The Establishment of the Sustainability Performance Indicators for Wetland Ecological Project: Using Construction Inspection Phase as Example

Ching-Mei Miao
Department of Civil Engineering, Chung Hua University, 707, WuFu Rd., Sec. 2, HsinChu 30012, Taiwan

Yan-Chyuan Shiau*, Chen-Chung Liu and Jen-Kuo Chang
Department of Construction Management, Chung Hua University, 707, WuFu Rd., Sec. 2, HsinChu 30012, Taiwan
*E-mail: miaomei589@hotmail.com; *ycshiau@ms22.hinet.net; E10416003@chu.edu.tw; e10416014@chu.edu.tw*

Abstract

The critical success factors of sustainable performance indicator (SPI) were investigated in this research. A wetland water purification project of a stream in Hsinchu was used as an example in this paper. The experiment information was integrated as feedback to correct the index library. The measurement from test results verifies the SPI from sample project case in some facet is consistent with the results of current inspection system. The research result can be served as reference for the sustainable development of ecological engineering achievements.

Keywords: SPI, Wetland, Sustainable Development, Ecological Engineering.

1. Introduction

1.1 *Background*

Over the past years, the Taiwanese Government has invested tremendous amount of resources, manpower and funds to build many artificial wetlands all over Taiwan with ecological engineering, and the results proved that water quality was in fact improved. However, numerous failures of artificial wetlands with ecological engineering still occur from time to time. After investigation, it was found that the stage of acceptance inspection was crucial to determine the success and remedy of the project as a whole. However, the problem of unsustainability during the stage of acceptance inspection has never been taken seriously. Instead of implementing project planning, design, construction and maintenance with sustainable thinking as a whole, the conventional approach of linear thinking still exists in the managerial concepts. With additional factors such as reduction of human resources by the government over recent years and the lowest bid of public works awarded, the engineering sustainability could not be realized effectively. Should the techniques in construction management and performance-based contracts be adjusted and improved, they could be used to solve the problem of engineering unsustainability [1].

1.2 *Sustainable performance target*

In order to study and draft sustainable performance target of artificial wetland work, relevant domestic and foreign policies on sustainable use of water resources need to be collected and analyzed. The sustainable performance in this research is based on environmental, social and economic aspects that are capable of performing self-repair and reaching a balanced state [2]. The environmental aspect refers to harmless continuity of all species and the environment; the social aspect refers to fair treatment and continuity to all species, and the economical aspect refers to an economy with reasonable, balanced and sustainable benefits.

2. SPI for Ecological Engineering of Wetlands

2.1 *Establishment of SPIM*

The SPIM (Sustainable Performance Indicators Method) is a measure of judgment integrated within level 3 quality control process of public works to determine compliance of sustainable performance [3]. The method is objective, clear and measurable with precise measuring process, threshold value, featured indicators of relative response time as well as properties such as preliminary indicator, process indicator, result indicator and driving indicator. Instead of a general scoring method of sustainable indicator evaluation mode, this research is based on procedures of SPI establishment and referred to suggestions provided by experts to construct the SPIM used during acceptance inspection on ecological engineering of artificial wetlands, which implements inspection operation according to inspection control chart of sustainable performance on ecological engineering of artificial wetlands and continuously sends back the results for rectification of SPI database.

2.2 *Inspection and control of SPI*

During the stage of acceptance inspection, this research implemented inspection and payment control on the standard of contractual service. In a contract with sustainable performance format, the official process contains a monthly report where each pricing with precise results receives payment; the unofficial process contains inspections on the standard of contractual service carried out randomly, weekly and upon receipt of a complaint, where SPI acts as the basis of inspection control and payment to ensure performance of work and routine services. Penalty or reduction in payment will be implemented should failure of compliance occur, and in case of severe violation, payment will be stopped or the contract terminated. Accordingly, the contractor needs to reach a minimum threshold value of service standard under the SPI contract, or additional penalties will be executed [4].

3. Actual Verification

3.1 *Case introduction*

In this research, a specific artificial wetland work in Hsinchu City, Taiwan was taken as the example. In this project, living sewage was discharged into specific streams after initial purification, entered into the wetlands via directed channels for further purification, and then discharged into a large river. The work content included the main structure (inclusive of pond and tank slope), riverbanks, alleyways and access roads in the work area. Clay crystallization was adopted to construct impervious layer of the tank base and slope; a gabion wall was applied for riverbanks; the protective fences, platforms and boardwalks were built with environmental friendly wood/plastic composites where earth excavation and backfilling provided balance and the surface was paved with re-generated asphalt.

3.2 *Results of actual verification*

From September to October 2014, this research carried out actual verification on SPI items completed for the water purification works on a specific artificial wetland in Hsinchu City. The inspection results recorded after measurements are shown in Table 1 and 2. The results of the SPI inspection in this case were not ideal since out of the 23 items of sectional inspection indicators according to the work progress, 14 items did not comply with the inspection indicator and a result rate of non-compliance at 61%, which exceeded the inspection determination standard of 40%. Therefore, this chosen case was an “unsustainable wholeness of work”. From inspection and construction results, it was found that the contractor did not have concepts of sustainable work and construction, yet still blamed the design unit for the poor work results, hence the contractor showed incapability in agility and flexible construction. Based on results of SPI actual verification on the case and compared to current public works audited, the work performance was marked B on September 4, 2014, which proved that results of SPI inspection on certain phases under this research were authentic.

4. Conclusions

The description of major achievement from this research includes the following:

- Compile and propose objectives of sustainable artificial wetlands with ecological engineering and key factors of success.
- Compile and propose SPIM at stage of acceptance inspection of sustainable artificial wetlands with ecological engineering.

- Provide operational experience of verified case on SPI at stage of acceptance inspection of sustainable artificial wetlands with ecological engineering.

Table 1 Summary of SPI test results over water purification work on artificial wetlands along river in Hsinchu City

Indicator No.	SPI	Description of compliance failure	Test results
SP01	Area of foundation subsidence	8m2 and 3.5m2 of subsidence per spot with total area of subsidence >11.5m2	2 spots in total
SP02	Area of slope collapse at pond / riverbank	1.6m2 and1.2m2 of collapse	4 spots in total
SP03	Pothole	Pothole at diameter of 28cm and depth of 12cm over foundation surface	1 spot in total
SP04	Monetary value converted from local material acquisition	Monetary value converted from local material acquisition ＞20% of total materials purchased	-
SP05	Amount of water flow in pond (leak amount)	Multiple collapses and holes in pond	16 spots in total
SP06	Water contamination in pond	Odor of water inlet & discharge, temperature, turbidity, pH value, electric conductivity, BOD5, TSS, CI–, NO2–+NO3–, NH4+, TKN, TP	-
SP07	Site cleanness	Plastic bottles were found all over the site and reinforcement abandoned by the ecological pool	5 spots in total
SP08	Toxicity measured from construction materials	Level of toxicity measured was ≦ legal specification. There shall be no toxic substance in the pond at all due to hazard of contamination.	-
SP09	Area of construction interference around the site	The moving path of construction machinery passed through the work area and riverbeds to collect local river stones at ecologically sensitive area.	3 spots in total
SP10	Proportion of ecological engineering area	For the ecological engineering work of stone laying by the pond, concrete was used as adhesive between rocks, which severely affected living environment of species in the pond.	2 spots in total
SP11	Planting timing and survival rate on the wetland	The area of plant survival over the wetland was 20%, 30%	3 spots in total
SP12	Proportion of ecological experts from engineering industry	The ratio of ecological experts from engineering industry /total number of construction personnel was ＞80% (most personnel and administrators have ecological expertise)	-
SP13	Number of air pollution incidence reported	Average number of incidence /Month was ≦1	1 case in total
SP14	Number of complaint on construction noise	Average number of incidence /Month was ≦2. The noise to surrounding areas should be reduced.	-
SP15	Number of citizen complaints or reports	Average number of incidence /Month was ≦3	-
SP16	Proportion of overall expense on accident prevention, reduction and damage for the river and riverbanks	1. Inferior construction quality was found on river diversion and stone revetment at impacting side of the site. The height and number of layers constructed was insufficient. 2. Inferior construction quality was found on stone revetment to riverbanks. The height and number of layers constructed for stone revetment at impacting side was insufficient.	2 spots in total
SP17	Proportion of expense on safety of site and surrounding areas, as well as accident prevention facilities and measures	There were no safety fences erected by the site and surrounding areas for separation. No safety fences were erected by personnel near the pond during construction and the personnel were not wearing safety protections.	3 spots in total
SP18	Proportion of expense on preserving historical remains	Expense on preserving historical remains was ≧1.5 times of valuating historical remains	-
SP19	Employment ratio between minority labors and general labors	Number of minority employees / general employees on site (monthly average) was ≧30%	-
SP20	Loose chipping	Broken and chipped finish of fences by wooden boardwalks were covered up with industrial tape. Concrete pieces chipped off from superstructure of the water intake well.	2 spots in total
SP21	Bulged or sunken pavement	The wooden floor of observatory platform bulged to height of 2.1cm and the pavement with bricks from environmental regeneration was sunken to depth of 1.8cm.	8 spots in total
SP22	Percentage of local labors over foreign labors	Local laborers was 5%	Sep. & Oct.
SP23	Proportion on amount of material procurement locally	The amount of material procurement locally /amount of material procurement remotely was ≧6 times	-

Table 2 Results of SPI site test over water purification work on artificial wetlands along river in Hsinchu City

SPI	Description of inconsistency to standard required	Method of site measurement	Duration of improvement

Area of pond /river slope collapse	Area of collapse at 1.6m2	Roller tape	Repair completed within 3 days
Pictures from inspection			

Through case study, this research implemented actual operation, testing and application to verify applicability of SPI at stage of acceptance inspection of sustainable artificial wetlands with ecological engineering, as well as whether the case of verification provides sustainable performance. The results obtained are described as follows:

- It is verified that this research can be operated practically.
- Through SPI of this research, the sustainable performance of site works can be tested at speed and convenience with simple tools, which extensively reduces funds spent on manpower and experiments.
- The results prove that certain phases and indicators of this research are consistent with status of level I/II QC (Quality Control) check and audit results on public works.
- The SPI inspection from this research has indeed driven contractors to think of more innovative methods of work performance and realizing establishment of sustainable work gradually.
- Compared to conventional inspection, the sustainable performance inspection carried out through SPI of this research can effectively test whether there is sustainable performance on the project or not.
- For SPI inspection implemented per current work progress on the case actually tested, the standard requested, method and tools of measurements, as well as responsive allowable tolerance or TOR (Time of Reaction) set out by the indicator items tested are all adequate in practical operation of testing.
- It is feasible and effective for verification done with indicator method that integrates work procedures with sustainable performance, which realizes the mode of sustainable work at stage of acceptance inspection of work for artificial wetlands with ecological engineering.
- For subsequent research, it is recommended to provide SPI that are more diversified and suitable, where a relevant SPI study can be commenced particularly on type, functions required and construction method of artificial wetlands.

5. References

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