Managing Information Flows for Quality Improvement in Construction

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Abstract

The construction industry has always been bedeviled with great difficulties in sharing information among its participants. Although many construction firms have claimed to be ISO 9000-certified, there is still missing an effective channel of information flow for quality management. There are information asymmetries in quality management from internal and external organizations. Internally, information asymmetry exists between contractor, subcontractors and suppliers; and externally, there is no information sharing mechanism between project departments; information feedback is more difficult than information transferring in a construction firm. This paper analyses the channel of information flow for quality management. It proposes to reengineer current management strategy for establishing an effective information network for quality management.

Keywords: Information flow, asymmetry information, quality management, projects

Introduction

It is almost a commonplace to describe the current business environmental setting as turbulent. The marketplace has become more global and service oriented and clients' tastes have become more demanding and sophisticated (Albino *et al.*, 2002). Under this circumstance, many firms have found it is increasing difficulties to compete. To survive in the current business environment, it is necessary to look for ways to improve quality and productivity in order to enhance their competitive edges (Tan *et al.*, 2003).

Since the introduction of ISO 9000 in 1987, the number of organizations certified under the scheme has been constantly increasing all over the world. The implementations and certifications of quality system on ISO 9001 have been a major activity for many organizations and become a widespread phenomenon (Yeung *et al.*, 2003). Many studies revealed that effective implementation of ISO 9000 quality standards can benefit the certified-organizations through the improvement of management control, efficiency, productivity, and customer services (Terziovski *et al.*, 2003). According to a survey conducted by the International Organization for Standardization (ISO), global ISO 9001:2000 registrations surpassed the 500,000 mark at the end of 2003 (ISO, 2004), in which it can show the concerns of quality improvement.

Among all industrial sectors, the construction industry has the third highest number of ISO 9000 certificates (Chini and Valdez, 2003). This indicates the construction firms' active attitude is facing the international standards series. In construction, the final product is produced by activities in process. However, construction process is not of a production line in the manufacturing industry but is composed of concurrent activities on a construction site. Quality assurance in construction focuses on process control (Arditi and Gunaydin, 1998). In practice, it is more difficult to implement the scheme for quality

assurance in the construction industry than in manufacturing industry due to the characteristics of the construction setting (Tam *et al.*, 2000). Hence the proportion of the construction firms of ISO 9001 certified which deemed ISO 9001 an effective quality management means is not high (Zeng *et al.*, 2004).

ISO 9001 focuses on confirming process conformance from the initial development of a product through production, test, installation and servicing. Information management has been a key factor affecting the effective implementation of the standard (Cipriano, 1995). The information management system required for this standard is not just a database with predefined reports; rather, it is the support for trouble-shooting, decision-making and knowledge management (Lari, 2002). Due to dispersed projects undertaken by a construction firms, effective information flows among project teams for a firm is very important in implementing quality assurance (Jaggar *et al.*, 2001).

There are number of literature studies on quality management in construction. Nevertheless much of the literature focuses on quality management system and factors affecting quality. It appears that little research was conducted to investigate information flows in quality management in construction. Thus this paper explores information requirements and information flows in quality assurance. The analysis could be helpful for quality management in pursuing continuous quality improvement in construction.

Previous studies

The literature has been descriptive; in particular, describing information flow in an organization for improving production and quality for the organizations. Albino *et al.* (2002) proposed a methodology to describe and analyze the information flows involved in the coordination of production process. They developed the concept of coordination load

associated with process based on (i) the structure of the considered process, in terms of dependencies among process tasks, (ii) the adopted coordination form, in terms of who decides and executes what, and (iii) the context, in terms of uncertainty, variability and equivocality. A study by Fok *et al.* (2001) explored the inter-relationships among three organizational factors: total quality management program adoption, information system development and culture.

Lari (2002) analysed the information requirements of ISO 9000 standards and identified the areas where a decision support system could be used. They developed a conceptual framework for company-wide information management, which explained the modular approach to the system development by introducing and empirically testing the prototype model in a corrective and preventive actions module. The proposed system will provide the conceptual structure for quality assurance information system within organizations. Beckett *et al.* (2000) described the practical application, in an industrial setting, of an information system designed to support continuous improvement. This system, based on a quality monitoring system, differs from conventional application in that it seeks to support both quality conformance and continuous improvements to design and research activities. Tan *et al.* (2003) proposed a quality information structure within WWW-based intranet infrastructure and analysed the role of quality information system (QIS) in the e-commerce integrated environment. Four main functions were constructed via six basic modules. Each function was described with IDEFO (what is the full name of IDEFO?) diagrams. Under this QIS, organizations will be better able to manager their quality related knowledge.

Some researchers paid attention to the role of information management in quality management in construction. Pietroforte (1997) proposed a conceptual framework for

interpreting the impact of different organizational forms of transaction on the use of information and communication in the building process. Baldwin *et al.* (1999) produced a generic model of the conceptual and schematic design process for building data flow diagrams. Ndekugri and McCaffer (1998) outlined information flows of basic management functions of the construction firm for planning, estimating, cashflow forecasting, cost control, and accounting.

Information and information requirements

Information definition

There are numbers of definitions on information. For example, Checkland and Howlell (1998) suggested that information could be defined as some data selected for a specific purpose. Information about a construction project quality is communicated to whoever needs it, whenever they need it, in whatever form they need it so that they meet their objectives for quality management and improvement (Ndekugri and McCaffer, 1988). It has stated that quality information management is concerned with communication and covers its acquisition, generation, preparation, organization and dissemination, evaluation and management of information resources (Jaggar *et al.*, 2001). Also, many researchers studied the characteristics of information flows and the coordination form within an organization (Austin *et al.*, 1994; Barua and Ravindran, 1996). Information flows are typically characterized by evaluating the number of messages and information processing activities that occur in firms. The uncertainty and equivocality of information result in the complexity of research on information flows (Jehiel, 1999).

Information in quality management system

The ISO 9000 standards describe a set of fundamental elements that enable the design and implementation of quality management systems. The ISO 9000:1994 standards contain three auditable certification standards, i.e., ISO 9001/2/3. They provide corresponding clauses for different types of business including companies that design their own products and services (20 clauses), companies that do everything except design (19 clauses), and companies where products and services can be verified only by inspections and tests (16 clauses).

Major changes were incorporated in ISO 9000:2000 version. The latest ISO 9001:2000 revision is based on the following eight quality management principles: (i) customer-focused organizations; (ii) leadership; (iii) involvement of people; (iv) process approach; (v) system approach to management; (vi) continual improvement; (vii) factual approach to decision making; and (viii) mutually beneficial supplier relationships. Based on these eight guiding principles, the 20 clauses of the ISO 9001:1994 were revised into the following five main management requirements: (i) quality management system; (ii) management responsibility; (iii) resources management; (iv) product realization; and (v) measurement, analysis, and improvement (see Figure 1). The ISO 9001:2000 standards integrated the three auditable certification standards, which places emphasis on process management and resource management and has commonality of architecture with ISO 9004, so that quality assurance requirements and quality management can be aligned holistically.

Figure 1 ISO 9001:2000 requirements

ISO 9001 is a documentation-based communication tool, therefore some information is indispensable according to certain clauses of ISO 9001 (Tan *et al.*, 2003). The types of information and their related clauses are listed in Table 1.

Table 1 The types of information and their related clauses of ISO 9001 standard

Information	Clauses	Descriptions
Document management	4.2.2 Quality manual	The organization shall prepare a quality manual that shall include a description of the elements of the quality management system and their interaction and the system level procedures.
	4.2.3 Control of documents	The organization shall establish quality management system level procedures for the operation of the quality management system. A master list or an equivalent document control procedures, identifying the current revision status of documents, shall be established and be readily available.
	4.2.4 Control of records	Quality records appropriate to the organization shall be maintained to demonstrate conformance to the requirements and the effective operation of the quality management system.

Message exchanges	5.5.3 communication	Internal	The organization shall establish and maintain procedures for internal communication between the various levels and functions regarding the quality management system and its effectiveness.
	7.2.3 communication.	Customer	The organization shall implement arrangements for communication with customers to meet customer requirements.
	5.6 Management review		To provide the management of information help to define, document and control their quality policy. Information requirements include review meeting to assess quality systems; organization chart, and job descriptions.
	6.2.2 Training		To provide information that can detect the training deficiencies and provide plans to keep all employees updated and equipped with the required knowledge. Information requirements include training records; training plans; courses; teachers; educational service providers; quality manual.
	8.2.2 Internal audits		To appraise processes to determine whether they are operating within their documented procedure and to decide whether they are effective for their intent. Information requirements include quality audit reports; corrective and preventive action reports; quality manual; quality plan; procedures; forms; standard operation sheets; checklists.

Information requirements in quality management

In the construction industry, contractors have to collect much external and internal information as information input for quality management. The external information required includes: i) client's requirements on quality; ii) project supervisors; iii) relevant quality standards for checking; iv) subcontractors; and v) material suppliers and vendors. And, internal information required includes: i) organization structure; ii) quality management system; iii) quality management plan; iv) information of construction technology; v) information of construction equipment; and vi) workers. The inputted information needs to be processed and utilized effectively and becomes conducive to quality management (see Figure 2).

Figure 2 Information flow chart

From Table 2, it indicates that information exchange is the necessary part in implementing the ISO 9000 successfully. Therefore it is important for construction firms to create environment and culture for sharing information.

Table 2 Major clauses of ISO 9000 on information exchange for quality management
in construction

Clause in ISO 9001:1994 vision	Clause in ISO 9001:2000 vision	Descriptions on important items
•Contract review (4.3)	•Documentation requirements (4.2)	Client's requirements on quality
• Document and data control (4.5)	•Documentation requirements (4.2)	Quality manual, quality records, quality checklists
•Purchasing (4.6)	•Purchasing (7.4)	Evaluation on subcontractors and suppliers
•Process control (4.9)	•Provision of resources (6.1)	Key construction process control
	• Planning of product realization (7.1)	
•Inspection and testing (4.10)	•Control of monitoring and measuring devices (7.6)	Key process and major material

• Control of nonconforming product (4.13)	•Control of nonconforming product (8.3)	Control measures
•Corrective and preventive action (4.14)	•Improvement (8.5)	Preventive action
• Handling, storage, packaging, preservation & delivery (4.15)	•Production and service provision (7.5)	Preservation of built parts
•Internal quality audit (4.17)	•Internal audits (8.2.2)	Common quality problems
•Servicing (4.19)	•Customer-related processes (7.2)	Feedback on quality from clients
•Statistical techniques (4.20)	•Analysis of data (8.4)	Sample data

Information flows in quality management

Given a construction firm, it has three levels within organizational structure including firm, sub-firms and project departments. The multi-level organizational structure renders many difficulties in information transferring and feedback (Loosemore, 1998). In general, the firm level but sub-firms level or project department level plays a pivotal role in certification of the ISO 9000 quality assurance systems. Much of the work including quality manuals and procedures document writing, training, internal audit and management review are organized and finished by the quality assurance group in the firm level. Indeed, the plan of quality assurance must be implemented by all the project departments. Thus information flows including information transferring and feedback among all the different levels in a construction firm will form the necessary foundation for effective quality management and quality assurance.

The ISO 9000 quality assurance systems highlight more effective information exchange in quality management. In this paper we assumed that information is transferred from high to low level (that is from firm to sub-firms and project departments), and

information feedback is from low to high level (that is from project departments and sub-firms to firm) (see Figure 3).

Figure 3 Information flows on quality management

The construction industry has always been bedeviled with great difficulties in sharing information among participants. In general two major kinds of information flows are including: (i) information transferring from project departments to firm; and (ii) information exchange between project departments. Information transferring is easier than information feedback due to the industry-specific characteristics. For example, according to requirements of “purchasing” in Clause 4.6 (in ISO 9000:1994), a contractor needs to create lists of qualified subcontractors and qualified material suppliers. When the firm has chosen the qualified subcontractors and material suppliers, he will create lists covered the qualified candidates and transfer the information to sub-firms and project departments. On the basis of the lists, each project department has to choose the candidate from the lists.

Barriers in information flows in quality management

To examine information barrier in business process is important for managing information flow in quality improvement. Theodoros and Phillip (2005) discussed three fundamental types of information barriers in market research and business intelligence executives. Stephen *et al.* (2004) discussed information problems in e-commerce system for construction material procurement and provided recommendation to avoid them. Ma *et al.* (2004) introduced the deficiencies in the information exchange process among multi-parties in project and discussed the way of using XML to support information exchange in construction projects.

In this paper, three types of barriers to information flows in quality management were examined, as outlined in Figure 4.

Figure 4 Barriers triangle in information flows in quality management

- (1) Organizational barriers: these are barriers due to the organizational structure of the firms involved in a construction project; include multi-level structure barriers and horizontal communication barriers.
- (2) Behavioral barriers: these are barriers mainly due to behavioral characteristics of

related persons and posts; include uncompulsory liability and lack of incentive mechanism.

- (3) Technical barriers: these are barriers mainly due to the technical characteristics of information in construction projects. Lack of information collaborative system and application in different projects are two main aspects.

For current organizational structure of most construction firms, multi-level structure and horizontal communication barrier might affect efficiency of information flows if there were no suitable information exchange process. According to the scope of information, the information management in a construction project can be divided into two categories, i.e. the management of internal information and that of exchanged information. The former denotes that within each party, for example, the information management within a contractor; while the latter denotes that across at least two parties to collaborate their activities. Multi-level structure and horizontal communication barrier are the main information barriers separated the former and later.

Given one of project departments found that some supplier provided non-conforming materials, he maybe delivered the information to sub-firm. The sub-firm would feedback the information to the firm, and then the firm transferred the information to other sub-firms, which would transfer it to their project departments (see Figure 5).

Figure 5 Current information flows in a construction

Note: the oval in shadow represents the project department unveiled that some supplier provided non-conforming materials.

From Figure 5, it indicates that it needs four steps for information flows from the beginning that one of the project departments found that some supplier provided non-conforming materials to other project departments obtained the information. In general the project department unveiling the problem could not sharing the information directly with other project departments due to horizontal communication barriers, namely, no economic and administrative links. Thus the complicated information flows resulted in problems, such as that, other project departments could not obtained the information if information flows suspension occurred. Under this case, it is possible for these project departments to continue purchasing materials from the unqualified supplier, which could result in severe effects on the final products constructed.

Therefore reengineering the existing information flow channels was a major consideration for the construction industry. If a project department found an unqualified subcontractor or material supplier, he should feedback the information to the firm immediately and transfer it to other project departments at the same time (see Figure 6).

Figure 6 Improvement of information flows in a construction firm

Note: the oval in shadow represents the project department unveiled that some supplier provided non-conforming materials. The dotted line represents the omitted information flows.

From Figure 6, it shows that all of the project departments share information and exclude the unqualified material suppliers. For intermediary processes of information flows, it decreases the risk of suspension of information flows. The unqualified subcontractor or supplier is then deleted from the firm's qualified lists in time.

Secondly, administrators' liability and incentive mechanism are missing in related information transfer processes, they might block information flows in quality improvement.

In the construction industry, asymmetry information includes two aspects from interior and exterior of a construction firm.

On one hand, asymmetry information is reflected from a contractor, subcontractors and suppliers. In general, subcontractors and suppliers could understand the contractor's requirement on quality. On the contrary, contractor grasps a little information on the competence of quality management of subcontractors and suppliers, *inter alia*, the small sizes. Moreover, there is no formalized division of work and economic relationship, but administrative link, between firm, sub-firms and project departments. The liability of the

leader in a firm for the performance of firm is different from project managers' liability. This is likely to tempt project managers to take high-risk decisions and actions. The potential success of the actions might lead the project managers to high rewards. Nevertheless, the failure of these actions could cause huge financial loss to the firm. Therefore quality problems in construction due to utilization of low quality materials are not strange in China. That is to a great extent dependent on reform of enterprise's ownership.

On the other hand, asymmetry information in a construction firm reflects the imbalance of information transferring and information feedback. The information on quality management transferred from the firm to sub-firms and project departments is much more than information feedback from the departments to firm. Project departments concentrate their attentions on construction quality of the project undertaken by them. In general, they did not share information with their counterparts directly.

Thirdly, information share among all parties and application in different construction projects can hardly technically realized if firms didn't have necessary IT infrastructure, information collaborative system and related business process. They are main technical barriers of information flows in quality improvement.

Discussion

Construction industry has two particular characteristics: (1) there are many participants involved in a single project. (2) combinations of participants are various in different construction projects. The former requires an effective information collaborative system to realize information share among multi-parties in a project. The later requires that this information collaborative system can be applied in different projects even the

combinations of participants are changed.

Consider these two characteristics, a web-based approach can be proposed to develop a system for information flows in quality management in construction projects. The use of the internet as the communication platform can help information transfer more effectively during the construction process. Developing a communication system for the multiparty in construction projects to collaborate on web can also improve information flows in construction project management. On the other hand, new participants in different projects can also learn to use such a web-based information system in little time and low cost. It is obvious that the technical problems can be overcome by utilizing the information and network technology that prevails in recent years.

Reengineering the existing information flow channels is necessary in the construction industry. For a project department, once he found information on construction quality, such as unqualified subcontractor or a material supplier, he should feedback the information to the firm immediately and transfer it to other project departments at the same time. Currently, information feedback step by step is not conducive to quality management.

Conclusions

The construction industry has always been bedeviled with great difficulties in sharing information among its participants. Information flows and exchanges are very important in implementing ISO 9001 and improving quality management. Due to the characteristics of the construction industry, information transferring is easier than information feedback in a construction firm's quality management. In general there are two information asymmetry including internal information exchanges and external information opacity.

Thus it is important for construction firms to reengineer their information flow channels for decreasing risk due to information flow suspension. That needs construction firms to create a culture and environment to conducive to sharing information.

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