ICT APPLICATIONS IN CONTRUCTION: A COMPARATIVE STUDY OF BENCHMARKS, BENEFITS, COSTS & RISKS BETWEEN HONG KONG AND AUSTRALIAN CONSTRUCTION FIRMS

Onuegbu O. Ugwu[1], Mohan M. Kumaraswamy[2], Thomas Ng[3]and Peter Love[4]

ABSTRACT
Information and Communication Technology (ICT) is generally perceived to offer competitive advantages in business process improvement. This paper reports a study that investigated the benchmarks, benefits, costs and risks in mobilizing ICT as perceived by stakeholders in the Hong Kong construction sector. The multi-stage study used a combination of questionnaire, structured interviews and *evidence-based* research methods, and then compared the results with another study conducted in Australia. The study shows that the benefits in construction business process improvement span across *strategic, tactical* and *operational* levels. The study also shows ICT projects are prone to different vulnerabilities and risks. These cumulatively impinge on their level of success from the point of view of ICT project management, use and diffusion at organizational level. The paper discusses these findings, their implications on ICT development, deployment, use and diffusion at organizational level. It gives recommendations for formulating successful ICT projects in the Architecture, Engineering and Construction (AEC) sector.

KEY WORDS

ICT infrastructure, vulnerabilities, benefits and risks, ICT investments appraisal.

1 INTRODUCTION
There is an abundance of documented literature (e.g. from past ASCE and CIB proceedings and other conferences on construction IT) that describes various research projects in construction, which focus on IT–driven construction process innovation. However, while the majority of the research focuses on developing improved product, process and computational models, there is a noticeable dearth of research that focuses on issues and factors that impinge on the uptake of IT systems in construction, including stakeholders' perceived benefits, costs and risks of IT systems in practice. An adequate understanding of perceived

1 Honorary Assistant Professor, Dept of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong SAR (HKSAR, China, Phone +852 2241 5699, FAX +852 2559 5337, oougwu@hkucc.hku.hk
2 Associate Professor, , Dept of Civil Engineering, The University of Hong Kong, Pokfulam Road, HKSAR
3 Associate Professor, Dept of Civil Engineering, The University of Hong Kong, Pokfulam Road, HKSAR
4 Professor, School of Management and Information Systems, Edit Cowan University, Australia & Dept of Construction Management, Curtin University, Australia

and expected benefits would facilitate an unambiguous understanding of user requirements and subsequent translation into system functional specifications during development. IT implementation in construction results in significant changes in design and management processes within the organization. It is therefore necessary to investigate critical success factors as well as inhibiting factors.

In the case of stakeholders' perception on IT benefits, costs, and benchmarks, previous literature review by Irani and Love revealed that only a limited number of studies have been conducted to examine the benefits, costs and risks of IT in the construction industry. Following this observation, Love and Irani, (2004) conducted a research study in Australia to examine the IT benefit and management practices of various organization types, such as those of architects, consulting engineers, consulting project mangers, quantity surveyors (QS) and contractors. Their reported study provided an overview and understanding of the perceived benefits, risks and benchmarks of IT in construction organizations in the Australian construction industry. However there has been no such detailed study reported in literature that has been conducted to understand the benefits, costs, risk and benchmarks as they underpin successful IT projects in the HKSAR construction industry. This paper reports the findings of the study conducted in Hong Kong to address the missing gap. It builds on the study conducted in Australia, but extends the scope and dimensions, to cover different sizes of construction organizations in the HKSAR. The comparison of similarities and differences between HKSAR and Australia underscores the fact that there exist different industry practices, operational environments, and different level of e-business and e-commerce technologies, and underpinning infrastructure.

2 RESEARCH MOTIVATION & OBJECTIVES

The HKSAR research study set out to investigate several related questions. The general problem addressed is: what are the critical success metrics, enablers and barriers that impact the implementation, adoption, usage and diffusion of ICT in the construction industry? This raises several related research questions: (1) What are the key enablers for successful IT implementation and use? (2) Are there specific technical, commercial, organizational, and human resource factors that impinge on IT implementation? (3) What are the main underpinnings and impetus for IT investment? Is it driven top-down (e.g. by top-level management as part of corporate policy/strategy) or bottom-up (e.g. by operational requirements of the workforce)? (4) What are the stakeholders' perceptions of actual benefits, risks, and benchmarks, in industry practice? (5) What is the appropriate framework to address the multi-dimensional aspects of IT implementation in construction (i.e. people, process and technology components). Such a framework should enable identification of at-risk IT projects during the early stages of project evaluation, and facilitate formulation of appropriate risk mitigation measures.

Thus the broad aim of the research was to investigate and identify answers to the above research questions and proffer potential solutions that are appropriate for ICT development and use in construction. However, the focus of this paper is on research question 4. Ugwu et al (2006) discuss further details on the research.

3 RESEARCH METHODOLOGY & FRAMEWORK

The research model was designed to investigate various related questions outlined in the preceding section. The research framework is broad and covered different dimensions of information and communications technology (ICT). These include; current applications of IT in construction, success and inhibiting factors, perceptions of IT application areas in solving construction problems, and organizational strategic directions in IT application. This paper focuses on the perceptions of IT solutions, benefits, costs and risks in construction as encapsulated in the framework. The research instruments include a combination of structured open-ended interviews, questionnaires and evidence-based research used for further validation.

Several research methods were adopted in the multistage research. The first stage conducted over the period 2002-2003, used a combination of pilot questionnaire survey, structured interviews with senior personnel of leading construction organizations in HKSAR, and deductive analysis techniques for interview protocol analysis (Ugwu et al 2003). The second stage of the study conducted over the period 2003-2004, used a combination of questionnaire-based survey and case-study/evidence-based research techniques. The ensuing section discusses the second stage survey in detail, as it underpins the discussions in this paper.

3.1 QUESTIONNAIRE SURVEY

In the second stage of the study, a sample target group for the questionnaire survey was selected from several sources including telephone directory “Yellow Pages”, the member lists of The Association of Consulting Engineers of Hong Kong, The Hong Kong Institute of Architects and The Hong Kong Institute of Surveyors. The questionnaires were mailed, with a stamped addressed return envelope enclosed (for respondents’ returns, with comments, and feedback) to 345 organizations, including architects, consultants, contractors, QS and private and public clients. However, following an initial very low response, telephone calls were made to contact some organizations to seek their cooperation on the survey. At last, forty valid responses were received from the survey, giving a total consolidated response rate of about 12%. Table 1 shows the grouping and other details of the questionnaires distribution. The survey was conducted over the period October to December 2003.

Table 1: Distribution of Questionnaire & sample groups based on organization types

Group	No. of Questionnaires Sent	Percentage to All Questionnaires Sent (%)	No. of Responses	Percentage of Responses (%)
Planner	15	4.35	0	0.00

Architect / Architect & Project Manager	189	54.78	16	8.47
Consultant	52	15.07	8	15.38
Contractor	51	14.78	8	15.69
Private Client	18	5.22	0	0.00
Public Client	8	2.32	5	62.50
QS	12	3.48	1	8.33
Other (Unknown)	/	4.35	2	0.00
Total	345	100	40	12.0

Notes: *Consultant*: Include organizations of consulting engineers and consultant project managers; *Public Client*: Include public enterprises and government departments; *Multidiscipline*: Include organizations that are involved in more than one discipline of work, such as architects, project managers and IT; *Other*: Include unknown organization types (i.e. those who did not indicate their organization type in the completed questionnaire) and others, such as specialist instrumentation and site investigation contractor

3.2 ANALYSIS OF SAMPLE CHARACTERISTICS

Table 1 provides a breakdown of the valid responses by respondent organization type. Of the 40 organizations in HKSAR, 50% employed less than 50 employees and 52.5% had a turnover of less than HKD 50 million. Thus, over half of the sample comprised of small and medium organizations. Based on the organization types, the whole sample is divided into 5 valid groups as described in Table 1. The data analysis in the later stage was then carried out based on this group division in order to provide a comparison of the survey results based on the different specialties of the responding organizations.

On individual group bases, the sample of architects is from mostly small and medium firms, which have less than 50 employees and had turnovers of less then HKD 50 million. In the group of consultants, they ranged from very small scale with less than 10 employees to very large scale with about 250 employees. Their turnover ranged from less than HKD 10 million to about HKD 250 million. Most of the contractors are large scale with over 100 employees and turnover of over HKD 100 million. However, it is important to note that in HKSAR, small and medium contractors (SMC) constitute a very significant critical mass for successful ICT deployment and diffusion in the construction sector. This is because the group (i.e. those that employ 1-49 personnel) constitute about 88% of organizations in Hong Kong, straddling across several sectors.

For the data analysis, rankings obtained from the respondents about the benefits, costs and risks that they had experienced were used to develop an "IT benchmark index" (IT_{bi}). In calculating the IT_{bi}, all the numerical scores for the benefits, cost and risk, key enablers and barriers constructs were transformed to indices to assess their relative rankings (Love and Irani 2004). The IT_{bi} was calculated using the following formula:

$$IT_{bi} = \frac{\sum w}{AN}, (0 \leq IT_{bi} \leq 1)$$

where,

w = weighting given to each factor by the respondent, which in this case ranged from 1 to 5, where 1 is "not at all" and 5 is "a very large extent".

A = the highest weighting, which is 5, and

N = the total number of respondents

4 COMPARISON WITH AUSTRALIAN STUDY

This section compares the results of the HKSAR study on benefits, costs and risks with the study conducted in Australia (Love and Irani 2004). However, it is important to note the following differences in the two studies; (i) the samples used in the two studies are not of the same size, and (ii) the HKSAR study examined the entire construction industry while the Australian study focused on small and medium enterprises in general. However the findings from both studies can be taken as indicative of the construction industry perceptions in both countries. The comparison uses a simple statistical analysis in which the rankings of the benchmark indices of various issues for both countries are compared. This benchmark statistic takes the view of all respondents into consideration without further sub-group analysis. This broad level comparison takes care of differences in the sample sizes[5]. Tables 2-7 in the ensuing sections show the rankings of the various benchmarks for the different studies.

4.1 STRATEGIC BENEFITS

The result in Hong Kong was very similar to that obtained in Australia at the strategic level of benefits. As presented in Table 2, “Improved organizational and process flexibility” and “improved customer/supplier satisfaction” ranked first and second respectively in both places. Generally, both sets of results from the two locations gave a similar pattern in the ranking based on the relevant IT benchmark index.

Table 2: Comparison of benchmark metrics for the strategic benefits of IT Between HKSAR & Australia

Strategic Benefits	ITsbi (rank)	
	HK N = 40	AU, N = 126
Improved organizational and process flexibility	0.705 (1)	0.668 (1)
Improved customer/supplier satisfaction	0.662 (2)	0.661 (2)
Enhanced competitive advantage	0.662 (3)	0.6 (4)
Improved growth and success	0.65 (4)	0.562 (5)
Improved customer/supplier relations	0.61 (5)	0.619 (3)
Reduced marketing costs	0.511 (6)	0.409 (9)
Leader in new technology	0.495 (7)	0.485 (7)
Market leadership	0.441 (8)	0.487 (6)
Improved market share	0.426 (9)	0.471 (8)

ITsbi – strategic benchmark index

4.2 TACTICAL BENEFITS

[5] Although the sample sizes are different, the total responses (HKSAR = 40, Australia = 120), can be deemed as statistically significant for the purposes of these comparisons.

Table 3 shows that there isn't a large difference between the relevant benchmark metrics in Hong Kong and Australia. 5 out of 9 items are closely ranked and both gave "improved service quality" the first rank. "Improved contract administration" was identified as a benefit by a considerable number of organizations sampled in Australia and ranked as second there. However, it was only ranked the fifth in Hong Kong with a relatively lower IT_{sbi} value of 0.621. On the other hand, "Improved teamwork" was ranked only sixth in Australia with a much lower IT_{sbi} value of 0.558 as compared with Hong Kong, where it is ranked 3. This may indicate a greater awareness and/or adoption of teamwork and collaboration but this needs to be tested further and validated.

Table 3: Comparison of benchmark metrics for tactical benefits of IT Between HKSAR & Australia

Tactical Benefits	IT tbi **(rank)**	
	HK N = 40	AU, N = 126
Improved service quality	0.75 (1)	0.682 (1)
Improved response to changes	0.692 (2)	0.649 (3)
Improved teamwork	0.655 (3)	0.558 (6)
Reduced time to compile tenders	0.646 (4)	0.529 (8)
Reduced time to prepare cost plans	0.621 (5)	0.572 (5)
Improved contract administration	0.621 (5)	0.673 (2)
Improved integration with other business functions (e.g. Estimating and on-site operations)	0.589 (7)	0.586 (4)
Promotes pro-active culture	0.575 (8)	0.551 (7)
Increased planning times	0.503 (9)	0.447 (9)

ITtbi – tactical benchmark index

4.3 OPERATIONAL BENEFITS

At the operational level of benefits, it was observed that "Improved ability to exchange data", "Improved quality of output", "Improved communication" and "Improved data management" were ranked in the first four places in both Hong Kong and Australia, but in different order. (Table 4) They all had high values of IT_{obi}, which ranged from 0.704 to 0.776. It showed that the benefits of improved management, exchange and communication of information are identified as significant operational benefits in both places due to the implementation of IT. This does not automatically mean that these benefits have been very well achieved, but it highlights the need for the necessary IT infrastructure that would facilitate achieving such operational benefits in construction organizations. It is also necessary to highlight that the top ranked operational benefit "improved ability to exchange data", is essentially a communication-centric support service that does not require much tacit knowledge/cognitive-oriented support business processing. This indicates that systems which provide such functionality are more likely be widely adapted and used at both intra- and inter-organizational levels.

Table 4: Comparison of benchmark metrics for operational benefits of IT Between HKSAR & Australia

	ITobi **(rank)**

Operational Benefits	ITobi **(rank)**	
	HK, N = 40	AU, N = 126
Improved ability to exchange data	0.775 (1)	0.76 (2)
Improved quality of output	0.76 (2)	0.704 (4)
Improved communication	0.74 (3)	0.774 (3)
Improved data management	0.71 (4)	0.776 (1)
Reduced paperwork	0.695 (5)	0.442 (13)
Improved response time to queries (e.g. requests for information - RFI)	0.687 (6)	0.675 (5)
Improved decision making	0.636 (7)	0.532 (9)
Improved forecasting and control	0.621 (8)	0.605 (6)
Reduced labour costs	0.595 (9)	0.454 (11
Reduced bottlenecks	0.59 (10)	0.447 (12)
Reduced lead times for financial reporting	0.579 (11)	0.591 (7)

ITobi – operational benchmark index

4.4 DIRECT COSTS

Table 5 shows the comparison of benchmark metrics for the direct costs of IT in Hong Kong and Australia. Generally, they showed similar major direct costs of implementing IT in both places. However, it was noted that the cost of consultancy support and installation engineers in Hong Kong were ranked the second and fourth respectively, while they were ranked the sixth and eighth in Australia, with much lower IT benchmark metrics. Moreover, "networking security" had a low ranking in both places as organizations of small and medium size do not invest heavily in networks and issues related to security costs are not considered to be very critical issue for them. However, security becomes a very significant issue when such organizations are required to use ICT systems in a wider context.

Table 5: Comparison of benchmark metrics for the direct costs of IT Between HKSAR & Australia

Direct Costs of IT	ITdci **(rank)**	
	HK N = 40	AU, N = 126
Hardware accessories	0.745 (1)	0.752 (1)
Consultancy support	0.705 (2)	0.532 (6)
Overheads (eg. running costs and consumables)	0.67 (3)	0.593 (4)
Increases in processing power	0.655 (4)	0.706 (2)
Installation engineers	0.655 (4)	0.489 (8)
Maintenance costs	0.635 (6)	0.544 (5)
Networking hardware and software	0.564 (7)	0.654 (3)
Training costs	0.55 (8)	0.471 (9)
Networking security (eg. firewalls)	0.55 (8)	0.492 (7)

ITdci – direct cost index

4.5 INDIRECT COSTS

Both the sampled organizations in Hong Kong and Australia gave similar rankings in terms of the indirect cost of IT as shown in Table 6. However, the benchmark metrics given by the organizations in Australia was lower then that found in Hong Kong on average. This may be due to the fact that the Australian samples are very much skewed toward SMEs while the Hong Kong study spans the entire construction industry sub-sector in the sample frame.

Table 6: Comparison of benchmark metrics for the indirect costs of IT Between HKSAR & Australia

Indirect Costs of IT	ITidci **(rank)**	
	HK N = 40	AU, N = 126
Cost of ownership: (eg. system support and troubleshooting costs)	0.626 (1)	0.602 (1)
Management effort and dedication to exploring the potential of the system	0.626 (1)	0.595 (3)
Employee time in detailing, amending and approving the computerization	0.615 (3)	0.581 (5)
Management & staff resources (eg. integrating computerized administration and control into work practices)	0.61 (4)	0.6 (2)
Management time	0.6 (5)	0.593 (4)
Employee training	0.6 (5)	0.52 (6)
Employee motivation (eg. maintaining employees interest in computer aided tasks)	0.521 (7)	0.466 (8)
Strains on resources	0.503 (8)	0.478 (7)
Organizational restructuring	0.479 (9)	0.402 (10)
Staff turnover (eg. increases interview costs and training costs etc)	0.426 (10)	0.339 (12)
Productivity losses	0.421 (11)	0.428 (9)
Changes in salaries as a result of improved employee flexibility	0.416 (12)	0.372 (11)

ITidci – indirect cost index

4.6 RISK FACTORS

Table 7 gives the comparison of benchmark metrics of risk factors in the two places. Both organizations in Hong Kong and Australia considered "uncertainty about how to measure potential benefits", "security issues" and "capital outlay with no guarantee of likely returns" as the major risks in implementing IT. However, a large difference was found in the benchmark ranking of "maintenance cost", which was ranked the first in Hong Kong, but the sixth in Australia. Similarly, "Technical uncertainty and lack of knowledge" is ranked fourth in Australia, but eighth in Hong Kong. "Lack of information systems infrastructure support for the IT investment" is ranked fifth in Australia but tenth in Hong Kong. This may be explained by the several investments in IT infrastructure as part of a strategic initiative by the government of the HKSAR.

Table 7: Comparison of benchmark metrics of Risk Factors Between HKSAR & Australia

Risk Factors	ITri **(rank)**	
	HK N = 40	AU, N = 126
Maintenance costs	0.605 (1)	0.506 (6)
Uncertainty about how to measure potential benefits	0.595 (2)	0.534 (2)
Security issues	0.59 (3)	0.539 (1)
Capital outlay with no guarantee of likely returns	0.59 (3)	0.525 (3)
Uncertainty about how to measure the costs involved	0.565 (5)	0.461 (8)
Training expenses on staff that leave the organization	0.535 (6)	0.454 (9)
Reluctance of employees to adapt to change	0.525 (7)	0.388 (11)

Technical uncertainty and lack of knowledge	0.515 (8)	0.518 (4)
Minimal IT expertise	0.5 (9)	0.501 (7)
Lack of information systems infrastructure support for the IT investment	0.485 (10)	0.508 (5)
Theft of software and hardware	0.455 (10)	0.391 (10)

ITri – risk benchmark index

4.7 STAKEHOLDERS' PERCEPTIONS OF OTHER ISSUES IN ICT IMPLEMENTATION

This section gives a summary of stakeholders' perceptions of issues concerning an organization's approach to implementing IT in the HKSAR study. These are issues listed by respondents themselves, but not all respondents provided a valid response to this question. Based on the available information as given by respondents, 'cost', such as upgrading cost, training cost and hardware and software cost, was identified as the most important issue in the implementation of IT. Security problems, such as protection of data loss and software virus, were other important issues that affect the IT implementation. Individual groups of public clients identified that government policy on IT greatly affects the implementation of IT in their organizations (i.e. departments). Other serious issues include planning of IT system, IT knowledge of staff, availability of resources and long-term maintenance. The distributions of the numbers of respondents that identified the respective issues are as follows: Cost – e.g. upgrading/training/hardware/software cost (10), Security – e.g. software bugs, data protection from unauthorized access, theft (5), maintenance (2), IT knowledge of staff – e.g. education of in-house staff (3), benefits – i.e. quantifying benefits (2), technology – fast pace of technology advancement/change (2), system compatibility – i.e. interoperability (1), planning – e.g. for system improvement/development and implementation at organizational levels (4), Government policy on IT – e.g. funding (3), and resources (3)

5 CONCLUSION & RECOMMENDATIONS

This paper has discussed benefits, costs and risks of ICT projects based on studies conducted in Hong Kong and Australia. The benefits span across strategic, tactical, and operational levels. The strategic benefits include improved organizational and process flexibility and improved customer/supplier satisfaction. The tactical benefits include improved service quality, improved response to change and improved teamwork, while the operational benefits include; improved ability to exchange data, improved data management, improved quality of output, and improved communication. The direct costs include hardware accessories, consultancy support, overheads, and increased processing power, while the indirect costs include ownership, management effort, and additional employee time in performing tasks such as detailing. Finally the risk elements include maintenance costs, uncertainty about methods and techniques to measure potential benefits, security, and no guaranteed return in capital outlay. These findings have several implications in successful ICT implementation, adoption and diffusion in the AEC sector.

As an illustration, at the heart of the evaluation process is the notion of benefits management. If construction organizations and firms are not obtaining the benefits sought, then the processes used for investment justification are inadequate and/or the organization needs to re-think their approach to IT adoption. This may even result in re-engineering business processes. The metrics identified in these cross national studies provide a basis for benchmarking; monitoring IT performance, and more importantly, impart the organization with a frame of reference for determining the extent to which business value is being obtained (Love and Irani 2004).

The research reported in this paper contributes to a better understanding of the perceptions of construction stakeholders on several issues that relate to IT implementation, adoption and use. These include benefits, costs and risks, a well as user acceptance and user resistance to adoption and usage. It therefore makes contributions from both practical and theoretical considerations. From a practical perspective, knowing the most critical factors would enable system developers and management to target efforts on such factors during various phases of IT project implementation. From a theoretical perspective, knowing these factors and issues, would enable construction IT researchers to develop appropriate research strategies, to investigate the problems. Further research is required to develop tools that would enable construction organizations to: (i) measure the ICT project success as part of post-project evaluation, along the identified benefits benchmarks metrics discussed in this paper; and (ii) perform quantitative risk analysis of ICT projects at the preliminary stages using the risk constructs. Such analysis would enable them to identify necessary risk management strategies before finalizing investment decisions.

ACKNOWLEDGEMENT

The University of Hong Kong (HKU) supported the work reported in this paper through seed-funding for the project: Security Vulnerability Assessment in Infrastructure Projects Design & Construction – Methodology & Computational Framework (Award No **10206090**).

REFERENCES

Love P. E. D, Irani Z (2004), "An Exploratory Study of Information Technology Evaluation and Benefits Management Practices of SMEs in the Construction Industry", *Information and Management*, 42, pp 227-242

Ugwu O. O, Ng S. T, Kumaraswamy M. M., 2003: "Key Enablers in IT Implementation – A Hong Kong Construction Industry Perspective", in *' Towards a Vision for Information Technology in Civil Engineering*', *Proceedings of 4th Joint International Symposium on Information Technology in Civil Engineering* (Flood I, Ed.), Nashville, Tennessee USA, 15-16 November 2003, ASCE's Technical Council on Computing Practices and European Group for Intelligent Computing in Engineering (EG-ICE), ISBN 0-7844-0704-5

Ugwu O. O, Kumaraswamy M. M., Ng T (2006): Information & Communications Technology (ICT) Applications in Construction, *Report of Surveys on ICT Applications, Benchmarks, Benefits, Costs, Barriers & Enablers, and Research & Development Issues in the HKSAR Construction Industry, CICID HKU, ISBN 962 8014 12 9*