A Scenario Simulation Study of Decentralization on Architecture, Engineering and Construction Companies

Authored by

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A SCENARIO SIMULATION STUDY OF DECENTRALIZATION ON ARCHITECTURE, ENGINEERING AND CONSTRUCTION COMPANIES
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ABSTRACT: Currently there is a propensity that decentralized hierarchy is adopted by organizations. Vast realms of research endeavor have been committed to understand the advantages and setbacks of decentralized organizations, and their results indicate that inadequate decentralization will constrain the creativity of employees while over decentralization may push the company towards chaos. However, little research exists in AEC (architecture, engineering and construction) industry to improve understanding or facilitate prediction of the equilibrium of decentralization. In response to the need, this study focuses on the bidding decision-making in AEC firms to understand how different degrees of decentralization impact on companies’ performance. Agent-based modeling (ABM) approach is applied to test different scenarios in a virtual AEC company. The results indicate that best performance can be achieved only with appropriate balance on centralization and decentralization. Also, when shifting the decision rights from top manager to low level managers or employees, sufficient information and knowledge should be provided to them simultaneously.

KEYWORDS: decentralization; AEC companies; agent-based modeling

INTRODUCTION
The emerging trend that organizations become less hierarchical and more decentralized has captured the attention from business and academic communities (Acemoglu et al. 2007). Rigid and obsolete centralized organizations, known as “Command-and-Control” organizations, have been changed and restructured to decentralized organizations dramatically (Alberts and Hayes 2003; Alberts et al. 2006; Post 2007). This especially occurs in the AEC (architecture engineering and construction) companies because they are mostly project-oriented organizations where new structures are in need to fit with new mentality of project management (Bresnen et al. 2004; Bresnen et al. 2005). The change is due to several reasons: high flexibility to deal with changing environment (Stacey 1996), improved organizational innovation (Hage and Dewar 1973; Chang and Harrington Jr 2000), low cost for information processing and knowledge sharing (Chang and Harrington Jr 2000), emphasis on employee and low-level managers’ creativity and autonomy (Ezzamel 1990; Brockhoff and Schmaul 2002), easy access to sharing resources (Helfat and Eisenhardt 2004), reducing risk and uncertainty (Govindarajan 1986), increasing interorganizational and global networking (Taylor and Levitt 2005; Di Marco et al. 2010; Wong et al. 2010), etc.

However, the benefits of decentralization can be countered by concerns of its potential negative impacts. Christie et al. (2003) pointed out that in decentralized organization,
transferring knowledge to decision-makers on low level of management is indispensable but can be costly. Therefore, a tradeoff between transferring knowledge and controlling costs is necessary (Christie et al. 2003). Also, an organization with an appropriate level of diversity will remain in its equilibrium, while an organization that incorporates overwhelming diversity among its agents’ schemas will tend to move toward chaos (Stacey 1996; Zhong and Low 2009). Moreover, for project-based organization, e.g. AEC companies, decentralization will result in privileging short-term performance on tasks or projects over long-term knowledge accumulation (Bresnen et al. 2004).

In response to the need of finding the desired equilibrium of centralization and decentralization, this study is conducted to analyze the influence of decentralization on companies’ performance. Also, this study attempts to explore that to what extent the decentralization will impact the performance of an AEC company. To narrow the research scope, the scenario of bidding decision-making of an AEC company is selected as the research subject to simulate how decentralization will influence on the bidding decisions and the performance of the company. The reason bidding decision-making is selected is because bidding decisions are recognized as the strategic decisions in AEC companies, which is a part of the entire bidding strategies (Fellows et al. 2001). Existing research on bidding-decision generally focuses on identifying the key factors that influence bid or no-bid (Flanagan and Norman 1982; Ahmad and Minkarah 1988; Shash 1993), but decentralization on bidding decision making or autonomy of low level managers are rarely mentioned. As Christie et al., (2003) summarized that the value of decisions will be mostly maximized if the decision-makers possess the knowledge valuable to those decisions. To facilitate bidding decision making, should the low-level manager or even the employees (estimator, scheduler, etc.) be given the autonomy or “decision rights”? To what degree decentralization will substantially improve the performance and maximize the company’s value? In response to these needs, a bidding decision model is established using ABM approach, and the influence of decentralization on different levels are simulated and analyzed.

This paper is presented in several parts. First, the literature in decentralization within project-based organizations, especially AEC companies, is reviewed to understand why decentralization is important to organizations and what gains and setbacks decentralization will lead to. Then, existing research on bidding-decision making is investigated to reveal the inadequacy of study on decentralized bidding decision-making. Then the methodology of this study is presented and a bidding decision-making model is established on 3 different decentralization levels under 5 scenarios. Each scenario is simulated to identify their emergent attributes. The results are presented and discussed and conclusions are summarized at the end of this paper.

BACKGROUND

Decentralization in AEC Companies

AEC companies are characterized with simultaneous implementation of various projects and control of multiple input sources (Yu et al. 2007). They are typically classified as
project-based or project-oriented organizations. In such organizations, decentralization, along with short term emphasis on project performance and distributed work, is one of the key features (Bresnen et al. 2004), and thus this type of organizations operate within networks of relations. Bresnen et al.'s (2005) further research pointed out that the distinctive feature of a project-based organization, including its decentralized and dispersed mode of working, affects the interactions of the inter-organizational nature.

Studies show that there is a propensity that decentralization can bring benefits in several aspects. First, firms in more heterogeneous environments are more likely to be decentralized because greater heterogeneity makes learning from the experiences of others more difficult (Acemoglu et al. 2007). A decentralized organization will allow and encourage a variety of views and ideas emerge from different groups (e.g., product management, sales), and decision making is dispersed (Olson et al. 2005). Also, a decentralized organization can push down the authority of decision-making to lower organizational levels (Daft 2009). Though it is possible that the decision making and implementation can take longer time, in a dynamic and complex environment, it is likely that the decentralized organization will produce more new ideas and more actual program changes than will a centralized organization in a long run (Robert and Wieland 1980; Olson et al. 2005). In addition, when a task is non-routine and takes place in a complex environment, decentralization is likely to be more effective because it empowers managers who are close to the issue to make decisions and implement them rapidly (Ruekert et al. 1985; Olson et al. 2005). The reason may be that decentralized control delegates authority to a manager, who potentially possesses more information than available in the public history (Acemoglu et al. 2007). The outcomes of these studies show that management in decentralized organization should not seek unanimous control and command but should work toward diversity and different voices in order to keep the system creative and on the edge of chaos (STRöh 1998; Zhong and Low 2009).

However, decentralization may also bring issues to the companies. As Alonso et al. (2008) raised: “...a central question in organizational economics is whether efficient communication and coordination are more easily achieved in centralized or in decentralized organizations”. Although Alonso et al.'s (2008) study concluded that decentralization can dominate centralization even when coordination is extremely important relative to adaptation, but many organizations, as they pointed out, abandoned decentralization and moved to centralization to accommodate increasing needs for coordination. Also, Christie et al. (2003) pointed out decentralization will lead to the shift of decision rights from the top managers to the low-level managers or specialties, and thus requires transferring knowledge to those with the right to make decisions. To maximize the value of companies, “knowledge transfer costs” and “control costs” must be balanced which leads to the trade-off of centralization and decentralization.

The contrary leads to the question whether there is a delicate equilibrium between centralization and decentralization in AEC companies. How can it be found if there is one? To explore the answers, one of the approaches is to set different AEC companies on different levels of decentralization and observe their consequent performances. However, due to the complex nature of operational processes in AEC companies, bidding decision-making instead of the entire
Bidding Decision-Making

To acquire additional projects, bidding is one of the most common approaches for AEC companies (Shash 1993). Therefore, bidding decisions are recognized as the strategic decisions in AEC companies, which is a part of the entire bidding strategies (Fellows et al. 2001). Numerous studies for bidding strategy exist, but most of them concentrate on determination of bidding price. The answer to the key question, “bid or not bid”, is still pending.

In response to answer this “bid or not bid” question, a strand of bidding decision literature posits that some key factors influences on the decision-making process, and thus they should be identified. Flanagan and Norman (1982) identified that bidding behavior is majorly influenced by five factors, including (1) size and value of the project, and managerial complexity; (2) regional market conditions; (3) current and projected workload of the tenderer; (4) type of client; and (5) type of project. Ahmad and Minkarah (1988) presented the factors affection the bidding decision from US contractors, and the result of 31 factors is listed including type of job, need for work, owner, historic profit, degree of hazard, location, labor environment, etc. Similar study is conducted by Shash (1993) that 55 factors and their importance rating from construction industry in UK. Though a relatively large number of factors should be considered for making decisions, they can generally be classified into 3 categories: (1) company situation and experience, like current workload, availability of staff, bonding capacity, etc.; (2) project nature, like delivery methods, project size, project type, project location, labor environment (union or non-union), etc.; and (3) competition, like number of competitors tendering, tendering duration, competitiveness of competitors, etc. These studies provide a general framework to make bidding decisions.

Though analyzing all this factors will be extensively complicated, some studies have been conducted with focusing on certain key factors for bidding decision-making. Drew et al. (2001) using regression model to analyze the effects of contractor’s bidding strategy and the client, type and size of the construction work. Data from large and reputable Hong Kong contractors are collected to test the model, and the results show that contractor’s bidding decision-making is seldom affected by type of construction work but significantly influenced by client type and project size. Bayer and Gann (2006) establish a system dynamic model to explore the relation between bidding strategies and workload dynamics, which including work load, quality, productivity, experiences, anticipated schedule, resource deployment, etc. The results show that overbidding can lead to increasing rework and amplify workload fluctuations. Also, a bidding strategy that uses staff who aren’t currently engaged in project work is superior to having a dedicated work acquisition department.

However, the aforementioned research explains the impacts of different factors on bidding strategies of contractors solely on abstracted and systematic level. Both regression model and system dynamic model are applied to understand aggregated behavior without bottom-up focus in AEC companies (Borshchev, 2004). Also, the change of organizational structures from centralization to decentralization is rarely considered, and thus the impact of decentralization can
hardly be reflected. With emphasis on employee focus, balanced bidding decision-making with consideration of both current workload and acquiring new projects is indispensable. Therefore, it drives the quest of studying on bidding decision-making upon decentralized organizational structure.

**METHODOLOGY**

In a response to the need of further research, this study is conducted by using ABM approach to establish a bidding decision model and analyze how decentralization influences bidding decision-making. ABM reproduces a system by simulating the simultaneous actions of various autonomous individuals, or agents, in a system (Du and El-Gafy 2011). Unlike top-down modeling approaches (e.g., System Dynamics, Discrete Event Simulation etc.), ABM provides insight into the fundamentals of process and sometimes leads to counterintuitive conclusions (Du and El-Gafy 2011). As an emerging computational simulation approach, it has been recognized as a suitable tool for capturing complexity (North and Macal 2007).

The bidding-decision model is established on 3 decentralization level under 5 scenarios based on different decentralization degree and autonomy (Table 1):

<table>
<thead>
<tr>
<th>Organizational Structure</th>
<th>Low-Level Employee Consideration</th>
<th>Decision-Makers Have Knowledge*</th>
<th>Low-Level Employee Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centralized</td>
<td>No</td>
<td>No</td>
<td>No decision-right</td>
</tr>
<tr>
<td></td>
<td><strong>Description:</strong> The high-level manager makes bidding decisions without knowledge or considering employees’ workload. Set as comparison reference.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
<td>No decision-right</td>
</tr>
<tr>
<td></td>
<td><strong>Description:</strong> The high-level manager will make decisions based on knowledge but without considering the employees’ workload. Set as comparison reference.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half-Decentralized</td>
<td>Yes</td>
<td>Yes</td>
<td>No decision-right</td>
</tr>
<tr>
<td></td>
<td><strong>Description:</strong> The high-level manager will make bidding decisions based on knowledge and employees’ workload.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decentralized</td>
<td>Yes</td>
<td>No</td>
<td>Have decision-right. Intelligent agent with memory but no knowledge</td>
</tr>
<tr>
<td></td>
<td><strong>Description:</strong> The employees will make decisions based on their current and past workload. But they don’t know their decisions’ influence on the company.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Yes

Yes

Have decision-right. Intelligent agent with memory and knowledge

**Description:** The employees will make decisions based on their current and past workload, and also the knowledge of their decisions’ influence on the company.

* The knowledge here includes several factors need to be considered when make bidding decisions, including project type, project profit, etc.

To evaluate the influence of decentralization structure upon the company, 5 performance indicators are selected, and their data are collected from the simulation. These performance indicators serve as measures to evaluate bidding decisions. The 5 performance indicators can be divided into 2 categories: (1) performance indicators on company level, including (a) **projects number** in certain amount of simulation time; (b) the rate of **projects delayed**; (c) the rate of **rework**; and (2) performance indicators on individual level, including (a) average rate of **idle time**; and (b) average rate of **workload** (Table 2).

Table 2. Performance Indicators for Current Project

<table>
<thead>
<tr>
<th>Categories</th>
<th>Indicators</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company</td>
<td>Projects number</td>
<td>The number of projects can be finished in a certain amount of simulation time.</td>
</tr>
<tr>
<td></td>
<td>Projects delayed</td>
<td>The percentage of the total number of the finished projects is completed over schedule.</td>
</tr>
<tr>
<td></td>
<td>Rework</td>
<td>The total percentage of the rework amount to the total work amount. Rework is generated from working errors of the employees which change dynamically corresponding to the workload.</td>
</tr>
<tr>
<td>Individual</td>
<td>Idle time</td>
<td>The percentage of the total time an employee has no project to work on over the total simulation time.</td>
</tr>
<tr>
<td></td>
<td>workload</td>
<td>The daily (one simulation step) work amount an employee must finish.</td>
</tr>
</tbody>
</table>

Figure 1 shows the context of the bidding decision model based on ABM approach. After the simulation started, the bidding decision-makers, who has the decision rights, will find new opportunities, evaluate them, and decide whether the company wants to bid on it or not. In a centralized and half-decentralized organization, the high-level manager has the decision-rights, while in a decentralized organization each individual of the employees possesses decision-right. If the decision-makers believe the project can benefit to the company, then the company will bid
on it and win the bidding under certain probability. After that, the project will be added to the model context (shown as the building figures in figure 1). Each new project will be assigned with certain number of employees (links from the buildings to the person figures in figure 1). The employees will work on the project with certain productivity until it is finished. Then the project will be removed from the model context and the employees will be released and stay idle until next project calls him to work on it. Repast Simphony is used as the platform for agent-based modeling.

![Figure 1. Model of Context of a Construction Company](image)

**SCENARIO DEVELOPMENT AND SIMULATION RESULTS**

**Centralized Organizational Structure**

Centralized organizational structure is modeled and used as reference for comparison. The organizational structure is divided into two scenarios. In both scenarios, only the high-level manager in the organization possesses right for bidding decision. In the first scenario, the manager makes bidding decisions only according certain time intervals without any knowledge. Contrary to manager’s ignorance in the first scenario, the manager evaluates new opportunities using bidding knowledge in the second scenario. The knowledge comes from two aspects: (1) project preference, including the project type, project profit, past experience on similar projects, etc.; and (2) company situation, including current workload, required work amount for company operation, etc. These factors are from existing literature of bidding strategies whereby priorities and weights of these factors are assigned based on those investigations. For both scenarios the model is simulated for one hundred times. Performance data are collected for scenarios and summarized to use as reference value. Table 3 shows the average value of the performance measures.

According to data presented in Table 3, manager possesses bidding knowledge can make better bidding decisions for the company. Though with compensation of certain amount of projects, the delay rate and rework rate are decreased and employees are under appropriate work load.
Table 2. Average Result of Performance Indicators of Centralized Organizational Structure

<table>
<thead>
<tr>
<th>Organizational Structure</th>
<th>Projects’ Performance (Ave.)</th>
<th>Employees’ Performance (Ave.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Performed No.</td>
<td>Delay Rate</td>
</tr>
<tr>
<td>Centralized</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without Knowledge</td>
<td>132.74</td>
<td>0.475</td>
</tr>
<tr>
<td>With Knowledge</td>
<td>104.34</td>
<td>0.321</td>
</tr>
</tbody>
</table>

*Productivity rate is defined as the employee’s current productivity divided by his work capability. When productivity rate is over one, the employee is overloaded.

Half-Decentralized Organizational Structure

In half-decentralized organization, the decision right still possessed by the high-level manager, but a bidding decision cannot be made without consideration of the employees’ workload. So the bidding attractiveness is evaluated by three attributes: project preference, need for work, and employees’ workload. Their relations can be defined in the following equation:

\[
BA_i = \frac{P_i \times (W / \sum_{j=0}^{m} W_j)}{IDI^*}
\]

Whereby \(BA_i\) is the bidding attractiveness of the \(i^{th}\) project; \(P_i\) refers to Project Preference, which is determined by project type, project profit, past experience on similar projects, etc.; \(W\) refers work amount for the company to keep its required level of operation. The summation of \(W_j\) (the work amount of \(j^{th}\) project) equals the current total workload of the entire company. The ratio of \(W\) to the current total workload measures the need for pursuing new work. IDI, or individual decentralization influence, is defined as the influence that each overwork employee imposes on the bidding decision. Larger number of IDI means the top manager has more concern about the each employee’s workload. It is powered by the numbers of overloaded employees (n) to demonstrate the employee work load. If the calculated result of Bidding Attractiveness is over certain threshold (set as 1 in this study), then this project will be bid and added to the model context with certain probability.

As an exploratory study, one of the key purposes of this study is to identify how decentralization level influences on company’s performance. In half-decentralized organizational structure, part of the innate appeal of simulation approach is it can potentially provide answer to the question: how consideration of each individual employee, IDI as aforementioned, influence on the bidding decisions and their consequent impact on performance. To explore the impact of change of IDI, sensitivity analysis is applied. The scenario is simulated over 20,000 times with IDI ranging from 1.0 to 6.0. Under each value of IDI, the ABM model is simulated 200 times.

For each IDI, the data of performance indicators are collected and analyzed. Figure 2 shows the number of projects performed during 10,000 simulation steps. The total number of...
projects is keeping declining when IDI increases, but the slope is becoming flat. Due to the requirement to maintain the company’s operation, it is optimal to keep the project number between 90 and 100. Under this range, the desired IDI should be maintained between 1.1 and 1.4.

As discussed before, for the company’s operation, the manager is obliged to keep the value of IDI around 1.1 to 1.4, i.e., a proper proportion of company bidding needs versus individual work load. According to that, the ranges of other performance indicators are presented in Figure 3.

The upper part of Figure 3 (a) shows the rework rate which is defined as total rework amount to the total work amount according to IDI values. The rework rate is declining also along the increasing of IDI value which shows the performance is improving too. The lower part of Figure 3 (a) shows the rate of the delayed projects to the total projects according to IDI values. The delay rate is declining as the IDI increases which indicates the performance of projects on schedule is improving. Apparently, for both performance indicators of delay rate and rework rate, a company would keep them as low as possible.

Figure 3 (b) shows the employees’ performance change according to IDI value. With increasing of IDI, the idle rate is inclining and productivity rate is declining. For both of them,
the slopes also show decreasing. For a company, employee’s productivity should be kept around their capability, which is around 1 in the chart, and idle rate is preferred to maintain as low as possible.

![Figure 3: IDI Influence on Projects’ Performance and Employees’ Performance](image)

While the influence of IDI on company’s performance can be understood by the analysis of the five performance indicators from Figure 2 and Figure 3, the following question is still pending: what bidding decisions have been made from the manager to improve the company’s performance? More specifically, as we know if IDI ranges from 1.1 to 1.4 the performance is optimal, but what are the attributes of the successfully bid projects? Do they show homogeneous attractiveness to the manager or they possess heterogeneous appeals to the decision-maker?

To explore the answer, the number of bidding attractiveness, as defined in equation (1), of all the projects added to the model context have been collected. Analysis shows that the values of bidding attractiveness disperse in a wide range, but with different probability. Most of them, more than 90% of the total projects, are within 1 to 30. Results of bidding attractiveness when IDI equals to 1.1, 1.2, 1.3 and 1.4 are shown in Figure 4. The figure shows that over 25% of all the projects’ bidding attractiveness is less than 2 and 50% of the total projects is less than 4. Only a very small portion of the projects has high appeal to the company. With analysis of the number, the distribution of the percentage of total project number shows that it approximately follows the gamma distribution. The dash line in figure 4 shows the gamma distribution with $\alpha=2.5$ and $\beta=1$. 
Finding the distribution of Bidding Attractiveness is important because AEC companies need to have stable operation and consistent flow of new projects. High value of Bidding Attractiveness means that new bidding opportunities have high appeals to the company, which can be interpreted that the company is persistently under high pressure of finding new projects. It indicates the company doesn’t have sufficient work amount to maintain stable operation. The results shown in Figure 4 confirm that half-decentralized structure allows company to keep stable project flow.

Full-Decentralized Organizational Structure

In the scenarios of full-decentralized organizational structure, the employees, rather than the top manager, possess decision-making rights. The manager, if existing, plays the role of a coordinator. This fully decentralized structure, though seldom adopted by contemporary AEC companies, has some practical examples. The feature of full decentralization is also acknowledged as “Workers Self-management” or “Autogestion” (Manz 1992; Liotta 2001). Simulating bidding decision-making under full-decentralized circumstance is able to discover if it will be helpful while AEC companies increase their decentralization degree.

Two scenarios of full-decentralization are applied as stated before: (1) employees without necessary knowledge; and (2) employees with necessary knowledge.
**Employees without Necessary Knowledge**

In this scenario, the employees possess no knowledge of current situation in the organization. They make bidding decisions solely relying upon their preference, which is determined by historical workload and current workload. Each employee will make their own decisions based on the following equation:

\[
BA_{ij} = \frac{IT / TT}{(OT / TT) \times (W_j / C)} \tag{2}
\]

Whereby \(BA_{ij}\) refers to the attractiveness of the \(i^{th}\) project to employee \(j\) (it equals \(P_j\) in this case, i.e., the self-preference of employee \(j\)). IT is the idle time, TT is the total time, and OT stands for the overload time. \(W_j\) means current work load of employee \(j\), and \(C\) refers to his/her capacity. If self-bidding attractiveness is more than 1, then this employee will vote to bid on this project, and vice versa. If a simple majority, which is more than 10 out of the 20 employees, favor to bid the project, then the company will bid on the project, and add it to the portfolio of projects if it wins the bidding. Table 4 shows the results of the simulation in the scenario.

**Table 4. Average Result of Performance Indicators of Decentralized Organizational Structure**

<table>
<thead>
<tr>
<th>Organizational Structure</th>
<th>Projects’ Performance (Ave.)</th>
<th>Employees’ Performance (Ave.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Performed No.</td>
<td>Delay Rate</td>
</tr>
<tr>
<td>Full-Dentralized (Without Knowledge)</td>
<td>77.26</td>
<td>0.182</td>
</tr>
</tbody>
</table>

*Productivity rate is defined as the employee’s current productivity divided by his work capability. When productivity rate is over one, the employee is overloaded.

The results show that without knowledge, the performance of the company is on a low level and can barely maintain the operation of the company. The employees tend to have more idle time and lower productivity. This scenario can be viewed as an extreme case, which is illustrated in McGregor’s Theory X (McGregor and Cutcher-Gershenfeld 2006). This hypothetic theory assumes workers inherently dislike work and their inherent laziness drives them to avoid work. Though unrealistic and disproved by many modern practices, the results show that without indispensable knowledge, decentralization fails to keep companies’ performance.

**Employees with Necessary Knowledge**

On contrary to the previous one, the scenario that employees possess necessary knowledge is more close to reality. “Knowledge workers”, as Lewis (2003) pointed out, exist in more decentralized environment and comprise the bulk of organizational personnel. Tapscott and Williams (2006) observed strong linkage existing in knowledge workers and innovation in organizations and thus knowledge workers are highly valued in organizations.

Therefore, in this simulation scenario, employees are still the decision makers and final
bidding decision will follow the same simple majority rule. However, when each employee makes decision, not only they will consider their self-preference but also related knowledge including need for work, project preference of the company, etc. Their decision will be based on the following equation:

\[ BA_{ij} = \alpha \times P_j + (1 - \alpha) \times K \]

Whereby \( BA_{ij} \) refers to the attractiveness of the \( i^{th} \) project to employee \( j \). \( P_j \) is the self-preference of employee \( j \) and \( K \) is the knowledge of the company. \( \alpha \) means the weight of self-preference and \( 1 - \alpha \) represents the weight of knowledge. As a decision maker, every employee needs to consider how to balance them.

With the change of \( \alpha \), the simulation data are collected and analyzed. Figure 5 and Figure 6 show when the influence of knowledge increases from 0 to 1, the as self-preference declines, how accordingly the company’s performance changes. The result confirms that when employees make decisions with appropriate knowledge, the performances on the company level and on the employee’s level both show positive increase. But the results also show that when knowledge > 0, the change of performances are not significant. It indicates that the different priorities of considering knowledge will not affect the performance in a significant manner.

**Figure 5. Knowledge Influence on Total Projects Number**
However, when the data been mined deeper, one inspiring relation between knowledge consideration and agree numbers of employees on bidding is discovered. As mentioned before, when a simple majority of the employees aligns agreement on bidding, a project will be bid. Therefore, the number of how many employees agreed on each successful project, showing the project attractiveness to these employees with decision rights, is also collected from the simulation. Figure 7 shows the distribution of bidding attractiveness under different knowledge influence. As the legend indicates, different color scales represent different number of employees agree on bidding, and the area of each color show its portion of the total projects. When there is no knowledge provided to the employees, their votes show substantial diversity. But with the increase of the influence of knowledge, this diversity starts diminishing and finally shows significant homogeneity.
Figure 7. Knowledge Influence on the Number of Employees Voting for Bidding

The line in Figure 8 presents the change of the mean number of employees voting for bidding. The result confirms the diminishment of diversity when employees make bidding decisions. The answer to this emergent phenomenon is that the diversity is only a collectivity of employees’ preferences. Contrary to this individual attributes from the employees, the knowledge is generally on company and project level, and different employees will receive similar, if not identical, knowledge. When they increasingly consider the knowledge and make bidding decisions, the alignment of voting will inevitably increase.
DISCUSSION

This study investigates how the shift of organization structure and thus “decision rights” will influence the performance of project-oriented organizations, especially AEC companies. Bidding decision-making is selected due to its importance to AEC companies as a part of the entire bidding strategies. Some of the findings of this study are worth of further discussion and potentially provide unique contribution to the research community.

1. As organizations increasingly emphasize on employee focus, decentralization can benefit organizations to certain extent. With comparison between scenarios of centralized structure and half-decentralized structure, performance shows significant improvement in half-decentralized organization. When the manager makes bidding decisions with consideration of the employees’ workload, the delay rate and rework rate of projects keep decreasing and the employees are able to enjoy less workload. As long as the manager can balance the focuses between organizational requirements and employees’ needs, and keep the work amount of companies in the allowed range (IDI from 1.1 to 1.4 in Figure 2), decentralization will benefit the companies.

2. Over decentralization, as the full-decentralized structure in this study, fails to improve the performance of bidding decision-making. The simulation results show that when given decision rights, the employees cannot maintain performance as the half-decentralized structure. Even with necessary knowledge, the total projects can be performed are around 85 which can hardly fulfill the organizational requirement. This seems to contradict with current trends of decentralization in other industries, and one possible reason to this question is that decentralized structure is adopted by creative industries and organizations. Studies show that decentralization and innovation have high correlations, and therefore, more autonomy and decision rights will allow employees in these organizations to unleash their creativity and
thus add value to the company (Hage and Dewar 1973; Chang and Harrington Jr 2000). These innovative workforce has formed a new “creative class” (Florida 2002). Construction industry, on the other hand, as a whole is lack of innovation (Eccles 1981; Koskela and Vrijhoef 2000; Tangkar and Arditi 2004; Taylor and Levitt 2005), and thus, lacks such a “creative class”. Therefore, the full-decentralized structure is less fit with operation of AEC companies.

3. Based on the comparison of the two fully-decentralized scenarios, it is discovered that knowledge workers are vital to organization and should comprise the majority of the personnel in a company. The simulation results (Figure 5 and Figure 6) indicate knowledge workers tend to be more responsible and make more effective decisions. This discovers that decentralization should not be only focus on the shift of decision right. When providing more autonomy to the low-level personnel, necessary resources, e.g. information and knowledge, should be provided to them.

4. In decentralized organization, exposure of knowledge to employees will decrease the diversity of their decisions. This emergent uniformity from a collectivity of employees is the consequence of influence from factors on system level, a.k.a., knowledge on project or company level. Without knowledge on project or company level, the autonomous employees will make decisions only based on their own preferences, and thus their individuality will dominate the decisions. However, when they possess the information and knowledge, and more important, when they understand how the information and knowledge are correlated with the organization and furthermore with themselves, they will be driven to make more responsible decisions. And these decisions will align with the goals to improve the performance in an AEC companies. Since the information and knowledge are similar or even identical (depend on how the employees process them), their decisions show homogeneity.

Due to the lack of study on decentralization in AEC companies, this study attempts to explore the influence of decentralization by using a simulation approach. As an exploratory study, it aims to provide answers of what the construction companies should do as well as what they should not (Couclelis 2002). One limitation of the study is some factors, like cooperative behaviors in a full-decentralized organization, are not considered and simulated. These factors, by influencing the formal and informal networks in a company, can affect the outcomes of bidding decision-making. Also, a consideration of the diversity of individual decisional processes should be considered in future work. All these limitations will try to be fulfilled in further research.

CONCLUSIONS

This research attempts to explore the influence of decentralization on project-oriented organizations. Bidding decision making of an AEC company is applied as the research subject because it is a part of the organizational strategy. To conduct this study, agent-based modeling approach is adopted to simulate scenarios of construction companies under different organizational structures, namely centralized structure, half-decentralized structure and fully decentralized structure. Data of the simulation are collected and analyzed to evaluate the
performance of the companies under different scenarios.

The study reveals that increase of decentralization will influence the performance of companies and inevitably lead to the shift of “decision rights” eventually. But this change cannot consistently bring positive outcomes. The simulation results prioritize half-decentralized organizational structure to others, because it enables the manager to achieve balance between maximizing company value and employee focus. Full-decentralized structure fails to achieve such balance due to the lack of innovation and “creative class” in construction industry and companies. This study also confirms that knowledge workers should comprise the majority of a construction company.

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