Environmental Management of Urban Construction Projects in China

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Abstract: This paper presents a systematic approach to environmental management of pollution and/or hazards caused by urban construction projects in China. It proposes a qualitative approach to assess and control the problem and a method to calculate the construction pollution index (CPI), which provides a quantitative measurement of pollution and/or hazards caused by the urban construction projects. Based on the analysis and discussions, the paper further proposes that major construction companies in China should obtain ISO 14001 Environmental Management System (EMS) certifications. By doing so, the construction companies can integrate the concept of environmental management into their construction management practice.

INTRODUCTION

Pollution and hazards caused by urban civil construction projects have become a serious problem in China. Sources of pollution and hazards from construction sites include dust, harmful gases, noises, blazing lights, solid and liquid wastes, ground movements, messy sites, fallen items, and so forth. These types of pollution and hazards can not only annoy residents nearby, but also affect the health and well-being of people in the entire city. For example, in big cities such as Shanghai and Beijing, air quality has been deteriorating due to extensive urban redevelopment activities (Li 1998).

In order to tackle the problems, the Chinese government has issued a number of laws and acts on environmental protection since the early 1980s. These laws and acts include the Oceanic Environment Act (issued in 1982), Water Pollution Protection Act (issued in 1984), Air Pollution Protection Act (issued in 1987), and Noise Pollution Protection Act (issued in 1989). In 1998, the Ministry of Construction also issued the first construction law that explicitly includes the liabilities and responsibilities of contractors in preventing and reducing the emission of pollutants to the natural environment.

This paper provides a systematic approach to dealing with environmental pollution caused by construction projects. This approach allows for both qualitative analysis and control and quantitative assessments through measuring the construction pollution index (CPI). We believe that the qualitative assessment and control method is useful because it can provide construction project managers with essential knowledge on how to limit environmental pollution to its minimum. The CPI is also necessary as it can be used to quantitatively measure the degree of pollution caused by particular construction projects. The concept of CPI can also help construction project managers to rearrange and revise construction plans and schedules in order to reduce the level of pollution and disturbance.

QUALITATIVE ANALYSIS OF POLLUTION AND HAZARDS GENERATED FROM URBAN CONSTRUCTION PROJECTS

Sources of pollution and/or hazards from construction activities can be divided into seven major types: dust, harmful gases, noises, solid and liquid wastes, fallen objects, ground movements, and others. In order to reduce and prevent the pollution and hazards, it is necessary to identify the construction operations that generate them. Table 1 lists construction activities that generate pollution and hazards and the corresponding methods for their prevention. The table is based on extensive studies of many construction sites in Shanghai, Beijing, and Hong Kong, as well as numerous discussions with many project managers.

Methods for preventing pollution and hazards can be divided into the following four categories.

- Technological
  This category recommends a range of advanced construction technologies that can reduce the amount of dust, harmful gases, noise, solid and liquid wastes, fallen objects, ground movements, and other sources of pollution and hazards. For example, replacing the impact hammer pile driver with the hydraulic piling machine can significantly reduce the level of noise generated by a piling operation.
- Managerial
  This category recommends the use of modern construction management methods that may help reduce the amount of dust, noise, solid and liquid wastes, fallen objects, and other sources of pollution and hazards.
- Planning
  This category emphasizes revising and rearranging construction schedules to reduce the aggregation of pollution and hazards and has an effect on dust, noise, solid and liquid wastes, fallen objects, ground movements, and other sources of pollution and hazards.
- Building Material
  Better building material can also help reduce pollution and hazards. This category has an effect on harmful gases, fallen objects, ground movements, and other sources of pollution and hazards.

The four categories of preventive methods and their effects are also summarized in Table 2.

We believe that by adopting the above preventive methods, it is possible to effectively control and reduce the amount of pollution and hazards generated from construction activities. In order to further analyze the effect of pollution and hazards, the next section describes a method to quantify the amount of pollution and hazards generated by a construction project.

Quantitative Analysis of Pollution and Hazards in Urban Construction Projects

As a construction project spans over a year or even longer, the methods for quantitative analysis have to be a continuous monitoring and assessment of the whole project duration. In

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TABLE 1. Causes of Pollution and Hazards and Preventive Methods

Type (1)	Causes (2)	Methods to prevent (3)
Dust	Demolition, rock blast	Static crushing/chemical breaking
	Excavation, rock drilling	Static crushing/chemical breaking/wet excavation/wet drilling
	Open-air rock power and soil	Covering/wet construction
	Open-air site and structure	Wet keeping/site clearing/mask
	Bulk material transportation	Awning/concrete goods/washing transporting equipment
	Bulk material loading and unloading	Concrete goods/packing and awning/wet keeping
	Open-air material	Awning/storehouse
	Transportation equipment	Cleaning
	Concrete and mortar making	Concrete goods
Harmful gases	Construction machine—pile driver	Hydraulic piling equipment
	Construction machine—crane	Electric machine
	Construction machine—electric welder	Bolt connection/pressure connection
	Construction machine—transporting equipment	Night shift
	Construction machine—scraper	Electric machine
	Organic solvent	Poison-free solvent
	Electric welding	Bolt connection/pressure connection
	Cutting	Laser cutting
Noise	Demolition	Static crushing/chemical breaking
	Construction machine—pile driver	Hydraulic pile equipment
	Construction machine—crane	Electric machine
	Construction machine—rock drill	Static crushing/chemical breaking
	Construction machine—mixing machinery	Concrete goods/prefabricated component
	Construction machine—cutting machine	Laser cutting machine/prefabricated component/soundproof room
	Construction machine—transporting equipment	
	Construction machine—scraper	
Ground movements	Demolition	Static crushing/chemical breaking
	Pile driving	Static pressing-in pile
	Forced ramming	Static compacting
Wastes	Solid-state waste—building material waste	Prefabricated component/recovery
	Solid-state waste—building material package	Recovery
	Liquid waste—mud/building material waste	Recovery
	Liquid waste—machinery oil	Material saving
Fallen objects	Solid-state waste—building material waste	Recycle of solid waste/technology improvement
	Solid-state waste—building material package	Recovery
	Liquid waste—mud/building material waste	Technology improving/recovery
	Liquid waste—construction water	Recovery
	Construction tools—scaffold and board	Safety control/reliable tools
	Construction tools—model plate	Technology improving/safety control
	Construction tools—building material	Technology improving/recovery
	Construction tools—sling/others	Safety control
Others	Urban transportation—road encroachment	Enclosing wall/night shift/underground construction
	Civic safety—demolition	Static crushing/chemical breaking
	Civic safety—automobile transportation	Overloading forbidden/speed limiting
	Civic safety—tower crane	Safety control
	Civic safety—construction elevator	Safety control
	Civic safety—foundation/earth dam	Safety control
	Urban landscape—structure exposed	Masking
	Urban landscape—night lighting	Using projection lamp
	Urban landscape—electric-arc light	Bolt connection/pressure connection/prefabricated component
	Urban landscape—mud/waste water	Drainage organization
	Urban landscape—civic facility destruction	Technology improving/plan preconception

this section, we present a method to quantitatively measure the amount of pollution and hazards generated by a construction project within its project duration. The method sets to measure the construction pollution index (CPI), as shown in (1).

$$\text{CPI} = \sum_{i=1}^{n} \text{CPI}_i = \sum_{i=1}^{n} h_i \cdot D_i \qquad (1)$$

where CPI = construction pollution index of an urban construction project; CPI_i = construction pollution index of a specific construction operation i; h_i = hazard magnitude per unit of time generated by a specific construction operation i; D_i = duration of construction operation I that generates hazard h_i; and n = number of construction operations that generate pollution and hazards.

In (1), parameter h_i is a relative value indicating the magnitude of a hazard generated by a particular construction operation in a unit of time. Its value is limited in the range of [0,1]. If $h_i = 1$, it means that the hazard can cause fatal damage or catastrophes to people and/or properties nearby. For example, if a construction operation can generate some noise and the sound level at the receiving end exceeds the ‘‘threshold of pain,’’ which is 140 dB (McMullan 1993), then the value of h_i for this particular construction operation is 1. If $h_i = 0$, then it indicates that no hazard is detectable from a construction operation. It is possible to identify values of h_i for all types of pollution and hazards generated by commonly used construction operations and methods. For example, according to the information on sound emission from piling driven machines, as well as the types of piles, we can formulate the content of Table 3, which contains values of h_i for some piling operations.

Information and such data as the emission levels of noise, harmful gases, and wastes are normally available in the spec-

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TABLE 2. Countermeasures of Construction Pollution in Urban Civil Engineering and Their Effects

Category (1)	Pollution and Hazards: Dusts (2)	Harmful gases (3)	Noises (4)	Ground movements (5)	Wastes (6)	Fallen objects (7)	Others (8)
Technological methods	★	★	★	★	★	★	★
Managerial methods	★	⊗	★	⊗	★	★	★
Planning methods	★	⊗	★	⊗	☆	⊗	★
Building material methods	⊗	★	⊗	☆	⊗	⊗	☆

Note: ★ = more effective; ☆ = partial effective; ⊗ = noneffective.

TABLE 3. Values of h_i for Some Piling Operations

Piling Operations (1)	h_i value (per day) (2)
1. Prefabricated concrete piles using drop-hammer driver	0.5
2. Sheet steel piles using drop-hammer driver	0.6
3. Prefabricated concrete piles using hydraulic piling driver	0.2
4. Sheet steel piles using hydraulic piling driver	0.3
5. Bored piling	0.1
6. Sheet steel piles using drop-hammer driver	0.7
7. Prefabricated concrete piles using static pressing-in driver	0.2

ifications of the relevant construction machinery and plant, or can be conveniently measured. These data can then be converted to h_i values by normalizing them into the range of [0,1]. In case no data are available for such conversion, then h_i values have to be decided based on users' experience and expert opinions.

Durations required for completing construction operations are measured in number of days. For example, the Shanghai Maxwell (Fig. 1) construction project involves a piling operation that includes the following activities and durations.

1. Driving prefabricated concrete piles using drop-hammer driver (duration 31 days)
2. Driving sheet steel piles using hydraulic piling driver (duration 57 days)

Then, according to (1), the value of the CPI for the piling operation is $0.5 \cdot 31 + 0.3 \cdot 57 = 32.6$. The overall CPI value for the project is 747.2. The value of the CPI reflects the accumulated amount of pollution and hazards generated during the length of a construction project.

It is also very useful to create a CPI bar chart, which is very similar to the ordinary bar charts used in construction scheduling, except that the thickness of the bars represents the h_i value for the corresponding construction operation. By integrating the concept of CPI into MS Project, which is a commonly used tool for construction project management, we can develop a system to neatly combine environmental management with project management, as shown in Fig. 1, in which h_i values are listed beside their corresponding construction operations. As the height of a bar represents the h_i value, the area of the bar represents the CPI value of the construction operation. The aggregation of the thicknesses of bars, as indicated at the bottom of the bar chart, represents the distribution of the CPI value during the whole project. This distribution is

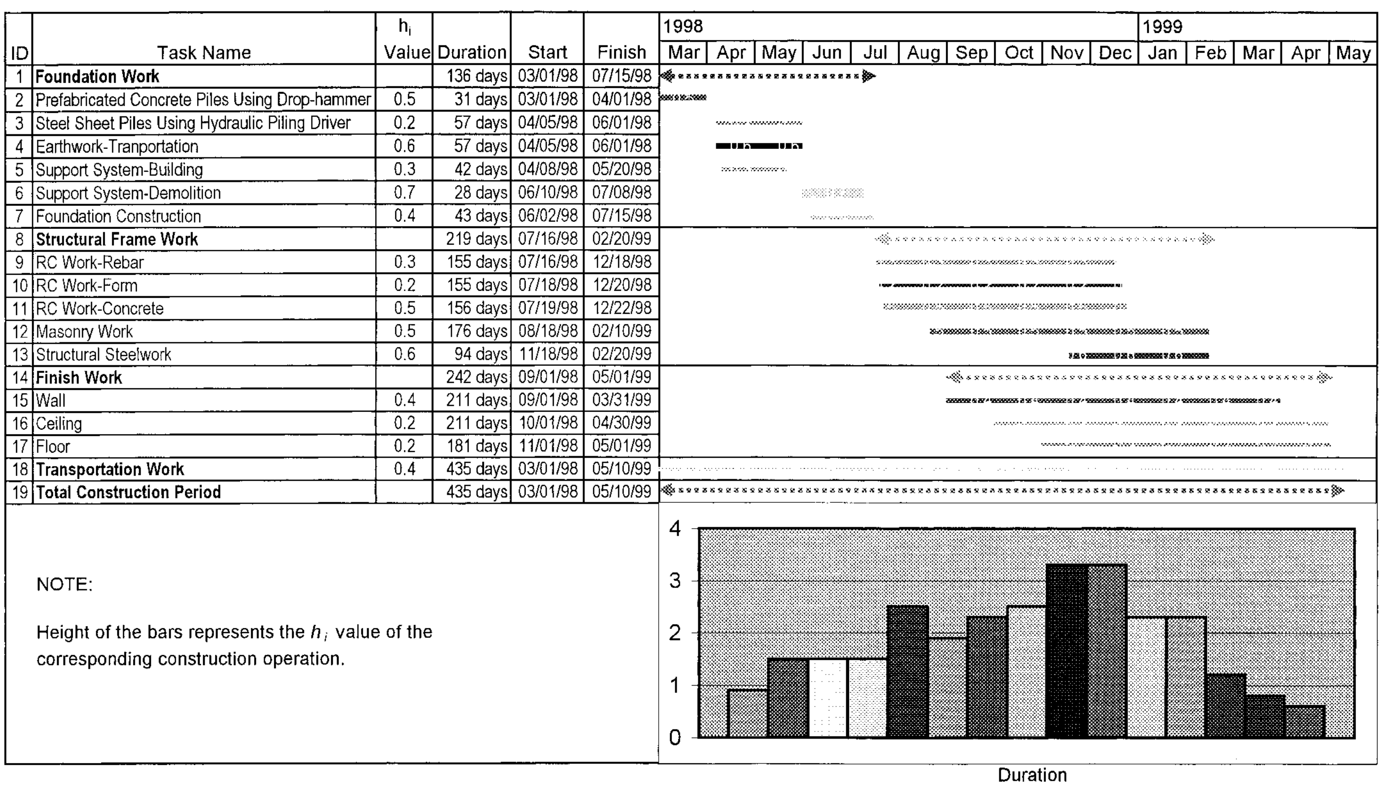

FIG. 1. Project Scheduling Together with Environmental Management

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particularly useful for project managers to identify the periods when the project will generate the highest amount of pollution and hazards. Therefore, preventive methods such as those listed in Table 1 can be used to reduce the amount of pollution and hazards during those periods. In this example, it can be seen from the distribution diagram in Fig. 1 that, during November to December 1998, the project generated the highest pollution and hazards, mainly because of the large amount of on-site mixing of concrete and masonry works. The project manager foresaw the problem and decided to reduce the amount of on-site mixing concrete in those months by using 25% ready-mixed concrete, which reduced the amount of noise generated from the on-site concrete mixing. This reduced the h_i value in November and December 1998 from 3.3 to 2.5, a 25% reduction, which also indicates that the amount of pollution and hazards has been reduced.

So far, a quantitative method for analyzing the magnitude of construction pollution and hazards has been presented. In order to ensure that the concept of environmental management is embedded in the daily practice of construction project management, we propose that major construction companies should obtain ISO 14001 Environmental Management System (EMS) certifications. Discussions of the ISO 14000 standards and ways of integrating the standards into construction project management are given in the next section.

INTEGRATING ENVIRONMENTAL MANAGEMENT WITH CONSTRUCTION MANAGEMENT

This section presents ISO 14000, the series of international standards on environmental management and the need for integrating environmental management into construction management. The ISO 14000 standards address the aspects of environmental management (Kloepfer 1997; ISO 1999; Peglau 1999; Quality Network 1999) shown in Table 4.

As a subset of ISO 14000, the EMS is a systematic approach to dealing with issues related to environmental management. It is a ''tool'' that enables a company of any size or type to control the impact of its activities, products, or services on the natural environment. Although many companies in other businesses have already obtained ISO 14001 EMS certifications, none of the construction companies (contractors) in China has such a certification. In order to build the concept of environmental management into construction management, we propose that it is fundamentally important for major construction companies in China to make necessary efforts to obtain certifications on ISO 14001 EMS.

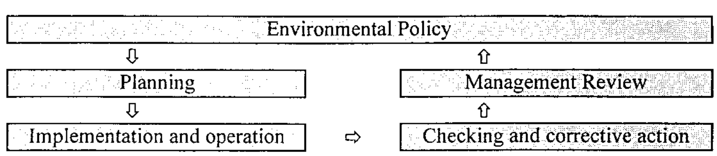
In the ISO 14001 EMS, environmental management is maintained through five stages (Fig. 2): Issuing environmental policies; planning; implementation and operation; checking and corrective action; and management review.

TABLE 4. ISO 14000 Series Standards

Standard (1)	Title/Description (2)
14000	Guide to Environmental Management Principles, Systems and Supporting Techniques
14001	Environmental Management Systems: Specification with Guidance for Use
14010	Guidelines for Environmental Auditing: General Principles of Environmental Auditing
14011	Guidelines for Environmental Auditing: Audit Procedures—Part 1: Auditing of Environmental Management Systems
14012	Guidelines for Environmental Auditing: Qualification Criteria for Environmental Auditors
14013/15	Guidelines for Environmental Auditing: Audit Programmers, Reviews and Assessments
14020/23	Environmental Labeling
14024	Environmental Labeling: Practitioner Programs—Guiding Principles, Practices and Certification Procedures of Multiple Criteria Programs
14031/32	Guidelines on Environmental Performance Evaluation
14040/43	Life Cycle Assessment General Principles and Practices
14050	Glossary
14060	Guide for the Inclusion of Environmental Aspects in Product Standards

ISO 14001 EMS requires construction management to establish systematic policies and methods to deal with problems related to environmental management. Specifically, the certification requires a construction company to establish objectives, targets, and programs for environmental management. A thorough analysis of all processes and methods used in construction operations is necessary in order to identify the sources and magnitude of pollution and hazards. Once the sources are identified, the construction company needs to make all necessary efforts to reduce the amount of pollution and hazards generated from a particular operation. Also, it is important to have a regular management review to ensure the suitability and sustainable implementation of the established policies and methods.

The establishment and implementation of ISO 14001 EMS requires total commitment and cooperation of all parties involved in the supply chain, including construction contractors, supervisors, designers, manufacturers, and investors (Cysewski 1995). However, in developing countries such as China, there are many difficulties and challenges ahead for implementing ISO 14001 EMS in the construction industry. The most formidable one is that efforts spent in environmental protection do not necessarily result in lower project cost and/or shorter



Notes:
①*Environmental Policy*: the environmental policy and the requirements to pursue this policy via objectives, targets, and environmental programs
②*Planning*: the analysis of the environmental aspects of the organization (including its processes, products and services as well as the goods and services used by the organization
③*Implementation and operation*: implementation and organization of processes to control and improve operational activities that are critical from an environmental perspective (including both products and services of an organization)
④*Checking and corrective action*: checking and corrective action including the monitoring, measurement, and recording of the characteristics and activities that can have a significant impact on the environment
⑤*Management Review*: review of the EMS by the organization's top management to ensure its continuing suitability, adequacy and effectiveness

FIG. 2. Key Stages of ISO 14000 EMS

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durations. In fact, introducing environmental management into construction management increases the project direct costs because, at present, contractors do not need to pay for the pollution and hazards generated by their projects, if they can get away without obeying current environment and construction laws. Another difficulty is that the awareness of environmental protection among the general public is low compared to that in many developed countries. People seem to be too busy accumulating personal wealth to worry about the natural environment. As a consequence, the public pressure on the construction industry for improving its environmental management is not very high.

With these difficulties and challenges in mind, we believe that it is important for the government to further reinforce relevant environmental protection laws on one hand, and promote the general education in the importance of protecting the natural environment on the other.

CONCLUSIONS

In order to tackle pollution and hazards generated by urban construction projects in China, we first presented a qualitative system to identify and categorize sources of pollution and hazards on construction sites. Methods for preventing or reducing the amount of pollution and hazards at the sources are provided. Then, a method is presented to quantitatively measure the construction pollution index (CPI), which indicates the accumulated pollution and hazards generated from a construction site. Integrated with MS Project, a popular scheduling software used by construction professionals in China, we developed a computer tool which can automatically generate the pollution and hazards distribution diagram over the project duration. The distribution diagram can assist project managers to identify the worst periods in terms of emission of pollution and to take necessary preventive measures to reduce the amount of pollution and hazards. The computer tool is being tested on different projects, and detailed descriptions of the computer tool and its test results will be reported in the future.

As the concept of environmental management is relatively new in China, we recommend that it is vital for major construction companies in China to obtain ISO 14001 EMS certifications. By doing so, construction companies will establish comprehensive policies and regulations and safe-guard the implementation of environmental management within the context of construction management.

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