Improving the Competence of Construction Management Consultants to Underpin Sustainable Construction in China

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ABSTRACT

As a vital component of construction professional services (CPS), construction management consultancy is in nature knowledge-intensive and client-tailored. Although recent studies have acknowledged the increasing role of this subsector of CPS in the attainment of sustainable construction, little attention has been given to the education and training of its main body, namely construction management consultants (CMCs). This study investigated the competence and knowledge structure of CMCs by taking China as an example. Using the methods of interview and questionnaire survey, three key competences of CMCs and the underpinned knowledge structure were identified. The identified competences are personnel quality, onsite practical skills, and continuing professional learning. Underpinned these competences are the knowledge structure composed of a number of disciplines including construction cost planning and control,

civil engineering and construction, engineering contract and law, and construction project management. The research findings lay a solid foundation for future studies to probe into the role of construction management consultants in the area of sustainable construction.

KEYWORDS

Sustainable construction; construction professional services; knowledge structure; construction education

INTRODUCTION

The construction industry has become both a vehicle for improving the quality of life and an entity that can determine the environmental and social sustainability of development efforts (Plessis, 2007). Such dual roles spell out the significant contribution of the industry to sustainable development. “Sustainable construction”, which means creating and managing a built environment based on resource efficient and ecological principles (Kibert, 1994; Manoliadis, Tsolas, & Nakou, 2006), outlines the sphere that the construction industry can reach sustainability. After a long evolution in ontology, the seed of “sustainable construction” has matured into a discipline comprising various practical and scientific issues (Hill & Bowen, 1997). One of the critical issues in the discipline is to determine a proper approach to keep sustainable construction informed in accordance with the hierarchical definitions of construction. In effect, the definition of construction ranges from site activity, project lifecycle, everything related to construction business to the broader process of human settlement creation (Irurah, 2001). Construction activities are executed for constructing physical facilities (i.e., buildings and infrastructures), which will normally last for decades. The sustainability performance of a physical facility is triggered to a large extent from its construction process, suggesting that sustainable construction is fundamentally activity-specific.

The activity-based nature of sustainable construction calls for adopting creativity, skills, know-how, and modern technologies as many as possible to implement cleaner production (Berggren, 1999). In this sense, sustainable practices make it necessary to improve interdisciplinary collaboration and multi-stakeholder partnerships on construction sites. Construction activities in general involve three primary stakeholders – clients, contractors and consultants. The former two stakeholders have attracted much consideration under the heading of sustainable construction, while the subject of consultants has not (Frattari, Dalprà, & Salvaterra, 2012; Riley, Pexton, & Drilling, 2003). As a result, there are two questions that have not been explored explicitly, namely what kind of consultants should be and how to educate and to train them effectively with the pace of sustainable development. Consultants provide a wide array of professional services to clients and on behalf of them monitor construction process and interact with contractors. They can exert immense influence on sustainability of to-be-built facilities by providing practical solutions to construction activities, varying from the use of cleaner, more efficient technologies to end-of-pipe management approaches. Furthermore, a full capacity of competitive consultants underscores a sustainable growth of construction industry. For instance, construction-related consultants in Hong Kong have built up a reputation outside the territory, and they have become an imperative factor of the industry's competitiveness (Wong, Ng, & Chan, 2010).

It is widely acknowledged that developing countries have met great challenges of finding a holistic approach to guarantee sustainability in the construction industries (Plessis, 2007; Ye, Shen, & Zuo, 2013). As one of the largest developing countries in the world, China appears to be a huge construction site

(Chen & Chambers, 1999; Lu, Ye, Flanagan, & Jewell, 2013). The challenge of the Chinese construction sector is not only to produce sufficient housing and infrastructures to the society, but also to do it in a socially and ecologically responsible way. There is an urgent need to address the aforementioned two questions in China's construction industry wherein sustainability challenges have been aware of. Recent years have witnessed special academic attention given to the evaluation of engineering consultants' capabilities (Ng & Chow, 2004), the performance of engineering consultants (Chow & Ng, 2007), and sustainable competitive advantages of project management consultants (Betts, 1994). Nonetheless, research works devoted to the competence of construction management consultants (CMCs) are very limited, and they have not pinpointed the ways to manage the competitiveness of CMCs properly in responding to social appeal for sustainable construction. In view of the intricacy of the subject, this paper presents takes an early step to investigate the key competence of CMCs and its underpinned knowledge by taking China as an example. By doing so, the research outcomes can lay a useful foundation for future studies to examine the contribution of CMCs to sustainable construction.

CHARACTERISTICS OF CONSTRUCTION MANAGEMENT CONSULTANCY

Construction management consultancy is an integral part of construction professional services (CPS) that are created by a set of knowledgeable consultants including architects, engineers, engineer-contractors, architect-engineers, engineer-architects, environmental, planners, and geotechnical engineers, landscape architects (Lu, Ye, Flanagan, & Jewell, 2013). In the CPS sector, CMCs refer in a different way to those professional organizations and/or individuals that offer a combination of skills as well as strategic and tactical solutions to the construction process. The services of CMCs are characterized by a framework of appropriate disciplines and ethics, and decision-making on construction activities in independent, scientific, and impartial manners (Bowen, Pearl, & Akintoye, 2007). The wide span of consulting business requires CMCs to own multi-disciplinary knowledge and experience such as civil engineering, construction technology, financial management, law, and regulation.

The services of construction-related consulting spread out along some established management procedures, which are usually set forth and can be tailored to satisfy different demands of clients. Alongside this strand, the study by Ezeldin and Abu-Ghazala (2007) unveiled three main steps of a quality management system for design consultants to operate, namely awareness, benchmarking of existing practice, and verifying the validation of consulting model. Previous studies have demonstrated that an efficient consulting procedure enhances the value chain of construction projects by interweaving clients with consultants tightly (Kometa, Olomolaiye, & Harris, 1996). This gives the suggestion that value engineering is a useful tool for clients to appraise the performance of CMCs, and clients have a profound effect on the performance of construction consulting firms. The effect in the view of Kometa *et al.* (1994) mirrors the main attributes of clients including financial stability, quality of management, organizational quality of client, past performance, client characteristics, client’s duty, and past experience.

There are two approaches for measuring the extent to which consultants are able to provide quality services. One is using a number of firm factors, such as the background of firms, past performance, and the capacity to accomplish the work and project approach (Cheung, Kuen, & Skitmore, 2002). The other is using some project-related factors, such as design submission number, clarity and comprehensiveness of drawings and documents, quality of design solution, and recommendations for reducing project risks (Chow & Ng, 2009). However, previous studies have pinpointed that the competitiveness of construction consulting business lies in technical accuracy and overall quality of people (Cheng, Proverbs, & Oduoza, 2006), and embraces a well-qualified team, a well-defined project approach, and effective communication

(Avila, 1997). As pointed out by Cheung *et al.* (2001), charismatic and participative leadership dominates the satisfaction of consulting team and eventually affect the performance of consultants. Soft skills such as conscientiousness, initiative, social skills, controllability and commitment have equivalent importance to construction consultants (Ling, Ofori, & Low, 2000). In a broader angle, the study by Ng and Chow (2004) suggested that consultants have technical capabilities, management capabilities, financial capabilities, and quality assurance and control.

CONSTRUCTION MANAGEMENT CONSULTANCY IN CHINA

Construction professional services (CPS) in China have undergone gradual changes after the successful development of some mega projects, such as Three Gorge Project and Qinhai-Tibet Railway Project (Lu, Ye, Flanagan, & Jewell, 2013). The current industrial landscape of CPS in China reflects an accumulative effect of long-time national reform and open-door policies on the construction sector (Lu, Ye, Flanagan, & Jewell, 2013). There are two major parts of CPS, namely, engineering architecture/design and construction management consultancy. The latter one includes construction supervision, project bidding agency and quantity surveying. As a typical subsector of CPS, CMCs originated from China's construction supervision system introduced to assist clients in improving construction process (Liu, Shen, Li, & Shen, 2004). In this system, construction consulting services are provided by construction supervision firms which employ engineers to supervise contractors' onsite activities. In effect, the growth of China's construction industry has been fuelled by an unfailing inflow of capital investment, advanced technologies and managerial approaches from either advanced countries or developed regions (Ling, Ibbs, & Cuervo, 2005). The participation of foreign production elements has advanced the traditional construction business paradigm to an internationally competitive one. With the increasingly diverse requirements and expectation of clients, construction supervision has maintained evolution to embrace CMCs.

Meanwhile, the sizeable urbanization as well as the emergence of numerous construction projects characterized by complicated technologies and management challenges has yielded tremendous opportunities for CMCs to prosper. According to the Report of New Urbanization in China (Niu, 2012), the urbanization rate of China will sustain an annual growth of 1 per cent until the year of 2020. This means that the Chinese construction industry would be facing a larger demand of housing development. Overwhelming housing demand could stir a rapid growth of construction consulting services. For instance, the subsector of construction cost consultancy has seen the increase of firms' income to RMB 80.685 billion and the employees to 237,100 in 2011. Both have an annual growth of over 10 percent in the past few years. In the meanwhile, the ascending complexity of projects and the related construction technologies highlight the importance of a closer involvement of CMCs in project delivery (Baccarini, 1996).

Previous studies have revealed close involvement of foreign engineering consulting firms in China's construction industry in recent years (Zhao, Zuo, Zillante, & Zhao, 2012). As reported, these foreign firms have exhibited a high level of professional capabilities in supplying a lifecycle span of services to marketplace. The services they offer include project briefing, conceptual design, and post-evaluation of project performance (Chang & Tsai, 2003). By contrast, Chinese CMCs are much more engaged in construction activities by placing the emphasis on project management triangle, namely, time, cost, and quality. They posses little advantage of design and technical innovation abilities, international construction experience, general project management, and financial management (Ling & Gui, 2009). Another distinctive weakness of CMCs goes to the narrow range of knowledge and services, the lack of modern consulting awareness and continuing education and training (Du, 2011).

METHODOLOGY

The quantitative approach was adopted as the main research method of this study. A preliminary list of competence factors and curriculums were formulated using the approaches of literature review and interview with scholars. The competence factors serve to answer the question what kind of CMCs should be, while the proposed curriculums are used to explore the knowledge structure of CMCs and how to train/educate CMCs effectively. Thereafter, a nationwide questionnaire survey was conducted to probe opinions on the preliminary list of key competence and curriculums. Data of the survey were eventually analyzed through the methods of factor analysis and cluster analysis.

Preliminary lists

According to the Regulation of Chinese Registered Consulting Engineers (2001), a qualified consultant must have professional ethics, positive attitudes towards consulting service, innovative potential, learning skill, construction experience, and teamwork. Part of these competence factors have been echoed in some recent studies (Lu, Ye, Flanagan, & Jewell, 2013; Yao & Luo, 2005). These competences of CMCs were well appreciated and summarized in Table 1.

Table 1 A preliminary list of CMCs' competence

Code	Items	References
I_1	Professional ethics	Yao and Luo (2005), the Regulation of Chinese Registered Consulting Engineers
I_2	Attitudes towards consultancy	Yao and Luo (2005), Wang (2000), the Regulation of Chinese Registered Consulting Engineers

I_3	Teamwork potential	Yao and Luo (2005), the Regulation of Chinese Registered Consulting Engineers
I_4	Creativity	The Regulation of Chinese Registered Consulting Engineers
I_5	Ownership, management and delivery of solutions to clients	Wang (2000), the Regulation of Chinese Registered Consulting Engineers
I_6	Interpersonal communication skills	Yao and Luo (2005), Wang (2000)
I_7	Information and technology skills	Wang (2000), the Regulation of Chinese Registered Consulting Engineers
I_8	Learning skills	Wang (2000), the Regulation of Chinese Registered Consulting Engineers
I_9	Application skills	Yao and Luo (2005), Wang (2000)
I_{10}	Organization skills	Wang (2000), the Regulation of Chinese Registered Consulting Engineers

In China, those universities launching construction management programs for bachelor's degree usually follow the curriculums recommended by an advisory panel under the leadership of the Ministry of Housing and Urban-Rural Development (MOHURD). The advisory panel is composed of well-known experts and the panel members meet at least twice per year to identify any new development and future trend of the construction industry. Thereby, they can offer useful advices on curriculum setting for relevant universities. Interviews with the chairperson of the advisory panel and the secretariat were conducted in December 2012 to identify those main construction management curriculums taught in Chinese universities. It was noted that the curriculums on construction management mainly comprise the disciplines of technology, economy, management, and legislation. Each one has a number of curriculums as described in Table 2. As confirmed by the secretariat, these curriculums are delivered by top Chinese universities including Tsinghua University, Tongji University, Southeast University, and Chongqing University to construction management students within four years.

Table 2 Disciplines and main curriculums

Category	Code	Variable	Category	Code	Variable

Technology	C_1	Civil engineering drawing (88 hours/5.5 credits)	Management	C_{13}	Management science (32 hours/2 credits)
	C_2	Construction materials (40 hours/2.5 credits)		C_{14}	Construction project management (48 hours/3 credits)
	C_3	Civil engineering surveying (48 hours/3 credits)		C_{15}	Financial management (40 hours/2.5 credits)
	C_4	Building architecture (64 hours/4 credits)		C_{16}	Operational science (40 hours/2.5 credits)
	C_5	Building structure (40 hours/2.5 credits)		C_{17}	Accounting (40 hours/2.5 credits)
	C_6	Construction equipments (32 hours/2 credits)		C_{18}	Construction cost planning and control (48 hours/3 credits)
	C_7	Urban planning (32 hours/2 credits)	Law	C_{19}	Economic law (32 hours/2 credits)
	C_8	Civil engineering construction (56 hours/3.5 credits)		C_{20}	Construction regulations (32 hours/2 credits)
Economy	C_9	Micro- or macro-economics (32 hours/2 credits)		C_{21}	Engineering contract and law (48 hours/3 credits)
	C_{10}	Engineering economics (48 hours/3 credits)		C_{22}	Administrative regulation (32 hours/2 credits)
	C_{11}	Banking and insurance (32 hours/2 credits)			
	C_{12}	Statistics (40 hours/2.5 credits)			

Questionnaire survey

A questionnaire form was formulated on the basis of the items listed in Tables 1 and 2. The questionnaire contains three sections. The first section introduces the objectives and scope of the survey. This section is also used to collect demographic data regarding the respondents' education background, professional areas, years of work, position, and company names. In the other sections, participants are invited to give opinions on the importance of proposed competences and main curriculums respectively. Respondents are particularly remaindered to mark the importance level per item by taking into account the principles of sustainable construction. A five-level Likert scale is employed to standardize respondents' feedbacks, namely 1 - extremely unimportant, 2 - unimportant, 3 - neutral, 4 - important, 5 - extremely important.

As the organizations that CMCs attach to scatter widely over the Chinese construction industry, it is quite difficult, if not impossible, to recognize the entire population for this study. Thus, the method of snowball sampling was employed to collect respondents' opinions. A small pool of initial informants was requested to nominate through their social networks other participants who have the knowledge/experiences of construction consulting. To avoid that those people who have many friends are recruited into the sample, informants were requested to send the questionnaire to those professionals they know in other regions. Invited respondents were encouraged to return their feedbacks by mail and by filling in online questionnaire. Consequently, 134 questionnaires were received. Of all the returned questionnaires, 115 were found valid. The participants included 19 executives, 37 project managers, and 59 production line CMCs. The participated respondents distributed over 19 provinces including Guangdong (15), Jiangsu (11), Chongqing (10), Beijing (9), Shanghai (9), Sichuan (9), Shandong (8), Zhejiang (7), Tianjin (6), Fujian (6), and Liaoning (5). Over 60 percent of respondents had four years of work experiences. While it is not easy to appreciate the representativeness of the sample to the population of CMCs in China, the composition of the respondents is useful to avoid prejudice and bias on the survey.

Data analysis

Reliability coefficients

Cronbach's alpha presents the reliability of the collected questionnaire data. With the assistance of SPSS 16.0 software, it was found that the Cronbach's alpha for the questionnaire data is 0.898, which is larger than the acceptable level 0.7 (Sale, Salter, & Sharp, 2004; Ye, Shen, & Tan, 2010). This indicates that the questionnaire scales have high internal consistency and reliability at the 5% significance level.

Factor analysis

The key competences of CMCs were extracted on the basis of the ten variables listed in Table 1 using the approach of factor analysis. In the discipline of construction management and economics, this approach has been frequently used to identify a number of uncorrelated factors from some potentially correlated variables (Ye, Li, & Shen, 2013; Lu, Shen, & Yam, 2008). Technically, factor analysis is an effective approach to identify the related variables by reducing the dimension of variables into a simplified framework. The simplified framework can provide more useful insights into the reaction of CMCs to the broadening concern of sustainable construction. As shown in Table 3, the value of KMO is 0.869, larger than an acceptable level (0.5). The Bartlett's Test of Sphericity is 580.82 with the significance level of 0.000. These coefficients indicate that the collected data are suitable for factor analysis.

Table 3 KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.869
Bartlett's Test of Sphericity	Approx. Chi-square	580.820
	df	45
	Sig.	0.000

Results of the factor analysis are listed in Table 4. As given in Table 4, the cumulative contribution percentage is 72.169%, suggesting that the vast majority of variance can be explained by the identified three factors. In appreciating the attributes and the components, these three factors were renamed personnel quality (F_1), onsite practical skills (F_2), and continuing professional learning (F_3) accordingly.

Table 4 Key factors extracted

Key Factor	Variable	Factor Loading	Corrected Item-Total Correlation	Variance Explained %	Total Variance Explained %
F_1	I_3	0.576	0.719	26.787	26.787
	I_4	0.846	0.616		
	I_5	0.705	0.692		
	I_6	0.640	0.706		
	I_{10}	0.650	0.584		
F_2	I_7	0.765	0.626	24.475	51.262
	I_8	0.782	0.743		
	I_9	0.819	0.640		
F_3	I_1	0.681	0.638	20.907	72.169
	I_2	0.823	0.513		

Furthermore, the following formula was adopted to calculate the relative importance indices of the ten variables. As a result, the mean values per variable under the headings of the key factors were derived as shown in Table 5.

Relative importance index = $\sum(aX)*100/5$

Where *a* is the score of a variable judged by respondents. X = n/N, where n refers to the number of questionnaires that have same scores for a certain variable, and N is the number of valid questionnaires.

Table 5 Importance indices of key factors

Key Factor	Variable	Relative importance index	Rank	Relative importance index [a]
F_1	I_3	90.26	2	87.97

	I_4	85.22	7	
	I_5	88.17	4	
	I_6	87.83	5	
	I_{10}	88.35	3	
F_2	I_7	81.39	10	83.48
	I_8	86.78	6	
	I_9	82.26	9	
F_3	I_1	92.00	1	88.17
	I_2	84.35	8	

a – mean values of the variables included.

Cluster analysis

The mean value per variable was used to calculate the importance levels of curriculums. Based on the mean values, the curriculums were ranked to present the importance levels as shown in Table 6.

Table 6 Survey results of the curriculums

Code	Mean value	Standard deviation	Rank	Code	Mean value	Standard deviation	Rank
C_{18}	4.270	0.882	1	C_6	3.626	0.821	12
C_8	4.235	0.902	2	C_{22}	3.617	1.014	13
C_{21}	4.235	0.994	3	C_{13}	3.574	1.018	14
C_{14}	4.191	0.907	4	C_{19}	3.565	1.027	15
C_{20}	4.087	1.022	5	C_3	3.504	0.912	16
C_1	4.052	0.877	6	C_9	3.357	0.870	17
C_5	4.026	0.863	7	C_7	3.296	0.917	18
C_4	3.965	0.888	8	C_{16}	3.278	0.978	19
C_{10}	3.948	0.887	9	C_{17}	3.226	0.956	20
C_2	3.826	0.901	10	C_{12}	3.165	1.017	21
C_{15}	3.643	0.993	11	C_{11}	3.104	0.862	22

Data in Table 6 were detected to identify whether the curriculums were similar in terms of their importance to the key competence. If this similarity does exist, the curriculums described previously can be integrated into fewer groups. Integration could simplify analysis of the knowledge structure of CMCs.

For this purpose, the technique of cluster analysis was then employed to look at CMCs' knowledge structure through the software package of SPSS 16.0. Cluster analysis is a statistical technique that classifies observations into common sets or groups (Ketchen & Shook, 1996). The derived importance index per curriculum is shown in Table 7 and these curriculums were further classified into four categories.

Table 7 Results of the cluster analysis

Code	Items	Importance level
C_{18}	Construction cost planning and control	4.270
C_8	Civil engineering construction	4.235
C_{21}	Engineering contract and law	4.235
C_{14}	Construction project management	4.191
C_{20}	Construction regulations	4.087
C_1	Civil engineering drawing	4.052
C_5	Building structure	4.026
C_4	Building architecture	3.965
C_{10}	Engineering economics	3.948
C_2	Construction materials	3.826
C_{15}	Financial management	3.643
C_6	Construction equipment	3.626
C_{22}	Administrative regulation	3.617
C_{13}	Management science	3.574
C_{19}	Economic law	3.565
C_3	Civil engineering surveying	3.504
C_9	Micro- or macro- economics	3.357
C_7	Urban planning	3.296
C_{16}	Operational science	3.278
C_{17}	Accounting	3.226
C_{12}	Statistics	3.165
C_{11}	Banking and insurance	3.104

FINDINGS AND DISCUSSION

Findings of the research were derived by summarizing the data analysis results shown in Tables 4 and 7. An in-depth face-to-face interview with a director of a local large construction consulting enterprise, the chairperson and the secretariat of the aforementioned advisory panel was afterwards conducted to discuss the research findings. The director is a senior CMC with work experience of over twenty-five years. Feedbacks of them were cited to verify the research findings.

CMCs' key competences

Table 5 summarizes the results of ten competences considered by the respondents. Interestingly, the survey results show that the importance indices of personnel quality (F_3), onsite practical skills (F_1), and continuing professional learning (F_2) are 88.17, 87.97 and 83.48 respectively. This signifies a high importance level of the key factors and the priority of the factor F_3 over the key competence of CMCs. The components of F_3 - Variables I_1 (professional ethics) and I_2 (attitudes towards consultancy) account for the vital importance of the key factor. Professional ethics (V_1) basically refers to the personal and corporate standards of behaviors expected of professionals, and prudence and resistance to corruption are the principal part of professional ethics (Suresh & Raghavan, 2005). The identification of this variable concurs with previous studies on the attribute of CPS that CMCs should have the obligation of confidentiality and carry out construction services in a fair, independent and professional manner (Bowen, Pearl, & Akintoye, 2007). As pointed out by the Chairperson, with the increase in population and diversity of practitioners' education backgrounds, CMCs in China have been confronting with considerable challenges with professional ethics. The situation has not been improved significantly (Ling & Lim, 2010), although professional societies in construction engineering, such as China Registered Constructor Association, have circulated some guidelines for its members to behave accordingly. In addition, Variable I_2 satisfies the Regulation of Chinese Registered Consulting Engineers which requires CMCs to have positive attitude towards consulting services. As pointed out by the interviewed director, construction management consulting is a kind of knowledge-intensive services, and it is very important that CMCs can behave proactively to help clients manage construction process to satisfy the requirement of sustainable construction. Therefore, this key competence (F_3) stresses that more efforts are needed to improve the personality of consultants to underpin the sustainable growth of the construction industry.

The factor of onsite practical skills (F_1) is appreciated as the second key competence of CMCs. F_1 elaborates the capabilities that CMCs must own in processing construction management consultancy on project sites. The survey results given in Table 4 show that this key competence is composed of teamwork potential (I_3), organization skills (I_{10}), ownership, management and delivery of solutions to clients (I_5), interpersonal skills (I_6), and creativity (I_4). As pointed out by the interviewed director, these five variables accord with the requirements of CMCs as stipulated in the Regulation of Chinese Registered Consulting Engineers. Specifically, Variable I_3 has the importance level of 90.26, suggesting that efficient cooperation with project team members deserves much attention in the way towards sustainability. The priority of teamwork potential is probably due to the fact that a vast majority of CMCs, who have a narrow range of knowledge and limited practical skills, are able to create quality services by working closely in a team (Du, 2011). Variables I_{10} and I_5 signify the necessity of CMCs to organize and to coordinate construction works efficiently. Variable I_6 highlights the value of communication skills of CMCs in comprehending clients' demands and delivering effective solutions in due time. Variable I_4 reveals that both differentiation strategies and innovative thinking are the ingredient of CMCs' competence to form competitive advantages, and it echoes the National Plan of Construction Consulting Services (2010-2015) on the demand of "increasing inputs into research and development of theories for construction management consultancy".

Continuing professional learning (F_2) is the third key competence of CMCs. The importance of this factor has been recognized in previous studies. The study by Chan & Chan (2002) opined that continuing professional development has been receiving increasing attention in recent decades, and China's professionals are required to establish life-long learning. The work by Ling and Gui (2009) found that that the knowledge of CMCs in China is not up-to-date. The interviewed secretariat pointed out that to improve the knowledge of CMCs, China CMC Association has established some programs of Continuing Professional Development (CPD) for practitioners to implement with the emphasis on economics, law, managerial and technical knowledge, learning and skills, and ethics. As indicated in Tables 4 and 5, I_8 (learning skills), I_9 (application skills), and I_7 (information and technology skills) are the sub-factors of this key competence (F_2). In effect, with the globalization of world economy, many new concepts such as lifecycle management, building information modeling, and green building are penetrating the minds of construction practitioners. To provide quality services, CMCs ought to keep learning new knowledge and update their knowledge structure constantly.

Knowledge structure of CMCs on the strand of curriculums

CMCs are knowledge providers to clients to manage construction activities on site. The richness in knowledge enables CMCs to interact with business partners and manage widespread construction activities. In this study, the knowledge structure of CMCs can be illustrated through identifying the key curriculums indicated by the respondents. As shown in Table 7, the higher the index, the more important the curriculum will be. With this in mind, it was found that construction cost planning and control (C_{18}) precedes over other curriculums in the domain of CMCs' knowledge. According to Porter (1980), cost leadership means being less expensive than competitors in the entire range of a company's activities. The strategy of cost leadership is apt for both extremely competitive business and fairly uniform project works (Warszawski, 1996). Therefore, this factor spells out the expectation and requirements posed by clients on

CMCs to own the cost leadership of construction project management. As revealed by the Chairperson, civil engineering and construction (C_8) is a key technical curriculum in China's university construction management education. In the study, this factor ranks second in contributing to CMCs' key competence. The identification of the factor aligns with the study by Tang *et al.* (2003) on that technology is the backbone of construction consulting service (Tang, Lu, & Chan, 2003).

Engineering contract and law (C_{21}) ranks third, implying that clients expect CMCs to engage in managing intricate business relationships which are dominated by stakeholders via the nexus of contracts. As pointed out by the interviewed director, the main reason for this factor is probably due to the fact that CMCs have poor awareness of contract and legislation. Understanding the fundamental business rules and practices in contract administration and procuring necessary resources at a lower price and deliver them construction site as scheduled is one of key responsibilities of CMCs. Construction project management (C_{14}) ranks fourth, indicating that CMCs need to employ specialized tools and techniques to solve problems related to schedule, budget, quality and other goals. Interestingly, civil engineering drawing (C_1) occupies a higher position in the knowledge structure of CMCs, highlighting the fundamental skills that CMCs need to acquire, such as computer aided design (CAD). This meets the opinion of the secretariat that the construction industry is labor-intensive with relatively low levels of knowledge; the application of new information technologies has achieved great progress in China.

Improving key competence for sustainable construction

Sustainable construction has been appreciated as a new promising development in the industry (Ye, Shen, & Zuo, 2013; Lu, Ye, Flanagan, & Jewell, 2013), although the practices are still in an infancy stage (Lu, Ye, Flanagan, & Jewell, 2013). As discussed above, the discipline of sustainable construction details a body of knowledge comprised of principles, approaches and techniques. According to the Chairperson interviewed in this study, the tenet of sustainable construction has posed great challenges onto the traditional university curriculum setting in China, necessitating the establishment of a new system that can address the problems of sustainable construction. The key competence of CMCs identified in the study includes personnel quality, onsite practical skills and continuing professional learning. While these three competences shed light on construction management programs in the higher education, they illustrate the direction that CMCs would be trained in the industry. Construction consulting firms are thus recommended to organize regular trainings to get frontline CMCs familiarized with multidisciplinary practices and deepening inter-professional collaboration on sustainable construction. Thereby, CMCs can assist the client better in managing sustainable construction business.

The key competences, which support CMCs to undertake predefined consulting services, usually result from a specific set of skills or production techniques that deliver additional values to clients. To survive from fierce business competition, an organization needs to protect its key competence and knowledge by following certain mechanisms, processes and systems (Chen, 2005). In this study, the knowledge learning of CMCs goes to the acquisition of new technology, new capability and effective leadership in the area of sustainable construction. The formulation of competence is exactly a process of knowledge creation and knowledge acquisition within construction consulting firms. Both the adaptive learning capability and a process of learning-by-doing deserve much attention. As revealed, the education of sustainable construction is mainly concerned with the subjects of construction cost planning and control, civil engineering and construction, engineering contract and law, construction project management, and civil engineering drawing. These main curriculums echo with the four pillars of sustainable construction -

social, economic, biophysical and technical (Hill & Bowen, 1997). Meanwhile, CMCs have the importance of possessing the knowledge of not only the construction process but also the development of the industry, in particular the availability of new sustainable technology and green materials to adhere to the principle of sustainable construction.

CONCLUSIONS

The agenda of urbanization in China has brought construction management consultants (CMCs) favorable development opportunities to serve clients better in line with the principle of sustainable construction. While the industrial size is expanding, construction consulting firms in China are competing strongly for competent CMCs to provide quality services to marketplace. The key competence of CMCs identified in this study comprises personnel quality, onsite practical skills, and continuing professional learning. Overall, the key competences accord with the attributes of construction consulting services as well as the increasingly diversified demands of construction clients with respect to sustainability. While the findings of this study could support the education/training of construction professionals in China, CMCs in the industry are recommended to appraise their personal competitiveness to meet the requirement of sustainable construction. The knowledge structure of CMCs ranges from construction technology, management science, economics, to legislation. The identification of knowledge structure favors construction consulting firms to train and to educate their human resources accordingly. The research findings are useful for China’s construction practitioners to improve professional services to guarantee sustainable industry growth at the early development stage. In considering that key competences are the firm's primary expertise and forms a source of sustained competitive advantage, it is implied that foreign construction consulting firms which are entering or to enter China’s construction industry might consider these key competences and the underpinned knowledge structure. This paper presents some early results of a two-step research which aims to orient the competence of CMCs towards sustainable construction. The research findings pave the way for the next research to look at the relationship between the competence factors and the knowledge structure, and the education of CMCs for the improvement of sustainable construction.

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