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Description	

Building the Knowledge Network in Software Project

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Abstract

One of the most important coordination techniques for software development is to build the effective knowledge network in a software project. The knowledge network, in this paper, refers to inter-functional relationships for obtaining customer needs. We investigated the knowledge networks employing a survey instrument to collect data from a variety of product processes in a Japanese SI (Systems Integration) firm. Our results indicate that we must take a contingency view into consideration to build an effective knowledge network in a software project.

1. Introduction

Information systems theory literature stress the importance of coordination, which refers to "the integration or linking together of different parts of an organization to accomplish a collective set of tasks" [1]. Since software development is a highly information-intensive work activity, a successful software requires tight coordination among the various efforts involved in the software development cycle [2]. However, the main concern of studies on project coordination so far have been the mechanisms or actions taken in projects (e.g., decentralization, formalization), not the actual interaction within projects.

In this paper, we tried to identify inter-functional relationships for obtaining customer needs in software development, what we call a knowledge network. We used the term "knowledge" because of that customer needs do not fit a specific mold. The interpretation of it is highly subjective and socially constructed and has much tacit dimension. For this reason, the term "knowledge network" may fit more to represent the personal interaction than the term "information network."

The structure of inter-functional relationships has had much attention in management studies. However, the knowledge network we report here is different from these studies in two respects. First, we are concerned only with the interactions of obtaining customer (client) needs. Today, identifying client requirements is critical to the success of a software project, especially for which offers solutions for their customer. It is apparent that personal interactions are critical for a success, however, prior studies have discussed the extent of the interaction among functions and then, what content of information is actually exchanged is not apparent. Limiting the content of interaction as customer needs will help clarify the effectiveness or efficiency of relationships.

Second, we took a contingency view in this problem by investigating which different knowledge networks are actually used and how they affect the success or failure of obtaining customer needs under specific conditions. The information-processing model introduces the concept of organizational information processing as an explanation for why context and structure should match for optimum organizational performance [3][4]. The consensus is that organizational performance is accomplished by the match or fit between the amount of information needed and the organizational information-processing capacity. However, taking the tacit dimension in customer needs into consideration, attention should be focused on knowledge processing not just information processing. Then, proving into the knowledge network under each condition can help to establish ideas for designing configurations that produce optimal performance.

The rest of the article is organized as follows. In the next part, we present a theoretical background for this problem. Subsequently, we empirically show the knowledge network and levels of obtaining or reflecting customer needs by a survey. Comparing the results under each environment, we then show the necessity of a contingency view for building a knowledge network within a firm.

2. Background

2. 1. Coordination Mechanisms for Software Development

Coordination mechanisms in software projects have been the focus of a number of investigations. Researchers identified several specific coordination mechanisms, including standards, hierarchies, targets or plans, slack resources, vertical information systems, direct contact, liaison roles, task forces, and integrating goals. Sabherwal classified these mechanisms into four main categories, as shown in Table 1 [5].

Table 1. Categories of Coordination Mechanism

Coordination Category	Examples
Standard	Compatibility standards Data dictionaries Design rules Error tracking procedures Modification request procedures
Plans	Delivery schedules Project milestones Requirements specifications Sign-offs Test plans
Formal Mutual Adjustment	Code inspections Coordination committees Design review meetings Hierarchies Liaison roles Reporting requirements Status review meetings
Informal Mutual Adjustment	Co-location Impromptu communication Informal meetings Joint development Transition teams

Though many types of coordination exist, the importance of personal interaction is unshaken. Kraut and Streeter empirically investigated under what conditions various coordination techniques for software development work well and concluded that personal communication was the critical factor for success [2]. The importance of personal communication would be more apparent when taking our concern, obtaining customer needs, into consideration. That is because customer needs have much tacit dimension in itself, and then, sharing of it is expected to require much personal interaction. Additionally, since software development is a highly social and interactive process, project coordination strategies must exhibit communication mechanisms that match or fit the task and social context associated with specific work units and project phases [6]. Therefore, characteristics (e.g., structure or density) of a knowledge network could vary in accordance with organizational environments such as customer type, task characteristics, or management constraints faced by organizations.

2.2. Contingency Factors for Coordination

What types of interactions are appropriate under what conditions is the primary concern for contingency theorists. The term contingency theory was coined by Lawrence and Lorsch [7], who argued that the amount of uncertainty and rate of change in an environment impacts the development of internal features in organizations. To cope with these various environments, organizations must create specialized sub-units with differing structural features: e.g., differing levels of formalization, centralized vs decentralized, planning time horizon [8]. Taking the contingency view into software development, appropriate inter-functional interaction (coordination) must be taken in accordance with environmental factors.

Kraut and Streeter abstracted several characteristics that may affect coordination in software development [2]. *Scale* is a fundamental characteristic of many software systems. If a software system is small, effective coordination can occur because a single individual or small group can direct its work and keep all the implementation details in focus. *Interdependence* is based on the need for integrating thousands of software modules to make them work correctly.

Unlike manufacturing, software development is a nonroutine activity. Zmud noted, "An important insight to understanding the problems associated with managing software development is that most difficulties can be traced to the uncertainty that pervades software development" [9]. *Uncertainty*, the absence of complete information, stems from the complexity of the environment and dynamism, or the frequency of changes to various environmental variables, or state-of-the-art technologies [9][10]. It also increases because specifications of the functionality of the software change over time.

Although many methods have been devised to cope with the combination of large size and interdependence, *informal communication* invariably has a valuable role in consensus formation, information sharing, and other activities for smooth coordination.

2. 3. Dimensions for Classifying Projects

Though there may be many aspects for contingency factors, we focused on three dimensions: customer type, technology-orientation, and management style. These dimensions will affect knowledge networks for the following reasons.

1. *Customer Dimension*

   Competitive hostility, market turbulence, and the ease of market entry all increase environmental uncertainty. One way to cope with uncertainty is to implement structural (often tight) mechanisms that enhance information flow. Then, if some kind of "match" or "fit" is expected, the more uncertainty, the tighter a knowledge network must be. In contrast, a weak knowledge network will be found when a project faces relatively lower uncertainty.

   The customer dimension adds uncertainty to software developments. For example, the size of systems used in government offices is often big, and thus, such projects require many resources, including time, money, many engineers, etc. Since the firms which can offer these resources are limited, market hostility is relatively low. By contrast, private firms require high standards (e.g., low price, high-quality) for developers and often functionality changes for specifications of the system. Also, because the resource constraint is relatively low, many firms can easily enter in this market. Then, uncertainty becomes relatively high, and a tight knowledge network should be expected to confront the uncertainty in the market. This discussion leads to our first hypothesis.

   H1: The customer dimension (i.e., government offices or private firms) is associated with the density (tight or loose) of knowledge networks.

2. *Technology-Orientation Dimension*

   The technology orientation serves as the foundation for the interest in advanced technology, which refers to the set of beliefs that puts technological interest first, while excluding customer needs. When the target customer is end consumer, because the purposes of using product vary person to person, the requirements for developing systems cannot be easily identified. In this situation, system developers tend to make efforts to equip many functions into the products to meet a variety of customer needs, instead of determining the "true" customer needs.

For this reason, technology-oriented projects do not need to determine customer needs as clearly as demand-pull type projects which offer B-to-B products. This leads to our next hypothesis.

H2: In technology-oriented projects, the density of knowledge networks is relatively loose, and the level of obtaining customer needs is relatively low.

3. *Management Dimension*

   It must not be a good assumption that coordination techniques are determined only by external factors. Taking internal factors into consideration, the differences of management style must create an important aspect. The differences may appear in many aspects. For example, when some projects are being done in regional branches at the same firm, whether it is in head office or regional branches must affect the level of customer needs.

   H3: The level of obtaining customer needs is affected by whether the project is in head office or regional branches.

3. Survey

3.1. Sample

To identify a knowledge network, we organized a survey at a large Japanese firm which mainly provides system integration services. All employees in this firm were asked to respond to a questionnaire. After excluding data from areas not directly associated with product (system) development such as human resources, we had 1,646 data, corresponding to a response rate of 37.4%.

3.2. Knowledge Network

Each respondent was asked if to obtain information related to customer needs with the following question: Do you have a contact to [the process] to get information related to customer needs? (Yes or No) In this phrase, [the process] means each software development stage: sales, analysis (system analysis), design (system design), code, test, maintenance, and customer as a source of customer needs. Since most of the respondents were in charge of tasks corresponding to two or more processes, the ratio of knowledge flow was calculated by a weighted average by an inverse number of processes overlapping of each respondent.

$$\alpha_{ij} = \sum_{n \in P_j} \frac{t_{n,i}}{h_n} \bigg/ \sum_n \frac{1}{h_n}$$

α_{ij} :   ratio of knowledge flow from process-i to process-j

$t_{n,i}$:   contact to process-i by respondent n (1 or 0)

h_n :   number of processes overlapping of respondent n

P_j :   a set of process-j involved

3.3. Organizational Characteristics

The level of obtaining or reflecting customer needs were measured by asking how well the work groups of respondents actually obtain or reflect customer needs. The correspondence questions are as follows (the response scale is: 1. strongly disagree - 7. strongly agree; on a Likert-Scale).

(a) obtaining customer needs: "your working group fully obtain customer needs."

(b) reflecting customer needs: "your working group fully reflect customer needs in your work."

From the subtraction between the levels of these variables, we can estimate the level of original effort for embodying customer needs into their work. For example, if the level of reflecting customer needs is higher than that of obtaining customer needs, the respondent is assumed to make his or her own efforts into the work.

3.4. Division Classifications

For our purpose, it is suitable that projects in this firm are classified. Though since so many projects are running in the firm, it is impracticable to identify what projects are under what conditions. Then, we alternatively consider division classifications as shown in figure 1, classifying 16 divisions in this firm into four types to meet our concern.

(a) Demand-Pull (government offices)
The divisions categorized in this type are offering made-to-order products, and their main customers are government offices. The main concern of customers is not the price or technical advancement but that products work stably. The number of competitors is limited, and thus, market turbulence seems to be relatively low.

(b) Demand-Pull (private firms)
The concerns of private firms for implementing systems have a wide range of aspects: price, delivery (deadline), quality, etc. Many competitors exist in the market, and thus, hostility between them is fierce. For this reason, it is reasonably assumed environmental uncertainty is higher than that of former type. In reality, the reputation of products this type of division offers is higher than that of other types.

(c) Technology-Push
Compared to the demand-pull type offering B-to-B products, the divisions in this type mainly offer consumer products (B-to-C products) like packaging softwares. The aim of these technology-oriented divisions for this firm is to pursue brand-new technologies that will be needed or used for future products.

(d) Regional Branch
The firm we investigated has six branch offices in Japanese regional area (head office is located in Tokyo). The aim of regional branches is to maintain close-ties with customers and deal with their problems or complaints about the systems as soon as possible. They offer a variety of products of demand-pull-type as well as technology-push-type that are also for government offices as well as private firms. All of the branches were initially operated by other firms. Three of them were merged just a few months before our survey was conducted. Other two were merged no more than three years ago. Thus, these branches must have been left old management styles that were originally developed by previous firms.
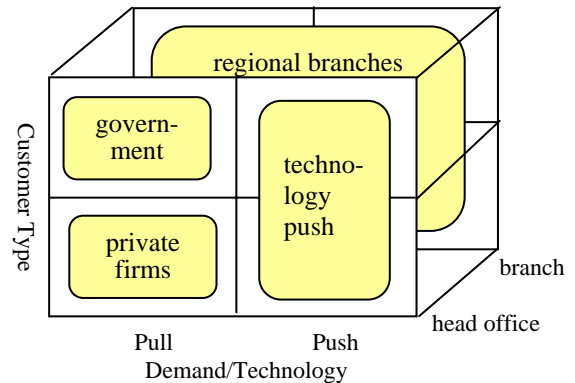

Figure 1. Division Classifications

4. Results

4.1. Case of Demand-Pull (government offices)

Figure 2 shows the extent to which process actually contact to obtain customer needs for each side communication. The arrows indicate the direction of choices to obtain customer needs. Heavy, thin, dashed arrows correspond to the extent of the knowledge flow. The threshold levels that distinguish these arrow types are settled by the average level in top order of 5-6th (heavy-thin), 10-11th (thin-dash), 15-16th (dash-none) knowledge flow using all data. The actual level of each is 0.823, 0.647, 0.540, respectively.

In the figure, each process has direct passes from 'customer', and the structure is distinctly different from the linear-processing model (i.e., water-fall model). It implies that because customer needs is somewhat 'sticky' in itself [11], downward processes directly ask what the real meaning of customer needs is. In addition, some back-flows exist at 'design to analysis' and at 'maintenance to analysis.' Additionally, 'sales' is isolated from other processes, showing that some kind of bottleneck exists between 'sales' and other processes. This is also confirmed in Figure 3, which shows the average level of obtaining and reflecting customer needs in each process. Both levels in 'sales' are very low compared to other processes. Moreover, the level of obtaining customer needs in 'sales' is higher than that of reflecting customer needs while inverse results are confirmed in other processes. This implies that 'sales' does not try to add an original effort into their work as compared with other processes. Maybe it is because that the main concern of sales persons is to maintain close-relationship with customer, rather than to identify the real customer needs or to convey it to other processes.
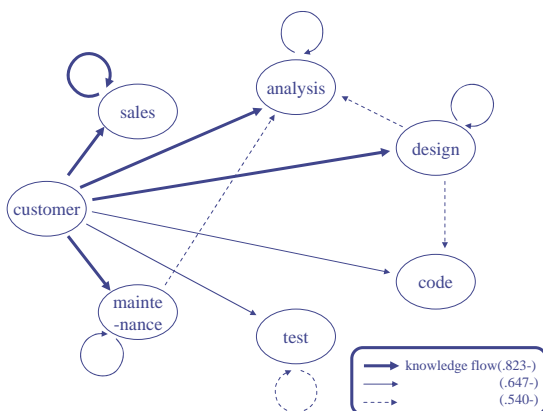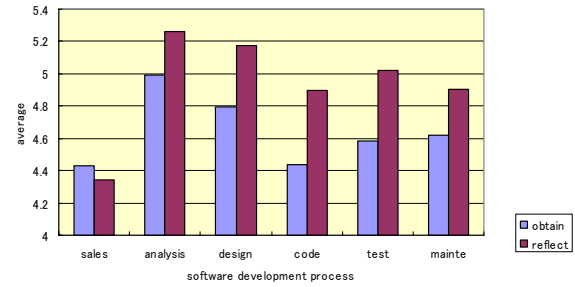

Figure 3. Customer Needs (government offices)

4.2. Case of Demand-Pull (private firms)

Comparing Figure 2 and 4, it is apparent whether customers are government offices or private firms has a great impact on a knowledge network. The knowledge network in this case implies that projects build tighter networks to face much environmental uncertainty. Additionally, both the levels of obtaining and reflecting customer needs in this type are higher than in other types, and the levels at each process are almost the same. Also, the down trend from 'analysis to code' confirmed in Figure 3 does not exist in this case.
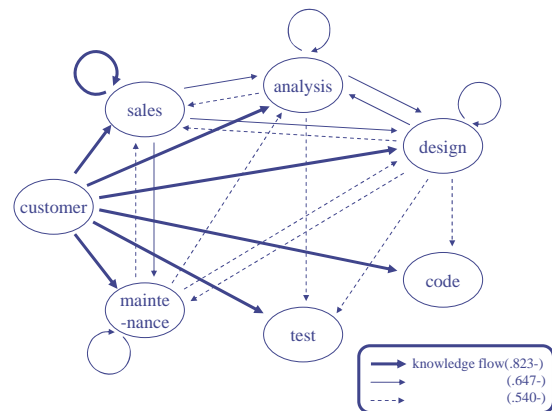

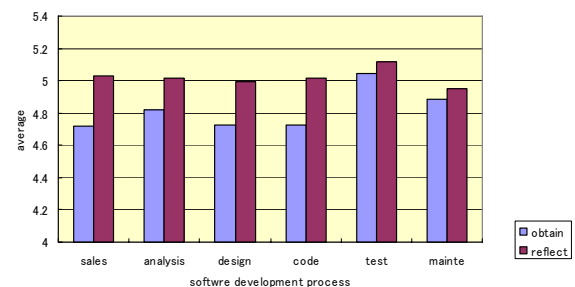Figure 4. Knowledge Network (private firms)

Figure 2. Knowledge Network (government offices)

Figure 5. Customer Needs (private firms)

4.3. Case of Technology-Push

The low density in a knowledge network in the case of the divisions of technology-push is caused because they cannot directly ask what products their customers (end consumers) need or want. They tend to rely more on their feelings or experiences rather than meeting with or hearing customers to estimate customer needs. In terms of obtaining customer needs, although the density of a knowledge network is loose, the level of it is estimated relatively higher in this type, which contradicts our hypothesis.
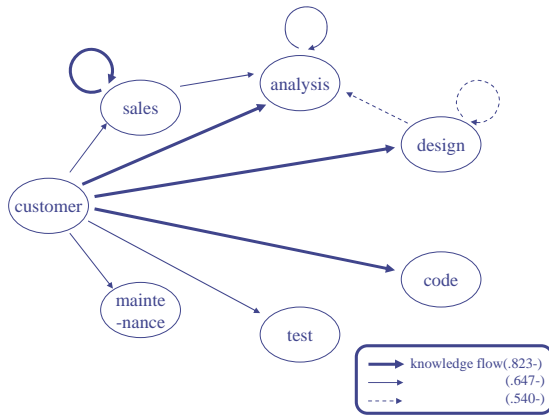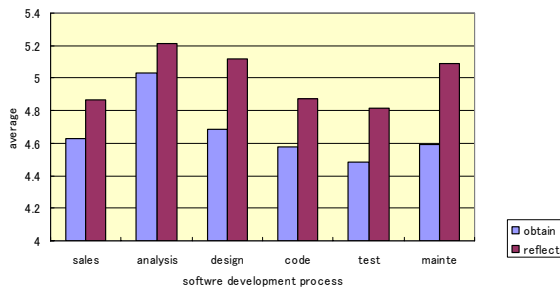

Figure 6. Knowledge Network (technology-push)

4.4. Case of Regional Branches

In the case of regional branches, the density of the knowledge network is almost at an average level. However, the level of obtaining and reflecting customer needs in this type is lower compared to that in other cases. This result implies that differences of management style (as we noted, regional branches were initially operated by another firm and must employ differing management styles) impact not on the knowledge network but on the level of obtaining or reflecting customer needs.
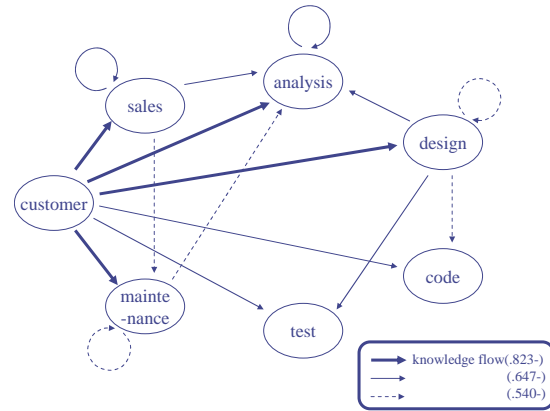

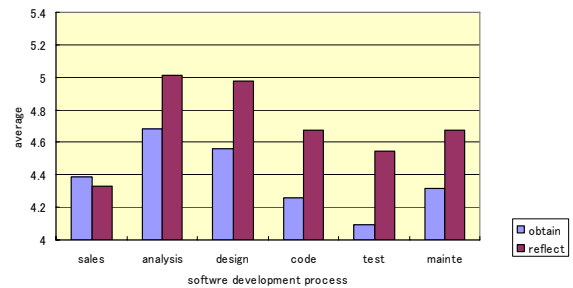Figure 8. Knowledge Network (regional branches)

Figure 9. Customer Needs (regional branches)

4.5. Summary

The results are summarized in Table 2. We knew the customer type affects the density or structure of the knowledge network, supporting H1. Additionally, the knowledge network is affected by the technology-orientation, though the level of obtaining or reflecting customer needs is not affected so strongly (H2 is partly supported). It is assumed that employees in this type must strongly rely on their own ideas for determining customer needs. In addition, the supposable management differences (i.e., head office or regional branches) relate to the level of obtaining or reflecting customer needs (H3 is supported). It implies that there may be other organizational factors that determine the level of customer needs than the knowledge network.

Figure 7. Customer Needs (technology-push)

Table 2. Summary of Results

	demand-pull (government)	demand-pull (private firms)	technology push	regiornal branches
knowledge network	average	tight	loose	average
level of custmer needs	average	high and even	average	low

5. Discussion

Taking a contingency view into account, the research problem becomes to be identifying the structure that maximizes performances for a given environment. Our first assumption is that the knowledge network must be the most determinative factor for the level of customer needs. Viewing knowledge networks under some conditions, our results show that it is partly true but there may be other factors that impede or foster obtaining or reflecting customer needs. Taking our results into consideration, focusing on organizational ability or culture is thinkable factor to interpret the backgrounder of this problem.

Some scholars have pointed out that organizational ability creates the basis for obtaining customer needs. Cohen and Levinthal argued that firms need absorptive capacity: the ability to recognize the value of new, external information, assimilate it, and apply it to commercial ends [12]. Kogut and Zander proposed a concept of combinative capability, which refers to the capacity of a firm to combine and recombine existing knowledge [13]. Related arguments have been discussed by many scholars [11][14][15]. Taking the tacit dimension in customer needs into consideration, the ability of abstracting meanings of customer needs through personal interactions may be a strong factor for determining the level of obtaining customer needs.

On the other hand, there is a standpoint that focuses on organizational culture or climate, that puts customer's interest first, while excluding those of other stakeholders such as owners, managers, and employees, in order to develop a long-term profitable enterprise [16]. A simple focus on information about the needs of actual and potential customers is inadequate without consideration of the more deeply rooted set of values and beliefs that are likely to consistently reinforce such a customer focus and pervade the organization. For example, Deshpande, Farley, and Webster noted that such a belief can be achieved only if it is complemented by a spirit of entrepreneurship and an appropriate organizational climate [17]. It is also considered as manifest in many aspects of organizational performance, and then, constructing such an organizational customer or culture must be the key antecedents of obtaining customer needs.

Whatever the standpoints are, organizational abilities or cultures cannot to be established in just a few years. In our analysis, the result in the case of regional branches implies that. Although a merger activity was done, the level of obtaining customer needs cannot be enhanced so rapidly. It is also expected that changing a knowledge network in a software project also takes considerable time. We therefore, had better to think that a long-time view is needed to take an action in this problem.

6. Conclusion

The primary concern in this paper was to investigate the knowledge network, and to determine how and to what extent it relates to the level of obtaining or reflecting customer needs. Although we do not prove into the mechanisms between them in detail, several results are worth highlighting.

The first point is that structures of the knowledge networks are complex and not like a linear-processing model (i.e., water-fall model). It suggests that customers have to show (or to be asked) their needs or wants to many processes. This implies that customer needs are sticky and cannot easily to be absorbed into a firm [11]. Taking the tacit dimension in customer needs into consideration, the ability to convert customer needs (often in tacit dimension) into software requirements (often in explicit dimension) is a central concern to attain effective network within a project.

Second, our analysis showed that the structure or density of a knowledge network is strongly affected by the environmental factors that each project faces. This could be caused by environmental uncertainty or technical orientation, and other factors. In addition, the knowledge network is a strong antecedent of obtaining customer needs, however, not a determining factor. Our analysis showed the level of obtaining customer needs is affected not only by knowledge networks but also by some other organizational abilities, such as absorptive capacity, organizational culture or climate, etc. It implies that when we want to build an effective knowledge network in a project, many factors must to be taken into consideration.

In this paper, we have focused only on the problem of knowledge networks or obtaining customer needs. Naturally, there must be other concerns to build an effective coordination or collaboration in software development. Nonetheless, the importance of personal interactions will have been a central issue. Until now, many researchers have pointed out the importance of this issue, however, in our view, it is not just a matter of the frequency of interaction but of careful coordination with environmental factors and organizational abilities. When we want to attain an effective collaborative works in software development, it is recommendable not to underestimate many aspects which we have taken up in this paper.

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