Implementation of Environmental Management in the Construction Industry of China

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The construction industry generates serious environmental impacts, comparing which with other industries, it lags far behind in implementing environmental management (EM). Using a structured questionnaire survey, this paper explores the characteristics of the Chinese construction firms including the environmental awareness in construction, behaviors towards environmental management and measures for environmental management. By means of analyzing the relative importance, the top five out of thirty factors affecting implementation of environmental management are: environmental consciousness of top leader; environmental consciousness of middle management; effective implementation of the relevant regulations on EM; legal system; and legal enforcement. Some measures are recommended including promoting environmental management by organizing training on environmental management and establishing a proper legal framework by the Chinese government.

Introduction

Degradation of the environment constitutes a main concern of the modern society. Each industrial sector may have adopted different strategies to tackle environmental issues because of its unique influence to the environment. So far, studies have been overwhelmingly focused on the manufacturing industry (Gil *et al.*, 2001). Meanwhile, the impacts on the environment caused from construction activities are also serious and need to be controlled nowadays (Bossink and Brouwers, 1996; Crawley and Aho, 1999; Govorushko, 1996; Ling and Lim, 2002). By comparing with the manufacturing industry, construction has been far lagging behind in implementing environmental management (EM) and/or environmental management system (EMS) based on ISO 14001 (Tse, 2001).

In China, the construction industry has undergone great changes due to rapid industrialization and urbanization over the past two decades (Flanagan and Li, 1997). While the rapid economic expansion creates the largest construction market in the world and brings about an unprecedented opportunity in the construction industry, pollution resulted from construction activities has become a serious problem. The environmental impacts not only annoy residents nearby, but also affect the health

and well-being of lives (Chen *et al.*, 2000). It is estimated that the annual solid waste from construction reaches 30~40% of the total urban solid waste in China (Zhang and Yang, 2001).

In this study, construction firms in China were surveyed to investigate their environmental concerns. Based on a structured questionnaire survey, the critical factors were identified. The objectives of this paper mainly focus on the following:

- To evaluate environmental impacts of construction;
- To examine behaviors towards environmental management;
- To explore measures for environmental management;
- To identify critical factors affecting implementation of EM; and
- To provide some recommendations for effective implementation of EM.

The Construction Industry and the Environment

The construction industry plays an indispensable role in providing physical assets to meet the growing societal needs. On the other hand, construction brings about detrimental effects, such as various forms of

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environmental pollution and resources depletion (Ofori *et al.*, 2000). The environmental consequences generated from the construction industry relate to many aspects including: (i) energy consumption; (ii) dust and gas emission; (iii) noise; (iv) waste; (v) water discharge; (vi) use of water resources; (vii) unnecessary building consumption; (viii) pollution from building materials; (ix) land use; and (x) use of natural resources (Clements, 1996; Morledge and Jackson, 2001; Poon *et al.*, 2001; Tilford *et al.*, 2000). Table 1 summarizes the relevant findings of the above.

ISO 14001 and the Construction Industry

Among the ISO 14000 EMS series issued by the International Organization for Standardization (ISO), ISO 14001 is the standard, following which an organization is to be audited (Zhang *et al.*, 2000). It provides guidelines to design and implement an EMS that help identify and define the organization's environmental policy, planning, the environmental aspects of its operations, legal and other requirements, objectives and targets for environmental improvement, and a set of environmental management programs (Ball, 2002; Steger, 2000).

Table 1: Environmental impacts of the construction industry.

Environmental impact	Author(s)	Main findings
Land erosion	Goudie (2000)	In the construction phase, the highest rates of erosion are produced when there is a large amount of exposed ground and much disturbance produced by vehicle movements and excavations. <ul style="list-style-type: none"> • The high rates of erosion during construction reached 18,764 (t /km² yr). • They were 10 times those from agricultural land (1,876 t /km² yr), 200 times those from grassland (94 t /km² yr) and 2,000 times those from forest (9 t /km² yr).
Energy consumption	Rohracher (2001)	About 40% of Austria's primary energy consumption results from the heating and operation of buildings. The production of buildings is both energy and resources intensive.
	Thormark (2001)	In Sweden, it was found that recycling of building made possible considerable saving of energy and scarce or non-renewable natural resources. The potential to increase energy saving is about 20-40% depending on the form of recycling.
Construction and demolition waste (C&D waste)	Lawson et al. (2001)	In UK, the construction industry produces 53.5Mt of C&D waste annually, of which 51% goes to landfill, 40% is used for land reclamation and only 9% is crushed for future use or directly recovered.
	Poon et al. (2001)	In Hong Kong, the construction industry is the major solid waste generator, and generated about 32,710 t of C&D waste per day.
Liquid waste	Morledge and Jackson (2001)	It was identified that a significant number (28%) of all substantiated pollution incidents across England and Wales are directly attributable to mineral-based fuels and oils, many of which are used extensively within the construction industry.
Gas emission	Hendrickson and Horvath (2000)	In USA, pollution emissions from major construction sectors as percentage of total: 3.4% of SO ₂ ; 1.9% of CO; and 15% of global warming potential (CO ₂ equivalent).
	Rohracher (2001)	In Austria, about 100 tons of CO ₂ , 150 kg of SO ₂ and 200 kg of NO _x are produced in order to provide the building materials for just an average single family house.
Noise	McMullan (1993)	A construction operation can generate some noise and the sound level at the receiving end exceeds the "threshold of pain", which is 140 db.
	EPD (2001)	In Hong Kong, there were 91% of noise pollution complaints from general construction works in 2000. There were 404 prosecutions and fines imposed upon contractors for the infringement against the Noise Control Ordinance, which is about 77% of overall prosecutions and fines on noise pollution.

ISO 14001 also requires a system of implementation and operation, including a clear structure of responsibility, program training, awareness and competence among all employees of the facility, internal and external communication of the EMS, a system of environmental management documentation and its control system, procedures for operational controls, emergency preparedness and response (Rondinelli and Vastag, 2000).

ISO 14001 includes provisions for creating a system of checking and corrective action for monitoring, measurement, and reporting non-conformance, taking corrective and preventative action, and record-keeping. It calls for EMS audits and a management review through which senior management reassesses the suitability, effectiveness, and adequacy of the environmental management system at appropriate intervals to assure continuous improvement (Morrow and Rondinelli, 2002).

Up to August 2001, there had been 836 organizations obtaining ISO 14001 certificates in China (CACEB, 2001), among which, there are only 21 construction firms (2.5%). This reflects a very different attitude of the construction industry towards ISO 9000 and ISO 14000 series (Zeng *et al.*, 2001).

Methodology

Before the survey, auditors of EMS and senior management representatives of nine construction firms including five ISO 14000 certified firms were interviewed and requested to provide information and verification in drafting the questionnaire. Then the structured questionnaires were sent to senior management representatives of 200 construction firms listed in the Dictionary of Quality System Certification Enterprises in China and finally 60 completed questionnaires had been received.

In the survey, the 60 construction firms fall into two categories of ownership: 52 state-owned (87%) and 8 sharing-holding enterprises (13%).

All the respondents were ISO 9000-certified, out of which, 20 (33%) construction firms are ISO 14001 certified. For the non-certified firms of ISO 14000, 28 (47%) firms opined that they would not seek certification of ISO 14000 in the near future if clients had no requirements. The other 12 (20%) firms felt they had intention to adopt EMS.

Results and Analysis

The analysis of the questionnaire is divided into several sections, first to assess the seriousness of the environmental impacts and behaviors towards environmental management in construction, then the measures taken in environmental management, such as training provided and resources facilitated. Lastly, factors affecting the construction firms in implementing environmental management will be analyzed.

Awareness of environmental impacts

Respondents were asked to indicate their views on the extent of impacts on the construction environment, including air, noise, water and waste (EPD, 2001). Table 2 lists the results.

Table 2: Evaluation of impacts of construction on environment

Item	Response	No. of responding firms	
Impacts of construction on environment	Obvious impact	43	(72*)
	Fairly impact	10	(16)
	No impact	7	(12)
	Others	0	(0)
	Total	60	(100)

* Figures in brackets are the percentages

Table 2 shows 72% of respondents considered obvious impacts of construction activities on the environment. The impacts are attributed to the pollution and hazards created in construction sites such as dust, harmful gases, noise, solid and liquid wastes (Henderickson and Horvath, 2000; Tilford *et al.*, 2000). Many construction managers only care about their immediate problems and view their top priorities as meeting the production schedule, cost targets and quality requirements while “environment” is not one of the project objectives. Hence, Ofori (1992) suggested to develop a culture of environmental protection and adopt “the environment” as the “fourth” project objective besides time, cost and quality.

Behaviors towards environmental management

Table 3 presents the behaviors of firms towards environmental management measured in terms of: 1. Whether the firm received complaints? 2. How to tackle the problem if there were complaints? 3. Whether the firm had been punished due to violation of environmental protection regulations?

Table 3: Behaviors of firms on environmental management

Item	Response	No. of all firms	
Whether the firm received complaints?	Always	0	(0*)
	Occasionally	42	(70)
	No	18	(30)
	Total	60	(100)
How to tackle the problem if there were complaints?	Conscientiously	52	(87)
	Perfunctorily	8	(13)
	Pay no attention	0	(0)
	Total	60	(100)
Whether the firm had been punished due to violation of environmental protection regulations?	Yes	23	(38)
	No	37	(62)
	Total	60	(100)

* Figures in brackets are percentages

70% of the respondents declared that they occasionally received complaints resulting from their construction works. In fact, public involvement is an important factor to promote environmental improvement. In general, complaints from the public on environmental issues are more frequent in the developed regions than the developing regions. As the World Bank (1997) indicated, the rate of complaints on environmental issues per 100,000 citizens in Shanghai, the biggest and richest city in China, was the highest and slightly more than 30 in 1993; while the figure in Sichuan (an inland province) was less than 10.

Although 30% of the respondents claimed that they hitherto had not received any complaints, the respondents recognized that it did not mean that there was no pollution generated from their construction works. It might be attributed to the fact that there were few official complaint channels.

Of the respondents, 87% agreed that they would consciously tackle the environmental problems if they received complaints and 13% proclaimed perfunctory in handling the complaints. Nevertheless, all the certified firms opined that they were conscientious in handling environmental problems and 38% claimed that they had been punished due to infringements of environmental rules. The punishment includes warnings, fines and suspension of construction works. All the punished respondents indicated that the punishment they received was slight.

Table 4: Measures for environmental management

Item	Response	No. of responding firms	
Whether the firm has rules on EM?	Systematic	4	(7*)
	Not systematic	47	(78)
	No	9	(15)
	Total	60	(100)
Whether the firm provides training on environmental protection?	Frequent training	5	(8)
	Occasional training	22	(37)
	No	33	(55)
	Total	60	(100)
Whether the firm employs staff on EM?	Full time staff	9	(15)
	Part time staff	41	(68)
	No	10	(17)
	Total	60	(100)

* Figures in brackets are percentages

Measures for environmental management

The questionnaire explored the measures taken on environmental management (before implementing ISO 14000 standards for the certified firms) including rules for EM, training, and human resources input. Table 4 lists the results on environmental management measures taken by the construction organizations.

In Table 4, only 7% of respondents considered that their firms had systematic rules on EM. Of the respondents, 78% indicated that their firms did not have any formal systematic rules. Supports from top management in the construction are demanded for enhancing the environmental concern of the middle level and frontline staff.

Of the respondents, 45% indicated that their firms frequently (8%) and occasionally (37%) provided training on EM and 55% acknowledged that they never had any training for their employees. In fact, the level of education and training for employees is a very important factor during the implementation process of EM (Shen and Tam, 2002). It should be useful in enhancing environmental awareness in the industry. Some pollutants such as dust in construction could easily be prevented if the workers on sites paid a little attention to it (Chen *et al.*, 2000).

Of the respondents, 15% indicated that their firms had full time staff in charge, and 68% and 17% had part time staff and no representatives at all. This indicated that majority of the construction firms were reluctant to increase resource input for EM. Although the short-time investment cost, including the employment of environmental staff, resources input, provision of training, etc. would be increased, the long-time benefit can be achieved (Shen and Tam, 2002).

Factors affecting implementation of EM

There are various factors affecting the implementation of EM (Shen and Tam, 2002; Ofori *et al.*, 2000). From our review of literature, thirty factors affecting the implementation of EM were identified. The respondents were asked to provide their opinions on the importance of factors by assigning scores from 1 to 5, where '1' represents the least important and '5' the most important. To determine the relative ranking of the factors, the scores were then transformed to relative importance index (RII) based on the following formula:

$$\frac{\sum w}{A * N}$$

(1)

where w is the weighting given to each factor by respondents, ranging from 1 to 5, A is the highest weight (i.e. 5 in the study) and N is the total number of samples.

Based on equation (1), the relative importance index (RII) can be calculated ranging from 0 to 1. Table 5 lists the relative importance indices and rankings of the factors.

(a) Culture

The respondents ranked "environmental consciousness of top leader" and "environmental consciousness of middle management" first and second, with a relative importance index of 0.900 and 0.833 respectively. The role of top leader in environmental management had been highlighted by many researchers (Fryxell and Lo, 2002; Sarkis, 1998). According to a study by Gupta (1995), 92% of 400 Central Executive Officers (CEO) and top leaders surveyed agreed that the environmental challenge was one of the central issues of the 21st century and top leaders are one of the seven critical elements for an effective proactive environmental management. Without strong top management support, the implementation of EM would not be successful (Gupta 1995; Quazi *et al.* 2001).

(b) Legal support

The respondents graded "legal system" and "legal enforcement" fourth and fifth, with a relative importance index of 0.765 and 0.760 respectively. The legal system and legal enforcement are prerequisites of effective environmental protection. In this survey, the current status of Chinese

Table 5: Ranking of the factors affecting implementation of EM

Ranking	Factors	RII	Problem center
1	Environmental consciousness of top leader	0.900	Culture
2	Environmental consciousness of middle management	0.833	Culture
3	Effective implementation of the regulations on EM	0.767	Management
4	Legal system	0.765	Legal
5	Legal enforcement	0.760	Legal
6	Resources input	0.750	Resources
7	Systematic operation regulations	0.733	Management
8	Professional expertise	0.733	Resources
9	Measures of environmental protection in construction	0.726	Management
10	Encouragement mechanism for clear production	0.715	Management
11	Safety protection	0.700	Management
12	Defined responsibility on EM	0.690	Organization
13	Minimizing environmental nuisance materials	0.683	Materials & equipment
14	Training on EM	0.667	Management
15	Old and outdated equipment	0.660	Materials & equipment
16	Technique guide in construction	0.657	Technology
17	Civilianized operation	0.657	Management
18	Emergency measures	0.650	Management
19	Innovation technologies	0.645	Technology
20	Information exchanges	0.640	Organization/management
21	Utilization of environment-friendly equipment	0.633	Materials & equipment
22	Inspecting instruments for EM	0.633	Materials & equipment
23	Quality first-line workers	0.600	Resources
24	Protection measures in material handling	0.583	Management
25	Protection measures in material storage	0.575	Management
26	Equipment maintenance	0.567	Materials & equipment
27	Records of environment management	0.562	Management
28	Encouragement mechanism of reducing wastage	0.550	Management
29	Construction duration	0.533	Management/technology
30	Re-utilization of resources	0.517	Resources

legal system and legal enforcement on environmental protection were explored and the results are shown in Table 6.

As shown, all the respondents agreed that China did not have a systematic legal framework regulating environmental protection. In recent years, the Chinese government has made great effort in enacting laws on environmental protection such as the ratification of Environment

Protection Act in 1989, Water Pollution Protection Act in 1984 and revised in 1996, Air Pollution Protection Act in 2000, Solid Wastage Pollution Protection Act in 1995, and Noise Pollution Protection Act in 1996. Regulations directly related to construction include the enactment of Construction Act in 1997 and Regulation of Environmental Management for Projects in 1998. However, the system of legal framework has serious flaws: administrative power always overrules judicial resolutions in which

courts and lawyers only play a minor role. There is a strong need to establish clearer liability for all stakeholders.

Moreover 90% of the respondents indicated that the legal enforcement was average (63%) and not stringent (27%). Currently administration still retains considerable powers, and can use its discretion to influence local environmental protection to suit other goals such as economic benefits and etc.. Violation of environmental laws often goes unpunished, especially in cases where enforcement is required by a body outside the immediate administrative area. Further, corruption, selective implementation of rules, the diffi-

Table 6: Evaluation on Chinese legal system on EM

Item	Evaluation of respondents	No. of responding firms
Act and regulations	Systematic	0 (0*)
	Average	41 (68)
	Not systematic	13 (22)
	Neutral (no idea for the respondents)	6 (10)
	Total	60 (100)
Legal enforcement	Stringent	6 (10)
	Average	38 (63)
	Not stringent	16 (27)
	Total	60 (100)

* Figures in brackets are percentages

culties of confronting local political leaders, the low status of those involved in administrating the system and so on form hurdles in administering these rules and regulations. Hence strict legal enforcements need to await improvement of the Chinese legal framework.

(c) Management

“Effective implementation of the relevant regulations on EM” and “systematic operation regulations” was ranked third and seventh, with a relative importance index of 0.767 and 0.733 respectively. Regulations on EM are the criteria for implementation of EM. However, majority of the respondents indicated that their firms did not have any formal systematic rules as aforementioned (see Table 4).

“Measures of environmental protection in construction” was ranked ninth, with a relative importance of 0.726. The environmental pollution generated from construction activities not only annoys residents nearby, but also impairs the health of construction workers in the frontline. Taking noise as an example, Table 7 lists the noise levels of the several industrial sectors.

Table 7: Noise level in several industrial sectors

Industrial sector	Noise level (db)	Maximum noise level (db)
Steel plant	80-120	140
Manufacturing	80-120	130
Construction	80-120	—
Electronic plant	65-100	—
Textile plant	80-105	110
Train transportation	80-120	—
Printing	70-95	95

Sources: Xu and Wang (1999)

Table 7 indicated that construction activities created serious noise pollution. An investigation revealed that the employees working under high level of noise ($\geq 95\text{db}$) might have the symptoms including insomnia (32%), headache (27%), palpitation (27%) and hypertension (12%) (Xu and Wang, 1999). Therefore, it is necessary to employ technical, managerial, planning measures for construction (Chen *et al.*, 2000).

(d) Resources

The respondents graded “resources input” sixth, with a relative importance index of 0.750. In the Chinese construction industry, the economic return is very low, and the average profit rate in the construction industry is around 1.5% in 2000. The rate of profit of the state-owned construction firms is declining from 2.0% in 1993 to 0.4% in 2000. Moreover, the number of money-losing firms increased and there were approximately 34.18% of state-owned firms running into deficit in 1998 (Sha and Lin, 2001).

On the other hand, the low environmental standards and weakly enforced environmental legislations discourage construction firms from implementing any environmental measures; for example, if solid waste from construction can be cheaply dumped in landfills, waste separation, recycling, etc. will not be considered. Under this circumstance, construc-

tion firms are reluctant to increase resources input for environmental improvement (see Table 4).

“Professional expertise” was ranked the eighth, with a relative importance index of 0.733. Traditionally, people in the construction industry are accustomed to give higher priority to saving cost, shortening construction duration and improving quality. Environmental improvement has not been underlined. The ISO 14001 series requires professionals not only understanding the international standards but also knowing the relevant laws, including national and local. Due to the lack of necessary trainings (see Table 4), this undoubtedly results in shortage of expertise on EM in the construction industry.

(e) Organization

“Defined responsibility on EM” was ranked the twelfth, with a relative importance index of 0.690. Ignoring problems or leaving them for others is an easy alternative unless responsibility is well defined. As environment, quality and safety are similar management functions, construction organizations will normally integrate quality and safety management together with environmental management to reduce the resources input.

(f) Materials/equipment

“Minimizing environmental nuisance materials” was ranked the thirteenth, with a relative importance index of 0.683. Taking wall materials for housing construction as an example, in China, there has been an increasing amount of housing construction (from 188 million m^2 in 1985 to 477 million m^2 in 1998) due to the huge demand for housing (Guan *et al.*, 2001). Traditionally, clay bricks have been extensively used. The most serious environmental effect of manufacturing clay bricks is devastation of volumes of land for cultivation. The government of some developed regions, such as Shanghai, has forbidden the use of clay bricks, which are substituted with hollow concrete blocks. Table 8 shows the benefits resulted from reforming wall materials in Shanghai from 1990 to 1996.

Table 8: Total environmental benefit of reforming wall materials in Shanghai (1990-1996)

Item	Environmental benefits
Saving energy (ton of coal equivalent)	0.5227 million
Saving farm land (hectare)	450
Utilization of slag (ton)	10.27 million

Table 8 shows that there is a splendid environmental benefit for substituting clay bricks with hollow concrete blocks. Although the Chinese government encouraged to reform wall materials over the past two decades, clay bricks have been extensively used in the less developed cities and rural areas.

Discussion and Recommendations

As indicated by many researchers, the role of government in promoting implementation of EM is very important (Tan *et al.*, 1999; Quazi *et al.*, 2001). However, environmental pollution is serious in the Chinese

construction industry. Therefore, the Chinese government is recommended to undertake the following aspects:

- As the environmental awareness of top leader and middle management were ranked first and second respectively, governmental departments should organize training courses and seminars on the subject of environmental management for the management of all construction firms. In practice, previous research indicates that strong EM is positively correlated to the financial performance of the firm (Klassen and McLaughlin, 1996). The training should include sharing of experience by those ISO-14000 certified firms. From their experience, participants could learn more about the implementation process and benefits.
- Due to the importance of legal support ("legal system" and "legal enforcement" were graded fourth and fifth), a proper legal framework for promoting environmental management is urgently demanded. Currently the major problem is the lack of local regulations consistent with the national standards. In addition, because the involvement of the general public is very important in promoting environmental protection (World Bank, 1997), it is necessary to establish channels for the public to address their complaints.

Conclusions

The construction industry generates serious environmental pollution including: energy consumption; dust and gas emission; noise; waste; water discharge; use of water resources; unnecessary building consumption; pollution from building materials; land use; and use of natural resources.

When compared to others, the construction industry has been far lagging behind in implementing environmental management. This is reflected from the following characteristics of construction firms:

- Lack of systematic rules;
- Shortage of training; and
- Reluctant to increase resources input.

There are various factors affecting the implementation of environmental management. These factors are related to the culture, legal systems, management, resources, organization, materials and equipment, and technology of the industry. On the basis of relative importance, the top five factors are found to be:

- environmental consciousness of top leader;
- environmental consciousness of middle management;
- effective implementation of the relevant regulations on EM;
- legal system; and
- legal enforcement.

According to the characteristics of the construction industry in China, the government should play an important role in promoting implementation of EM. The measures include: (1) to organize training courses and seminars for the management of construction firms; and (2) to establish a proper legal framework and strict legal enforcement. As enhancing the environmental awareness is also important for private developers, training courses should also be extended to serve them.

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