INFORMATION TECHNOLOGY AND COLLABORATION IN THE CANADIAN CONSTRUCTION INDUSTRY

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ABSTRACT

Information plays an essential role in construction because it specifies either the resulting product (design information) or the activities that need to be carried out in order for the product to be constructed (management information). The new information technology is impacting how this information is exchanged and how organizations operate because its purpose is to facilitate the exchange and management of information and it holds a lot of potential for the fragmented construction industry. To better understand this impact, a survey was carried out in Canada to inquire about communication, efficiency, and IT usage. Its focus is on collaboration among the various stakeholders. Collaboration implies that people with at least one common goal interact (through efficient communication), share (through generous cooperation) and coordinate themselves (through synchronicity). Little is known about the technologies used and how they impact collaboration. How do stakeholders interact? What information is shared? How does coordination occur between firms and within firms across functional lines? This exploratory study aims at providing insight into these questions. The authors created a questionnaire designed to assess issues related to information technology usages. The questionnaire has eight parts: socio-demographic questions to identify the context of the respondent and his/her firm; questions on IT usage which listed 17 different communication methods or devices (from fax to web portals and groupware) and evaluated their usage frequency as well as their perceived efficiency; questions on preferred IT use requested the most efficient technology or communication modality for contacting specific stakeholders; questions on the frequency of electronic transfer of key documents; questions to assess the perceived performance of the individual

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and the team; questions to identify if there is resistance to the adoption of IT; and questions on interdependence to assess how the respondents perceived the importance of their relationships with key stakeholders. The preliminary results indicate that people in the construction industry prefer traditional, low-tech communication modalities across stakeholders and project phases such as phone calls, face-to-face meetings, and e-mail. The respondents did not perceive in general a high resistance to the adoption of IT and they see their work only as relatively interdependent with that of other stakeholders. Given the high fragmentation of the construction industry, improvements in communication efficiency would positively impact project performance.

KEY WORDS

Construction industry, Survey, Information technology, Collaboration, Information exchange.

In the USA, construction accounts for approximately 10% of the gross domestic product (GDP) and about $450 billion (1996 estimates in US dollars) (Castle, 1999). In Canada, the situation is similar:, construction accounts for approximately 5.4% of the GDP and about $55 billion (for 2003 in 1997 Canadian dollars) (Industry Canada, 2005). Despite these figures, the industry lags behind others in terms of mechanisms fostering coordination among key players, in part because of how the industry is fragmented. The scarcity of applied research conducted on and in the industry could be a reason (Goczol & Scoubeau, 2003).
The construction industry is comprised of an array of intertwined businesses roughly divided into two types : design and construction (Castle, 1999). The construction industry is characterized by two kinds of fragmentations. The first occurs vertically and refers to different businesses or functional groups handling the different phases of the building delivery process. For example, design is the province of architectural and engineering firms while construction itself is taken care of by an array of contractors. The second kind of fragmentation is horizontal. Design and construction may include many, typically small firms providing complementary pieces to the overall puzzle (i.e., different firms handle different systems: structure, mechanical systems, envelope, interior, etc.). Construction project thus occur across these different fragmented contexts where intra-organizational and inter-organizational factors affect team effectiveness, much like what is occurring in other sectors due to globalizing pressures (Gibson, Zellmer-Bruhm, & Schwab, 2003). Consequently, perhaps even more than in other industries, the construction industry would greatly benefit from enhanced communication and collaboration (Grilo, Betts, & Mateus, 1996).

Collaboration implies that people with at least one common goal *interact* (through efficient communication), *share* (through generous cooperation) and *coordinate* themselves (through synchronicity) (Levan, 2004). Hence, one can see that, by definition, fragmentation greatly hinders collaboration across the value chain. This problem is compounded by the industry's low technological involvement (Castle, 1999) and our experience as to adversarial climate generated by the way projects are procured.

INTERACTION

Little is known of what IT means construction industry stakeholders prefer to use to interact, or is considered more effective whether the problem is considered from the sender's perspective, the receiver's perspective or as a function of project phases.

The concept of technological uncertainty might be a valuable lens to answer this question (Shenhar, 2001). Shenhar (2001) suggests that the ways problems are solved in a project management environment depend on a continuum of technological uncertainty. Two elements are necessary to understand the continuum: the complexity of the technology involved in the outcome of the project (e.g., a bungalow vs. a highrise) and the complexity of the technology involved in producing the outcome of the project (e.g., a hammer vs. a GPS controlled bulldozer). At the low uncertainty end of the continuum, when both technologies are known, management can afford to be rigid and place less emphasis on communication. At the high uncertainty end of the continuum, both are unknown and need to be harnessed during the project. This context calls for speeded decision making, management flexibility, and richer and less formal communications. In a highly interdependent work process designed to create something new, communication among project team members needs to be efficient (MacMillan, Entin, & Serfaty, 2004) and persuasive (Chiocchio & Lafrenière, Submitted) to be effective. Because of the vertical and horizontal fragmentation of the construction industry, it is unclear that such high velocity high quality communication is possible.

An interesting problem arises when we use this continuum and deploy it though construction project phases and across industry stakeholders. For example, relatively complex IT tools are used during design among architects (e.g., 3D representations Computer assisted design software such as Autocad). This IT may not be recognized as useful or efficient by other stakeholders during this phase or at later phases. Hence, fragmentation also occurs across technologies.

SHARING

The construction industry is undergoing a paradigm shift with respect to the exchange and management of information. To keep abreast of these changes, two studies were made to assess the penetration of and the use of information technology (IT) in the industry.

In 1998, a survey on the current and planned use of IT and its impact on the architecture, engineering, and construction (AEC) industry in Canada was conducted (Rivard, 2000). It was found that many business processes are now almost completely computerized and the tendency is toward a greater computerization of the remaining processes. IT has also raised productivity in most business processes and has resulted in an increase in the quality of documents, an increase in the speed of work, better communications, simpler and faster access to common data as well as a decrease in the number of mistakes in documentation. However, the benefits of IT come at a cost since the complexity of work, the administrative needs, the proportion of new operations and the costs of doing business have all increased. Furthermore, although the Internet has been adopted by most firms surveyed, design information is still exchanged in its traditional form.

A related study gathered eleven case studies from across Canada in the summer of 2002 to define an initial compendium of Best Practice in the use of IT in construction (Rivard et al., 2004). The professionals interviewed included architects, engineers, general contractors, and owners at the cutting edge in their use of IT. The documentation of their pioneering use of IT demonstrated how useful these technologies can be and what potential pitfalls are of concern. The following technologies were demonstrated: 3D CAD; commercial Web portals; and in-house software development.

COORDINATION

Explicit coordination occurs when team members articulate their plans, actions and responsibilities (MacMillan et al., 2004) either using task programming mechanisms or by simply communicating about it (Espinosa & Javier Lerch, 2004; Serfaty, Entin, & Johnston, 1998). Highly coordinated interaction is mostly implicit. Implicit coordination occurs when individual's actions rely upon a shared understanding that lessens the need for obvious and deliberate communication on coordination (Espinosa & Javier Lerch, 2004). Arguably, a shared mental model is acquired first through explicit coordination communication (MacMillan et al., 2004). Coordination is improved when team members can explain other members' actions, be updated on tasks, develop accurate expectations about members' actions and have shared vocabulary (Espinosa & Javier Lerch, 2004). Recent work on multi-team issues using undergraduate psychology and business students reveal that a shared mental model fully mediates the relationship between the leader strategy (external and overarching) and inter-team coordination (Dechurch, 2003).

In the construction industry, it is unclear if or how coordination, explicit or implicit, occurs between firms and within firms across functional lines. The concept of team may not even apply. If it does, teams working towards proximal goals often have difficulties aligning themselves with other teams despite sharing a distal goal (Tjosvold, 1984).

To summarize, although some advocate the better use of communication as a coordination tool in the construction industry and imply that trust among and between stakeholders is essential (Goczol & Scoubeau, 2003), not enough is known to deliberately and efficaciously act to ameliorate communication and impact construction project performance. Despite the importance of communication in project management (Pinto & Slevin, 1988) and the importance of the construction industry as a sector of the economy in North America, research focussing on communication in this industry is surprisingly scarce (Goczol & Scoubeau, 2003).

This exploratory study aims at providing insight into means by which key players in the construction industry communicate. Key questions are: Who uses what technologies? With whom do they use them with? During what phases of construction projects do they primarily use them? Does it make individual and teams more efficient and productive?

METHOD

QUESTIONNAIRE

The authors created a questionnaire designed to assess issues related to information technology usages. **Socio-demographic** questions were asked such as age, background (e.g., engineer, architect, technologist, and management), number of subordinates, and position of respondent, as well as type of firm (e.g., architecture, engineering, general contractor), type of construction (e.g., residential, commercial), budget size of construction projects, and number of employees.

IT usage. A list of 17 communication methods or devices was then elaborated based on a literature review, available technologies and authors' experience in the field of construction : a) typical face-to-face meetings, b) phone with one colleague, c) phone or video conferencing, d) fax, e) private courier, e-mail f) with and g) without attached documents, documents obtained from h) an FTP site or i) web portal, devices such as j) paget, k) regular cell phone, l) walkie-talkie type cell phone, electronic planner (or personal digital assistant) m) without and n) with cell phone capacity, o) portable computer on construction site, p) groupware, and q) chat. Technology and devices were referred to in plain language and examples were given (e.g., for web portals : "Bricsnet, Constructware, etc." and for chat : "MSN Messenger, ICQ, Yahoo Group, etc.") to maximize chances that those unfamiliar with the technology's name could still know what was described.

Perceived efficiency because of IT usage. For each of the items on the list, participants were first asked to rate usage on a five point scale (i.e., 1=unknown technology, 2=never, 3=sometimes, 4=often, 5=very often). Second, using a 5 point Likert scale (1=does not apply, 2=strongly disagree, 3=somewhat disagree, 4=somewhat agree, 5=strongly agree), participants were asked to rate the extent to which they agreed with the following statement: "My usage of this technology makes me more efficient in my projects in general".

Prefered IT use. Third, again referring to items on the list, participants were asked to determine the most and second most efficient technology or communication modality for communicating with a) internal team members, b) internal stakeholders, c) clients, d) professionals, e) general contractors, f) higher management, g) during the feasibility study, h) during design, during construction j) while coordinating clients, professionals and contractors, k) while managing contractors and suppliers, l) commissioning, m) during project close-out.

Electronic document exchange. The issue of electronic document exchange was further investigated by asking the frequency at which a) architectural programs, b) design documents, c) construction documents, d) specifications, e) bidders' information requests, f) calculations, g) orders and billing, and h) minutes of meetings are sent (1=does not apply, 2-never, 3=sometimes, 4=half the time, 5=often, 6=always).

Performance. Performance was assessed using 5 questions derived from Gibson et al., (2003). Using a 7 point Likert scale (1=does not apply, 2=strongly disagree, 3=moderately disagree, 4=slightly disagree, 5=slightly agree, 6=moderately agree, 7=strongly agree), participants were asked to self-report the extent to which, in their projects in general, a) they meet objectives of their projects, b) clients are satisfied with their work on projects, c) they

met agreed deadlines, d) the work they did is of excellent quality, and to what extent e) they worked efficiently. The same five questions were used but slightly modified to so that the point of view adopted was that of the team (e.g., clients are satisfied with the work of my team).

Resistance to IT. Using the same Likert scale, participants were asked to rate the extents to which internal and external stakeholders resist the use of technology. More specifically, in addition to a) themselves, the list included b) their internal team, c) other internal stakeholders, d) clients, e) professionals, f) general contractors, g) sub-trades, and h) the firm's senior management.

Interdependance. The same scale was used to assess the extent to which participants perceived their field fragmentation. More specifically, they were asked to rate how much interdependence was needed between them and a) their internal team, b) other internal stakeholders, d) clients, e) professionals, f) general contractors, g) sub-trades, and h) their firm's senior management.

PROCEDURE

This paper's third author distributed French versions of the questionnaires either electronically using e-mail lists or by hand during presentations through Montréal's PMI chapter. Participants were instructed to anonymously fill the questionnaires electronically or by hand and fax it to the first author, thus protecting their confidentiality. A total of 26 employees from 15 companies replied.

RESULTS

Participants were mostly male (80.8%), usually architects (38.5%) or engineers (42.3%). Approximately a quarter of the firms was architects companies (23.1%) or specialized contractors (23.1%). Most companies were involved in new constructions (46.2%), renovation projects (15.4%), or both (30.7%). Approximately 81.8%, 86.4%, 45.5% and 86.4% of the firms devoted at least 30% of their time or less to residential, commercial, institutional, and industrial construction, respectively. Typical projects' scope were 1 M$ or less (11.5%), between 1 and 10 M$ (30.8%), between 10 and 50 M$ (19.2%) and 50 M$ or higher (19.2%). A total of 23% of firms had less than 30 employees, none had between 31 and 50 employees, 42.3% had between 51 and 100 employees and 34.6% had more than 100 employees. The majority of participants were project managers (34.6%), while others were senior managers (19.2%), professionals (15.4%), and technicians (7.7%). On average, each had 30.4 (*SD*=51.4), 29.4 (*SD*=40.1), 5.3 (*SD*=4.5) employees under their supervision, respectively (technicians had none). Overall, more than four fifths (88%) of participants had held their positions for at least 15 years and the rest for more than 15 years.

Table 1 shows to what extent each technology or communication is used by participants and how they perceived this technology makes them more efficient. E-mails, with or without attached documents, is the most frequently used method of communication, followed by phone calls and face-to-face meetings. Similarly these methods of communications are perceived to contribute to personal efficiency. At the other end of the spectrum, groupware,

planners with cell phone capacity, walkie-talkie type cell phones and chat appear to not be used frequently. Research participants also do not perceive these IT to contribute to their efficiency. Hence, there is consistency between IT usage and perceived contribution to personal efficiency for high and low frequency of IT usage. In addition, most IT have small standard-deviations, indicating high agreement. IT with the highest standard-deviation include planners without cell phone capacity and regular cell phones. In terms of how IT devices are perceived to contribute to personal efficiency, there less consensus overall, compared to IT usage. With average ratings between 3 and 4 and a fairly high standard-deviations, documents obtained on FTP sites and regular cell phones, are not clearly contribute to higher efficiency.

In terms of which technology or communication mode was considered the most or the second most efficient as a function of key stakeholder, results clearly show that the telephone is the method of choice. Overall, participants favored using the phone individually to communicate with internal team members (69.2%), with internal stakeholders (73.1%), with clients (53.9%), with professionals (61.6%), with general contractors (50%), and with higher management (57.7%).

With respect to which technology or communication mode was considered the most or the second most efficient as a function of project phase, results are also quite clear. Participants favored face-to-face meetings to communicate during the feasibility study (50%), during construction design (46.2%), during construction to coordinate clients, professionals and contractors (50%), during construction to manage contractors and suppliers (53.8%), commissioning (46.2%), and during project close-out (38.5%).

Hence, our sample clearly favoured traditional communication modalities such as the phone or face-to-face meetings, irrespective of internal or external stakeholder and of project phase.

Table 2 shows the rate at which documents are exchanged electronically. Electronic documents sent the most frequently include construction documents, minutes of meetings, design documents, and specifications. Calculations and orders of billing are not sent as frequently.

Table 3 presents self-reported performance data regarding as well as respondent's perceived team performance. Results are high for all items, especially regarding participants' perception of their own performance. They are also lenient regarding their team, although with slightly more variability.

Table 4 outlines results regarding resistance of IT and perceived interdependence. For the most part, it appears that participants do not perceive high levels of resistance to technology among stakeholders. Should there be some resistance, sub-trades and general contractors would be the direction in which participants would point to.

In terms of how participants perceive their work to be interdependent with that of other stakeholders, results are consistently moderate. Participants see higher interdependence between them and their internal team and internal stakeholders. On average, they appear to "slightly agree" that there is interdependency between them and all other stakeholders, including clients.

DISCUSSION

SUMMARY

Overall, results show that survey respondents in the construction industry use traditional means of communication such as phone calls, face-to-face meetings, and e-mail. They appear to prefer face-to-face and phone calls across stakeholders and project phases, although they report all three modalities contribute to their efficiency. Hence, it appears they prefer richer forms of communications (e.g., face-to-face and phone) to less rich modalities (e.g., e-mail) (Baltes, Dickson, Sherman, Bauer, & LaGanke, 2002). When they use electronic document exchanges, they send task related documents more often (e.g., construction documents) but also send minutes of meetings. Participants appear highly lenient when rating their performance and that of their team. Their perception of resistance to technology is not blatantly negative. Finally, interdependence is seen as only moderately high.

CONCLUSIONS

One way to reflect on these results is to attempt to identify what would be the needs of the construction industry keeping in mind that the industry is fragmented and that construction projects require high synchronicity and high interdependence within and between organizations. Three complementary views are proposed to explain why our results show that traditional communication modalities (i.e., phone and face-to-face) were favoured, irrespective of stakeholder type (i.e., internal or external) and of project phase.

First, based on the CONNET Model, Grilo et al. (1996) argued that six issues need to be addressed in the construction industry: both hub and supplier need to a) invest in a power dependence relation; b) foster collaborative, trust-based, and long-term relationships; c) invest in sharing more than just administrative information; d) invest capital; e) share information regarding their internal processes and change them; and finally, f) overcome hurdles.

Our results show a somewhat low perception of interdependence. Perceived low interdependence is surprising in an industry so clearly defined by input-process-output mechanisms. This may indicate low-trust relationships and is certainly not conducive of rich communications on internal processes, even less of eventual coordinated mutual changes of these internal processes.

Second, Balates et al.'s, (2002) framework suggests that collaboration in a highly fragmented industry may call for rich communications. Third, using Shenhar's (2001) technological uncertainty framework, one might argue that the construction industry is a low to medium-tech industry and therefore, may not require high velocity and richness.

These potentially conflicting perspectives may explain some of the results, especially the preference for low-tech IT and the preference for rich communication means such as face-to-face. However, the idea that these might be equally efficient across stakeholders or project phases, as our results suggest, is counterintuitive. First, most competency frameworks argue that good communication requires adaptation by definition. Second, communication around design is more conceptual and may call for more creativity, less rigidity and higher velocity

hence, richer forms of communication (e.g., face-to-face). Communication regarding construction may be more straightforward, more technical and more task oriented suggesting that less rich forms of communication are sufficient (e.g., e-mail and electronic exchange of technical information).

So, is the construction industry addressing its own needs by communicating and using IT as it is? We believe the answer is no. Future research should describe the industry's needs and further investigate the relationship between communication and individual and project performance using, as we did here, frameworks such as Grilo, et al. (1996), Shenhar's (2001) and Balates et al.'s, (2002). These results hint that improvements in communication efficiency would positively impact project performance in the construction industry.

LIMITATIONS

The most important limitation of this study is its sample size. However, not much applied research is conducted on this topic and industry.

The other important limitation is the use of self-report procedures to assess individual and team performance. To avoid common error variance problems, performance assessment from the immediate supervisor should be added to the instruments used. However, and quite ironically, because the industry is so fragmented, it is difficult to easily impose one common performance assessment method, a conclusion similar to what has been observed in multinational teams (Gibson et al., 2003).

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Table 1 : Technology or communication mode's frequency of usage and perceived efficiency because of usage.

	IT usage		Perceived efficiency because of IT usage	
Technology or communication mode	***M***	***SD***	***M***	***SD***
a) Face-to-face meetings	4.35	0.63	4.76	0.52
b) Phone with one colleague	4.50	0.65	4.72	0.61
c) Phone or video conferencing	2.75	0.53	3.33	1.55
d) Fax	4.12	0.86	4.44	0.65
e) Private courier	3.42	0.90	4.12	1.01
f) Email with attached document	4.54	0.58	4.80	0.58
g) Email without attached document	4.58	0.64	4.76	0.52
h) Doc. obtained from an FTP site	2.72	0.89	3.78	1.54
i) Doc. obtained from web portal	2.17	0.95	2.42	1.77
j) Pager	2.31	0.84	1.65	1.19
k) Regular cell phone	3.58	1.27	3.64	1.66
l) Walkie-talkie type cell phone	2.28	1.10	1.70	1.40
m) Electronic planner without cell phone capacity	2.85	1.29	2.61	1.83
n) Electronic planner with cell phone capacity	2.24	1.09	1.67	1.34
o) Portable computer on construction site	2.58	1.10	2.39	1.67
p) Groupware	2.00	1.08	1.68	1.29
q) Chat	2.29	1.04	1.75	1.26

Note: Scale for frequency: 1=unknown technology, 2=never, 3=sometimes, 4=often, 5=very often; Scale for efficiency: 1=does not apply, 2=strongly disagree, 3=somewhat disagree, 4=somewhat agree, 5=strongly agree.

Table 2 : Frequency of documents sent electronically as a function of type of technology

	Frequency	
Technology	***M***	***SD***
a) Architectural programs	3.48	1.39
b) Design documents	4.10	1.22
c) Construction documents	4.36	1.19
d) Specifications	4.00	1.41
e) Bidders' information request	3.58	1.32
f) Calculations	2.72	1.37
g) Orders and billing	2.76	1.20
h) Minutes of meetings	4.28	1.62

Note: Scale for frequency: 1=does not apply, 2-never, 3=sometimes, 4=half the time, 5=often, 6=always.

Table 3 : Self-reported performance and individual's perception of team performance

	Individual		Team	
Technology or communication mode	***M***	***SD***	***M***	***SD***
a) Meets objectives of the project	6.65	0.56	6.33	1.26
b) Satisfies clients	6.71	0.45	6.37	1.23
c) Meets deadlines	6.42	0.81	6.13	1.31
d) Excellent quality	6.65	0.49	6.48	1.20
e) Works efficiently	6.54	0.65	6.15	1.32

Note: Scale for individual and team: 1=does not apply, 2=strongly disagree, 3=moderately disagree, 4=slightly disagree, 5=slightly agree, 6=moderately agree, 7=strongly agree.

Table 4 : Resistance to technology and interdependence among stakeholders

	Resistance to technology		Perceived interdependence between respondent and…	
Stakeholder	***M***	***SD***	***M***	***SD***
a) Themselves	3.20	1.89	---	---
b) Their internal team	3.72	1.79	6.50	1.36
c) Other internal stakeholders	3.64	1.63	6.27	1.28
d) Clients	3.92	1.82	5.65	1.72
e) Professionals	3.40	1.53	5.85	1.71
f) General contractors	4.29	1.90	5.62	1.70
g) Sub-trades	4.64	1.73	5.19	1.74
h) Firm's senior management	3.75	1.89	5.81	1.52

Note: Scale for individual and team: 1=does not apply. 2=strongly disagree. 3=moderately disagree. 4=slightly disagree. 5=slightly agree. 6=moderately agree. 7=strongly agree.