# Chapter II

## Environmental Performance Indicators for Construction Project

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### 1 Introduction

Environmental degradation becomes a worldwide concern. Various reports on environmental related problems have been widely reported within the media and existing research works. So (2002) reported that Hong Kong starts 2002 with thick smog and air pollution have soared to its highest level in two years. Connolly (2001) noted that the Sydney bushfires had left a significant aftermath as air pollution peaked to almost five times the national Australian standard. Gonzalez (2002) wrote that the collapse of the World Trade Center in New York and subsequent fires had produced some of the highest air pollution ever studied. In China, the State Environment Protection Bureau (SEPB) reported that 72% of major cities in China had TSP (total air suspended particle) of 200mg/m3 while the World Health Organization standard is only 90mg/m3 (SEPB, 1998). The ozone layer continues to weaken and natural resources such as coal are fast exhausting. The capacity of the Earth to sustain life is now seriously under threat. Thus, the general public is becoming increasingly supportive to the mission of "sustainable development", defined as … "development which meets the needs of the present without compromising the ability of future generation to meet their own needs" (WCED, 1987).

Construction activity is generally considered as a major contributor to environmental pollution, noted by various research works. For example, McDonald's research (1996) reports that 14 million tons of wastes are put into landfill in Australia each year, and 44% of this waste is attributed to the construction industry. According to Zhang et al. (2000a), construction-contributed environmental pollution has been increasing in China in line with its fast urban development since the early 1980s. The standards of major environmental indicators such as sulfur dioxide (SO2) emissions and total air-suspended particulates (TSP) are far worse than international standards.

Construction activity is one of the major contributors to the environmental impacts, which are typically classified as air pollution, waste pollution, noise pollution and water pollution (EPD, 1999). Poon (2000) reported that the waste generated by the building and demolition of construction projects assumes a large proportion of environmental waste in Hong Kong. Uher (1999) suggested that construction activities have a significant impact on the environment across a broad spectrum of off-site, on-site and operational activities. Off-site activities concern the mining and manufacturing of materials and components, the transportation of materials and components, land acquisition, and project design. On-site construction activities relate to the construction of a physical facility, resulting in air pollution, water pollution, traffic problems, and the generation of construction wastage. March (1992) observed the construction industry's environmental impacts under the categories of ecology, landscape, traffic, water, energy, timber consumption, noise, dust, sewage, and health and safety hazards. Shen et al. (2000) classified construction environmental impacts as the extraction of environmental resources such as fossil fuels and minerals; extending consumption of generic resources, namely, land, water, air, and energy; the production of wastes that require the consumption of land for disposal; and pollution of the living environment with noise, odors, dust, vibrations, chemical and particulate emissions, and solid and sanitary waste. Hendrickson and Horvath (2000) considered the five largest toxic air emissions from construction, including sulfur dioxide (SO2), nitric dioxide (NO2), volatile organic compounds (VOC), toxic releases to air, and hazardous waste generated. They noted that these environmental emissions are particularly from the four largest construction sectors in the United States, namely, highway, bridge, and other horizontal construction; industrial facilities and commercial and office buildings; residential one-unit buildings and other construction such as towers, sewer and irrigation systems, and railroads. Wu (2003) investigated comprehensively the factors affecting the environment during construction.

## 2 Indicators for measuring project environmental performance (PEP)

A number of studies have been undertaken to investigate the environmental effects caused by construction projects through examining various attributes.

A typical list of attributes include land use, existing site dereliction, natural habitat destruction, use of natural resources, air emissions and pollution, noise pollution, use of water resources, discharges and water pollution, site drainage, waste, comfort disturbance, energy consumption, health and safety (EPD, 1999; Poon, 2000; Hendrickson et al., 2000; Griffth et al., 2002; Shen et al., 2000; Chen et al., 2002; and CET, 1999). At more micro-level, construction related factors contributing to environmental pollution are usually classified into various categories such as dust, harmful gases, noise, solid and liquid wastes, fallen objects, ground movement, and chemicals (Wooley et al., 1997; Chen et al., 2002; Yohanis et al., 2002; Pasquire, 1999 and CIRIA, 1999).

By synthesizing the above literatures, a list of indicators for measuring the environmental performance of construction projects can be formulated (Wu, 2003). The adequacy of these indicators has been examined through interview discussions with construction professionals and academics. As a result, 11 indicators were selected, including air pollution, noise and vibration pollution, water pollution, construction & demolition waste, chemical waste, material storage leakage/spillage, dangerous goods, flora & fauna protection, land contamination, site cleanliness, and environmental management system. The causes affecting the performance of these indicators are also investigated, as presented in Table 2-1.

Table 2-1 Project environmental performance indicators and the causes affecting their performance

| Environmental performance indicators | Causes contributing to indicator performance |
|---|---|
| Air pollution | Toxic fumes from the operation of plant and equipment, organic solvent, electric welding, and dust from site clearance, soil excavation, movement of mobile powered mechanical equipment, piling, material handling or storage, building demolition, concrete batching and sand or grit conveyor system (HCL,2002). |
| Noise and vibration pollution | Plant and equipment operations; piling and drilling; site vehicles movement (HCL, 2002); erection or dismantling of formwork or scaffolding; rubble disposal; steel bars handling and hammering works (BD, 1997; HCL, 2002). |
| Water pollution | On-site activities and groundwater released during piling foundation, civil and building works; toilet waste of site staff and workers, contaminated surface runoff on site from rainwater; contamination and blockage of drains due to excavated material, silt or debris (HCL, 2002; CET, 1999). |
| Construction & demolition waste | A mixture of surplus materials arising from site clearance, excavation, construction activities, refurbishment, renovation, demolition, maintenance and road works, including non-inert waste (bamboo, timber, vegetation, packaging wasted and other organic materials) and |

| | |
|---|---|
| | non-inert waste (rocks, bricks asphalt, and uncontaminated soil) (HKPC,2001) |
| Chemical waste | Surplus adhesives, surplus pesticides, spent paints, petroleum products, spent lubrication oil and grease, spent mineral oil, spent acid and alkaline solutions, spent solvent, surplus waterproofing supplement (HCL,2002; CIRIA,2000). |
| Material storage leakage/ spillage | Leakage from the storage of materials (general); leakage from the storage of Liquefied petroleum Gas (LPG); spillage of Bentonite; leakage from the storage of paints; and spillage during handling of paints (HKG, 1992) |
| Dangerous goods | Ways of keeping dangerous goods (CIRIA,2000) |
| Flora & fauna protection | Damage/remove of trees and other organic lives during construction and demolition (CIRIA,2000) |
| Land contamination | Soil erosion, land contamination from on-site operations and dumping construction wastes |
| Site cleanliness | Debris and mud on roads left from site operations, operating vehicles and / or construction plant, damage to nature resources/ utilities, poor site hygiene resulting in mosquito breeding and rodent infestation, hygiene, site security, impacts on antiquities and monuments (BD, 1997) |
| Environmental management system | Establishment and implementation of an environmental management system. |

## 3 Indicator benchmarks

In order to measure the level of the performance of the environmental indicators established in Tab.2-2, it is necessary to establish the indicator performance benchmarks. Benchmarking is a multi-faceted technique to incorporate "best practices" and establish rational performance goals, thus operational gaps can be identified and proper measures can be adopted to eliminate such gaps (Yasin, 2002). Benchmarks are performance measurement standards derived from benchmarking best practices (Camp, 1989). There are two types of benchmarks, namely descriptive benchmarks and quantitative benchmarks. Descriptive benchmarks are defined from the best practices that deliver the outputs completely satisfying customers. The quantitative benchmarks are the conversion of benchmark practices to operational measures (Camp, 1995).

Previous research (Shen et al. 2005a) appreciates the difficulties encountered for measuring quantitatively the environmental performance of construction projects, and descriptive benchmarks are considered more suitable to be used in this circumstance. Although there are no existing benchmarks available for measuring the environmental performance of construction activities, several typical literatures provide valuable references. These references include the General Specification for Civil Engineering Works published by Hong Kong

Government (HKG, 1992), the various legislations and regulations such as Hong Kong's APCO (Air Pollution Control Ordinance Chapter 311) (1997), Hong Kong's ETWB (Environmental, Transportation and Works Bureau) (1999 and 2000), NCO (Noise Control Ordinance Chapter 400) (1997), DGO (B) (Dangerous Goods Ordinance Chapter 295 Sub-legislation B) (2000), and WDO (Waste Disposal Ordinance Chapter 354) (1997). By taking into account of these references, the sample benchmarks for measuring the environmental performance during construction process are proposed, as shown in Tab.2-2 (Wu, 2003; Shen et al, 2005a). The formulation of these benchmarks has incorporated the comments received from the professionals and academics who offered the interviews during the cause of this study.

Table 2-2 Sample of proposed benchmarks for measuring project environment performance indicators

| Indicator | Benchmarks | Credit |
|---|---|---|
| Noise Pollution and Vibration | Noise from construction work other than percussive piling | |
| | A construction noise permit (CNP) is required for the use of powered mechanical equipment for the purpose of carrying out construction work between the hours of 7 pm and 7am on weekdays or at any time on Sunday or a public holiday (NCO, 1997). | Y/N (1/0) |
| | A CNP is required for the carrying out of any prescribed construction work (including erection or dismantling of formwork or scaffolding; loading, unloading or handling of rubble, wooden boards, steel bars, wood or scaffolding material; and hammering) at any place within a designated area between the hours of 7 pm and 7 am on weekdays or at any time on Sunday or a public holiday (NCO, 1997). | Y/N (1/0) |
| | Noise from percussive piling | |
| | Percussive piling between the hours of 7pm and 7am on weekdays (except Sunday and public holidays) (NCO, 1997). | Y/N (1/0) |
| | Percussive piling between the hours of 7pm and 7am on weekdays or at any time on Sunday or a public holiday is prohibited (NCO, 1997). | Y/N (1/0) |
| | For all contracts for which tender date falls on or after 1 July 1997 – the use of diesel hammers for Percussive Piling shall be prohibited ( ETWB, 1997). | Y/N (1/0) |
| | Noise from hand-held percussive breakers and air-compressors | |

| | |
|---|---|
| Hand-held percussive breakers heavier than10kg and air-compressors capable of supplying compressed air at 500kpa or above used for construction work are required to comply with specified noise emission standards and to affix a Noise Emission Label (NEL)when being operated (NCO(C), 2000; NCO(D), 2000) | Y/N (1/0) |
| Noise from blasting | |
| Blasting shall not be carried out on General Holidays and before 8:30am or after 5:30 pm on any day (HKG, 1992). | Y/N (1/0) |
| Vibration from blasting trials | |
| Blasting trials shall be carried out for each proposed blasting procedure to demonstrate that the resulting ground vibrations at locations stated in the Contract or instructed by the Engineer can be satisfactorily predicted, recorded and are within acceptable limits, and shall not adversely affect the safety and stability of adjoining structures, installations, slopes and land (HKG, 1992). | Y/N (1/0) |
| Unless stated otherwise permitted by the engineer, the vibration at the adjoining sloes and land due to blasting measured in terms or peak particle acceleration and peak particle velocity shall not exceed the values stated in the Contract(HKG, 1992). | Y/N (1/0) |
| Vibration from piling works | |
| The vibrations due to piling works at structures, utilities and previously installed piles measured in terms of peak particle velocity shall not exceed 25 mm/s (HKG, 1992). | Y/N (1/0) |
| Noise emissions from vehicles | |
| Every vehicle propelled by an internal combustion engine shall be fitted with a silencer, expansion chamber or other contrivance suitable and sufficient for reducing, as far as may be reasonable, the noise caused by the escape of the exhaust gases from the engine (RTO (A), 1996). | Y/N (1/0) |

# 4 System dynamics method for environmental performance assessment

*Dynamic factor affecting project environmental performance (PEP)*

Sidwell (1990) suggested that construction projects follow a life cycle that is goal oriented but subjects to the impacts of various dynamics. Ford (1995) contended that the difficulties of performing and managing construction business activities are due to the fact that construction projects are technically complicated and interact with a large number of dynamic, social, and environmental factors. EI-Rayes and Moselhi (1999) considered a construction project as a dynamic system and investigated the approach of optimizing project performance by using dynamic programming technique. Adeli and Karim (1997) developed a neural dynamics model to identify solutions for optimizing the time-cost performance in implementing a construction project. Love et al. (2002) suggested a conceptual framework for helping to understand the dynamics that affect construction project performance. In this framework, dynamic factors affecting project performance are classified into attended dynamics and unattended dynamics. Both attended and unattended dynamics are considered as having either positive or negative impacts to project performance.

Project performance traditionally refers to the outcomes of construction cost, construction time, and construction quality; the identification of dynamic factors in the existing studies mainly concerns these aspects. When the contents of project performance are focused on project environmental performance (PEP), factors affecting project performance need to be reviewed. Factors affecting PEP can be identified through examining the contents for a construction to contribute to attaining sustainable development. Considering that the typical principles of sustainable development are described as including three attributes, namely, the sustainability of economic development (E), the sustainability of social development (S), and the sustainability of environmental development (En) (WCED, 1987), PEP dynamic factors can be formulated through examining the attributes En, which can be sub-divided into three sorts, namely, environmental impact (EI), utilization of environmental resources (ER), and contribution to sustainability (CS) (Shen et al., 2005b).

During implementation of a construction project, the performance of the environmental attributes, EI, ER and CS, are affected by various factors at different stages across its life cycle. In a typical classification, the life cycle of a construction project is divided into five stages, namely, inception stage, construction stage, commission stage, operation stage and demolition stage (Shen et al., 2002b). Some studies have examined the factors affecting EI, ER and CS at different stages of a project (Shen et al., 2002b; Shen et al., 2005b). By referring to previous studies, a list of dynamic factors affecting project environmental performance can be identified; these factors are shown in

Tab.2-3.

***Formulating project environmental performance (PEP) prototype model using system dynamics method***

System dynamics method is widely used for understanding a system that is complex, dynamic and with nonlinearly interacted variables. Existing studies have presented examples of applying system dynamics method in identifying solutions for identifying solutions for improving construction project management effectiveness. Love *et al*. (2002) presented a framework in using system dynamics method for dealing with dynamic feedbacks in managing a complex project system. Ford (1995) identified various dynamic factors affecting project development process, which provides useful reference in improving the effectiveness of project development by properly responding to those major factors.

Table 2-3 Major variables affecting PEP of a construction project

| Project stage | Project environmental performance (PEP) | | |
|---|---|---|---|
| | EI | ER | CS |
| Inception | Land pollution<br>Ecology impact | Extraction of raw materials | Bio-diversity protection |
| Construction | Toxic generation<br>Waste generation<br>Air pollution<br>Water pollution<br>Noise pollution | Energy consumption<br>Water consumption<br>Materials consumption | Green building materials<br>Energy saving<br>Water saving |
| Commission | - | Decoration materials | Paperless advertisement |
| Operation | Toxic generation<br>Waste generation<br>Air pollution<br>Water pollution<br>Noise pollution | Energy consumption<br>Water consumption<br>Materials consumption | Ecology regeneration |
| Demolish | Waste generation | Energy consumption | Recycle materials<br>Reuse materials<br>Reclaim materials |

By using system dynamics method, Pena-More and Li (1999) introduced a dynamic planning procedure for implementing design-and-build type construction projects. This procedure enables a dynamic plan that incorporates the dynamic feedbacks and responds accordingly to the impacts of various dynamics. Chritamara *et al*. (2002) developed a model by using system dynamics principles for evaluating project management procedures, with application of the model being aimed at mitigating time and cost overruns. System dynamics approach was used as a typical simulation technique for evaluating the decision-making performance. Dolol and Jaafarl (2002) used system dynamics approach as a simulation tool to establish baseline value of a construction project. This approach provides an alternative method for optimizing investment decisions when project performance is assessed across the project life cycle.

By applying the model PEP developed by Shen *et al*. (2002b), project environmental performance is measured by the attributes: En. The model is described as follows:

$$PEP(t) = \int_0^t f(EI(t), ER(t), CS(t))dt \qquad (1)$$

Where EI(t), ER(t) and CS(t) denote respectively the contribution of the three environmental attributes, namely, environmental impact, utilization of environmental resources and contribution to sustainability, to the environmental performance. The parameters are defined as deterministic functions with time by considering that the relations between values of the parameters and time can be established across project life cycle.

However, it is considered that the functions EI(t), ER(t) and CS(t) should not be considered as deterministic as the relationships between the performance of the parameters and time are uncertain due to the impacts of dynamic factors. Therefore, the application of the model PEP has limited effect. To go around this weakness, system dynamics method is used to simulate the impacts of uncertain factors on the value of PEP.

System dynamics has four elements defined within a system: (a) stock; (b) flow; (c) converter; and (d) connector, as shown in Fig.2-1 (HPS 1997; Mohapatra, 1994). A stock collects all those in-flows and also serves as the source where out-flows come from. A flow serves as a vehicle to delivery information to or drain information out from the stock. The value of a flow can be positive or negative. A positive flow is an in-flow and will fill in the stock, and a negative flow is an out-flow draining the stock. A converter serves a utilitarian role in selecting proper values and functions of parameters in the model. The connector is an information transmitter connecting elements. When a system becomes more complex, there will be more connectors.

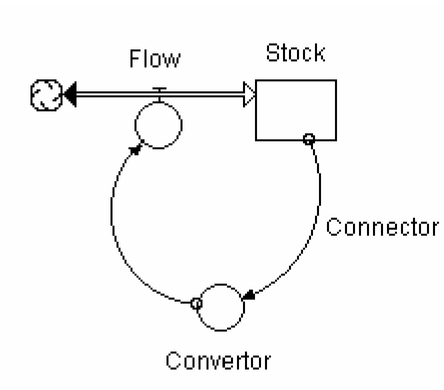


Fig.2-1 A model of system dynamics approach

In Fig.2-1, the volume of stock will change at different time points as both in-flows and out-flows will be generated when time goes on. The relationship between the stock and flow are established as follows:

$$Stock(t) = Stock(t - dt) + (Flow)dt \quad (2)$$

and

$$Stock = \int (Flow)dt \quad (3)$$

For assessing the environmental performance of a construction project by using system dynamics approach, the measure project environmental performance (PEP) is considered as a stock, and an impact from dynamic factors on the value PEP can be considered as a flow. Therefore, an increase or decrease of the parameters EI(t), ER(t) and CS(t) discussed above can be considered as the flows to PEP. For example, when a project brings an contribution to sustainability, namely, an increase in CS(t), a positive impact to the value PEP is received. This will produce an in-flow to the stock, and the volume of PEP will increase. An increase in PEP indicates that a positive contribution to project environmental performance is received. On the other hand, PEP will decrease if an out-flow occurs, indicating that a negative impact to project environmental performance is received. This may be due to that environmental pollution is induced in implementing a project. A converter is employed to define the level of influence of each flow on the stock PEP, or the way in which the flow influences the value PEP. To simplify the analytical process, the calculation of the value PEP is proposed as a weighted value between the dynamic factors, which can be written as the following dynamic model:

$$\begin{cases} PEP(t) = \int_0^t W_{EI}(t)I_{EI}(t)dt + \int_0^t W_{ER}(t)I_{ER}(t)dt + \int_0^t W_{CS}(t)I_{CS}(t)dt \\ W_{EI}(t) + W_{ER}(t) + W_{CS}(t) = 1 \\ I_{EI}, I_{ER}, I_{CS} \in [-100,100] \end{cases} \quad (4)$$

Where $I_{EI}(t)$, $I_{ER}(t)$ and $I_{CS}(t)$ denote respectively the dynamic functions of generating environmental impact, utilization of environmental resources and contribution to sustainability from implementing a construction project. The values of the variables $I_{EI}$, $I_{ER}$ and $I_{CS}$ are defined as relative measures within the interval *[-100,100]*. Variables $W_{EI}$, $W_{ER}$ and $W_{CS}$ denote respectively the weights of environmental impact, utilization of environmental resources and contribution to sustainability to PEP. By applying these parameters to the model defined in Fig.2-1, a prototype model of PEP using system dynamics method can be developed as shown in Fig.2-2.

In Fig.2-2, the stock (PEP) collects three types of flows, namely, environmental impact (IEI), utilization of environmental resources (IER) and contribution to sustainability (ICS). The three converters (WEI, WER and WCS) can adjust the volume of the three types of flows. This adjustment implies that efforts can be devoted to improve IEI, IER and ICS. It is noticed that feedback loops exist from the stock PEP to the three attributing factors (environmental impact factor, utilization of environmental resources factor and contribution to sustainability factor), and from PEP to three flows IEI, IER and ICS. The feedback loops are used to indicate that whilst PEP is determined by the three flows, the volume of PEP will also influence the flows in return. For example, when PEP is large, the flows can be adjusted by a reduction from the three flows. Thus the values of IEI, IER, and ICS are changeable by applying adjustment measures (i.e. the converters "?" in Fig.2-2). The existing volume of PEP and other dynamic factors will decide the value of adjustment.

In fact, all the variables $I_{EI}$, $I_{ER}$, $I_{CS}$, $W_{EI}$, $W_{ER}$ and $W_{CS}$ are changeable. To demonstrate the principle of the model PEP in a simple way, it is assumed that the weighting factors, $W_{EI}$, $W_{ER}$ and $W_{CS}$ are constants. Therefore the connections between the stock and weighting factors in Fig.2-2 become redundant. And model Eq.(4) cam be revised as the following PEP prototype model Eq.(5), and Fig.2-2 can be modified into Fig.2-3.

$$\begin{cases} PEP(t) = W_{EI}\int_0^t I_{EI}(t)dt + W_{ER}\int_0^t I_{ER}(t)dt + W_{CS}\int_0^t I_{CS}(t)dt \\ W_{EI} + W_{ER} + W_{CS} = 1 \\ I_{EI}, I_{ER}, I_{CS} \in [-100,100] \end{cases} \tag{5}$$

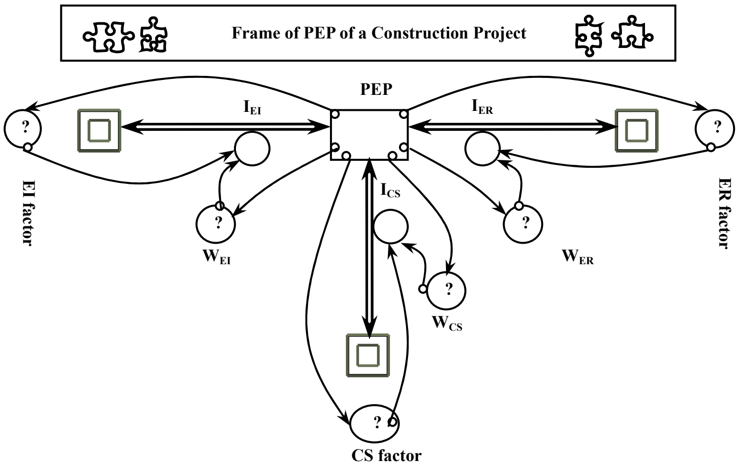


Fig. 2-2 Prototype model of PEP using system dynamics

## 5 Computer-based scoring method for measuring PEP

***Parameters used for assessing project environmental performance (PEP)***

Questions are raised when assessing project environmental performance. What contribute(s) to project environmental performance in implementing construction activities? What represent(s) project environmental performance? How do we measure the level of project environmental performance? These questions can be described in three groups of parameters: (1) the project environmental performance factors, which contribute to or affect project environmental performance; (2) the environmental performance indicators, which are used to represent project environmental performance; and (3) the indicator benchmarks, which are used to measure the level of indicator performance. These parameters will be employed in building up a model for the calculation of environmental performance score (EPS).

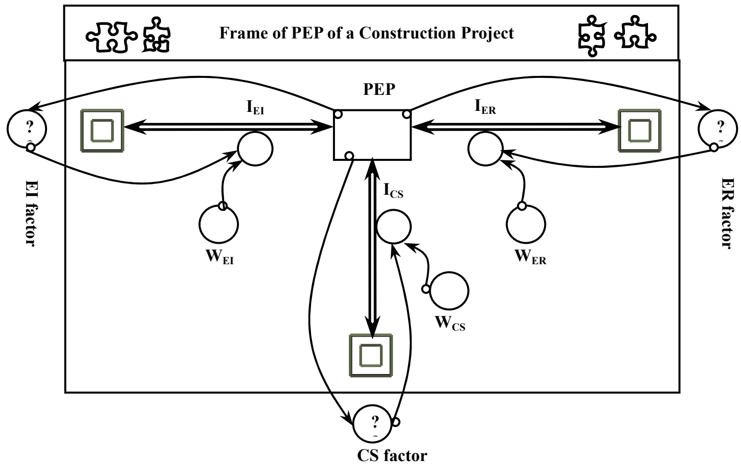


Fig.2-3 A simplified prototype model of PEP using system dynamics

<u>Identification of the factors affecting project environmental performance</u>

Existing studies have examined the factors contributing to, or affecting, a building's environmental performance with focus on the aspects of land, energy, water, and material (CIB, 1998; Wu, 2003). These factors are usually discussed under the categories of design; architecture works; structural works; site management; project organization; resources, coordination, and control; documentation, programming, and process; and others (HK-BEAM in 1999). However, a contractor's activities are mainly undertaken during construction stage, and the factors affecting its environmental performance are mainly relevant to site operation and management. These factors can be grouped under five groups: operational activities (F1), site management (F2), project management (F3), environmental management technology (F4), and environment management policy within the organization (F5). Sub-factors can be drawn under each category, and Tab.2-4 provides the hierarchy of environmental performance factors during a contractor's activities (CET, 1999; Uren and Griffiths, 2000; Wathey and O'Reilly, 2000; HKPASSWG, 1997).

<u>Formulation of the indicators measuring project environmental performance</u>

Various indicators have been presented in previous studies for measuring environmental performance in implementing construction activities, such as Building Research Establishment Environment Assessment Method (BREEAM) (BRE, 1998), LEED (USGBC, 2001), Green Building Tool (GBTool) (GBC, 2000), and HK-BEAM (CET, 1999).

Table 2-4 Factors affecting PEP during construction

| | |
|---|---|
| F1 (Operational activities) | (1) Structural operation (earthwork and excavation; formwork; reinforcement; concrete; waste treatment)<br>(2) External and internal operation (wall, roofing, and isolation; component installation; plumbing and drainage; ornament and painting; surrounding and landscaping; waste treatment |
| F2 (Site management) | (1) Site performance (site security; material storage and security; cleanliness and care)<br>(2) Health and safety (health provision; safety) |
| F3 (Project management) | (1) Project organization (project organization structure; construction planning; environmental management task force)<br>(2) Project resources (labor quality; plant quality; materials quality)<br>(3) Coordination and control (coordination performance; control and supervision quality; cooperation culture)<br>(4) Project documentation (project manual; project progress reports)<br>(5) Project programming (program; progress control methods; project milestones) |
| F4(Environmental management technology) | (1) Project communication technology (project management software packages; intranet/internet system; information management expertise)<br>(2) Environmental protection technology (energy and resource saving technology; pollution reduction technology; waste reduction technology)<br>(3) Expertise (environmental protection professionals; environmental protection facilities) |
| F5(Environment management policy) | (1)Environmental protection regulations (environmental protection law; environmental regulations on building activities)<br>(2) Company environmental management policy (establishment of environment management system; application of environmental management standards ISO 14000) |

For example, noise pollution, air pollution, water pollution, ecology impact, construction, and demolition management are used in HK-BEAM. The use of materials and resources, and energy use are adopted in the system LEED. Other studies provide more detailed indicators (Wooley *et al.*, 1997; Yohanis and Norton, 2002; Pasquire, 1999; and CIRIA, 1999).

Based on the previous studies, the indicators for measuring project environmental performance are proposed to include: general environmental impact ($I_1$), utilization of environmental resources ($I_2$), contribution to sustainability ($I_3$), public impact ($I_4$), and care for labor ($I_5$). Further indicators can be developed under each first-level indicator. A list of detailed environmental performance indicators was compiled by this research team and sent to professionals for assessing the suitability of the indicators through a survey. According to the survey results, a list of second-level indicators has been chosen, as shown in Tab.2-5. There are, in total, 20 indicators at second level in the indicator structure, denoted as $I_{x\text{-}y}$, and they are used to indicate the results of a contractor's environmental performance (Wu, 2003).

Table 2-5 Structure of the environmental performance indicators during construction

| First-level indicator | Second-level indicator |
|---|---|
| $I_1$ (General environmental impact) | $I_{1-1}$ (Ecology impact)<br>$I_{1-2}$ (Toxic generation)<br>$I_{1-3}$ (Waste generation)<br>$I_{1-4}$ (Air pollution)<br>$I_{1-5}$ (Land pollution)<br>$I_{1-6}$ (Water pollution)<br>$I_{1-7}$ (Noise pollution) |
| $I_2$ (Utilization of environmental resources) | $I_{2-1}$ (Extraction of raw materials)<br>$I_{2-2}$ (Energy for manufacturing materials)<br>$I_{2-3}$ (Transportation resources)<br>$I_{2-4}$ (Energy consumption on site) |
| $I_3$ (Contribution to sustainability) | $I_{3-1}$ (Materials recycling)<br>$I_{3-2}$ (Resources/materials reusing)<br>$I_{3-3}$ (Energy saving) |
| $I_4$ (Public impact) | $I_{4-1}$ (Public health effect)<br>$I_{4-2}$ (Public safety)<br>$I_{4-3}$ (Public image) |
| $I_5$ (Care for labor) | $I_{5-1}$ (Site hygiene condition)<br>$I_{5-2}$ (Training provision)<br>$I_{5-3}$ (Safety measure provision) |

Indicator benchmarks

Values or scores will be allocated to individual performance indicators when the assessment is conducted to examine the environmental performance committed during the construction of a specific project. However, it is necessary to have criteria or benchmarks for scoring. There are no benchmarks available for assessing project environmental performance, but existing methodologies provide valuable references. These methodologies include BREEAM ( BRE, 1998), LEED ( USGBC, 2001), GBTool (GBC, 2000), HK-BEAM (CET, 1999), HPBG (DDCNY, 1999), and A Guide to Green Construction Practices (GGCP) by the Hong Kong Productivity Council (HKPC, 2001). As an alternative approach, the sample indicator benchmarks for measuring project environmental performance are proposed, as shown in Appendix (Wu, 2003, Shen et al 2005a). In applying the proposed benchmarks to a particular construction process, the consideration will be given to whether the concerned contractor has met the individual benchmarks defined for each indicator.

Calculating the EPS

The value of EPS is defined as the total score collected from the assessment results on all second-level environmental performance indicators, which are subdivided from five first-level indicators (see 5). The calculation for EPS can be derived from the following model:

$$EPS = \sum_{i=1}^{5} W_i S_i \qquad (6)$$

Where $S_i$ is the score gained by the environmental performance indicator $I_i$. It is considered that differences exist in contributing to the level of environmental performance among the five first-level indicators; thus, a relative weighting value, $W_i$ is employed to denote the relative significance of each $I_i$ among all the five first-level indicators.

As structured in Table 2-5, each first-level indicator $I_i$ consists of various second-level indicators $I_{i-j}$. It is considered that individual second-level indicators $I_{i-j}$ have different weightings to Ii. Thus, the score $S_i$ is structure as the weighted score from assessing the second-level indicator $I_{i-j}$, which can be written as:

$$S_i = \sum_{j=1}^{x} w_{ij} S_{ij} \qquad (7)$$

Where x denotes the number of second-level indicators under the first-level indicator $I_i$. The structure in 5 indicates that first-level indicators $I_i$ (for i=1,…,5) have been identified as consisting of different numbers of second-level indicators. For example, $I_1$ has seven second-level indicators, and $I_2$ has four second-level indicators. Furthermore, in model (7), $w_{ij}$ denotes the relative significance of the indicator $I_{i-j}$ among all the second-level indicators grouped under the first-level indicator $I_i$. $S_{ij}$ denotes the performance score obtained by the indicator $I_{i-j}$.

A survey was conducted to the Chinese construction industry for establishing the values of the relative weighting parameter $W_i$ and $w_{ij}$ (Wu, 2003). The questionnaire was designed to allow project managers or engineers working in construction firms to indicate the relative importance of various environmental performance indicators. Respondents were invited to indicate the relative significances between indicators in pairs. According to the responses, the calculation results are derived in Table 2-6 and Table 2-7.

Table 2-6 Weightings between the five first-level indicators $W_i$

| $I_i$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ |
|---|---|---|---|---|---|
| $W_i$ | 0.481 | 0.252 | 0.166 | 0.061 | 0.040 |

Table 2-7 Weightings between second-level indicators under each first-level indicator $w_{ij}$

| $w_{ij}$ | $I_{i-1}$ | $I_{i-2}$ | $I_{i-3}$ | $I_{i-4}$ | $I_{i-5}$ | $I_{i-6}$ | $I_{i-7}$ |
|---|---|---|---|---|---|---|---|
| $I_1$ | 0.31 | 0.33 | 0.125 | 0.09 | 0.045 | 0.065 | 0.035 |
| $I_2$ | 0.245 | 0.606 | 0.048 | 0.101 | | | |
| $I_3$ | 0.324 | 0.601 | 0.075 | | | | |
| $I_4$ | 0.258 | 0.105 | 0.637 | | | | |
| $I_5$ | 0.731 | 0.188 | 0.081 | | | | |

Therefore, the calculation of $S_i$ mainly requests for the input of the value of $S_{ij}$, which represents the level of the performance of the indicator $I_{i-j}$. By referring to the benchmarks proposed in Appendix, it can be noted that the performance of $I_{i-j}$ is affected by various environmental factors, which have been described in detail in 4. An alternative method for obtaining the value of $S_{ij}$ is to consider as to what extent these environmental factors are under control in a particular practice. To demonstrate the principle of the analysis in this study, the five primary level factors are focused on, namely, operational activities ($F_1$), site management ($F_2$), project management ($F_3$), environmental management technology ($F_4$), and environment management policy ($F_5$). The method for measuring the value of $S_{ij}$ is therefore formulated as follows:

$$S_{ij} = \frac{\sum_{n=1}^{5} x_{i-j}^{n}}{\sum_{n=1}^{5} F_{i-j}^{n}} \qquad (8)$$

$F_{i\text{-}j}^{n}$ denotes the maximum credits that the environmental factor $F_n$ (for n=1,…,5) can contribute to the indicator $I_{i-j}$. This is the outcome when the indicator $I_{i-j}$ has met all its benchmarks. By referring to proposed benchmarks (see Appendix B), the maximum credits $F_{i\text{-}j}^{n}$ can be counted and established in Table 2-8. For example, factor $F_1$ is involved in four benchmarks, which are used to measure the indicator $I_{1-1}$; thus, it is considered that the factor can contribute four credits to $I_{1-1}$ if all benchmarks of $I_{1-1}$ are satisfied.

Table 2-8 Maximum credits $\mathbf{F_{i\text{-}j}^{n}}$ that the environmental factor n contributes to the indicator $I_{i-j}$

| $F_{i\text{-}j}^{n}$ | $F_1$ | $F_2$ | $F_3$ | $F_4$ | $F_5$ |
|---|---|---|---|---|---|
| $I_{1-1}$ | 4 | 1 | 5 | 5 | 0 |
| $I_{1-2}$ | 4 | 2 | 5 | 3 | 4 |
| $I_{1-3}$ | 10 | 5 | 14 | 7 | 6 |
| $I_{1-4}$ | 3 | 6 | 10 | 5 | 7 |
| $I_{1-5}$ | 2 | 3 | 4 | 2 | 1 |
| $I_{1-6}$ | 2 | 7 | 8 | 6 | 2 |
| $I_{1-7}$ | 7 | 2 | 9 | 5 | 4 |
| $I_{2-1}$ | 0 | 0 | 2 | 2 | 2 |
| $I_{2-2}$ | 1 | 0 | 3 | 3 | 3 |
| $I_{2-3}$ | 0 | 3 | 4 | 3 | 2 |
| $I_{2-4}$ | 1 | 1 | 3 | 3 | 1 |
| $I_{3-1}$ | 2 | 3 | 8 | 6 | 4 |
| $I_{3-2}$ | 2 | 4 | 8 | 7 | 4 |
| $I_{3-3}$ | 1 | 2 | 4 | 2 | 3 |
| $I_{4-1}$ | 2 | 1 | 2 | 1 | 0 |
| $I_{4-2}$ | 3 | 3 | 3 | 2 | 0 |
| $I_{4-3}$ | 0 | 5 | 5 | 0 | 0 |
| $I_{5-1}$ | 3 | 4 | 7 | 2 | 5 |
| $I_{5-2}$ | 4 | 5 | 7 | 4 | 4 |
| $I_{5-3}$ | 5 | 7 | 9 | 5 | 1 |

The variable $x_{i\text{-}j}^{n}$ in model (8) denotes the actual credits that the environmental factor n has contributed to the indicator $I_{i\text{-}j}^{n}$ in a particular application. The value of $x_{i\text{-}j}^{n}$ will be obtained by judging the actual environmental performance of the indicator $I_{i-j}$ against its benchmarks. Those benchmark requirements that have been satisfactorily met will be selected. The factors associated with the selected benchmarks will be awarded with one credit. As a result, the number of credits that the environmental factor $F_n$ (for n=1, … , 5) has contributed to the indicator $I_{i-j}$ can be counted. For example, the factor $F_1$ may contribute two credits to the indicator $I_{1-1}$, whilst it could contribute the maximum credits of four.

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Appendix Proposed benchmarks of environmental performance indicators

| Indicator | Credit | Benchmarks | Contributing factors |
|---|---|---|---|
| $I_{1-1}$ | 1/0 Y/N | Using less timbers and replacing timbers with bamboo and other materials. | F1, F3, F4 |
| | 1/0 Y/N | Avoiding using insulation materials made with polystyrene product on sites. | F1, F3, F4 |
| | 1/0 Y/N | Using less materials made of synthetic polymer such as fiber-reinforced cement. | F1, F3, F4 |
| | 1/0 Y/N | Using less nylon, synthetic foams, and vinyl/PVC coverings. | F1, F3, F4 |
| | 1/0 Y/N | Using less metal sheets and promoting the use of reclaimed tiles/slates. | F2, F3, F4 |
| $I_{1-2}$ | 1/0 Y/N | Specifying particle board and fiberboard to conform to relevant standards (HK-BEAM). | F1, F3, F5 |
| | 1/0 Y/N | Excluding use of treated timber where it is not recommended in relevant codes and standards (HK-BEAM). | F1, F3, F5 |
| | 1/0 Y/N | Using unleaded paints (HK-BEAM). | F1, F3, F4, F5 |
| | 1/0 Y/N | Avoiding burning the waste of plastic foams, PVC, plywood, resin and polymer-bonded slates, organic coating, synthetic fibers, carpet fibers, rubbers, etc., onsite. | F2, F3, F4 |
| | 1/0 Y/N | Avoiding using asbestos products on sites. | F1, F2, F3, F4, F5 |
| $I_{1-3}$ | 1/0 Y/N | Implementing a waste management plan (LEED). | F1, F3, F4, F5 |
| | 1/0 Y/N | Recycling and/or salvaging at least 50% (by weight or volume) of construction, demolition, and land clearing waste (LEED). | F1, F3, F5 |
| | 1/0 Y/N | Using modular materials on sites (HPBG). | F1, F3, F4, F5 |
| | 1/0 Y/N | Listing out the materials to be salvaged for reuse in the contract documents (HPBG). | F3, F5 |
| | 1/0 Y/N | Training provision to working staff for waste reduction (HPBG). | F1, F3, F4, F5 |
| | 1/0 Y/N | Coordinating the ordering and delivery of materials among all contractors and suppliers to ensure that the correct amount of materials is delivered and stored at the optimum time and place (HPBG). | F2, F3, F4 |
| | 1/0 Y/N | Providing access for waste collection vehicles (HK-BEAM). | F1, F2, F3 |
| | 1/0 Y/N | Providing facilities for sorting out wastes onsite (HK-BEAM). | F1, F2, F3, F4 |
| | 1/0 Y/N | Arranging materials purchase for the aim of waste minimization (GGCP). | F2, F3 |
| | 1/0 Y/N | Using more precast units (GGCP). | F1, F3, F4 |
| | 1/0 Y/N | Using more steel formworks and less timber formworks (GGCP). | F1, F3 |
| | 1/0 Y/N | Undertaking properly excavation works to avoid excessive excavated materials (GGCP). | F1, F3 |
| | 1/0 Y/N | Encouraging manufacturers to reuse or recycle packaging materials (GGCP). | F2, F3, F4 |
| | 1/0 Y/N | Planning remediation action for cleaning up the possible contaminated land (GGCP). | F1, F3, F5 |
| $I_{1-4}$ | 1/0 Y/N | Applying mitigation measures for controlling dust and air emissions (HK-BEAM). | F1, F3, F4, F5 |
| | 1/0 Y/N | Complying with an air quality management plan (HK-BEAM) (Y/N). | F3, F4, F5 |
| | 1/0 Y/N | Providing a carbon dioxide (CO2) monitoring system for collecting feedback data (LEED). | F2, F3, F4, F5 |
| | 1/0 Y/N | Controlling fiber or particle release during installation of insulation (HPBG). | F2, F3 |
| | 1/0 Y/N | Providing hoarding along the entire length of project site boundary (GGCP). | F2, F3, F5 |

| | | | |
|---|---|---|---|
| | 1/0 Y/N | Providing effective dust screen, sheeting, or netting to enclose scaffolding built around the perimeter of a building (GGCP). | F1, F3, F5 |
| | 1/0 Y/N | Using water sprays for watering unpaved areas, access roads, construction areas, and dusty stockpiles regularly to keep dusty surfaces wet (GGCP). | F2, F3, F4 |
| | 1/0 Y/N | Regularly inspecting construction plants and vehicles to ensure that exhaust emissions are under control (GGCP). | F2, F3, F5 |
| | 1/0 Y/N | Applying wire meshes, blast nets, or other covers on top of the blast area to prevent the flying off of rocks and to suppress dust generation (GGCP). | F1, F3, F4 |
| | 1/0 Y/N | Avoiding open burning for the disposal of construction waste (GGCP). | F2, F3, F5 |
| $I_{1\text{–}5}$ | 1/0 Y/N | Planning for remedial methods to solve site contamination, such as removing toxic materials (LEED). | F1, F3, F5 |
| | 1/0 Y/N | Limiting site disturbance to planting soil and outside area by earthwork (LEED). | F1, F2, F3, F4 |
| | 1/0 Y/N | Using textured paving (rather than smooth surfaces) for outside approaches, so that soils are scraped off shoes (HPBG). | F2, F3, F4 |
| | 1/0 Y/N | Preventing loss of construction soil by stormwater runoff (LEED). | F2, F3 |
| $I_{1\text{–}6}$ | 1/0 Y/N | Planning stormwater management methods (LEED). | F2, F3, F5 |
| | 1/0 Y/N | Providing site stormwater treatment systems (LEED). | F2, F3, F5 |
| | 1/0 Y/N | Providing facilities to deal with polluted water such as the wastewater from concreting, batching, etc. (HK-BEAM). | F1, F2, F3, F4 |
| | 1/0 Y/N | Providing monitoring facilities for monitoring the quality of water (HK-BEAM). | F2, F3, F4 |
| | 1/0 Y/N | Providing site drainage system (temporary ditches, drainage pipes) to collect site water runoff for treatment (GGCP). | F2, F3, F4 |
| | 1/0 Y/N | Providing site sanitary facilities (portable chemical toilets, septic tanks for holding discharge from toilets, bathrooms, and kitchens) and properly collecting contents of these toilets/septic tanks for disposal (GGCP). | F2, F3, F4 |
| | 1/0 Y/N | Covering the open stockpiles of construction materials (e.g., aggregates, excavated materials, sand and fill materials) during rainstorms to prevent the washing away of construction materials, soil, silt, or debris into any nearby drainage system (GGCP). | F2, F3, F4 |
| | 1/0 Y/N | Covering adequately all manholes at the sites and temporarily sealing them to prevent washing down of silt or debris into the drainage system (GGCP). | F1, F3, F4 |
| $I_{1\text{–}7}$ | 1/0 Y/N | Complying with noise control levels specified in relevant standards (HK-BEAM). | F1, F3, F5 |
| | 1/0 Y/N | Providing noise control measures (HK-BEAM). | F1, F3, F5 |
| | 1/0 Y/N | Using mechanical and plumbing devices that generate less noise and dampen the noise generated during ductwork and piping operation (HPBG). | F1, F3, F4 |
| | 1/0 Y/N | Avoiding locating mechanical equipment or noisy devices adjacent to noise-sensitive areas (HPBG). | F2, F3, F4 |
| | 1/0 Y/N | Preventing noise transmission by providing measures to absorb noise and vibrations (HPBG). | F2, F3, F4 |
| | 1/0 Y/N | Employing offsite concrete batching plant rather than onsite production, whenever appropriate (GGCP). | F1, F3, F4 |
| | 1/0 Y/N | Disposing rubble through plastic (rubber) chutes instead of metal chutes (or use rubber linings in chutes and dumpers to reduce impact noise) (GGCP). | F1, F3, F4 |

| | | | |
|---|---|---|---|
| | 1/0 Y/N | Restricting nighttime working to low-noise activities to ensure no excess of acceptable noise level (GGCP). | F1, F3, F5 |
| | 1/0 Y/N | Operating noisy activity at times when dwellings are more likely to remain unoccupied (GGCP). | F1, F3, F5 |
| $I_{2-1}$ | 1/0 Y/N | Using more regionally manufactured building materials whenever applicable (LEED). | F3, F4, F5 |
| | 1/0 Y/N | Using salvaged, refurbished, or reused materials whenever applicable (LEED). | F3, F4, F5 |
| $I_{2-2}$ | 1/0 Y/N | Using as much as possible locally or regionally manufactured building materials (LEED). | F3, F4, F5 |
| | 1/0 Y/N | Using as much as possible building materials with recycled and reused contents (LEED). | F3, F4, F5 |
| | 1/0 Y/N | Implementing a waste management plan during materials manufacturing (LEED). | F1, F3, F4, F5 |
| $I_{2-3}$ | 1/0 Y/N | Implementing a proper plan for arranging site transportation (less interruption to the public) (LEED). | F2, F3, F4 |
| | 1/0 Y/N | Providing a certain level of onsite fuel refueling facilities for project vehicles (LEED). | F2, F3, F4 |
| | 1/0 Y/N | Providing staff a certain level of mass transit, electric vehicles, carpooling, and other less polluting means of transportation (HPBG). | F2, F3, F5 |
| | 1/0 Y/N | Using as much as possible (a minimum of 20%) building materials and products that are manufactured regionally or locally (LEED). | F3, F4, F5 |
| $I_{2-4}$ | 1/0 Y/N | Implementing an energy management plan across all energy consumption activities during the construction (HPBG). | F1, F2, F3, F4, F5 |
| | 1/0 Y/N | Limiting electrical demand during peak hours by turning off nonessential equipment (HPBG). | F3, F4 |
| | 1/0 Y/N | Only providing the HVAC system when necessary and avoiding doubling of heating and cooling (HPBG). | F3, F4 |
| $I_{3-1}$ | 1/0 Y/N | Highlighting the recycle of the structures, facade, and materials demolished from site office (BREEAM). | F3, F4, F5 |
| | 1/0 Y/N | Providing an easily accessible area on site for collecting, separating, and storing the building materials for recycling including (at a minimum) paper, corrugated, glass, plastics, and metals (LEED). | F2, F3, F4, F5 |
| | 1/0 Y/N | Using as much as possible materials with recycled contents (LEED). | F2, F3, F5 |
| | 1/0 Y/N | Establishing a waste management plan for ensuring maximization of material recycling (LEED). | F3, F4, F5 |
| | 1/0 Y/N | Highlighting materials with good recycled content, typically including structural fiberboard, metal, timber formwork, laminated paperboard, fiberglass insulation, plastic foam insulation, glass fiber-reinforced insulation, floor tiles, plastic fencing, playground surfaces, etc. (HPBG). | F1, F3 |
| | 1/0 Y/N | Identifying manufacturers and reclaimers who recover construction/demolition products for recycling (HPBG). | F3, F4 |
| | 1/0 Y/N | Highlighting the recycle of masonry materials (e.g., brick, concrete block and stone) (BREEAM). | F1, F3, F4 |
| | 1/0 Y/N | Providing multiple recycling facilities for site use (BREEAM). | F2, F3, F4 |
| $I_{3-2}$ | 1/0 Y/N | Highlighting the reuse of structures, facade, and materials demolished from site office (BREEAM). | F3, F4, F5 |
| | 1/0 Y/N | Providing an easily accessible area for collecting reusable building materials or components (LEED). | F2, F3, F4, F5 |
| | 1/0 Y/N | Using as much as possible reusable components or materials (LEED). | F2, F3, F5 |
| | 1/0 Y/N | Establishing a waste management plan for ensuring the maximization of materials reusing (LEED). | F3, F4, F5 |

| | | | |
|---|---|---|---|
| | 1/0 Y/N | Highlighting the reuse of masonry materials (e.g., brick, concrete block, and stone) (BREEAM). | F1, F3, F4 |
| | 1/0 Y/N | Providing multiple reusing facilities for site use (BREEAM). | F2, F3, F4 |
| | 1/0 Y/N | Recovering excess groundwater from sump pumps or rainwater runoff for use as a source of recycled water (HPBG). | F2, F3, F4 |
| | 1/0 Y/N | Encouraging onsite reuse of scrap material (HPBG). | F1, F3, F4 |
| $I_{3-3}$ | 1/0 Y/N | Using as much as possible local materials suppliers for saving transportation energy (HPBG). | F3, F4, F5 |
| | 1/0 Y/N | Providing training on energy saving across all staff (HPBG). | F2, F3, F4 |
| | 1/0 Y/N | Establishing an energy-saving plan for use across all site activities (BREEAM). | F1, F3, F5 |
| | 1/0 Y/N | Implementing a regular check of the function of HVAC services equipment (HK-BEAM). | F2, F3, F5 |
| $I_{4-1}$ | 1/0 Y/N | Reminding the public of unhealthy activities or materials operated by posting messages in prominent and assessable locations (HPBG). | F1, F3, F4 |
| | 1/0 Y/N | Providing dedicated areas on the construction site for the storage of harmful materials; signage indicating the storage of potentially harmful materials should also be displayed in these areas (GGCP). | F1, F2, F3 |
| $I_{4-2}$ | 1/0 Y/N | Providing adequate separation and protection of public or occupied areas from construction areas (HPBG). | F1, F2, F3, F4 |
| | 1/0 Y/N | Adopting sufficient measures to protect dust, moisture, and particulates from construction/demolition activities (HPBG). | F1, F2, F3, F4 |
| | 1/0 Y/N | Providing safety sign board in locations accessible to the public (HPBG). | F1, F2, F3 |
| $I_{4-3}$ | 1/0 Y/N | Visiting the site neighbours (e.g., local schools, residential blocks, local groups, etc.) and explaining the operations of the construction project (GGCP). | F2, F3 |
| | 1/0 Y/N | Informing the public of environmentally friendly measures adopted by the construction company to minimize nuisance to them (GGCP). | F2, F3 |
| | 1/0 Y/N | Establishing an environmental hotline to receive environmental complaints and suggestions for improving environmental performance (GGCP). | F2, F3 |
| | 1/0 Y/N | Reporting the company's environmental initiatives within magazines and other publications (GGCP). | F2, F3 |
| | 1/0 Y/N | Applying for awards for the recognition of the efforts contributed in protecting the environment (GGCP). | F2, F3 |
| $I_{5-1}$ | 1/0 Y/N | Providing working office with air quality in line with relevant standards (BREEAM). | F2, F3, F5 |
| | 1/0 Y/N | Reminding working staff of those unhealthy activities or materials by posting signs in prominent and assessable locations (HPBG). | F1, F3, F5 |
| | 1/0 Y/N | Using mechanical devices for safe mixing of harmful substances such as cleaning solutions or chemical consumption (HPBG). | F2, F3, F4 |
| | 1/0 Y/N | Providing adequate ventilation for operating indoor activities (HPBG). | F1, F3, F4 |
| | 1/0 Y/N | Checking regularly to ensure that all furnishings are thoroughly cleaned or shown to be clean (BREEAM). | F1, F3, F5 |
| | 1/0 Y/N | Ensuring smoking ban or smoking allowed only in designated and separately ventilated rooms (BREEAM). | F2, F3, F5 |
| | 1/0 Y/N | Minimizing the use of polluting equipment and materials such as adhesives, floor waxes, polishes, detergents, etc. (BREEAM). | F2, F3, F5 |
| $I_{5-2}$ | 1/0 Y/N | Providing training to all working staff on safety, hygiene and health issues (HPBG). | F2, F3, F4 |
| | 1/0 Y/N | Ensure all employees are acquainted with the organization's environmental policy and environmental initiatives (GGCP). | F1, F2, F3, F4, F5 |
| | 1/0 Y/N | Ensure all staffs are aware of the legal liabilities associated with their activities, both to themselves and their employers (GGCP). | F3, F5 |

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| | 1/0 Y/N | Promote environmentally responsible attitude (GGCP). | F1, F2, F3 |
| | 1/0 Y/N | Providing database on policy and legal information on environment protection from corporate sources, relevant government authorities and industry associations (GGCP). | F3, F4, F5 |
| | 1/0 Y/N | Establish a procedure to ensure relevant information on legal requirements is communicated to employees effectively (GGCP). | F1, F2, F3 |
| | 1/0 Y/N | Establish a procedure to keep track of changes to environmental requirements and to update the environmental requirements accordingly (GGCP) | F1, F2, F3, F4, F5 |
| $I_{5-3}$ | 1/0 Y/N | Using mechanical devices for safe mixing of harmful substances such as cleaning solutions or chemical consumption (HPBG). | F2, F3, F4 |
| | 1/0 Y/N | Providing adequate ventilation for operating indoor activities (HPBG). | F1, F3, F4 |
| | 1/0 Y/N | Providing workers safety measures for avoiding the breath of the particulates of cement, which contains heavy metals and some suspected carcinogens. | F1, F2, F3, F4 |
| | 1/0 Y/N | Providing safe areas where workers will eat meals and snacks (HPBG). | F2, F3 |
| | 1/0 Y/N | Posting signs to inform site workers of good practices for handling and storing materials (GGCP). | F2, F3 |
| | 1/0 Y/N | Providing dedicated areas on the construction site for the storage of materials; this is particularly important for materials with the potential to harm people and the environment; signage indicating the storage of potentially harmful materials should also be displayed in these areas (GGCP). | F1, F2, F3 |
| | 1/0 Y/N | Storing potentially harmful materials with roofed, secondary containment to ensure that any spills are contained and to minimize contaminated stormwater runoff (GGCP). | F2, F3, F4 |
| | 1/0 Y/N | Keeping an inventory of all materials stored onsite, in particular for the materials with the potential to harm people and the environment (GGCP). | F1, F2, F3, F4, F5 |
| | 1/0 Y/N | Obtaining relevant safety data from material suppliers and keeping the data onsite where employees can access them (GGCP). | |