated unit (Carley and Reminga 2004). The Meta-Matrix framework can be viewed as an extension of the PCANS (Krackhardt and Carley 1998) model of organizations. In the PCANS model, the primary components are a collaboration (social) network, a task network, and a knowledge network. Many other network based approaches focus only on the relations in a single matrix (such as personnel and the relations among them which are typically referred to as social network measures) so the PCANS model and the Meta-Matrix framework are substantially more comprehensive.

In the Meta-Matrix framework, organizations can be defined by classes of entities (often referred to as nodes) such as personnel, knowledge, resources, tasks, and organizations or groups. ORA (Carley and Reminga 2004) is a network analysis tool that detects risks or vulnerabilities of an organization's design structure using a limited form of the Meta-Matrix framework that consists of four classes of nodes: [A] personnel (often referred to as agents), [K] knowledge, [R] resources, and [T] tasks. From these four classes of nodes, ten interaction or relation networks can be defined:

1. Communication Network between Agents (and other Agents) [A]
2. Knowledge Network between Agents and Knowledge [AK]
3. Capabilities Network between Agents and Resources [AR]
4. Assignment Network between Agents and Tasks [AT]
5. Information Network between Knowledge (and other Knowledge) [K]
6. Training Network between Knowledge and Resources [KR]
7. Knowledge Requirement Network between Knowledge and Tasks [KT]
8. Resource Substitute Network between Resources (and other Resources) [R]
9. Resource Requirement Network between Resources and Tasks [RT]
10. Precedence Network between Tasks (and other Tasks) [T]

Note that the names of these interaction or relation networks are generic. In some contexts, these names may not be that appropriate.

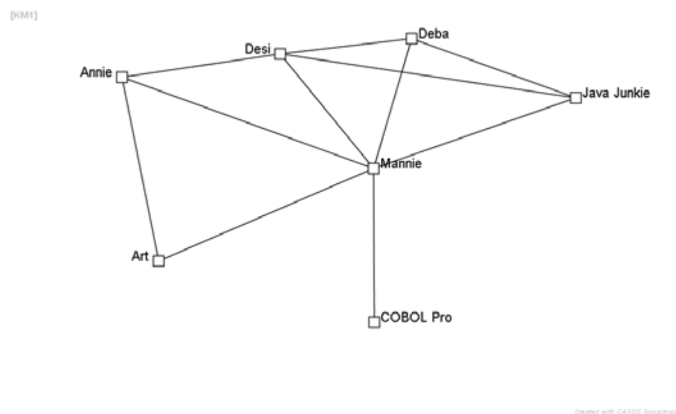
AN EXAMPLE MODEL

In the previous section, the presentation of the Meta-Matrix framework has been rather general and abstract. In this section, the Meta-Matrix framework will be used to model a hypothetical software development firm from a knowledge management perspective. The example has been deliberately simplified so that the explanation is not overly complex. The order of presentation of the model will be as follows. First, the agents and their relationships will be discussed. Second, the tasks and additional relationships will be added to the model. Third, the knowledge categories and additional relationships will be added to the model. Fourth, the resources and additional relationships will be added to the model

First, the agents and the communication network will be described. The agents are: Mannie (the manager), Art (the planner/architect), Annie (the analyst), Desi (the designer), Deba (the DBA), Java Junkie (Java programmer), and COBOL Pro (COBOL programmer). The communication network is depicted in Figure 1. From Figure 1, the following relationships are shown: Mannie communicates with everyone; Art communicates with Annie and Mannie; Annie communicates with Art and Mannie.; Desi communicates with Annie, Deba, Java Junkie, and Mannie; Deba communicates with Desi, Java Junkie, and Mannie; Java Junkie communicates with Desi, Deba, and Mannie; and COBOL Pro communicates with Mannie.

Second, the tasks, precedence network, and assignment network will be described. For this example, only four basic development tasks (from a traditional systems development life cycle perspective) will be included: Planning, Analysis, Design, and Implementation. The precedence network will follow the traditional "waterfall" so Planning leads to Analysis which leads to Design which leads to Implementation. In Figure 2, the assignment network is shown. From Figure 2 the following relationships are shown: Mannie and Art are assigned to Planning; Art and Annie are assigned to Analysis; Deba and Desi are assigned to Design; and Deba , Desi, Java Junkie, and COBOL Pro are assigned to Implementation.

Figure 1. Communication network



Third, the knowledge categories, information network, knowledge requirement network, and knowledge network will be described. For this example, only seven categories of knowledge will be included: Java, COBOL, OOP (Object Oriented Programming), SQL, DB (DataBase), SDLC (System Development Life Cycle), and Project Planning. The information network has only the following five relationships: Java-COBOL, Java-OOP, SQL-DB, DB-SDLC, and SDLC-Project Planning. The knowledge requirement network has only the following 12 relationships: SDLC is related to all four tasks; Project Planning is related to Planning; DB and SQL are related to Design and Implementation; and Java, COBOL, and OOP are related to Implementation. In Figure 3, the knowledge network is shown. From Figure 3 the following relationships are shown: COBOL Pro only knows COBOL; Java Junkie knows Java, OOP, DB, and SQL; Deba knows DB, SQL, and SDLC. Annie and Desi only know SDLC; Art knows SDLC and Project Planning; and Mannie only knows Project Planning.

Fourth, the resources, resource substitute network, capabilities network, resource requirement network, and training network will be described. For this example, there will be two types of resources: tools and

Figure 2. Assignment network

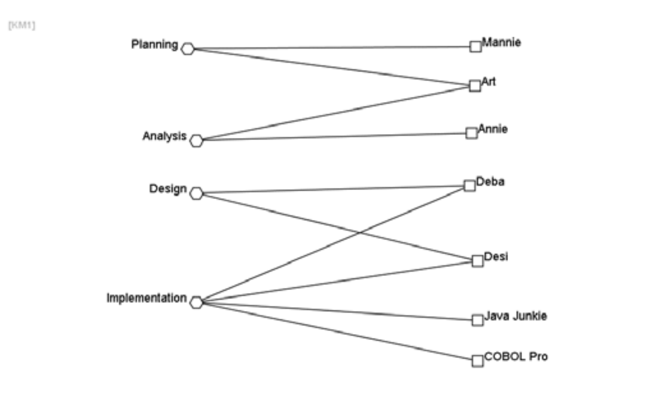


Figure 3. Knowledge network

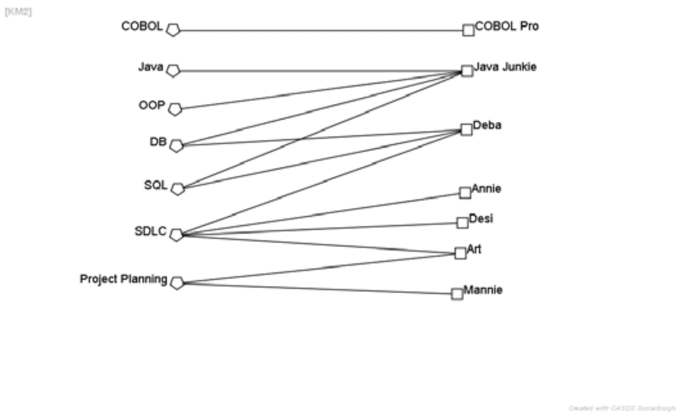
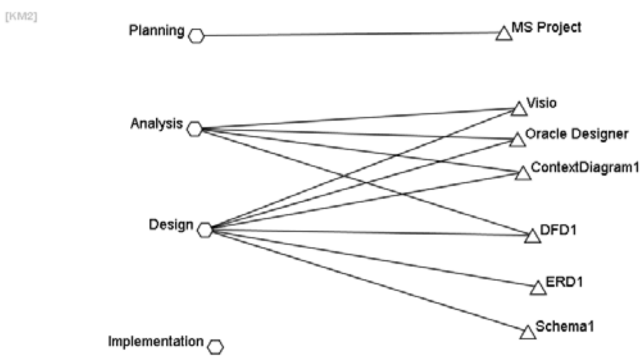


Figure 4. Resource requirement network



completed development diagrams. The three tools are Visio, MS Project, and Oracle Developer. The four completed diagrams are ContextDiagram1, DFD1 (Data Flow Diagram #1), ERD1 (Entity-Relationship Diagram #1), and (database) Schema1. The resource substitution network has only the following six relationships: Visio was used to create ContextDiagram1 and DFD1; Oracle Designer was used to create ERD1 and Schema1; ContextDiagram1 is conceptually related to DFD1; and ERD1 is conceptually related to Schema1. The capabilities network has only the following 11 relationships: Deba developed ERD1 and Schema1 using Oracle Designer; Mannie has expertise in MS Project; Art, Annie, and Desi use Visio; Art and Annie developed ContextDiagram1; and Annie and Desi developed DFD1. The training network has only the following 10 relationships: SDLC is related to Visio, MS Project, Oracle Designer, ContextDiagram1, DFD1, ERD1, and Schema1; SQL and DB are related to Schema1; and Project Planning is related to MS Project. In Figure 4, the resource requirement network is shown. From Figure 4 the following relationships are shown: Planning was done with MS Project; Analysis and Design was done using Visio and Oracle Designer; through Analysis, ContextDiagram1 was developed; through Design, DFD1, ERD1, and Schema1 were developed.

CONCLUDING REMARKS

There are a large number of performance measures associated with a Meta-Matrix model. The measures are rooted in social network analysis (Wasserman and Faust 1994) where the focus is on a single perspective or matrix. These measures have been extended to the multiple perspectives of the Meta-Matrix framework. In addition, new measures have been developed (and are being developed). Discussion of the technical details of these measures is beyond the scope of this introductory paper. Instead a brief overview of the measures will be presented here.

The measures can be divided into seven categories. Critical employee (actor) risk measures are based on an employee having exclusive knowledge, resource, or task assignments. Resource allocation risk measures are based on how the organization's resource allocation affects its ability to complete tasks. Communication risk measures are based on the level of communication and the authority structure of the organization. Redundancy risk measures focus on knowledge, resource, and task redundancies of the actors. Task risk measures are based on task precedence and task assignment. Personnel interaction risk measures are based on the presence or absence of agents communicating. Performance risk measures focus on task completion. (Carley and Reminga 2004)

In using the ORA software tool, there are currently a number of model limitations. Probably, the most severe limitations are: (1) there are only four categories of nodes, (2) the categories are restricted to actors, knowledge categories, resources, and tasks, (3) only one matrix of each network type is permitted, and (4) the model can not very over time so the analysis is static.

Overall, the Meta-Matrix framework seems like a very promising modeling structure to perform knowledge management assessment. The Meta-Matrix framework is a fairly new mathematical approach to model the various network relations of an organizational system. Specifically, the framework focuses on the (1) agents, (2) knowledge categories, (3) resources, (4) processes or tasks, and (5) the relationships within and between the four classes.

REFERENCES

Alavi, M. and Leidner, D. (1999), "Knowledge Management Systems: Issues, Challenges, and Benefits", *MIS Quarterly*, 25(1), pp. 107-136.

Allee, V. (1997), *The Knowledge Evolution: Expanding Organizational Intelligence*, Butterworth-Heinemann, Newton, MA.

Argote, L. and Ingram, P. (2000), "Knowledge Transfer: A Basis for Competitive Advantage in Firms", *Organizational Behavior and Human Decision Processes*, 82(1), pp. 150-169.

Bohn, R. (1994), "Measuring and Managing Technological Knowledge", *SloanManagement Review*, Vol 36 No 1, pp.61-74.

Brooking, A. (1996), *Introduction to Intellectual Capital*, The Knowledge Broker Ltd., Cambridge, England.

Carley, K. M..and Reminga, J. (2004), "ORA: Organization Risk Analyzer", *Carnegie Mellon University Technical Report*, CMU-ISRI-04-106

Chow, C., Deng, F., and Ho, J. (2000), "*The openness of knowledge sharing within organizations: a comparative study of the United States and the People's Republic of China*", *Journal of Management Accounting Research*, 12(1), pp. 65-95.

Churchman, C. W. (1972), *The Design of Inquiring Systems: Basic Concepts of Systems and Organizations*, Bencis Books, New York.

Cross, R. and Parker, A. (2004), *The Hidden Power of Social Networks*, Harvard Business School Press, Boston.

Davenport, T. & Prussak, L. (1998). *Working Knowledge*, Harvard Business School Press.

Gold, A., Malhotra, A., and Segars, A. (2001), "Knowledge Management: An Organizational Capabilities Perspective", *Journal of Management Information Systems*. 18, pp. 185-214.

Grant, R.M. (1996a), "Prospering in dynamically-competitive environments: Organizational capability as knowledge integration", *Organization Science*, 7, 4.

Grant, R.M. (1996b). "Toward a knowledge-based theory of the firm", Strategic Management Journal, 17 (Winter Special Issue), pp. 109-122.

Ives, W., Torrey, B., and Gordon, C. (1997), "Knowledge Management: An Emerging Discipline with A Long History", *Journal of Knowledge Management*, 1(4), pp. 269-274.

Kogut, B. and Zander, U. (1996), "What do firms do? Coordination, identity, and learning", *Organization Science*, 7, pp. 502-518.

Krackhardt, D. and Carley, K. M. (1998), "A PCANS Model of Structure in Organizations", *Proceedings of the 1998 International Symposium on Command and Control Research and Technology*, pp. 113-119.

Lin, H and Lee, G. (2004), "Perceptions of senior managers towards knowledge-sharing behavior", *Management Decisions*, 42(1), pp. 108- 125.

Markus, M.L. (2001), "Toward a Theory of Knowledge Reuse: Types of Knowledge Reuse Situations and Factors in Reuse Success", *Journal of Management Information Systems*, 18(1), pp.57-93.

McDermot, R. (1999), "Why information technology inspired but cannot deliver knowledge management", *California Management Review*, 41(4), pp. 103-117.

McQueen, R. (1998), "Four Views of Knowledge and Knowledge Management," in *Proceedings of the Fourth Americas Conference on Information Systems*, E. Hoadley and I. Benbasat (eds.), pp. 609-611.

Nahapiet, J. and Ghosal, S. (1998), "Social Capital, Intellectual Capital, and the Organizational Advantage", *Academy of Management Review*, 23(2), pp. 242-266.

Nevis, E., DiBella, A., and Gould, J. (1995), "*Understanding organizations as learning systems*", *Sloan Management Review*, 36(2), pp. 73-85.

Nonaka, I. (1994), "A Dynamic Theory of Organizational Knowledge Creation", *Organization Science*, 5(1), pp. 14-17.

Nonaka, I., and Konno, N. (1998), "*The concept of `Ba': building a foundation for knowledge creation*", *California Management Review*, 40(3), pp. 40-54.

Nunamaker, J.F. Jr., Romano, N.C. Jr., and Briggs, R.O. (2002), "Increasing Intellectual Bandwidth: Generating Value from Intellectual Capital with Information Technology", *Group Decision and Negotiation*, 11(2), pp. 69-86.

O'Dell, C. and Grayson, C.J. Jr. (1998), *If Only We Knew What We Know*, The Free Press, New York.

Spender, J.-C. (1994), "Organizational knowledge, collective practice and Penrose rents", *International Business Review*, 3, 4.

Spender, J.-C. (1996), "Making knowledge the basis of a dynamic theory of the firm", *Strategic Management Journal*, 17 (Winter Special Issue).

Wasserman, S. and Faust, K. (1994), *Social Network Analysis: Methods and Applications*, Cambridge University Press, Cambridge, England.

Watson, R. (1999), *Data Management: Databases and Organizations*, John Wiley Publishing, New York.

Wexler, M. (2001), "The who, what and why of knowledge mapping", *Journal of Knowledge Management*, 5, pp. 249-263.

Zack, M. (1999), "Developing a Knowledge Strategy", *California Management Review*, 41(3), pp. 125-134.