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# THE IMPACT OF ORGANIZATION STRUCTURE ON DESIGN COORDINATION PERFORMANCE IN CHINESE DESIGN INSTITUTES

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## ABSTRACT

Due to tight project schedule, interdisciplinary design coordination is always far from sufficient, which leads to design change even construction delay and cost overrun in construction stage. Research on design coordination has given little attention to the impact of organization structure. This paper aims to explain how organization structure in a design team affects design coordination performance. Inspired by Winch's river metaphor, this paper has developed a structural-process-performance research model to explain the relationship between organization structure and design coordination performance. To test the research model, 210 questionnaires are collected from practitioners in design institutes in China. Path analysis are conducted to test the relationship between organization structure, information processing amount and quality, coordination mechanism, and design coordination performance. Empirical study found out, by directing information into vertical coordination, centralization of authority has a negative impact on design coordination performance between disciplinary leader and designer and a positive effect on coordination performance between project manager and disciplinary leader. At the same time, centralization of authority also has negative impact on design coordination performance by reducing information processing amount. The negative impact could be supplemented by increasing the level of standardization, as standardization has positive effect on design coordination performance by increasing the use of coordination by schedule. It is also found out that the correlation between information processing quality and coordination process performance is much stronger than that between information processing amount and coordination process performance. For practitioners, it provides a framework to analysis the impact of organization structure on design coordination performance as well as enriching information processing theory by developing four dimensions to measure perceived information quality. For practitioners, the implication is helpful

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for designing better project organization to achieve better design coordination performance.

**KEYWORDS**

Design coordination, organization structure, performance, information processing

## INTRODUCTION

Changes in construction projects are very common and could lead to project delays and cost overruns. Lu and Issa (2005) believed that the most frequent and costly changes are often related to design, such as design changes and design errors. Hence, design stage is of primary importance in construction project life-cycle (Harpum, 2004). There are three common types of design deficiencies (Korman et al., 2003; Mokhtar, 2002). The first type is design information inconsistency. For example, location information of a specific wall on the architectural and structural drawings are different.The second type is mismatches/physical interference between connections of components. For example, duct dimensions in building service drawings are not matching related pass/hole dimensions in structural drawings. The third type is component malfunctions. For example, in electricity drawings, a room’s electrical supply is designed to suit classroom activities, while architectural drawings designate the room as a computer lab. Based on a questionnaire survey of 12 leading Canadian design firms, Hegazy, Khalifa, and Zaneldin (1998) reported eight common design problems, all of which were due to insufficient and inadequate communication and information exchange between interdisciplinary designers (e.g., delay in obtaining information, not everyone on the team getting design change information). Mydin et al.(2011) also echoed that lack of design coordination is a major contributors to design errors. Due to lack of design coordination, design drawings often carry design errors, especially mismatch between different disciplinary drawings. In order to mitigate this type of design errors, building information modeling (BIM) software has been introduced to detect clash (Gao,2011). it is well appreciated that one of major functions of BIM tools is to detect whether clashes exist. However, BIM tools can not solve those problems automatically. Rather design coordination is considered the key to help solve design errors. The performance of design coordination will be affected by multiple factors, in particular the organization structure of design institute.

Organization structure design is a main part of organization design (Van de Ven et al., 2013). Organization design is a classic topic in organization study. Research interest in it began in the early 1900s, exploded after the 1960s and began to decline in the mid-1980s (Barry, 2011); recently, however, there has been a resurgence of research interest (Van de Ven et al., 2013). Project based organization or project team is an important organization form nowadays. Due to increasing complexity and uncertainty in construction projects, organization structure design in project team is a challenge. It is therefore important to understand how organization structure affects design coordination performance in order to design a suitable organization structure in project team.

Existing research on design coordination mainly focus on information flow but neglect organization structure. Borrowing Winch’s (2010) river analogy, although one is interested in the information flow (water flow) that forms the final delivery, it is through altering the organizational structure (riverbank) in design project team that one manages that information flow. The importance of organization structure can be explained by Winch’s (2010) river analogy. Although what is of interest in a river is the flow of water, which irrigates crops, provides a transport route, enables the generation of hydroelectric power. It is through altering the river banks that the river flow is shaped. For example, dams and weirs create lakes and power; dykes and canals control direction. The relationship between river bank and river flow can be applied to interdisciplinary design coordination in design institutes. Building design is project-based activity. The term “project organization structure” reflects the temporary organization structure in design project team.Project organization structure can shape the process of interdisciplinary coordination, thus impact on design coordination performance. In this study, a model is developed to explain how project organization structure in design institutes affects design coordination performance, and the model is tested and explained in the context of Chinese design institute.

## DEVELOPMENT OF RESEARCH FRAMEWORK

### THE CONCEPT OF INTERDISCIPLINARY COORDINATION

According to Adam Smith(1776), the need for coordination comes from the division of labour. In order to improve productivity, division of labour and mass production developed very fast. This posed the problem of coordinating the fragmented production process(Winch, 1992).The division of labor in undertaking construction projects began to emerge in the 19th century (Walker, 1984), and resulted in a growing reliance on higher education to train experts in specific divisions. Building-related education is commonly engaged in several disciplines. For example, architecture, structural engineering, land surveying, quantity surveying, construction management, building services engineering, and others. However, each discipline is implemented through different courses. This division in discipline education is highlighted in the Banwell Report (1964). As a result of this education practice, the responsibility of design managers and that of construction managers have been separated (Gray & Hughes, 2001). Mydin et al.(2011) also pointed out that there is serve lack of coordination between design and construction in practice. There is a lack of will throughout the world to break down disciplinary walls and reform the education process.

It is acknowledged that specialization in training can shorten the time that takes a person to become an expert in a specific professional area. However, such specialization oriented education causes difficulty of coordination in practice between different specialized professionals. Therefore, the promotion of interdisciplinary design coordination is the focus of this study.

### COORDINATION AS INFORMATION PROCESSING ACTIVITY

Malone (1988) has defined coordination activity from information processing perspective. Activity in organization can be classified as either production activity or coordination activity (Malone, 1988). Coordination activity is defined as the additional information processing activity performed by multiple actors pursuing a goal that a single actor pursing the same goal could not perform. In this study, design coordination activity refers to the additional information processing activity performed when people from different disciplines work together to complete a building design. It includes retrival information, communication (discussion or negotiation), and transferring information. Referring to Winch (2010)' s metaphor, although what is of interest is the information flow, we can not manage the information flow without considering the organization structure. We have to change the organization structure in order to shape the information flow.

With this discussion background, this research aims to explore the impact of organization structure in design institutes on design coordination performance in the context of China. The research framework is presented in Figure 1.

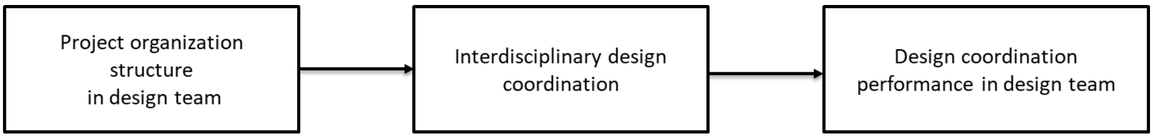


Figure 1 Research framework

## DEVELOPMENT OF RESEARCH MODEL

### CONSTRUCTS FOR CAPTURING THE CHARACTERISTICS OF PROJECT ORGANIZATION STRUCTURE

The internal differentiation and patterns of relationships amongst major components within an organization is typically defined as organization structure (Thompson, 1967). Coordination activity mainly concerns information processing, includes information retrival, information communication, and information transfer. In other words, coordination indicates transferring information from decision-making center to related people in project organization.  In project team, some people are responsible for making decisions, some for implementing those decisions, and others still for communicating these decisions through intermediate layers to people at the operational level. Centralization in project organization structure describes the location of the decision making center. After a decision is made, information about the decision must be transferred to related people in the organization. The information transfer channel can be impersonal (e.g., accomplished by programming), personal (horizontal or vertical) or group-based (scheduled or unscheduled meetings) (Dietrich et al., 2013; Van de Ven et al., 1976).It can be seen that, organizational structure is the way in which responsibility and authority are allocated inside an organization, and in which work procedures are carried out by organizational members (Blau, 1970; Dewar et al., 1980); the former is related to centralization, and the latter to standardization. The composite dimensions of centralization and standardization emerge consistently in studies on the dimensions of organizational structure, and are also two foci for this study.

There are two typical approaches to analyze the appropriateness of organizational structures, namely Configurationism and Cartesinanism (Donaldson, 2014). By configurationsim, organizations are divided into various categories, such as mechanistic organizations which rely on established rules to maintain controls, and organic organizations which rely more on mutual adjustment). It is nevertheless difficult to classify an organization into a specific category as often an organization employs both established rules and mutual adjustment. Therefore, the Configurationism approach has been criticized for inaccuracy by the Aston camp (Donaldson, 2001; Donaldson & Luo, 2014). In line with this, an alternative approach called cartesinanism approach has developed various variables to capture the characteristics of organizational structure, such as centralization and standardization. This approach is also named as aston approach because this approach was firstly introduced by research teams in Aston University. Aston approach is therefore applied in this study to measure organization structure.

Centralization in organization structure reflects the involvement of authority in decision-making. Dalton et al. (1980) asserted that, “centralization involves the locus of authority to make decisions in organizations, and the degree of centralization refers to the dispersion of decision-making authority throughout the organization.” Aiken and Hage (1966) developed a construct to measure centralization in decision- making, namely “degree of hierarchy of authority” (DHA). DHA is defined as the extent to which members are assigned tasks, and then provided with the freedom to implement them without interruption from supervisors (Aiken & Hage, 1966). A low level of DHA indicates subordinates enjoy a high level of job autonomy. Degree of hierarchy of authority is applied in this study to measure centralization in project organization structure. This measurement has been validated by Dewar et al. (1980) and found to be both reliable and valid. It is still used by current researchers (Wang, 2003; Li et al., 2008).

Generally, there are two types of standardization − technical and management. The former consists of technical standards and specifications. In the building design industry, these include both national technical standards at the industry level and accumulated technical solutions at the firm level. Industry-level standardization provides a basis for reducing information-related transaction costs, promotes economic efficiency, and facilitates interchanges amongst different sections (Heras - Saizarbitoria & Boiral, 2013; Nadvi & Waltring, 2004). Management standardization prescribes or limits the behavior and procedures of organization members by defining job duties, rules, and workflows(Dalton et al., 1980). As this study address, similar to most management research, thus standardization refers to management standardization, unless otherwise indicated.

### VARIABLES TO MEASURE DESIGN COORDINATION PERFORMANCE

As for the focus of the performance measurement, some focus on process performance and some focus on outcome performance (Campbell et al., 1993). In this research, both coordination process performance and design product performance (as outcome) are taken in to consideration. Design product performance is a representation of design outcome performance. It is postulated that coordination process performance affects positively design product performance.

Most studies on performance has focused on product performance but neglect the performance of final product is determined by process. In this study, Coordination process performance is used to measure design coordination performance. The variable of "coordination process performance" refers to the extent to which one member has effective information processing with another person in the design team.

### PARAMETERS TO CAPTURE INTERDISCIPLINARY DESIGN COORDINATION

In referring to the research framework in Figure 1, project organization structure affects design coordination performance in design project through interdisciplinary design coordination activity. There area group of parameters which can capture interdisciplinary design coordination activity, including coordination mechanism, information processing amount and information processing quality.

#### Coordination mechanism

Coordination mechanism describes the pattern of the composition of information processing actors and information processing channels. Interdisciplinary design coordination is interdisciplinary information processing activity. Four aspects are concerned when information processing activity for design work is analyzed in this study.including1) actors who conduct information processing, 2) information processing channel, 3) information processing amount and 4) information processing quality. Actors and information processing channels determine the features of coordination mechanism. There are typically two types of coordination mechanisms: impersonal coordination mechanism and personal coordination mechanism.

In the circumstance where information seeker does not get information directly from information provider, information is stored in an impersonal object. This way is called impersonal coordination (Donaldson & Luo, 2014), or coordination by programming (March and Simon, 1958). According to Van de Ven and Delbecq (1976) ,coordination by programming includes the use of established plans, schedules, forecasts, formalized rules, policies and procedures, standardized information and communication systems. Departure from these rules, human discretion does not enter into the determination of what, where, when and how roles are to be articulated to accomplish a given set of tasks (March and Simon,1958). Rather, roles and their articulation are formally prescribed in impersonal, standardized blueprints or action programs (Thompson, 1967). Timeline is such a typical impersonal coordination mechanism. For example, railroad standard time was invented as a coordination mechanism for trains operating across different zones in US (Okhuysen and Becky, 2009). Similary in design coordination, pre-planned information exchange schedule is a similar coordination mechanism. Based on such schedule, interdependent design team members know what kind of information he/she should submit to whom at what time.

Another type of coordination mechanism is personal coordination mechanisms, or coordination by feedback in another word (March and Simon, 1958).There are four types of personal coordination mechanisms: vertical communication, horizontal communication, scheduled group meeting and unscheduled group meeting.

Vertical communication is the tightest coordination mechanism in a centralized organization (Mintzberg, 1979). People reply heavily on it when coordinating their activities with other departments. Vertical communication is a form of direct coordination. It is achieved by having one person issue orders or instructions to several others whose work interrelates (Mintzberg, 1979). It is acknowledged that vertical coordination is an efficient means of processing information, but is more expensive than other approaches. Horizontal communication can be called as lateral(Galbraith 1994) or non-hierarchical coordination. It can be vested in a designated coordinator with no formal authority over the individuals whose tasks require coordination (Lawrence &Lorsch, 1967).Group meetings enable participants to exchange opinions, perceptions and judgments directly. It is acknowledged as a information processing mechanism, including immediate feedback, the number of cues and channels utilized, personalization, and language variety (Daft & Wiginton 1979; Daft & Lengel, 1986). This richness allows participants to reach a consensus on equivocal cues, and come to a collective judgment. Daft and Lengel (1986) asserted that the strength of group meetings is their ability to facilitate overcoming differences, and building understanding and agreement.

**Information processing amount**

Information processing amount is the sum of information processed in all coordination mechanisms. Insufficient information processing will result in poor design performance (e.g. problems in new project development, project failures), as it cannot supply necessary information (Patrashkova et al., 2004). In addition, previous studies suggest that an increase in communication is related to good performance in high workload situations (Mathieu et al.,2000). It is therefore postulated that project organization structure direct information processing amount has a positive effect on design coordination performance.

**Information processing quality**

The parameter “information processing quality” also has positive effects on design coordination performance. In other words, the improvement of information processing quality will contribute to design coordination performance. Maltz(2000) found that, different coordination mechanisms have different effects on information processing quality. Thus, it is postulated that coordination mechanism affects design coordination performance through the parameter of “information processing quality”.

Information processing quality is usually measured by perceived information quality is a concept applied to measure, which refers to the extent to which an individual perceives information received from a sender as being valuable. It is commonly appreciated that a receiver’s perceptions of information quality influences the degree to which he or she is willing to act on it. At the cognitive level, people expect to receive information that are helpful to the problem at hand. They will choose sources that are perceived to have a greater probability of providing relevant and reliable information (Choo, 2005). Thomas et al. (1998) has identified four variables to represent information processing quality: clarity,understanding, timelinessand completeness. Maltz (2000) used four similar variables in discussing perceived information quality: credibility, comprehensibility , relevance and timeliness.

In this study, accuracy, relevance, understanding and timeliness are used to present the multi-dimensional construct, information processing quality(IPQ). Accuracy refers to the degree to which information is perceived by the receiver to be a reliable refection of the real situation. Relevance denotes the degree to which the information is appropriate for the user’s task. Understanding refers to the perceived clarity of the information received. Timeliness represents whether the information is transmitted on time to allow the receiver to complete the task.

## RESEARCH MODEL

Based on above discussion and research framework in Figure 1, the research model is developed, as shown in Figure 2.

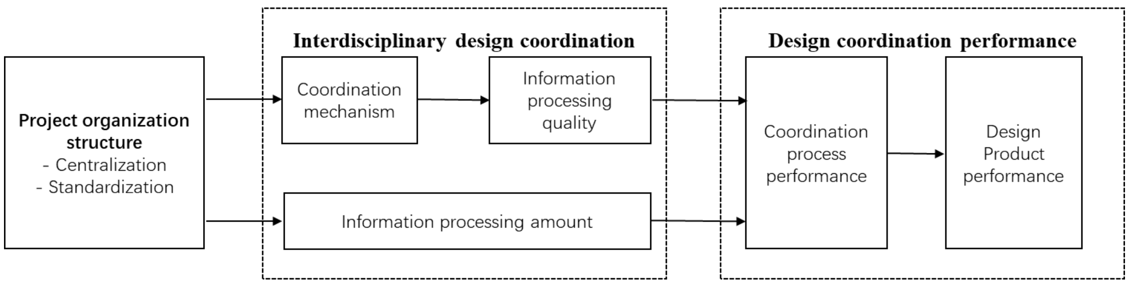


Figure 2

The main aim of this research model is to explain how project organization structure in a design team affects design coordination performance through facilitating or constraining information processing in interdisciplinary coordination mechanism.

## RESEARCH METHODS

### DATA COLLECTION METHOD

Web-based questionnaire survey was applied to collect quantitative data for this investigation. The target respondents in this survey were participants in building design project teams from design institutes in Mainland China. Respondents were chosen based on three criteria; specifically, respondents should: (1) have participated in a project that had been completed within the past one year (as they would be asked to recall design coordination activity); (2) have been either a project design manager, discipline leader, or designer/engineer (top managers was excluded); and (3) have been in one of the following disciplines during the project – project management, architecture, structure engineering, mechanical engineering, electrical engineering, plumbing engineering, or BIM engineering.

1174 questionnaire responses were received, of which 219 were completely answered, yielding a completion rate of 18.7%. Ten questionnaires were dropped in data analysis as obvious data out-liners. Each respondent reported data on his/her dyadic interdisciplinary design coordination with from two to seven disciplines (see table 1). As the level of analysis was dyadic interdisciplinary design coordination, each questionnaire was split into two to seven samples. Data on both intra- and inter-discipline coordination were collected. The study's focus was on inter-discipline coordination, and the total sample size in the inter-disciplinary coordination data set was 698 (sum of figures in grey background).

Table 1 Matrix of dyadic coordination samples

| | GD | Archi. | SE | ME | EE | PE | BIM |
|---|---|---|---|---|---|---|---|
| GD | 2 | 5 | 5 | 2 | 2 | 2 | 2 |
| Archi. | 15 | 65 | 65 | 44 | 44 | 44 | 44 |
| SE | 12 | 66 | 66 | 38 | 38 | 38 | 38 |
| ME | 2 | 15 | 15 | 6 | 6 | 6 | 6 |
| EE | 1 | 12 | 12 | 2 | 2 | 2 | 2 |
| PE | 2 | 11 | 11 | 7 | 7 | 7 | 7 |
| BIM | 3 | 19 | 19 | 9 | 9 | 9 | 9 |

Notes: GD: General Drawing; Archi.: Architecture; SE: Structure Engineering; ME: Mechanical Engineering ; EE: Electrical Engineering; PE: Plumping Engineering; BIM: Building Information Modelling;

### RESEARCH CONTEXT

A design institute undertakes design work for different projects (see Figure 3), and each project design team is assigned a project design manager by the design institute (known within the institute as a project manager). In China, where this empirical research was conducted, a design contract is usually awarded to a single design institute that includes all disciplinary teams. The design institute then assigns a design team for the project, hereinafter referred to the project design team. In China, project design teams usually consist of a discipline leader and designers/engineers from at least six different disciplines (general planning, architecture, and structural engineering, mechanical engineering, electrical engineering, and plumbing engineering), all employed by the same design institute. General planning teams are responsible for connecting on-site elements with off-site elements, such as existing transportation or drainage networks. Mechanical engineering teams are responsible for HVAC (heating, ventilation and air conditioning) design, electrical engineering teams for designing power, lighting and (sometimes) IT systems, and plumbing teams for water supply and drainage layout design. Sometimes, the three disciplinary teams are formed into a single MEP (mechanical/electrical/plumbing) team, similar to a building services team. In addition, some project design teams include other consultant teams, such as quantity surveying and BIM teams. There are at least three levels within each project design team: project design manager; disciplinary leader; and designer or engineer.

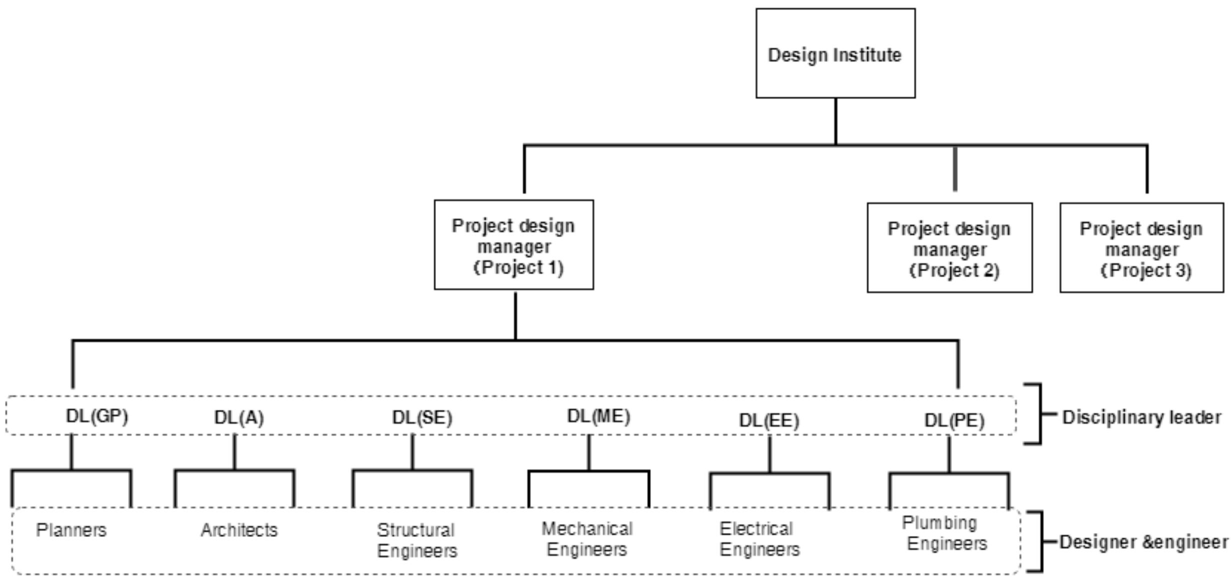


Figure 3 The composition of a project design team in China

**MEASUREMENT OF CONSTRUCT**

## Organization structure

Degree of hierarchy of authority is defined as the extent to which members are assigned tasks, and then provided the freedom to implement them without interruption from supervisors. Akien and Hage (1966) used degree of hierarchy of authority as an organization-level construct. While, in a pure bureaucratic organization, an organization's/team's hierarchy of authority can be the same for all people, it is more likely to be different in practice in other organizations, as whether a supervisor interferes in a subordinate's decision-making process is affected by that subordinate's capacity to work independently. Therefore, in this study, the degree of hierarchy of authority is used only to describing the relationship between one subordinate and his/her supervisor. In addition, it was found (during interviews with respondents in the questionnaire pilot section) that hierarchy of authority in a project design team varies greatly, as leaders are more likely to empower more experienced subordinates. To sum up, when discussing the concept of hierarchy of authority in this study, the unit of analysis is individual and the level of analysis is the project level.

Table 1 Measurement scale of centrality of authority

| Construct | Code | Description | Factor loading | Cronbach's alpha |
|---|---|---|---|---|
| centrality of authority | cent_a1 | Even small matters have to be referred to someone higher up for a final answer. | 0.7696 | 0.8271 |
| | cent_a2 | I have to ask my supervisor before I do almost anything. | 0.7818 | |
| | cent_a3 | Any decision I make has to have my supervisor's approval. | 0.7324 | |

**Standardization**

Standardization in organizations refers to extent to which job duties, rules, and workflows are defined. Benlian and Hess (2007) claimed to have applied the formalization measurement developed and validated by Dewar et al. (1980); however, it was found that what Dewar et al. (1980) had actually done, was to examine and validate the measurement developed by Aiken and Hage (1966) and Aiken and Hage (1968). Upon reexamination, it was found out the all three sub-constructs of formalization (job codification, rule observation and job specificity) have problems, either in terms of reliability or discriminant validity. In the end, Rondeau et al.'s (2000) standardization measurement was applied, as factor analysis showed it had good reliability, shown in Table 2.

Table 2 Measurement scale of standardization

| Construct | Code | Description | Factor loading | Cronbach's alpha |
|---|---|---|---|---|
| standardization | std1 | The duty of my job is well documented. | 0.8277 | 0.8714 |

| | | | | |
|---|---|---|---|---|
| | std2 | The work flow related to my job in project team is well documented. | 0.8719 | |
| | std3 | The evaluation method of my job is well documented. | 0.7389 | |

**Coordination mechanisms**

Five coordination mechanisms that enable interdisciplinary information processing in design coordination are focused on in this study: information exchange schedule; vertical communication; horizontal communication; scheduled group meeting; and, unscheduled group meeting. All five coordination mechanisms can be tailored to suit specific projects. Vertical communication refers to coordination by one’s supervisor. For designers, it denotes coordination by their disciplinary leader or the project manager; for disciplinary leaders, it denotes coordination by the project manager. Horizontal communication refers to direct communication with a member of another discipline team. Respondents were asked to indicate the extent to which they used each of the five coordination mechanisms, using a five-point scale (0=never; 5=to a large extent).

**Information processing amount**

Communication frequency is applied to measure information processing amount, using a five-point scale. Respondents were asked to indicate the frequency with which they communicated with designers from other discipline teams (1=zero, 2=less than once monthly, 3= several times monthly, 4= several times weekly, 5= several times daily).

**Information processing quality**

Referring to the communication literature, perceived information quality (PIQ) is used to measure information processing quality(IPQ). PIQ refers to the extent to which an individual perceives information received from a sender to be valuable. PIQ is regarded as a multi-dimensional construct, including the dimensions of accuracy, relevance, understanding and timeliness.

The measurement and reliability structure of the measurement scale is shown in Table 3, below:

$$\mathrm{PIQ} = \frac{\mathrm{accuracy} + \mathrm{relevance} + \mathrm{understanding} + \mathrm{timeliness}}{4}$$

Table 3 Measurement scale of perceived information quality

| Dimensions | Measurement items | Cronbach's alpha |
|---|---|---|
| accuracy | The information sent by them was accurate. | 0.6376 |
| | They sent me conflicting information.(R) | |

| | | |
|---|---|---|
| relevance | They communicated important details of design information. | 0.8796 |
| | They provided information necessary in design decision making. | |
| understanding | It was easy to follow their logic. | 0.9541 |
| | Their terminology and concepts were easy to understand. | |
| | They presented their ideas clearly. | |
| timeliness | They provided information in a timely manner. | 0.669 |
| | Their information on design change was too late. | |
| | They gave me information that were "old hat". | |

**Coordination process performance**

Coordination process performance refers to the extent to which the respondent (focal unit a) conducts effective information processing with another person in the design team (unit j). It is a dyadic concept. Dyadic coordination performance is drawn from Sherman and Keller's (2011) research, and is measured with a five-item scale examining. The measurement and reliability structure is shown in table 4 .

Table 3 Measurement scale of perceived information quality

| Construct | Code | Description | Factor loading | Cronbach's alpha |
|---|---|---|---|---|
| CP | cp1 | the extent to which the focal unit *a* had an effective working relationship with unit *j*, | 0.937 | 0.9728 |
| | cp2 | the extent to which unit *j* fulfilled its responsibilities to unit *a*, | 0.9426 | |
| | cp3 | the extent to which unit *a* fulfilled its responsibilities to unit *j* | 0.9201 | |
| | cp4 | the extent to which the coordination was satisfactory | 0.9318 | |
| | cp5 | the positive or negative effect on productivity as a result of the coordination | 0.9383 | |

**Design product performance**

Design product performance measurement is contextualized in terms of design coordination, and gauged by evaluation standards – i.e., criteria describing an individual's or organization's strengths and weaknesses in pursuing project goals. It was suggested that one can locate actual performance using a standard scale. One important aim of ensuring sufficient interdisciplinary information exchange is to deliver a set of qualified drawings on time and within budget; hence, design product performance consists of three dimensions – quality, cost and schedule. Design product performance is measured at the project level and refers to completion of design of the design deliveries by the project design team.

Subjective measurement is used in this study, because it is more representative of the team performance domain than objective measurement. It is acknowledged that objective measurement is least likely to be contaminated by performance-irrelevant content (e.g., rater bias), but objective measurement is given up because comparing quantitative design error numbers is meaningless due to different criteria in defining design quality in different design institutes. In addition, the ratee's perspective (Campbell et al., 1993) is used in performance evaluation in this study. Respondents were asked to report the extent to which his/her design delivery on a specific project met quality, budget and time expectations.

## DATA ANALYSIS AND RESULTS

Table 5 lists descriptive statistics and correlations for research variables

Table 5 Descriptive Statistics and correlations for research variables

| Variables | | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | cp | 3.56 | 0.98 | 1 | | | | | | | | | | | | | | | | |
| 2 | PIQ | 3.22 | 0.91 | 0.80*** | 1 | | | | | | | | | | | | | | | |
| 3 | IA | 3.03 | 1.11 | 0.60*** | | 1 | | | | | | | | | | | | | | |
| 4 | IR | 3.46 | 1.14 | 0.70*** | | | 1 | | | | | | | | | | | | | |
| 5 | IU | 3.34 | 0.99 | 0.75*** | | | | 1 | | | | | | | | | | | | |
| 6 | IT | 3.05 | 1.09 | 0.63*** | | | | | 1 | | | | | | | | | | | |
| 7 | dq | 3.84 | 0.85 | 0.39*** | | | | | | 1 | | | | | | | | | | |
| 8 | ds | 3.93 | 1.11 | 0.24** | | | | | | 0.66*** | 1 | | | | | | | | | |
| 9 | dc | 4.00 | 1.26 | 0.29*** | | | | | | 0.59*** | 0.58*** | 1 | | | | | | | | |
| 10 | iefd | 3.30 | 1.33 | 0.44*** | | | | | | 0.19* | -0.01 | 0.13 | 1 | | | | | | | |
| 11 | cbsched | 3.25 | 1.12 | | 0.41*** | | | | | | | | | 1 | | | | | | |
| 12 | cbh | 3.01 | 2.59 | | 0.29*** | | | | | | | | | | 1 | | | | | |
| 13 | cbv | 5.52 | 3.25 | | 0.08 | | | | | | | | | | | 1 | | | | |
| 14 | cbsm | 2.78 | 1.20 | | 0.25** | | | | | | | | | | | | 1 | | | |
| 15 | cbusm | 2.45 | 1.37 | | 0.21* | | | | | | | | | | | | | 1 | | |
| 16 | ca | 2.65 | 0.88 | 0.08 | 0.05 | | | | | | | | 0.00 | 0.08 | 0.00 | 0.03 | -0.02 | -0.05 | 1 | |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | std | 3.32 | 0.86 | 0.06 | 0.07 | | | | | | | | -0.06 | -0.02 | -0.04 | -0.07 | 0.06 | 0.13 | 0.23** | 1 |

*** p<0.001, ** p<0.01, * p<0.05 (pearson correlation) ;

**Organization structure and design coordination**

Mediation is not defined statistically; rather statistics can be used to evaluate a presumed mediational model (David Kenny, 2016). To reduce the complexity of statistical model, measurement model of organization structure are presented beforehand in the section of measurement of constructs. Path analysis is applied to test the mediating role of the use of coordination mechanism, and perceived information quality. Path analysis is structure equation model(SEM) with a structural model, but no measurement model.

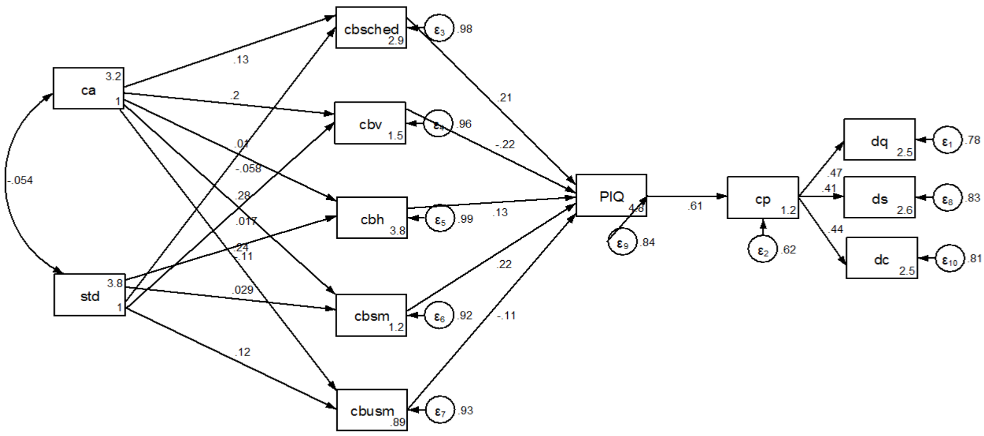


Figure 4 The mediator role of information processing quality (designer group)

**M**odel fit statistics: chi-square (46, ms)= 750.084; p>chi-square= 0.000 ; CFI=0.270; RMSEA=0.282; p(RMSEA)=0.000)

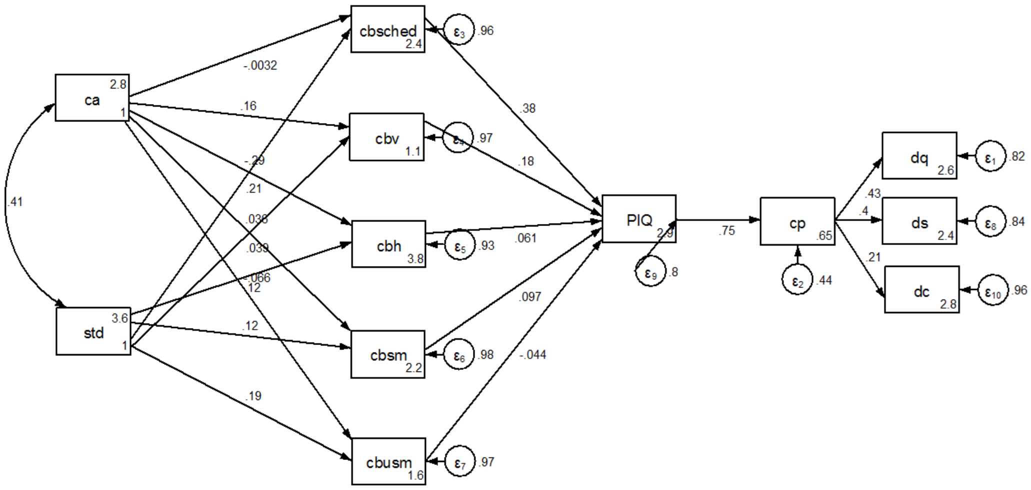


Figure 5 The mediator role of information processing quality (disciplinary leader group)

(model fit statistics: chi-square (46, ms)= 874.514; p>chi-square= 0.000 ; CFI=0.357; RMSEA=0.261; p(RMSEA)=0.000)

The results are listed in the following table:

Table 6 Path analysis between coordination mechanism, information processing quality and design coordination performance

| Path | designer group | | | disciplinary group | | |
|---|---|---|---|---|---|---|
| | Beta | Std.Err. | P>z | Beta | Std.Err. | P>z |
| cbsched <-ca | **0.135**** | 0.071 | 0.057 | -0.003 | 0.066 | 0.961 |
| cbsched <-std | -0.058 | 0.071 | 0.415 | **0.211***** | 0.065 | 0.001 |
| cbv<-ca | **0.196***** | 0.070 | 0.005 | **0.156**** | 0.066 | 0.018 |
| cbv<-std | 0.017 | 0.071 | 0.808 | 0.039 | 0.066 | 0.557 |
| cbh<-ca | 0.010 | 0.072 | 0.884 | **-0.292***** | 0.063 | 0.000 |
| cbv<-std | -0.113 | 0.071 | 0.113 | **0.116*** | 0.064 | 0.071 |
| cbsm<-ca | **0.280***** | 0.067 | 0.000 | 0.036 | 0.067 | 0.586 |
| cbsm<-std | 0.029 | 0.069 | 0.674 | **0.115*** | 0.066 | 0.082 |
| cbusm<-ca | **0.239***** | 0.068 | 0.000 | -0.066 | 0.066 | 0.321 |
| cbusm<-std | **0.116*** | 0.069 | 0.095 | **0.185***** | 0.065 | 0.005 |
| PIQ<-cbsched | **0.211***** | 0.070 | 0.003 | **0.382***** | 0.062 | 0.000 |
| PIQ<-cbv | **-0.217***** | 0.084 | 0.010 | **0.184***** | 0.062 | 0.003 |
| PIQ<-cbh | 0.132 | 0.081 | 0.105 | 0.061 | 0.067 | 0.363 |

| | | | | | | |
|---|---|---|---|---|---|---|
| PIQ<-cbsm | **0.224**** | 0.108 | 0.037 | 0.097 | 0.082 | 0.238 |
| PIQ<-cbusm | -0.106 | 0.112 | 0.345 | -0.044 | 0.078 | 0.569 |
| cp<-PIQ | **0.614***** | 0.046 | 0.000 | **0.748***** | 0.027 | 0.000 |
| dq<-cp | **0.469***** | 0.057 | 0.000 | **0.426***** | 0.049 | 0.000 |
| ds<-cp | **0.410***** | 0.061 | 0.000 | **0.404***** | 0.050 | 0.000 |
| dc<-cp | **0.435***** | 0.059 | 0.000 | **0.212***** | 0.057 | 0.000 |
| cov(ca,std) | 0.054 | 0.072 | 0.452 | **0.407***** | 0.051 | 0.000 |

*** p<0.01, ** p<0.05, * p<0.1; n=192 for designer group; n=265 for disciplinary group;

Results show that the degree of centralization of authority is positively related with coordination by vertical communication in interdisciplinary information processing for both the designer group (beta = 0.196, p<0.01) .For the disciplinary leader group, the degree of standardization was positively related with the use of design information exchange schedule (beta=0.211, p<0.001) and the use of coordination by scheduled meeting in interdisciplinary information processing; however, the relationship was not significant for the designer group.

Results show that PIQ was significantly positively related with coordination process performance for both groups (beta=0.614, p<0.001/ beta=0.748, p<0.001); Sub-dimensional analysis (see Table 5) showed that, for both groups, perceived information relevance, information understanding and information timeliness were positively related with coordination process performance. The relationship between perceived information accuracy and coordination process performance was significant positive for the disciplinary leader group (beta=0.167, p<0.01) and less significantly positive for the designer group (beta=0.072, p=0.097), suggesting that the designers were more tolerance of information inaccuracy.

Results (in Tables 6) confirmed that coordination process performance was significantly positively related with design product performance. For both groups, coordination process performance was significantly positively related with design quality performance (beta=0.469, p<0.001/ beta=0.426, p<0.001), design schedule performance (beta=0.410, p<0.001/ beta=0.404, p<0.001), and design cost control performance (beta=0.435, p<0.001/ beta=0.212, p<0.001).

To understand more deeply the effect of PIQ, the construct was analyzed in terms of four dimensions: information accuracy; information relevance; information understanding; and information timeliness. Regression analysis was conducted to reveal the effect of coordination mechanisms on sub dimensions of PIQ, and the effect of sub dimensions of PIQ on coordination process performance. The results are shown, in table 7.

Table7 The impact of coordination mechanism on perceived information quality

| Coordination mechanism | Group | IA | | IR | | IU | | IT | |
|---|---|---|---|---|---|---|---|---|---|
| | | Beta | Std.Err. | Beta | Std.Err. | Beta | Std.Err. | Beta | Std.Err. |
| cbsched | designer | **0.223*** ** | 0.037 | **0.238*** ** | 0.046 | **0.220*** ** | 0.045 | **0.232*** ** | 0.050 |
| | disciplinary leader | 0.240 | 0.041 | **0.288*** ** | 0.047 | 0.305*** | 0.044 | **0.362*** ** | 0.052 |
| cbv | designer | -0.036 | 0.026 | 0.007 | 0.032 | **-0.106*** ** | 0.031 | **-0.091*** ** | 0.035 |
| | disciplinary leader | **0.108*** ** | 0.029 | **0.153*** ** | 0.033 | **0.062*** ** | 0.031 | 0.026 | 0.036 |
| cbh | designer | **0.141*** ** | 0.025 | **0.184*** ** | 0.031 | **0.262*** ** | 0.030 | **0.176*** ** | 0.034 |
| | disciplinary leader | **0.083*** | 0.024 | **0.100*** ** | 0.027 | **0.132*** ** | 0.025 | 0.025 | 0.029 |
| cbsm | designer | **0.148*** ** | 0.062 | **0.217*** ** | 0.076 | -0.060 | 0.075 | 0.069 | 0.084 |
| | disciplinary leader | 0.039 | 0.053 | **0.260*** ** | 0.060 | 0.038 | 0.057 | 0.038 | 0.066 |
| cbusm | designer | **0.162*** ** | 0.064 | -0.007 | 0.079 | **0.230*** ** | 0.078 | 0.004 | 0.087 |
| | disciplinary leader | 0.012 | 0.052 | **-0.156*** ** | 0.059 | -0.001 | 0.056 | 0.012 | 0.066 |
| CP | designer | **0.167*** ** | 0.054 | **0.200*** ** | 0.045 | **0.478*** ** | 0.049 | **0.193*** ** | 0.037 |
| | disciplinary leader | **0.076*** | 0.046 | **0.383*** ** | 0.044 | **0.274*** ** | 0.052 | **0.271*** ** | 0.038 |

The results shows that the use of different coordination mechanism affects design coordination performance: 1) as for the impact on information accuracy: all coordination mechanism is positively related with perceived information accuracy in designer group; only the use of coordination by vertical and horizontal communication is positively related with perceived information accuracy in disciplinary leader group; 2) as for the impact on information relevance: all coordination mechanism is positively related with perceived information relevance in disciplinary leader group; while the contribution of coordination by vertical communication and unscheduled meeting on perceived information relevance is not significant in designer group. 3) as for the impact on information understanding: in designer group, the contribution of coordination by information schedule, horizontal communication and scheduled meeting is positive, the contribution of coordination by vertical communication is negative, and the contribution of coordination unscheduled meeting is not significant; in disciplinary leader group, the contribution of coordination by information schedule, vertical and horizontal communication is positive, and the related with perceived information understanding; the contribution of coordination by meetings are not significant. 4) as for the impact on information timeliness: the use of coordination by vertical communication in designer group is negatively related with perceived information timeliness; the use of coordination by information schedule in both groups and coordination by horizontal communication in designer group is positively related perceived information timeliness. All dimensions of perceived information quality is positively related with design coordination performance. To sum up, it supports that perceived information quality mediates the relationship between coordination mechanism and design coordination performance.

Information processing amount is the sum of all information processing through all coordination mechanisms.

Table 8 Information processing amount as mediator for designer group(n=192)

| Path | Beta | Std.Err. | z | P>z | 90% Conf. Interval | |
|---|---|---|---|---|---|---|
| iefd<-ca | -0.112 | 0.071 | -1.580 | 0.113 | -0.251 | 0.027 |
| iefd<-std | -0.107 | 0.071 | -1.510 | 0.132 | -0.246 | 0.032 |
| cp<-iefd | 0.136 | 0.071 | 1.930 | 0.054 | -0.002 | 0.275 |

Table 9 Information processing amount as mediator for disciplinary leader group(n=265)

| Path | Beta | Std.Err. | z | P>z | 90% Conf. Interval | |
|---|---|---|---|---|---|---|
| iefd<-ca | **-0.385** | 0.087 | -4.440 | 0.000 | -0.555 | -0.215 |
| iefd<-std | 0.093 | 0.090 | 1.030 | 0.305 | -0.084 | 0.270 |
| cp<-iefd | **0.128** | 0.042 | 3.070 | 0.002 | 0.046 | 0.210 |

Tables 8 and 9 show that, for disciplinary leaders: 1) centralization of authority was negatively related with information processing amount (beta=-0.385, p<0.001); for the designer group, the relationship was not significant. 2) No significant relationship was found between standardization and information processing amount. 3) Information processing amount was positively associated with coordination process performance (for the designer group, beta=0.136, p<0.1; for the disciplinary leader group, beta=0.128, p<0.05).

**DISCUSSION**

Both information processing amount(IPA) and information processing quality (IPQ) are positively related with design coordination performance, the impact of IPQ is stronger. The result is consistent with former research on decision effectiveness, in which the impact of information quality is stronger(Keller &Staelin,1987). It suggests that more attention should be paid on improving IPQ. To improve information processing quality, effort can be made on improving information accuracy, relevance, understanding and timeliness.

Information processing amount is the sum of all information processing through all coordination mechanisms. Generally,this study confirmed that project organization structure affects design coordination performance by directing information flow into different coordination mechanisms. Therefore, the following discussion focus on the mediating role of coordination mechanism on the relationship between organization structure and design coordination performance.

As one kind of impersonal coordination, coordination by information exchange schedule has positive contribution on perceived information timeliness. The result is consistent with existing literature. Besides that, this study shows its positive contribution on the other three dimensions (accuracy, relevance, and understanding). While, its contribution on information accuracy is not significant for disciplinary leaders. Possible that is information exchange schedule is good at exchange information embedded in documents. Disciplinary leader normally deal with more ad hoc information processing. As a whole, it indicates that to implement impersonal coordination mechanism where it is possible has potential to increase coordination effectiveness. The positive relationship between management standardization and the use of information exchange schedule is significant in disciplinary leader group but not significant in designer group. Further research is needed to investigate the group differences as well the labour division of coordination task between project manager, disciplinary leader and designer.

Centralization of authority in project organization structure is positively related with the use of vertical coordination for both group. The use of vertical coordination has a negative effect on information processing quality due to its negative effect on perceived information understanding and information timeliness. Possible reason is that, clarification is not sufficient through vertical communication due to high power distance between disciplinary leader and designer in Chinese organization culture. For academic, it indicates that power distance moderate the relationship between coordination mechanism and design coordination performance. For practice, it reminds the supervisor to spare some effort in making sure the subordinate has achieved mutual understanding with him/her.

For disciplinary leaders ,coordination by schedule and vertical coordination are effective coordination mechanisms. Different from designer group, the use of vertical coordination has a negative effect on information processing quality. Therefore, it suggests having more horizontal communication for designers, as the results show horizontal communication has positive contribution for all dimensions of information quality in designer group. The adjustment could be made through empowerment or allocating more coordination task to designer in job design.For designers group, coordination by schedule as and group meeting are effective coordination mechanisms.

By directing information into vertical coordination, centralization of authority has a negative impact on design coordination performance between disciplinary leader and designer and a positive effect on coordination performance between project manager and disciplinary leader. At the same time, centralization of authority also has negative impact on design coordination performance by reducing information processing amount. The negative impact could be repaired by increasing the level of standardization, as standardization has positive effect on design coordination performance by increasing the use of coordination by schedule.

## CONCLUSION AND FURTHER RESEARCH

This paper has developed a structural-process-performance research model to explain the relationship between organization structure and design coordination performance. It is found out that,by directing information into vertical coordination, centralization of authority has a negative impact on design coordination performance between disciplinary leader and designer but a positive effect on coordination performance between project manager and disciplinary leader. At the same time, centralization of authority also has negative impact on design coordination performance by reducing information processing amount. The negative impact could be supplemented by increasing the level of standardization, as standardization has positive effect on design coordination performance by increasing the use of coordination by schedule. It is also found out that the correlation between information processing quality and coordination process performance is much stronger than that between information processing amount and coordination process performance. Coordination process performance is positively related with design product performance.

This research has focused on interdisciplinary coordination. Although different discipline teams can be drawn from either one firm or from different firms, this study did not distinguish between the two, given that most design task is assign to a single design institute in the context of mainland China where the empirical study is conducted. Further research could investigate the role of organization boundaries in interdisciplinary design coordination.

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