COORDINATION AT DIFFERENT STAGES OF THE PRODUCT DESIGN PROCESS

Antonio J. Bailetti*, John R. Callahan* and Sean McCluskey**

*** School of Business and**

Department of Systems and Computer Engineering

Carleton University

**** Andersen Consulting**

***R&D Management*, 28(4), October 1998**

ABSTRACT

This paper addresses the following question: how does the coordination challenge faced by managers change over the life of time bound projects such as product design. We use coordination structure, an approach to modeling organizational situations that highlights concurrent responsibility interdependencies rather than the more traditional task interdependencies. We explain coordination structure and use it to capture the responsibility interdependencies in a sample of complex system design projects drawn from two different organizations. We use this data: to illustrate the differences possible in the responsibility interdependencies that can exist within design projects from different organizations and at different project key points; to identify a set of four basic modules, or groupings, of responsibility interdependencies useful for modeling design organizations; and to generate a set of testable hypotheses on how the coordination challenge faced by project managers can vary between organizations and over project key points.

LIST OF TABLES

LIST OF FIGURES

INDEX TERMS

design and development

system products

coordination

interdependencies

stages

COORDINATION AT DIFFERENT STAGES OF THE PRODUCT DESIGN PROCESS

I. INTRODUCTION

New product development is increasingly the key to competitive advantage in a wide variety of industries. Coordination underlies many of the management problems in designing products rapidly and effectively. During a design project, what must be coordinated changes. For the most part the approaches suggested in the research literature on coordination do not explicitly incorporate changes over time. In contrast, the focus of this paper is on the time varying interdependencies typical in product design organizations.

We use coordination structure, an approach to modeling organizational situations that highlights concurrent responsibility interdependencies rather than the more traditional task interdependencies. We explain coordination structure and use it to capture the responsibility interdependencies in a sample of complex system design projects drawn from two different organizations. Using coordination structure provides a number of distinct advantages: it captures a system level view of the interdependencies in an organization; it is built on responsibility interdependence which is a more useful perspective than task interdependence in high uncertainty situations like product design; it can be used to provide diagrams useful to managers attempting to achieve a shared view among project stakeholders; and it can incorporate standard social network research analysis methods.

We use the coordination structure data: to illustrate the differences possible in the responsibility interdependencies that can exist within design projects from different organizations and at different project key points; to identify a set of four basic modules, or groupings, of responsibility interdependencies useful for modeling design organizations; and to generate a set of testable hypotheses on how the coordination challenge faced by project managers can vary between organizations and over project key points.

In the next section, we place the paper in the context of the literature on interdependence and coordination. In section III, we define coordination structure. We describe the sample and data collection in section IV. In section V we outline the steps taken to analyze the data. In section VI we present the results of this analysis. In section VII we develop some generalizations about coordination at various stages of product design and present some testable hypotheses. Finally, section VIII summarizes the paper.

II. THE LITERATURE ON INTERDEPENDENCE AND COORDINATION

Time bound projects such as product design and development change as they move through different stages. What must be coordinated will also change -- this is the focus of this paper. Coordination is an important factor for new product success (Clark and Fujimoto 1991, Cooper 1979, Cooper and Kleinschmidt 1987, Rothwell et al 1974, Wheelwright and Clark 1992, Zirger and Maidique 1990). However, as pointed out by Adler (1995), the product development literature does not explicitly deal with how coordination changes over time.

Underpinning the literature on coordination is research on the forms interdependence can take. A fundamental reference is Thompson (1967). He suggested three types of interdependence: pooled, sequential and reciprocal. In pooled interdependence, interdependent units in an organization contribute to the organization and are in turn supported by it while having no direct work interactions. Sequential interdependence is asymmetric. The work outputs of one unit are the inputs for the other. Reciprocal interdependence exists when an output from each unit becomes and input for the other. Van de Ven et al (1976) added a fourth, team interdependence, to describe the situation when several units are reciprocally interdependent. Other conceptual frameworks for interdependence have been developed (Crowston 1997, Kiggundu 1981, McCann and Ferry 1975, Victor and Blackburn 1987). For example, Victor and Blackburn developed a framework that allows an empirical assessment of differing amounts of interdependence.

Crowston (1997) suggests modeling interdependence in terms of tasks and resources. As outlined below, we use responsibility interdependence rather than task interdependence. The resources that Crowston uses are specific examples of the work objects that we use as the basis for interdependence.

Adler (1995) studied coordination across the design/manufacturing interface in product development projects. He developed a taxonomy of types of design/manufacturing coordination mechanisms and a way of conceptually ordering them for such time bound projects. This paper complements Adler's research by focusing on the changing nature of concurrent responsibility interdependencies that require coordination, and by providing a more detailed analysis of coordinated interfaces within the design function.

Brown and Eisenhardt (1995) review the literature on product development as a whole and organize it into three streams: rational plan, communication web, and disciplined problem solving. The research approach presented here falls within the communication web stream. Although coordination structure is not a communication network, coordination structure captures the linkages in a product development organization that underlay the communications required for rapid and effective product development.

III. COORDINATION STRUCTURE

Product development commonly involves numerous interdependencies among individuals and groups in an environment of high task uncertainty. It is useful to think of such interdependencies as existing at two levels: task interdependence and responsibility interdependence. When an organization carries out work for which the necessary tasks are well understood and stable, task is a useful perspective. This would be the case in most building construction, for example, where the characteristics of the tasks necessary for construction are well understood. This is not the case in many situations relevant to R&D management in which individuals and/or groups carry out interdependent responsibilities for which the required tasks are not well understood. We argue that a system level view of responsibility interdependencies facilitates understanding of the coordination issues involved in situations of high task uncertainty (Bailetti and Callahan 1993, Bailetti, Callahan and DiPietro 1994). Coordination structure provides such a view.

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). The present paper takes a next step. It uses coordination structure as a basis for the gathering and analysis of data. The data analysis leads in turn to the development of testable hypotheses on how the coordination challenge faced by project managers can vary between organizations and over project key points

IV. DATA COLLECTION

Data were collected from eight system development projects from two companies. Company A, an integrated telecommunications equipment manufacturer, produces standard designs to be manufactured and sold to a variety of customers. Company B, a weapons systems R&D organization, produces custom designs for individual customers. We chose the companies because the system development projects that they undertake are of sufficient size, complexity and uncertainty that coordination would be a significant management challenge in each project. The two companies have very different organizational structures: the telecommunications equipment manufacturer is organized around projects, the weapons systems R&D organization around functions.

We selected four projects from each company. Projects were selected so that each would be at a different keypoint in their development. We defined four project keypoints. The first marked the allocation of resources by a manager to help define a new product concept. The second marked the allocation of development funding. The third was the midpoint of development. The fourth was the midpoint of field testing. Using keypoints rather than project phases eliminated the problem of overlapping phases common in product development projects.

Table 1 describes the eight projects in the sample.

Table 1

Sample Projects

	Keypoint 1: manager allocates resources to help define a new product concept	Keypoint 2: case for development funding is made	Keypoint 3: midpoint in development	Keypoint 4: midpoint in field testing
Company A: Telecommu-nications equipment manufacturer	Project A1: Product platform	Project A2: Intelligent network services	Project A3: Advanced intelligent network	Project A4: Data switch
Company B: Weapons system R&D organization	Project B1: Composite manufacturing equipment	Project B2: Energy storage wheel	Project B3: Micro-mechanical inertial measurement system	Project B4: Interferometric fiber optic gyro

For each project, we interviewed the design manager of the project and two other individuals selected by the design manager who were directly involved in the project -- a total of 24 initial interviews. The design manager was the manager responsible for the creation, development and delivery of an acceptable design. That is, the design manager was the person charged with allocating responsibilities among the individuals and groups involved in a project and coordinating these interdependent responsibilities effectively.

Each interview followed the same protocol and identified the relevant actors, shared work objects and associations between actors and shared work objects *active in the project at the time*. The appropriateness of the expected keypoint for each of the eight projects was also verified. In a second interview, design managers reviewed and synthesized the data provided by themselves and the individuals that they had selected to produce a single coordination structure for each project. These coordination structures provide a system level view of the concurrent responsibility interdependencies that the design managers had to ensure be coordinated.

Terminology that differed by respondent was standardized using the actor and shared work object definitions given in Table 2.

Figure 1 shows a diagram of the coordination structure for project A1.

Table 2

Actors and Shared Work Objects

Actors

ARCHITECT - creates and manages system development

BUSINESS CHAMPION - runs the business for which the product is being developed, and controls the financial resources required for development

CUSTOMER - defines customer value and purchases products

DESIGN TEAM - creates and manages component subsystem development

MANUFACTURING - accepts the system development for manufacturing

PRODUCT CHAMPION - links the development project with customers and resource sources

SPECIFICATION - uses customer requirements to create product specifications and to aid in the creation of system development

SYSTEM INTEGRATION - integrates the component designs into an integrated system

SYSTEM TEST - creates the test plan and manages system tests

Share Work Objects

component design - design of a component subsystem

customer requirements - characteristics required of the product in terms that customers value such as functionality, price, quality, etc.

integration & test plan - strategy and plan based on this strategy to integrate and test the system development

integrated system - system capable of satisfying customer requirements

interface specifications - specification of the interface between component subsystems

product concept - description of product functionality, target market and customer benefits

product specification - specification of the characteristics that the product will be designed to have

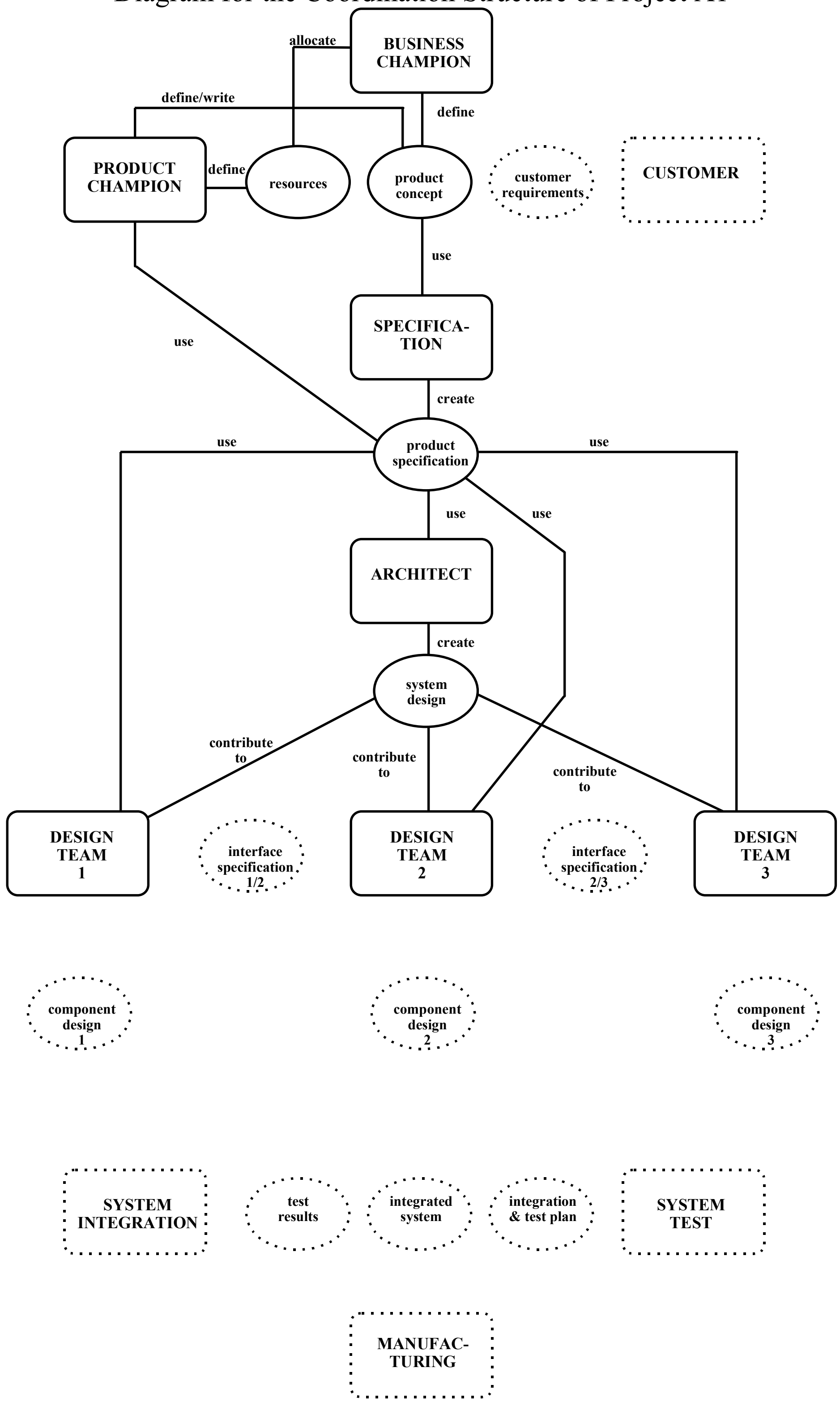
resources - financial resources required for development

system design- overall design of the system to deliver on product requirements

test results - results of system tests

Figure 1

Diagram for the Coordination Structure of Project A1



At keypoint 1 in project A1, there were seven actors with interdependent responsibilities for the evolution of four shared work objects. The *BUSINESS CHAMPION* and *PRODUCT CHAMPION* had interdependent responsibilities around the definition and allocation of *resources* for the project, and the definition of the *product concept*. A *SPECIFICATION* group was using the *product concept* to create a *product specification*. The *ARCHITECT* and three *DESIGN TEAM*s were using the *product specification* to develop a *system design*. The *PRODUCT CHAMPION* was also using the *product specification*.

Note that all of the actor to shared work object responsibility associations in the figure were active concurrently. They were not sequential responsibility "hand-offs" from one actor to another. Note also that a number of actors and shared work objects found in other projects were not present.

V. DATA ANALYSIS

Table 3 provides summary statistics for all eight of the coordination structures. We included comprehensiveness (total number of actor and work object elements), connectedness (number of associations per element) and complexity (total number of associations), measures that Calori, Johnson and Sarnin (1994) had applied to social networks. We recognized that there are other measures that we could have used. We felt, however, that the measures that Calori et al had applied were intuitive and simple, and captured important properties of the sample coordination structures. Comprehensiveness and complexity capture the overall size of the challenge faced by the project manager. Connectedness captures how tightly interrelated are the project elements that must be coordinated.

Table 3

Summary Statistics for the Sample Project Coordination Structures

Project	**Comprehensiveness** (actors/objects/total)	**Connectedness** (associations per element)	**Complexity** (total no. of associations)
A1	(7, 4, 11)	1.36	15
B1	(6, 8, 14)	1.71	24
A2	(9, 8, 17)	1.47	25
B2	(5, 6, 11)	1.73	19
A3	(7, 9, 16)	2.38	38
B3	(8, 8, 16)	1.75	28
A4	(7, 8, 15)	1.67	25
B4	(6, 7, 13)	2.00	26

We were also interested in how similar or consistent two coordination structures are. Baker and Hubert (1981) provide a very intuitive and simple approach for measuring the consistency of two social networks. They counted the total number of common actor to actor associations. We adapted their measure by counting the number of common actor to work object associations. Table 4 presents the consistency between project coordination structures measured in this way. The figures on the diagonal in Table 4 measure a project's consistency with itself and so are the complexity measures from Table 3.

Table 4

Pairwise Consistency between the Sample Project Coordination Structures

Project	**A1**	**B1**	**A2**	**B2**	**A3**	**B3**	**A4**	**B4**
A1	15	4	4	3	5	4	4	3
B1		24	7	1	7	7	5	3
A2			25	2	12	6	11	3
B2				19	9	8	5	8
A3					38	18	13	14
B3						28	11	17
A4							25	8
B4								26

VI. RESULTS

In this section, we present the results of the analysis from the three types of data: the coordination structures themselves; the summary statistics for the coordination structures; and the pairwise consistency data.

Coordination structures

A striking similarity in the coordination structures for both companies was that *system design* was not used as a shared work object for projects advanced in the development cycle. *System design* was not being used as a shared work object in projects A3, B3, A4 and B4. For all four projects at keypoints 3 and 4, *DESIGN TEAMS* were using *product specification* to guide the design process rather than *system design*. The *ARCHITECT* actor dropped out even earlier than the *system design* shared work object. There was no *ARCHITECT* actor in projects B2, A3, B3, A4 and B4.

Similarly, *MANUFACTURING* played a minor role in the data for both companies. *MANUFACTURING* was perceived as a relevant actor only by the design manager of project A4.

A striking difference between the projects for the two companies centered on the place of *resources* as a shared work object. *Resources* was not a shared work object for the keypoint 3 project from company A, the telecommunications equipment manufacturer, but was for the keypoint 1, 2 and 4 projects. On the other hand, there were no interdependencies centred on *resources* for the projects from company B, the weapons system R&D organization, beyond keypoint 1.

At keypoint 1, interdependencies between actors in the projects from both companies centered on the shared work objects *resources*, *product concept*, *customer requirements*, *product specification* and *system design*. Over successive keypoints, interdependencies centred more on the shared work objects *component designs*, *interface specifications*, *integration & test plan*, *test results* and *integrated system* for both companies. Late in the design cycle, interdependencies centered on *customer requirements* for company A projects. This was not the case for company B projects.

The roles played by actors and shared work objects also varied by keypoint. Consider two specific examples from the company A projects:

i) The *DESIGN TEAM*s had different responsibilities at each keypoint. In project A1, they were contributing to *system design.* In project A2, they were using *customer requirements* and *system design* to create and use *interface specifications* and to create *component design*s. They were also contributing to the development of *integration &*

test plan. In project A3, they had the same responsibilities as at keypoint 2 but were also influencing the evolution of the *integrated system* and using *test results*. In project A4, their responsibilities were to use the *integrated system* and coordinate with *MANUFACTURING* around *component design*s.

ii) In project A1, *integration & test plan* was not part of the coordination structure. In projects A2 and A3, *SYSTEM TEST* was evolving *integration & test plan* with contributions from the *DESIGN TEAM*s. In project A4, these actors were using *integration & test plan* to verify *component design*s.

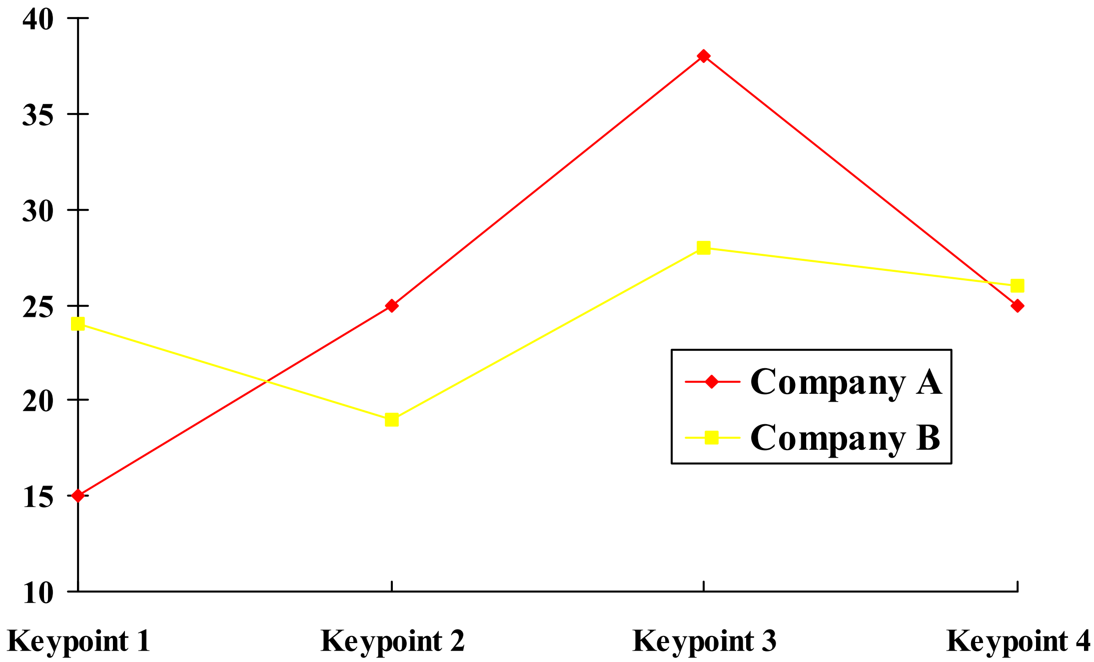
Summary statistics

Systematic differences in the coordination structures of the sample projects were also evident in the summary statistics in Table 3. The complexity of the coordination structure diagrams for the company A projects (as measured by the number of actor to shared object associations) started at 15 for keypoint 1, increased to 25 at keypoint 2 and to 38 at keypoint 3, and then decreased to 25 at keypoint 4. The corresponding complexity for company B projects were 24, 19, 28 and 26. Figure 2 shows the complexity of the coordination structure diagrams for the eight projects.

Figure 2

Complexity of Coordination Structure Diagrams

of the Eight Sample Projects at Different Keypoints



Pairwise consistency

The pairwise consistency data provides a quantitative measure of the similarity of the coordination structure diagrams for pairs of projects. Consider two specific examples. Projects A2 and A3, the two projects from company A at keypoints 2 and 3, were quite similar. Twelve of the 25 associations linking actors to shared objects in the coordination structure of A1 are also found in that of project A2. On the other hand, project A2 was not consistent with project B2 at the same keypoint. Only six of the 25 associations in A2 were also found in B2.

From Table 4 we calculate that the average pairwise consistency between the four projects at keypoints 1 and 2 was 3.50. The corresponding average pairwise consistency for the four projects at keypoints 3 and 4 was 13.5. Average pairwise consistency is higher for sample projects late in the development cycle than for projects early in the cycle.

The average pairwise consistency between company A projects was 8.17. The corresponding figure for company B projects was 7.33. In other words, the coordination structures of the company A projects were more similar to each other than were the company B projects.

The average pairwise consistency between projects at the same keypoint was 8.00, less than that between company A projects at different keypoints and more than that for company B projects at different keypoints. Thus, the company A projects were more similar to each other on average than were the pairs of company A and company B projects at the four keypoints. This was not true for company B projects.

VII. COORDINATION DURING PRODUCT DESIGN

The use of coordination structure provided system level representations of the responsibility interdependencies between individuals and groups in a sample of eight system development projects, at four different keypoints. These representations are based on actor associations with shared work objects. Although the sample is a small one, we make the following observations:

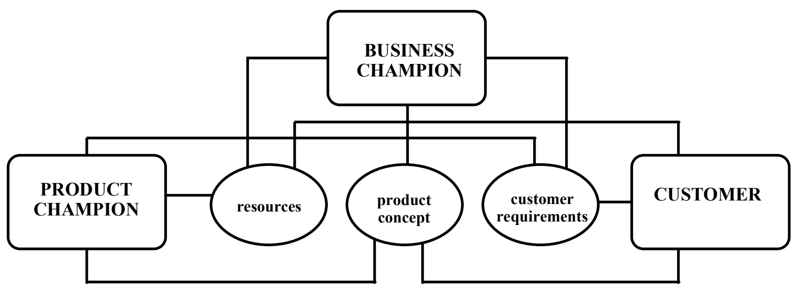
1. The evolution of coordination structure from one point in time to another can be modeled as the linked evolution of four basic modules, or groupings, of commonly associated actors and shared work objects. The four (Opportunity Specification, System Development, Detailed Design, and System Integration) are diagrammed in Figure 3.

Figure 3

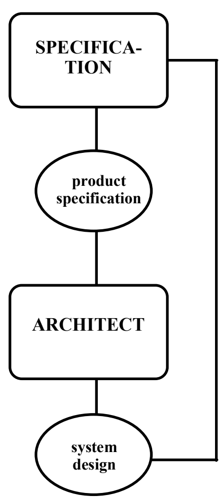
Four Basic Modules Identified in the Coordination Structures

of the Eight Sample Projects

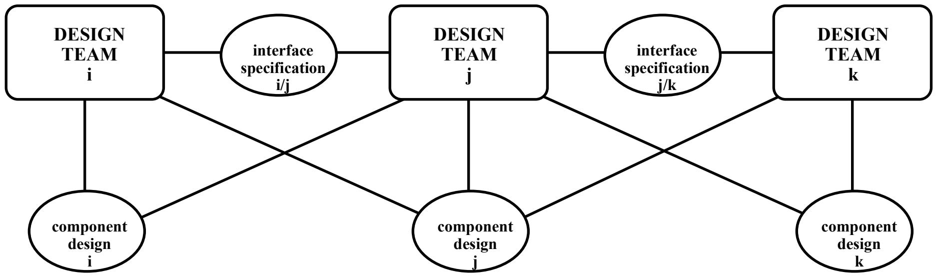
Module 1: Opportunity Specification



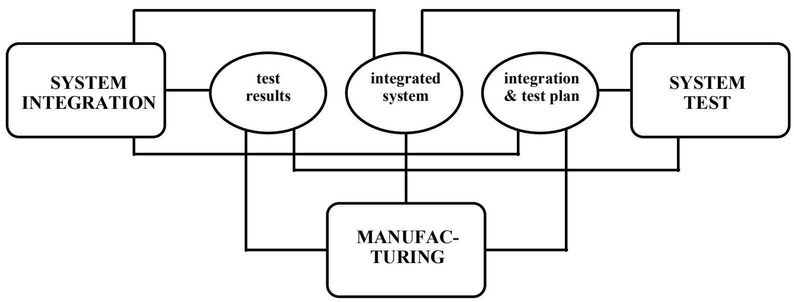
Module 2: System Development



Module 3: Detailed Design



Module 4: System Integration



In module 1, Opportunity Specification, three actors (*BUSINESS CHAMPION*, *PRODUCT CHAMPION*, and *CUSTOMER*) have interdependent responsibilities centred on three shared work objects (*resources*, *product concept*, and *customer requirements*). In module 2, System Development, two actors (*SPECIFICATION* and *ARCHITECT*) have interdependent responsibilities centred on two shared work objects (*product specification* and *system design*). In module 3, Detailed Design, *DESIGN TEAM*s are responsible for using *interface specifications* to create and modify *component designs*. In module 4, System Integration, the actors *SYSTEM INTEGRATION*, *SYSTEM TEST* and *MANUFACTURING* have interdependent responsibilities centred on three shared work objects: *integration & test plan*, *test results,* and *integrated system*.

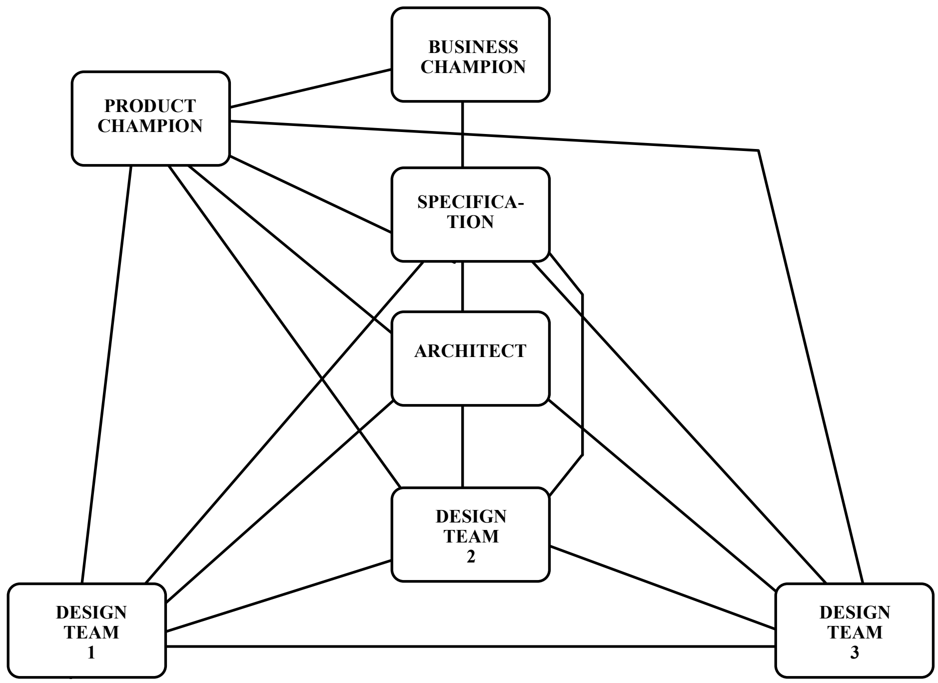
Components of all four modules can be present in a coordination structure that supports product design (see, for example, Figure 1). Any one of the modules may be more or less critical at a given point. The early stages of the design cycle centre more on the configuration of actors and shared objects in the Opportunity Specification module than those in the other modules. The configuration of actors and shared work objects in the System Integration module characterize the end stage of the design cycle.

2. Implicit in any coordination structure are two networks: a social network of actors and a network of shared objects. Figure 4 shows the social network of actors and the shared object network implicit in the coordination structure of Project A1 diagrammed in Figure 1.

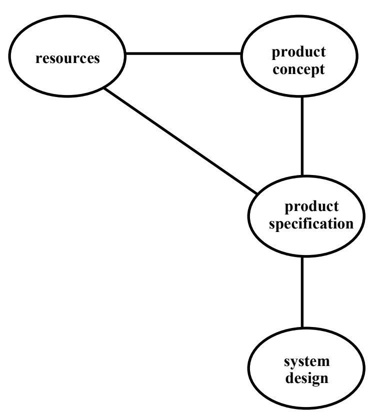
Figure 4

The Social Network of Actors and the Shared Object Network Implicit in the Coordination Structure of Project A1

Social Network of Actors



Shared Object Network



In general, the links between actors in a social network take the form of communications channels (Allen 1977) and other forms of social interaction such as advice and trust (Kilduff and Krackhardt 1994). Social networks have been well studied. Networks of work objects have not, although they provide an interesting way of viewing design both as a product and a process. The design of a product can be viewed as a network of work objects that pertain to the product design, design process and project management. Objects such as *customer requirements*, *product specification*, *system design*, *component design*, and *integration & test plan* collectively represent "the design" of a product being developed. The evolution of this network must be managed in order to respect not just the logic determining the evolution of individual objects but also that which links them together.

3. At a given keypoint in the design process, the differences between the coordination structures of the two companies can be thought of as variations from the four basic modules outlined above. This suggests that the nature of the responsibility interdependencies present and the managerial coordination problems that flow from them may vary systematically for projects from different companies. For example, the coordination structures of standard and custom product design projects may deviate from the four basic modules in ways that are predictable and different.

Of course, there are other factors at work. For example, custom design organizations may adopt modular product technology and product platform concepts that allow them to reuse product design modules for multiple custom design projects. Design projects in such organizations may have coordination structures that more closely resemble those of standard product firms than do more traditional custom design firms.

4. The consistency of coordination structure among a company's projects can also vary by company. In the sample, the coordination structures of the projects from company A, the telecommunications equipment manufacturer, were more consistent than were the corresponding coordination structures from company B, the weapons system R&D organization. This difference again may reflect the fact that company A designs standard products whereas company B produces custom designs.

5. As illustrated by example in section VI, the roles played by individuals and groups can vary over the life of a project. The associations between these individuals and groups and the work objects that they share with others specify the changing nature of these roles.

6. The nature of work objects also changes over the life of a project. For example, the actual specification of a work object such as *integration & test plan* becomes more specific and of higher quality during a project. Less obvious, but evident from the sample data, is the fact that the role played by work objects and their associations with the individuals and groups participating in a project may also vary.

7. The presence of *resources* as a shared work object for company A projects late in the development cycle as opposed to its absence from projects B2, B3 and B4 may reflect the general importance of resources as a continuing design manager concern in standard product companies. In standard product companies, resources are generated and allocated continuously by internal actors whereas, in a custom design organization, resources are part of a defined contract with a specific customer.

From the results of the data analysis, we make the following testable hypotheses which can be used as the basis for further research in this area:

H1: The complexity of design projects reaches a maximum during the mid-point of development.

H2: The inter-project consistency among design projects at the late stage of development is higher than that of projects at the early stages of development.

H3: Inter-project consistency is higher in companies which design standard products than it is in companies that develop custom product designs.

H4: System design stops being used actively in design projects once detailed design of component subsystems begins.

H5: The role of system architect is not filled in design projects once detailed component subsystem design begins.

H6: Project resources are a more significant ongoing concern for design managers in standard product companies than for design managers of companies that develop custom designs.

VIII. SUMMARY

We have used coordination structure to analyze the interdependencies between individuals and groups that occurred in a sample of eight design projects drawn from two different companies. The results of this analysis support the notion that coordination challenge facing the design manager changes over the life of a project, reaching a maximum for the design manager at the midpoint of development.

We have identified four modules: Opportunity Specification, System development, Detailed Design, and System Integration, that may form the basis of reusable structures for use in designing other design project organizations. This form of reuse is being actively pursued in software engineering (Wartik and Prieto-Diaz 1992). Building a library of such reusable organizational structures holds the promise of facilitating better and faster specification of the requirements of product development organizations; faster and more effective design of product development organizations; and increased reuse of effective product development organization designs (Alexander 1977, Coplien 1995).

The approach used in the paper complements other more traditional forms of analysis such as information processing (Allen 1977, Allen and Hauptman 1987, Clark and Fujimoto 1991). Coordination structure provides the foundation upon which information is communicated and processed. As a result, coordination structure lends itself well to the modeling of concurrent processes. The approach also enables meaningful comparison of product development organizations from different firms at different times. For example, we can now examine the different configurations of architect, system integrator and customer and the work objects they share across different firms, and how the roles that they fulfill change over time.

During data collection, coordination structure data were gathered from three individuals for each project. There were obvious and significant differences between the diagrams derived from these data that seemed to relate to the roles of these respondents in the projects. Coordination structure diagrams can be used as a form of cognitive map (Fiol and Huff 1993). This opens the prospect of using such diagrams as a visual way of establishing a shared view among the stakeholder actors in a project in order to increase product development efficiency and effectiveness (Dougherty 1992).

Using coordination structure also holds promise as a tool to allow managers to go from organizational design principles to design rules. The existing literature has identified various design principles, but the implementation of design rules derived from these principles is just beginning (Baligh, Burton and Obel 1996). Coordination structure provides a detailed way to apply these principles in specific design projects.

The small and non-random nature of the sample used is an obvious limitation of the research presented in the paper. It remains for further research to test the robustness of the observations made on a larger sample of product development projects. The main contribution of this paper, however, is that it provides a way to examine how the coordination challenge facing managers changes during the life of time bound projects such as product design.

REFERENCES

Adler, P.S. (1995) “Interdepartmental Interdependence and Coordination: The case of the design/manufacturing interface”, Organization Science, vol.6, no. 2, pp. 147-167, March-April.

Alexander, Christopher, et al. A Pattern Language. New York: Oxford University Press, 1977.

Allen,T.J. (1977) Managing the Flow of Technology. Cambridge, MA: The MIT Press.

Allen,T.J. and O. Hauptman (1987) "The Influence of Communication Technologies on Organizational Structure: A conceptual model for future research", Communication Research, vol. 11, no. 5, pp. 575-587, October.

Bailetti, A.J. and J.R. Callahan (1995a) "Managing Consistency between Product Development and Public Standards Evolution", Research Policy, vol. 24, no. 6, December.

Bailetti, A.J. and J.R. Callahan (1995b) "Specifying the Structure which Integrates a Firm’s Skills with Market Needs", R&D Management, vol. 25, no. 2, pp. 227-240, April.

Bailetti, A.J. and J.R. Callahan (1993) "The Coordination Structure of International Collaborative Technology Arrangements", R&D Management, vol. 23, no. 2, pp. 129-146, April.

Bailetti, A.J., J.R. Callahan and P. DiPietro (1994) "A Coordination Structure Approach to the Management of Projects", IEEE Transactions on Engineering Management, vol. 41, no. 4, pp. 394-403, November.

Baker, F.B. and L.J. Hubert (1981) "The Analysis of Social Interaction Data: A nonparametric technique", Sociological Methods and Research, 9, pp. 339-361.

Baligh, H.H., R.M. Burton and B. Obel (1996) "Organizational Consultant: Creating a useable theory for organizational design", Management Science, vol.42, no. 12, December, pp. 1648-1662.

Brown, S.L. and K.M. Eisenhardt (1995) "Product Development: Past research, present findings, and future directions", The Academy of Management Review, vol. 20, no. 2, pp. 343-378.

Calori, R., G. Johnson and P. Sarnin (1994) "CEO's Cognitive Maps and the Scope of the Organization", Strategic Management Journal, vol. 15, no. 6, pp. 437-457, July.

Clark, K.B. and T. Fujimoto (1991) Product Development Performance: Strategy, Organization and Management in the World Auto Industry. Boston, MA: Harvard Business School Press, 1991.

Cooper, R.G. (1979) "The Dimensions of Industrial New Product Success and Failure", Journal of Marketing, vol. 43, pp. 93-103.

Cooper, R.G. and E.J. Kleinschmidt (1987) "New Products: What separates winners from losers?", Journal of Product Innovation Management, vol. 4, pp. 169-184.

Coplien, J.O. (1995) "A Development Process Generative Pattern Language", AT&T Bell Laboratories, http://www.bell-labs.com/user/cope/Patterns/Process/index.html.

Crowston, K. (1997) "A Coordination Theory Approach to Organizational Process Design", Organization Science, vol. 8, no. 2, pp. 157-175, March-April.

Dougherty, D. (1992) "Interpretive Barriers to Successful Product Innovation in Large Firms", Organization Science , vol. 3, no. 2, pp. 179-202.

Fiol, C.M. and A. S. Huff (1993) "Maps for Managers: Where are we? Where do we go from here?", Journal of Management Studies, vol. 29, no. 3, pp. 267-285.

Kiggundu, M.N. (1981) "Task Interdependence and the Theory of Job Design", Academy of Management Review, vol. 6, no. 3, pp. 499-508.

Kilduff, M. and D. Krackhardt (1994) "Bringing the Individual Back In: A structural analysis of the internal market for reputation in organizations", Academy of Management Journal, vol. 37, no. 1, pp. 87-108.

McCann, J.E. and D.E. Ferry (1975) “An Approach for Assessing and Managing Inter-unit Interdependence”, Academy of Management Review, vol. 4, no. 1, pp. 113-119.

Rothwell, R., C. Freeman, A. Horsely, V.T.P. Jervis, A.B. Robertson and J. Townsend (1974) "SAPHHO updated - Project SAPHHO Phase II", Research Policy, vol. 3, pp. 258-291.

Thompson, J.D. (1967) Organizations in Action: Social Science Bases of Administrative Theory. New York, NY: McGraw-Hill.

Van de Ven, A.H., A.L. Delbecq and R. Koenig, Jr. (1976) “Determinants of Coordination Modes within Organizations”, American Sociological Review, vol. 41, pp. 322-338.

Victor, B. and R.S. Blackburn (1987) “Interdependence: An Alternative Conceptualization”, Academy of Management Review, vol. 12, no. 3, pp. 486-498.

Wartik, S. and R. Prieto-Diaz (1992) "Criteria for Comparing Reuse-Oriented Domain Analysis Approaches", International Journal of Software Engineering and Knowledge Engineering, vol. 2, no. 3, pp. 403-431.

Wheelwright, S.C. and K.B. Clark (1992) Revolutionizing Product Development. New York, NY: The Free Press.

Zirger, B.J. and M.A. Maidique (1990) "A Model of New Product Development: An Empirical Test", Management Science, vol. 36, pp. 867-883.