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Water management for eco-friendly urban and highway construction

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Abstract

The paper briefly reviews the urbanization, including highway construction, impact on the hydrology and aquatic ecosystem. The emphasis is to discuss recent advances in various engineering measures, i.e., best management practices or BMPs, which would help mitigate the negative impacts and help restore the aquatic biological integrity. These BMPs include vegetative practices such as bioretention cells, grassed swales, and constructed wetlands, with emphasis on the low impact development (LID) practices, which are gaining nationwide adaptation in recent years. Such BMPs can be integrated into the landscape and therefore also offer aesthetic benefits. The paper also discusses a number of issues that needed to be addressed before a full watershed implementation of BMPs in Taiwan.

Keywords: urbanization impacts, stormwater management, low impact development, best management practices, bioretention cells, swales, constructed wetlands, implementation strategies.

Introduction

It has long been recognized that urbanization, including highway construction, can cause a significantly negative, sometimes even irreversible, impact on the ecosystem. For example, a poorly planned urban development could contribute to the loss of habitat, which represents a severe threat to the impacted region's biodiversity. Specifically, studies have shown that the degradation of physical and chemical qualities of water, attributed to urbanization, directly affects fish population in rivers, streams and other water bodies. Numerous studies have also shown that urbanization plays a significant role in the degradation of water quality. It is, therefore, imperative to minimize the impact of urban development including road construction on water quality in order to protect the integrity of the ecosystem.

The Clean Water Act (CWA) is the cornerstone of surface water quality protection in the United States. The primary goal of the CWA is "to restore and maintain the chemical, physical, and biological integrity of the nation's waters." In 1987, the US Congress amended the CWA to initiate a national effort on nonpoint source pollution (NPS) control. Under Section 319, states address the NPS problem by identifying and quantifying the extent of NPS pollution, and developing and implementing management strategies for its control. Most recently, the US Environmental Protection Agency (USEPA) has instituted the Total Maximum Daily Load (TMDL) program, which calls for the integrated control of both point and nonpoint sources of pollution in a watershed. Currently, the TMDL program is the main driving force behind the water quality management activities in watersheds throughout the United States.

Watershed management measures commonly include structural and nonstructural best management practices (BMPs). Structural BMPs are engineered facilities that detain, filter or retain pollutant-carrying stormwater runoff, such as bioretention cells, detention ponds, constructed wetlands, grassed swales and strips or buffers, and underground treatment tanks. Nonstructural BMPs are management practices aimed at reducing the generation of pollutants at their sources, such as street cleaning, land use control and nutrient management. Under the premises that biological integrity can be attained when the physical and chemical properties of water bodies are adequately maintained, the implementation of watershed BMPs is, therefore, an important step in reaching the goals outlined in the CWA.

This paper reviews the impact on the aqueous environment due to urban development and highway construction, and describes best management practices that help mitigates such impacts, especially certain practices pertaining to the "green" or "eco-friendly" types of practices such as bioretention cells, swales, buffer strips and constructed wetlands. The emphasis is on how to manage "water" for eco-friendly urban construction and road building.

Impact of Urbanization and Highway Construction

The major impact of urbanization on the water environment can be summarized as follows:

- Hydrology – Higher flood peaks, larger runoff volume, faster flood flows, less evapotranspiration, and less groundwater recharge.
- Water quality – Larger wastewater volumes, enhanced sediment and erosion processes, and stormwater runoff pollution.
- Aquatic biological integrity – Habitat loss, biodiversity, toxicity, etc.

Figure 1 depicts the hydrologic impact of urban development.

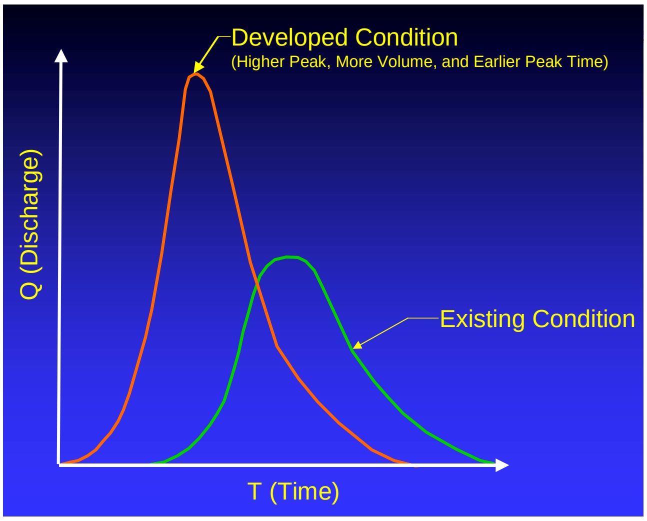

Figure 1. Hydrologic Impact of Urbanization

Highway construction impacts include excessive sediment yield during construction and runoff pollution from pavements and right-of-ways. For example, hydrologic changes due to site cleaning, grading, increased imperviousness and landscape maintenance can cause stream channel instability, which could lead to stream bank erosion and habitat degradation (Federal Highway Administration or FHWA, 2000). Also, runoff containing deicing compounds is toxic to fish, plants and other wildlife. Other harmful pollutants in highway runoff include nutrients, herbicides, trace metals, and oil and grease. Some forms of petroleum hydrocarbons have been found to be carcinogenic. In addition, highway culverts at stream crossings could hinder the movement of aquatic fauna.

Practices for Eco-friendly Urban Development and Highway Construction

One of the most prominent examples of eco-friendly stormwater management practices in the United States is what is generally called 'Low-Impact Development', or LID. LID is an innovative technological approach to stormwater management and ecosystem protection where hydrologic controls are integrated into every aspect of a site's design to mimic the predevelopment hydrologic regime (Coffman, 2004). LID focuses on how to design developed areas in a manner that maintains ecosystem and hydrologic functions. LID maintains or restores the hydrologic regime and manages stormwater by fundamentally changing conventional site design to create an environmentally and hydrologically functional landscape that mimics all natural watershed hydrologic functions (volume, frequency, groundwater recharge, evaporation and discharge).

LID techniques are simple and effective, and are significantly different from conventional engineering approaches, which emphasize the piping of water to low spots removed from the development area as quickly as possible. Instead, LID uses micro-scale techniques (sometimes known as 'ultra-urban' techniques) to manage precipitation as close to where it hits the ground as possible. Instead of large investments in complex and costly engineering strategies for stormwater management, LID strategies integrate green space, native landscaping, natural hydrologic functions, and various other techniques to generate less runoff from developed land. This involves strategic placement of linked lot-level controls, such as bioretention cells, buffer strips, swales, and other ultra-urban best management practices (BMPs) that are designed to address specific pollutant loads as well as stormwater timing, flow rate, and volume issues.

One of the primary goals of LID design is to reduce runoff volume by infiltrating rainfall water to groundwater, evaporating rainwater back to the atmosphere after a storm, and finding beneficial uses for water rather than exporting it as a waste product down storm sewers. The result is a landscape functionally equivalent to predevelopment hydrologic conditions, which means less surface runoff and less pollution damage to lakes, streams, and coastal waters. LID practices include such techniques as bioretention cells or rain gardens, grass swales and channels, vegetated rooftops, rain barrels, cisterns, vegetated filter strips and permeable pavements. Many of these techniques both reduce runoff volume and filter pollutants from water before it is discharged into receiving watercourses.

Grassed Swales

Swales are grassy depressions in the ground designed to collect storm water runoff from streets, driveways, rooftops and parking lots. Two general types of grassed swales are generally designed: 1) a dry swale, which provides water quality benefits by facilitating stormwater infiltration, and 2) a wet swale, which uses residence time and natural growth to treat stormwater prior to discharge to a downstream surface water body. Both dry and wet swales demonstrate good pollutant removal, with dry swales providing significantly better performance for metals and nitrate. (FHWA, 2000). The primary pollutant removal mechanism is through sedimentation of suspended materials. Therefore, suspended solids and adsorbed metals are most effectively removed through a grassed swale. Both dry and wet swales demonstrate good pollutant removal, with dry swales providing significantly better performance for metals and nitrate. Dry swales typically remove 65 percent of total phosphorus (TP), 50 percent of total nitrogen (TN), and between 80 and 90 percent of metals. Wet swale removal rates are closer to 20 percent of TP, 40 percent of TN, and between 40 and 70 percent of metals. The total suspended solids (TSS) removal for both swale types is typically between 80 and 90 percent. In addition, both swale designs should effectively remove petroleum hydrocarbons based on the performance reported for grass channels (FHWA, 2000). Table 1 shows the pollutant removal efficiencies for some grassy and vegetated swales used for stormwater conveyance and treatment in the United States.

Table 1 - Pollutant removal efficiencies for grassy swales (from FHWA, 2000)

Design	Pollutant Removal Efficiencies (%)					
	TSS	Metals	Nutrients			Source
			TN	NO_3	TP	
Grassed channel	68		23	-2	43	City of Austin (1995)[1]
Vegetated swale (61-m)	21-95	-	-	-	32-85	Yu, et al., (1993)[2]
Vegetated swale (30-m)	49	13	-	-	33	Yu, et al., (1994)[2]
Grassed swale	30	11	-	-	Neg.	Yu and Kaighn (1995)[1]
Grassed swale	-	(-25)-92	(-14)-25	-	(-48)-48	Yousef, et al., (1985)[1]
Grassed swale (61-m)	83	30-72	-	-	29	Kahn, et al., (1992)[2]

[1] Removal efficiencies based on concentrations
[2] Removal efficiencies based on mass loading.

Bioretention Cells

One of the key LID techniques is a bioretention cell (sometimes referred to as a “rain garden”). Bioretention is a terrestrial-based (up-land as opposed to wetland), water quality and water quantity control practice using the chemical, biological and physical properties of plants, microbes and soils for removal of pollutants from storm water runoff. Some of the processes that may take place in a bioretention cell include: sedimentation, adsorption, filtration, volatilization, ion exchange, decomposition, phytoremediation, bioremediation, and storage capacity (Prince George’s County, 2002). Figure 2 shows a typical bioretention system.

Figure 2. Typical 'Rain Garden' Bioretention System

Bioretention systems are more than simply creative landscaping. They are engineered systems that have been designed and installed to promote the biological, physical and chemical treatment of stormwater runoff, as well as to promote the infiltration of stormwater runoff in order to help restore the character of the natural hydrologic cycle of the area. Bioretention cells are comprised of six basic components (USEPA, 2000). These are:

- Grass buffer strips that reduce runoff velocity and filter particulate matter,
- Sand bed that provides aeration and drainage of the planting soil and assists in the flushing of pollutants from soil materials,
- Ponding area that provides storage of excess runoff and facilitates the settling of particulates and evaporation of excess water,
- Organic layer that performs the function of decomposition of organic material by providing a medium for biological growth (such as microorganisms) to degrade petroleum-based pollutants. It also filters pollutants and prevents soil erosion,
- Planting soil that provides the area for stormwater storage and nutrient uptake by plants. Often the planting soils contain some clays which adsorb pollutants such as hydrocarbons, heavy metals and nutrients, and
- Vegetation (plants) that function in the removal of water through evapotranspiration and pollutant removal through nutrient cycling.

Figure 3 shows a schematic drawing of a typical bioretention cell constructed to transport stormwater runoff from a parking lot.

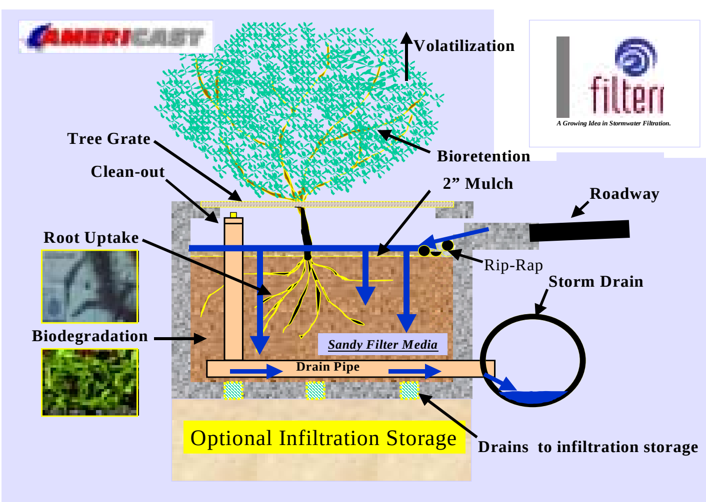

Figure 3. Schematic of a Bioretention Cell

The various pollutant transport and transformation processes active in a bioretention are illustrated in Figure 4.

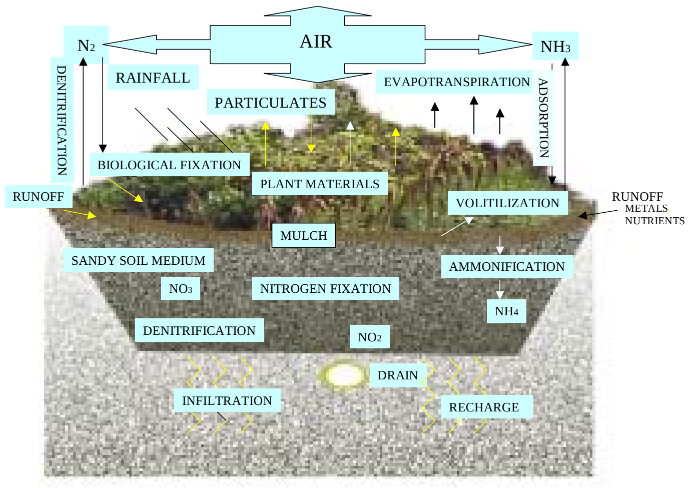

Figure 4. Nitrogen Cycle in a Bioretention Cell

(Source: USEPA, 2000)

Laboratory and some limited field tests have shown good removal capabilities of some pollutants such as 80 – 90% for total suspended solids (TSS); 40 – 50% for total phosphorus (TP), and 50 – 90% for heavy metals (FHWA, 2000, Yu and Wu, 2004). One significant advantage for using bioretention cells as a water management measure in urban areas is the fact that bioretention cells can be designed as part of the urban or highway landscape.

Ecological Detention Systems

LID technologies are generally applicable for small-scale contributing areas. For large drainage areas (e.g., greater than 0.5 hectares) bioretention may not be practical due to its storage capacity limitations. In these cases larger systems, such as ponds and wetlands are generally used to treat stormwater (Center for Watershed Protection, 1996). Such larger stormwater management structures include retention ponds, detention ponds, and constructed wetlands. These practices, when properly designed and maintained, can enhance the aesthetic values of the landscape and also help mitigate some of the negative impact of development on the ecosystem.

An example of a constructed stormwater treatment wetland for a highway application is given in Figure 5 below. Both detention ponds and constructed wetlands have shown good to excellent pollutant removal capabilities. For example, removal rates of 60 – 90% for TSS, 50 –80% for TP, and 30 –60% for metals have been reported (FHWA, 2000, Yu et al., 1994). High removal rates have also been reported for constructed wetland systems (FHWA, 2000)

Figure 5. Constructed Wetland in a Highway Medium

In addition to pollutant removal, constructed wetlands offer the most potential for creating the ancillary benefits of wildlife habitat, public recreational uses such as bird watching and nature study, and surface runoff flow retention.

Summary of Pollutant Removal Efficiencies of Various BMPs

Since the use of BMPs was promoted in the mid-1980's, numerous laboratory as well as field tests have been conducted to test the pollutant removal efficacies of different types of BMPs. Currently a joint effort is being made by the American Society of Civil Engineers (ASCE) and the US Environmental Protection Agency (USEPA) to develop and maintain a comprehensive national and international database on BMPs. The ASCE/EPA BMP database now includes several hundred BMPs and is being expanded to include LID-type of BMPs. Table 2 below is a recent list of median efficiencies of major types of BMPs.

Table 2 - Median Pollutant Removal (%) of Stormwater Treatment Practices (Center for Watershed Protection, 2000)

	TSS	TP	Sol P	TN	Nox	Cu	Zn
Stormwater Dry Ponds	47	19	- 6.0	25	4.0	26[1]	26
Stormwater Wet Ponds	80	51	66	33	43	57	66
Stormwater Wetlands	76	49	35	30	67	40	44
Filtering Practices[2]	86	59	3	38	-14	49	88
Infiltration Practices	95[1]	70	85[1]	51	82[1]	N/A	99[1]
Water Quality Swales[3]	81	34	38	84[1]	31	51	71

[1] Fewer than 5 data points

[2] Does not include vertical sand filters and filter strips

[3] Refers to open channel practices designed for water quality

N/A = Data are not available

TSS = Total suspended solids; TP = Total phosphorus; Sol P = Soluble phosphorus;

TN = Total nitrogen; NOx = Nitrate and nitrite; Cu = copper; Zn = Zinc

Major Watershed Management Issues in Taiwan

Background

Taiwan is an island nation with a land area of 36,002 km^2 and a 1999 population of about 22 million. The topography is characterized by tall mountains in the middle and eastern, plains in the western and southern part of he island. The annual rainfall averages over 2,500 mm (about 98 inches) but distributes very unevenly throughout the year. Furthermore, on average almost 80% of the runoff goes into the sea because of the steep terrain and short lengths of the rivers and streams. Therefore in Taiwan reservoirs represent the major source of water supply. In 1999, there are more than 60 reservoirs, supplying roughly 70% of the total water usage in Taiwan.

In recent years, many reservoirs in Taiwan have been seriously impacted by excessive urbanization and industrialization in their watersheds. Highland farming, construction, lack of wastewater treatment and effective conservation practices all contribute to water quality problems such as siltation, eutrophication, etc. For example, a 1995 report estimated that the effective storage capacity of some reservoirs were down to only 75% of the design capacity due to siltation.

Major Issues

1. Laws and Regulations on Watershed Protection

For example, the current water pollution control act does not cover nonpoint source pollution. It does not address wetland protection either. There are many laws and regulations on the books, but enforcement has always been difficult, especially when citizen property rights are impacted.

2. Organizational Issues

Functions of different agencies sometimes overlap and not very well defined. Cooperation among agencies needs to be strengthened.

3. Water Quality Protection

Control of point sources is not adequate. Many studies on nonpoint source characterization and BMP efficiency have been done recently. However, full-scale implementation has not been started.

4. Citizen Concerns

Environmental awareness is still relatively low. Some residents in watersheds demand unreasonable "compensation" when their lands are taken for building conservation measures.

BMP Implementation Issues in Taiwan

Regulatory Framework

In the 1980’s, Virginia environmental agencies tried to encourage various sectors to install BMPs on a “voluntary” basis. However, the strategy did not work very well. The current regulations established at the federal, state, and local levels serve as a “driving force” for nonpoint pollution control and therefore BMP implementation activities in the US. It seems that, in order to efficiently reach set goals for watershed water quality protection, a regulatory framework is needed. Requiring eco-friendly engineering practices for government-sponsored engineering projects, e.g., highway building is a very good strategy because this will set examples and generate valuable information for other potential implementations. For privately sponsored construction projects such as shopping malls and residential sites the developers might be persuade to use multi-purpose BMPs, such as wet ponds, to gain “aesthetic values” and water quality protection credits.

The regulatory framework could be established at either the central or the local government level, or both. Tax benefits could also be used as a motivational tool.

Cost and Maintenance

One of the key issues in BMP implementation is: who should pay for the construction and maintenance costs associated with the BMPs? In the US, for public construction projects including road building, BMP cost is part of the overall construction cost and the responsible agency (e.g., transportation departments in the case of highway construction) would maintain the facilities. For private projects, the developer would construct the BMPs and the users (e.g., homeowners associations in the case of residential developments) would be responsible for the maintenance costs.

BMP costs depend largely on the type of BMP and many other site-specific factors such as land value, labor and material costs, etc. The FHWA report in 2000 cited some preliminary costs for BMPs. For example, a bioretention cell system could cost about $25,000 per impervious hectare area served. On the other hand, swales and filter strips would cost much less, about $4,000 to $5,000 per impervious hectare served.

Technical Issues

Because nonpoint pollution problems are very site-specific, there is virtually no “one-size-fits-all” type of approach in controlling NPS pollution. Rainfall, and therefore runoff characteristics in Taiwan are quite different from those in the US. Factors such as topography, soil, agricultural practices (e.g., tea gardens are prevalent in Taiwan), climate, etc., all impact the selection and the design of BMP that are appropriate for Taiwan. Some of the most important design-related questions are:

- What should be the design frequency for

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storms? (In the US, a 10-year frequency is commonly used for runoff quantity control, whereas a 2-year or lesser storm is used for quality control). The sizing of BMPs and therefore their cost depend on the design frequency selected. The choice of an appropriate design frequency should be carefully determined with consideration given to both the economics and the degree of protection or treatment desired.

- Should the control of the "first-flush" of the runoff (usually the first 0.5 in or 13 mm runoff volume), which is adopted in many states in the US, be considered in Taiwan? The reason of choosing the first 0.5 in of runoff to treat is because literature data suggested that the first flush runoff generally contains a very significant amount of the total pollutant loads generated by a single storm. Such a phenomenon may or may not be the case in Taiwan.
- Should the underground type of BMPs such as bioretention cells, vault structures and sand filters be considered as preferred BMPs in Taiwan? These BMPs require little space and would be less vulnerable to vector problems, which should be a concern in Taiwan because of the warm weather year-round.
- What type of pollutant parameters should be considered as "priority" pollutants to be controlled? For example, given that water temperature is an important parameter for fish such as the Formosan Salmon, the design criteria of the BMPs then should include water temperature as a key parameter.

Other Issues

Other important issues relating to a full-scale BMP implementation include: special provisions for certain sectors in the society, e.g., BMP implementation for the agricultural sector, especially farmers, partnership with environmental groups, public education strategies, etc.

Conclusions

Urbanization, including highway construction, could cause significant negative impact on the aquatic ecosystem. There are a number of engineering practices, called BMPs, can be employed to mitigate these negative impacts. BMPs such as bioretention cells, vegetative buffer strips and swales, and constructed wetlands can be integrated into the landscape and therefore providing both water quality management and aesthetic benefits. The full implementation of BMPs in watersheds requires a well-planned strategy, which needs to address issues such as a regulatory framework, cost and maintenance, technical and other issues.

References

[1] Center for Watershed Protection. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices. 2nd Edition. Ellicott City, Maryland.

[2] City of Austin. 1995 (draft). Characterization of Stormwater Pollution for the Austin, Texas Area. Environmental Resources Management Division, Environmental and Conservation Services Department, City of Austin, Austin, Texas.

[3] Coffman, L. 2004. Low Impact Development Technology: - An Innovative Decentralized Approach To Stormwater Management Water Quality. Proceedings of the Fourth International Conference on Watershed Management and Urban Water Supply. Shenzhen, China, pp: 633-638.

[4] Federal Highway Administration (FHWA). 2000. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Available at: http://www.fhwa.dot.gov/environment/ultraurb/index.htm

[5] Khan, Z., C. Thrush, P. Cohen, L. Kulzer, R. Franklin, D. Field, J. Koon, and R. Horner. 1992. Biofiltration Swale Performance, Recommendations, and Design Considerations. Municipality of Metropolitan Seattle, Water Pollution Control Department, Seattle, WA.

[6] Prince George's County. 2002. Bioretention Manual. Division of Water and Environment Resources, Largo, Maryland.

[7] U.S. EPA. 2000a. Low Impact Development (LID) – A Literature Review. EPA 841-B-00-005. Washington, D.C.

[8] _______. 2000b. Principles for the ecological restoration of aquatic resources. Rep. No. EPA841-F-00-003, Office of Water, Washington, D.C.

[9] Yousef, Y.A., M.P. Wanielista, H.H. Harper. 1985. Removal of Highway Contaminants by Roadside Swales. Transportation Research Record 1017:62-68.

[10] Yu, S.L., S.L. Barnes, and V.W. Gerde. 1993. Testing of Best Management Practices for Controlling Highway Runoff. Virginia Department of Transportation, Report No. FHWA/VA-93-R16, Richmond, VA

[11] Yu, S.L., R.J. Kaighn, and S.L. Liao. 1994. Testing of Best Management Practices for Controlling Highway Runoff, Phase II. Virginia Department of Transportation, Report No. FHWA/VA-94-R21, Richmond, VA.

[12] Yu, S.L., and R.J. Kaighn. 1995. The Control of Pollution in Highway Runoff through Biofiltration. Volume II: Testing of Roadside Vegetation. Virginia Department of Transportation, Report No. FHWA/VA-95-R29, Richmond, VA.

[13] Yu, S.L., and J. Wu. 2004. Laboratory and Field Testing of Ultra-Urban Best Management Practices. Proceedings of the National Low Impact Development Conference, University of Maryland, College Park, MD.

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Strategies and ecological engineering considerations of road construction in Taiwan

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Abstract

The application of ecological engineering to road and highway construction has only recently been accepted in Taiwan. Therefore, Taiwan's government has much work ahead. While certain improvements have been made to current and existing management systems, there are still many problems that officials will need to address in the forthcoming years to achieve a sustainable development. This paper proposes some solutions to improve Taiwan's continued application of ecological engineering to road and highway construction.

Keywords: Ecological Engineering, Road Construction, Highway

Introduction

Roads and highways are the lifeblood of public and private transportation to any developing country. However, the construction of roads and highways require the use of advanced mechanical equipment and the exploitation of inlands. These usually impact the general ecosystem of the country by influencing environmentally-sensitive areas. According to Forman and other ecological experts, road construction may cause consequences such as: 1) over-mowing on the roadsides may have an impact on the animals relying on plants; 2) road construction and traffic accidents may do harm to animals; 3) noise made by vehicles, exhaust pollution, and visual irritation may have influence on the ecosystem; 4) roads section the habitats of animals and plants, causing the isolation effect and shatters of habitats, and reducing even extinguishing the amount of creatures; 5) draining of sewage, pollutants, and chemical pollution dashes nearby forms of life in waters; 6) the network of roads has impacted the structure of the landscape, ravaged the ecological gradient, reduced varieties of creatures, and produced turbulence from horizontal growth of each form of life (Forman, 1998).

In reality, protecting the ecosystem has always been the faith of all human beings. Such faith was clearly recognized by the United Nations in 1992 when it delivered the "*Rio Declaration on Environment and Development*" which is also called the "*Earth Charter*." This declaration emphasized that human beings lie on the center of caring for sustainable development, that they ought to bear a harmonious nature and a life rich in productivity and that they should satisfy this generation and their offspring by offering the need required to the environment and development. From this new perspective, Forman guides us to two useful perspectives when evaluating the impact of road construction in our society. Forman considers two very important perspectives: (1) sustainable development and (2) respecting the land that nurtures us (Forman, 2003). The first perspective for sustainability requires an understanding that some things must grow (such as jobs, productivity, wages, capital and savings, profits, information, knowledge, and education) and some things must not grow (such as pollution, waste, and poverty). "Sustainable development" is defined as "the path of economic, social, environmental, and political progress that aim to meet the needs of today without compromising the ability of future generations to meet their needs" (Randolph, 2004). The second perspective for sustainability is in effect the society's respect of the land that nurtures us. This requires an appreciation of the important attributes such as soil and water and our dependence of such attributes as humans. In effect, there exists a "sustainable system" in the field of ecological engineering that corresponds to ecological rules and integrates human beings and natural environment in order to let both live and thrive.

While developed countries such as the United States, Japan, and Germany have established more concrete policies, supporting measures, and regulatory systems of Eco-technology (such as the promotions of Eco-technology through appropriate government agencies in recent years), we hope that in Taiwan, our own government will be able to achieve the goal of sustainable development through road construction and that the environment will be ecologically protected and remain safe. Moreover, we in Taiwan also hope to establish important foundations of managing ecological systems and encouraging the development of the field of ecological engineering.

With this as backdrop, I hope to present to the reader of this paper the development of ecological engineering to road and highway construction in Taiwan; the problems that government officials face in integrating the concept of “sustainable system” to Taiwan’s existing road construction plans; and recommend improvements to the existing system.

Application of Ecological Engineering to Road Construction.

Countermeasures for Ecological Road Construction.

In his book entitled, “Introduction to Ecological Engineering Methods” (2003), Professor Lin Cheng-yang introduced in a succinct, table format certain countermeasures for ecological road construction. Those countermeasures outline certain considerations that ecologists should examine before planning road construction.

An important corollary to Professor Lin’s countermeasures is Professor Tsai, Hou-nan’s proposed principles for applying Ecological Engineering presented in his book *Ecological Technology for Road Construction* (2003). Professor Tsai breaks down the principles of life cycles of road construction into four phases: (1) the feasibility evaluation and planning phase; (2) the design phase; (3) the constructional phase; and (4) the operational maintenance and management phase. In each phase, Professor Tsai details three separate courses of action, those being the process flow for road development, the applications of ecological engineering, and the presentation of measures. Please see Table 1.

Professor Shui-Wei Wu (Wu, 2004) also proposed the concept of the life cycle of road engineering. Following are the two diagrams of the systematic development and planning framework. Please see Figure 1 and Figure 2.

Road Constructions in Taiwan.

According to the statistics from Directorate General of Highways, the total length of all highways in Taiwan around the end of 1951 was 17,096 KM, and at the end of 2000, 19,767 KM. The average length in every 100 square kilometers was 55.6 KM, and the increased range of growth was merely 15% more than the original figure; however, the total area of highway collapses zoomed from 145,815 square meters in 1951 to 1,505,780 square meters in 1991, and the increased range was 10.32 times. Countermeasures for Ecological Engineering on highway constructions are shown in Table 2. Most parts have been taken into consideration by Directorate General of Highways; however, there are still some respects that require reinforcement.

Table 1. Principles for Life Cycles of Road Construction to Apply Eco-technology

	Process Flow for Road Development	Applications of Ecological Engineering	Presentation of Measures
Feasibility Evaluation and Planning phase	● Submission of Plan for Road Development ● Valuation of Feasibility ● Planning Phase (to select road corridor) ● Submission of Environmental Impact Statement (EIS) for Approval	● Investigation and Analysis of Space within Route Research Area ● Environmental Impact Assessment of Alternative Possibilities and Selection of A Most Preferred	● Ecological Environmental Investigation within the Planning Area ● MEFA, Mitigation Plan, Habitat Compensation, ● Discussion on Corridor alignment & Structural Form

Design phase	● Initial Design Phase (Route Announcement) ● Detailed Design Phase ● Makeup submission of Environmental Impact Variance Analysis for Approval	● Investigation of the Environment & target Subjects pertinent to Applied Ecological Engineering Method ● Taking into account the Environmental Assessment Promises & Planning for related Environmental Impact Mitigation Measures	● Discussion on Road Structural Form (Bridge, tunnel, Road-works) & detailed remediation ● Discussion on Construction Plan (Methods, construction roads, Construction facilities, Environmental Protection Measures ● Use of porous pavement ● Insurance of Animal moving path ● Discussion on right-of-way separation facilities and alternative routes ● discussion on the protection design to prevent gutter animals from intrusion ● Discussion on the effect of road lighting on the surrounding vegetation ● Discussion and valuation of habitat compensation ● preservation & reuse of surface soil germplasm bank ● protection and reinstatement of original drainage corridor & water resources ● use & relocation of native plants ● Discussion on the slope form & ecological landscaping
Constructional phase	● Presentation of Construction Plan by Party B ● Construction Mobilization	● Planning for Environmental Management Measures during Construction ● Concrete Construction Management and Supplementary Penalties ● Presentation of Environmental Monitoring Plan during Construction	● Identify the possible interference with environment the construction may cause ● Plan for a Construction Plan with minimum obstructions ● Road selection & Environmental Rehabilitation ● Drainage Divergence & prevention of wastewater ● prevention of noise ● Dust Suppression ● Other environmental protection concerns during construction (logging, interference from animals & the vicinity)
Operational Maintenance and Management phase	● Devolution of Tasks ● Operational Maintenance and Management	● Plan for Environmental Management Measures needed in the Maintenance and Management Phase ● Continuous Monitoring Plan on the Environment ● Review of efficacy produced by related facilities	● Environmentally Sound Maintenance and Management Plan ● Environmental Monitoring Plan during Operational Phase ● Utilization of green Sources ● Maintenance and Management Plan at Minimum Cost ● Encouraging widespread of Eco-environmental protection Plan

Source: "*Ecological Technology for Road Construction*" (2003) by Hou-nan Tsai, Min-yuan Chou, and Hui-ying Lu, translated by Meng-Li Lin.

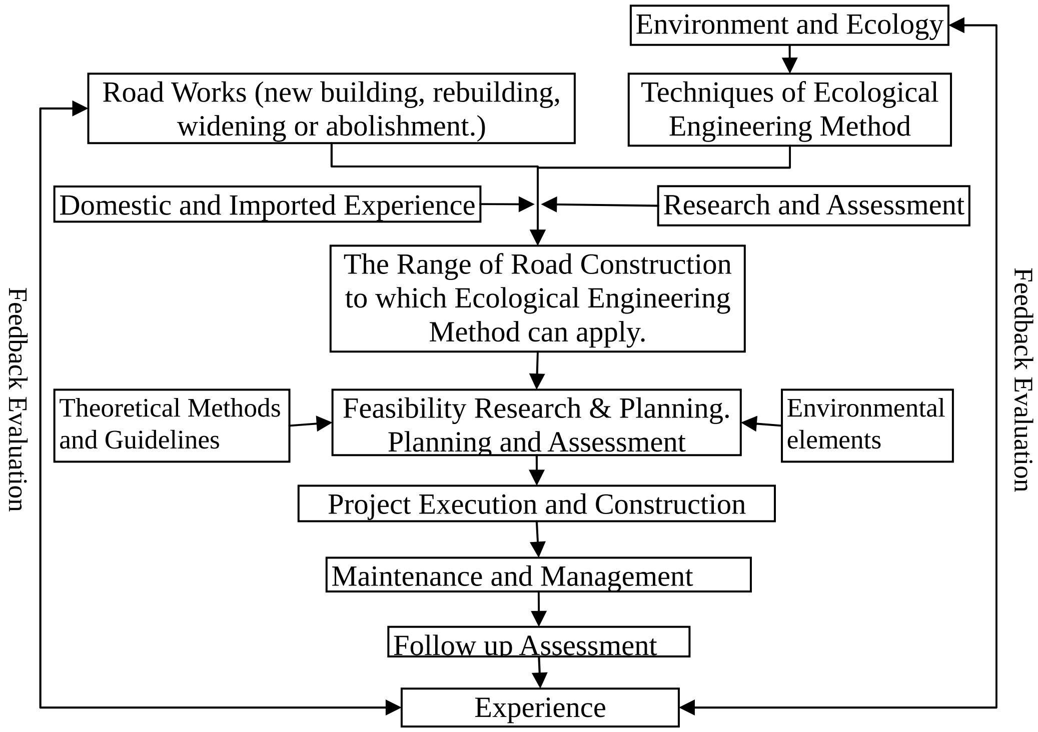

Figure 1. Systematic Development Framework Chart of Ecological Engineering for Road Construction

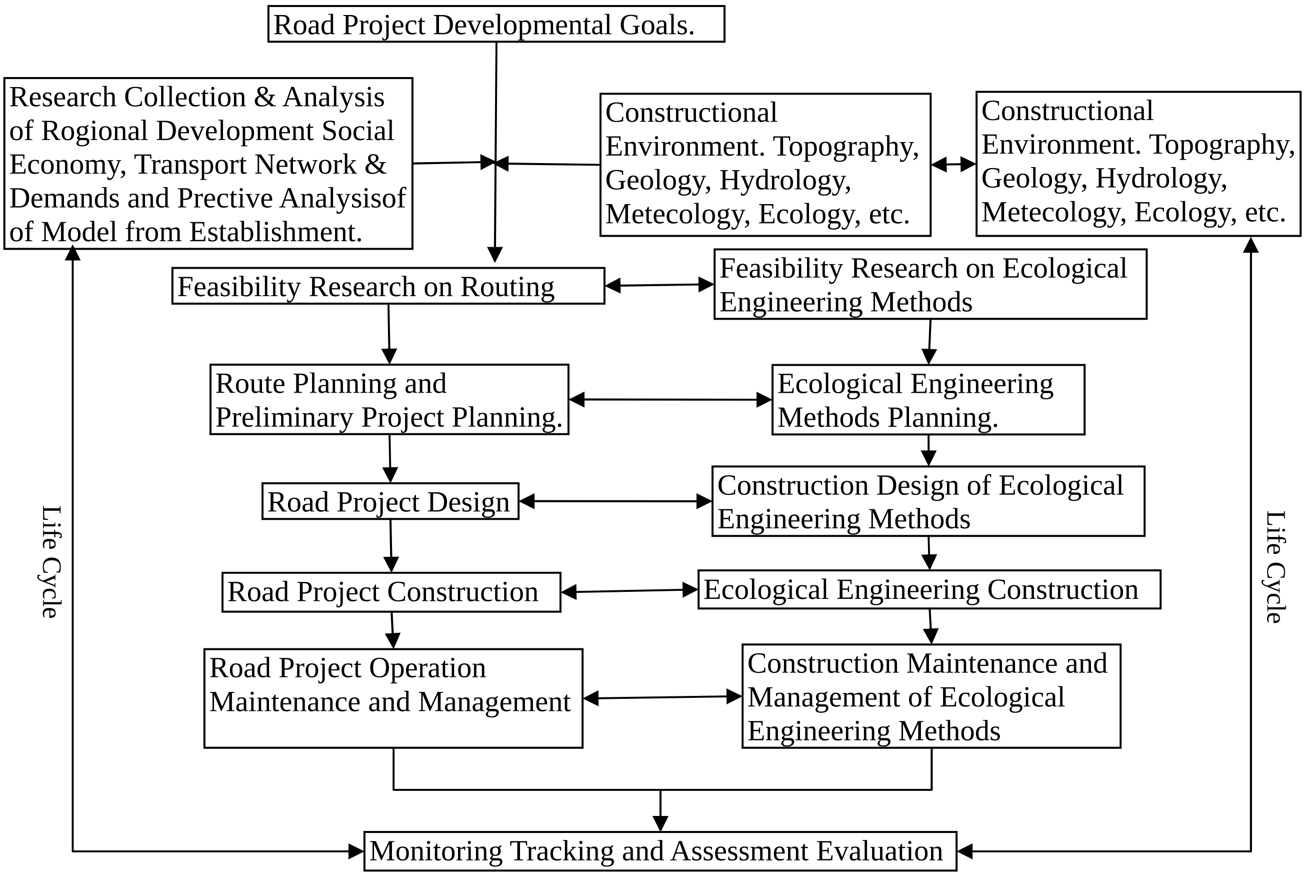

Figure 2. Systematic Planning Framework Chart of Ecological Engineering for Road Construction

Source of Figure 1 & 2: *"Initial Conception of the First Draft about Road Ecological Engineering Plan"* by Shui-Wei Wu (2004), translated and redrawn by Meng-Li Lin.

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Table 2. Directorate General of Highways' Countermeasures for Ecological Road Design

Countermeasures for Ecological Road design	Examples of Directorate General of Highways	***Remarks***
Route Choosing		
Linear Examining and Improvements		
Examining Structure Styles		
Bridges	◎	Replace High-piling Soil with a Viaduct Bridge
Tunnel (Entrance)	◎	Restoration of Landscape
Retaining Wall	◎	Stone Retaining Wall
Embankment and Side Slope Gradient	○	Natural Side Slopes
Fence	◎	Landscape Balusters
Safety Involved in Waters	◎	Bridges with Huge Spans
Plant-cultivation by Birds		
Preventing animals from entering the routes for vehicles	◎	Fence
Prevention and Remedies of Light Pollution	◎	Equipped with Lampshades
Warning Signs and Billboards	◎	
Shifts and Replacements of Habitats	◎	Box Culvert
Preservation of Topsoil		
Plant-cultivation and Transplants of Primitive Plants	◎	Preservation of Original Plants
Renovation of Habitats		
Remedies for Ecosystem or Alternative Methods		
Other (Management)	◎	Noise Control when under Construction

◎：Totally Taken into Consideration ○：Partly Taken into Consideration

The spirit of Ecological Engineering is Sustainable Development, which is also taken as a lingua franca, emphasizing that we should never sacrifice benefits of our offspring just for satisfying the benefit of contemporary people. Basically speaking, before promoting Ecological Road Design, it is necessary to have extensive knowledge about the ecological environment. According to the investigation and analysis of construction processes and ecosystem, it all of us in each field must continue to learn and make efforts to purchase the maximum benefit, reduce the impact that road construction will make on nature, build up an environment with variety of habit at and species, and thus achieve the goal of "Harmony of Heaven and Humanity."

Promotion of Ecological Engineering on Road Construction in Our Country

While conceptions of ecological engineering in Europe and in the Americas can be traced to more than sixty years ago, in Taiwan such concepts have only been introduced in recent times. In its efforts to bridge the gap, Taiwan's Executive Ministry in the year 2000 announced an ambitious plan of creating Taiwan into a "Green Silicon

Island," the Executive Yuan advanced a plan called "The Scheme for Green Silicon Island" and "Major Plans for National Development--A Plan to Establish Water and Green" whereby "national construction will put emphasis on striking a balance between ecosystem conservation and economic development." In fact, in September 2000, the Fourth Discussion in the Sixth National Council of Technology explained that sustainable development and the welfare of all citizens should be the new target of public construction and further advanced a plan called "Promoting Development of Green Engineering Technology." Parallel with this initiative, the National Development Commission under Executive Yuan further passed "The Actions of National Sustainable Development of the Executive Yuan." The Public Construction Commission, the interested agency, insisted on the distinctions of Human-Center, High-Quality, and Sustainable Development in domestic public construction. It also reaffirmed its conclusion, made in the Fifth Main Discussion (Sustainable Development) during "The Council of National Public Construction for the New Century" held in September 2001, that some public green engineering systems, such as construction automation, green construction, ecological engineering, should be established and emphasized in the 21st century.

In furtherance of the above, the Public Construction Commission established the "Consulting Squad for Ecological Engineering" in 2002, and in that same year in August, they defined Ecological Engineering as "an ecology-based and safety-oriented engineering method applied to do less harm to Nature since we have to make preservation for varieties of living beings and sustainable development rooted in the ecosystem." During 2002-2003, the Public Construction Commission also held several "Meetings of Consulting Squad for Ecological Engineering." Moreover, in order to promote Ecological Engineering, the Public Construction Commission occasionally held seminars, instructions, and exhibitions of Eco-technology in order to educate the engineering staff about basic eco-technological concepts and ideas. In addition, larger international forums were also conducted for exchanging and sharing the experiences of other countries.

In order to promote consistent application of ecological engineering to the country's road construction, the Public Construction Commission requested that all governmental departments and commissions to build up teams to promote ecological engineering in September 2001. The Ministry of Transportation and Communication thus established, "A Team for Promoting Ecological Engineering" on June 17th, 2002 to supervise and direct the subordinate units under Ministry of Transportation and Communication to undertake the operations of ecological engineering. The following missions were assigned to the squad after the first meeting:

1. Medium-range and long-range plans of "Ecological Engineering" should be submitted by the sub-units.
2. Each sub-unit should undertake declarations, directions, and instructions in turn.
3. Each sub-unit should, according to its professional field, make brochures and reference books on Ecological Engineering.
4. Holding an exhibition of Ecological Engineering in December 2003 in coordination with Executive Yuan.

In 2003, 300 more employees of Directorate General of Highways gathered for group by group training. Members of the first group were comprised mainly of people from engineering advisory companies and units under the Ministry of Transportation and Communication while members of the second group were comprised mainly of deputies of the Directorate General of Highways. Other classes will be held in the future and may be entrusted to academic units.

In April 2003, the Ministry of Transportation and Communication submitted its timetable to achieving its goal of "Promoting Ecological Engineering and Resource Recycling, and Establishing the Maintaining and Managing System of Public Construction." This goal includes the more specific goals of increasing the proportion of adopting Ecological Engineering in 19 categories of public constructions from 15% in 2003 to 60% in 2005, drafting the plans for realizing Ecological Engineering, drafting the guidelines of judging Ecological Engineering, retraining technicians, architects, and engineers of authorities concerned, amending present acceptance criteria, collecting examples of Ecological Engineering work abroad, establishing an information platform for Ecological Engineering, developing domestic research on Ecological Engineering, holding Conferences on Eco-Technology regularly, offering encouragement to admirable services of Eco-Technology and construction works, encouraging the authorities to increase the proportion of adopting Ecological

Engineering in constructions, establishing the systems of planning and examining budget for maintaining public constructions, and establishing the cost-estimation system for the operation and management of some important public constructions with a budget more than one billion dollars.

On September 17, 2003, the Public Construction Commission invited all interested departments and commissions to discuss about how to achieve the stated goal within the established timetable. During the discussions, the Directorate General of Highways submitted several research plans relating to ecological engineering on "The Study of Applied Methods of Ecological Engineering in Provincial Highway No. 18 & Performance on Demonstration Constructions", "The Study of Applied Methods of Ecological Engineering in Provincial Highway No. 8, Provincial Highway No. 8A--Central Cross-Island Highway, and Provincial Highway No. 21--New Central Cross-Island Highway & Entrustment of Demonstration Construction Undertakings", and a explanatory sheet of 31 planned road (and bridge) constructions in 2004. In addition, the Public Construction Commission proposed that the Ministry of Transportation and Communication should examine the software facilities of transportation construction, such as the designs of main roads, branches, or escape ramps, and amend regulations of highway designs.

Problems Arising From Failure to Consider the Ecosystem in Road Construction in Taiwan.

On April 14, 2003, the vice chairman of Public Construction Commission, Kuo Ching-jiang pointed out several problems that arose from Taiwan's failure to consider the ecosystem during a speech he delivered on the topic of "The Trend and Promotion System of Ecological Engineering." Mr. Kuo observed that there were 1) unnecessary or improper excavations that lead to unstable side slopes and further calamities; 2) the side slopes of highways are sealed with cement, which destroy the ecosystem; 3) the side slopes sealed by cement may collapse and cause disasters; 4) the plants framed in the cemented side slopes are scoured off during the typhoon season; 5) newly-built highways continuously collapse and bring about changes to the ecosystem; 6) cemented side slopes devastate the landscape; and 7) open tunnels cannot be used to solve the problems of collapses.

In response to those problems, Mr. Kuo proposed the following solutions by applying principles of ecological engineering on road construction.

1. Apply software and hardware to meet the demands of traffic, including definite road signs, speed limit, guideposts, curves, narrows, and escape notices. Provide people with instruction and training of correct road-using, and employ reflectors at road curves.
2. Reduce interference with the environment and the ecosystem, including doing proper ecological investigations, carefully-choosing routes to prevent from improper separations of natural habitats, making courses for animals, and avoiding building ways with high road embankment.
3. Avoid over-excavation that makes unstable mountain slopes, including choosing proper routes, reducing lanes and width of roads in environmentally-sensitive areas, applying grading requirement effectively, and avoiding unstable geological structures.
4. Preventing rainfalls in mountains from changing the river course, including doing water lateral-intercepting to lead the rainwater to mountain slopes with plant-cultivation, and avoid using New Jersey Concrete Barriers as they will collect rainwater.
5. Meet the needs for traffic with the least number of lanes for vehicles, including doing investigations of traffic flows and estimation of traffic demands, employing escape ramps and passing lanes to replace designs of double lanes, encouraging people to use mass transportation system, and adopting reversal lanes to solve different traffic flows in different hours.
6. Stabilize side slopes with Eco-technology, including studying the factors of unstable side slopes and trying to solve them, avoiding using concrete to increase the burden of the earth, stabilizing the slopes of gravels with rockslide-proof nets, bushes, and vines, but not concrete. Stabilize mountain slopes with plants and discuss problems with other departments and commission to solve them.

Application of Ecological Engineering to Recent Constructions in Taiwan.

In view of Mr. Kuo's proposed solutions, concerned authorities in Taiwan have adopted the policies mentioned above, not only applying Ecological Engineering in new constructions, but also amending original roads with ecological principles. Some related and typical examples are shown in Table 3.

Table 3. Some Representative Examples on the Authorities Concerned Applying Ecological Engineering in Recent Related Constructions

Construction Type	Countermeasures	Unit	Examples
Stability of Side Slopes	Piling and Fencing	Directorate General of Highways	1. Provincial Highway No. 3, 80K+100~+250 (Figure 3-6) 2. Provincial Highway No. 21, 119K (Figure 7) 3. Route No. 149A, 28K+180 Piling, Fencing, and Plant-cultivation on the left side (Figure 8-10)
		National Expressway Engineering Bureau	National Highway No. 3, 97K+600
	Plant-Cultivation	Directorate General of Highways	1. Provincial Highway No. 11, 15K, Construction for stabilizing Side Slopes (Figure 11) 2. Provincial Highway No. 20, 127K+200, Restoration of Roadbed after Typhoon Dorothy 3. Route No. 110, 32K+700, Restoration for collapses caused by Typhoon Na-Li (Figure 12-13)
		National Expressway Engineering Bureau	1. National Highway No. 3, 9K+000-+450 2. National Highway No. 3, 85K+300, 81K+000
	Retaining Walls with Dry-stone Masonry	Directorate General of Highways	1. Route 149A, 54K, Slope Protection with Dry-stone Masonry (Figure 14) 2. Route 169, 10-12K, Slope Protection with Ladder-style Dry-stone Masonry (Figures 15-16) 3. Route 172, Restoration Construction: Mud and Stone Sliding at the Headstream of Chong Chong Bridge (Isolating the stream and the protected area by piling the stones on the site, Figure 17)
	Framed Retaining Walls	National Expressway Engineering Bureau	National Highway No. 3, 38K+100, Framed Retaining Walls
	Gabion Slope Protection	Directorate General of Highways	Provincial Highway No. 18, 28K, Construction for Gabion Slope Protection (Figure 18)
Drainage	Drainage Pavement	National Expressway Engineering Bureau	National Highway No. 3, 132K+513-+713
Bridges	Viaduct Bridge to Replace High-piling of Soil	Directorate General of Highways	Provincial Highway No. 88, Kaohsiung-Chaocho
		National Expressway Engineering Bureau	National Highway No. 3 Shindian Interchange
	Huge Span over Water Habitats	Directorate General of Highways	1. Provincial Highway No. 4 Kanjin Bridge (Figure 19) 2. Provincial Highway No. 3 Jingshan Bridge

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		National Expressway Engineering Bureau	National Highway No. 3, 4K+339-4K+784, Maling Bridge
	A Bridge with Single Pillar and Single Plane of Fracture	National Expressway Engineering Bureau	National Highway No. 5, 16K+794-17K+604, Shiding Viaduct Bridge
Tunnels	Minimum of Excavations and Restoration of Landscape	Directorate General of Highways	1. Provincial Highway No. 7, 36K+200, Rong-hua Tunnel 2. Provincial Highway No. 78, Bagua Mount. Tunnel (Figure 20, Under Construction) 3. Provincial Highway No. 84, 37K+300, Zomalai Tunnel
		National Expressway Engineering Bureau	National Highway No. 3, Jing-mei Tunnel
	Replace Excavations with Tunnels	National Expressway Engineering Bureau	The Tunnel of Eastern Highway, Suao-Hoping 2A (Under Design)
Box (Tube) Culvert	Courses for Living Beings	Directorate General of Highways	Prov. Highway No. 66 Guanyin-Daxi, Prov. Highway No. 68 Nanliao-Chudong, Prov. Highway No. 72 Houlong-Wenshui, Prov. Highway No. 76 Hanbao-Tsaotun, Prov. Highway No. 78 Taixi-Kuken, Prov. Highway No. 82 Dongshi-Chiayi, Prov. Highway No. 84 Peimen-Yujing, Prov. Highway No. 88 Kaohsiung-Chaocho (Figure 21)
		National Expressway Engineering Bureau	National Highway No. 5, 9K+382
Balusters	Landscape Balusters and Barriers	Directorate General of Highways	1. Provincial Highway No. 8, 141K+300 (Figure 22) 2. Provincial Highway No. 8, 182K+200 (Figure 23) 3. Provincial Highway No. 19A, Mashan Bridge
	Preventing Animals from Crossing Barriers	Directorate General of Highways	Prov. Highway No. 66 Guanyin-Daxi, Prov. Highway No. 68 Nanliao-Chudong, Prov. Highway No. 72 Houlong-Wenshui, Prov. Highway No. 76 Hanbao-Tsaotun, Prov. Highway No. 78 Taixi-Kuken, Prov. Highway No. 82 Dongshi-Chiayi, Prov. Highway No. 84 Peimen-Yujing, Prov. Highway No. 88 Kaohsiung-Chaocho (Figures 24-25)
Illumination and Traffic Control	Wireless Tower	National Expressway Engineering Bureau	Guanxi Section of National Highway No. 2
	Illumination	Directorate General of Highways	Provincial Highway No. 88, Streetlights equipped with Lampshades at Wandan Interchange to avoid affecting the growth of crops (Figures 26-27)
		National Freeway Bureau	National Highway No. 2, 0K-0K+700, Construction for setting fiber-optical tubes
Service Areas	Preserve Existent Precious Plants	National Expressway Engineering Bureau	National Highway No. 3, 320K+094, Dong Shan service Area
	Plans for Landscape Engineering in Service Areas	National Expressway Engineering Bureau	National Highway No. 5, 18K+500, Nan-ao Service Area

	Water-pervious Pavement of Parking Space	National Expressway Engineering Bureau	National Highway No. 3, 276K+715
Interchanges	Landscape Improvement	National Freeway Bureau	National Highway No. 1, Landscape Engineering at Yuan Shan Interchange and Taipei Interchange
	Make Swamps in the green area	National Expressway Engineering Bureau	National Highway No. 3, Nantou Section, 5K+300, Eastern Tsaotun Interchange
Others	Plant-cultivation on roadsides	Directorate General of Highways	1. Provincial Highway No. 1, Ping-Er Highway 2. Provincial Highway No. 3, Meishan-Kuken 3. Provincial Highway No. 7, 76K+000-78K+600 4. Provincial Highway No. 8, 135K+600
		National Freeway Bureau	Improvement for Plant-cultivation from CKS Airport to Yingge Interchange
	Maintenance of Air Quality	—	Water the construction sites, clean the vehicles, and cover dust-proof canvas on the trucks carrying gravels.
	Noise Control	—	Set up iron-sheet fences on the construction sites, decrease the number of vehicles accessing the construction sites, and avoid working in the night.
	Effluent and Sewage Management	—	Temporary sand-interceptions and drainage work, such as protections of embankments and slopes, dredging of drainage, tube culverts, and waterways.

Source: Information on the websites of National Freeway Bureau, National Expressway Engineering Bureau, Directorate General of Highways, and their subordinate departments (2004), translated by Meng-Li Lin.

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Take several cases from Directorate General of Highways for example:

Stability of Side Slopes

(1) Piling and Fencing

Figure 3. Status of Provincial Highway No. 3, 80K+100, Before Construction

Figure 4. Provincial Highway No. 3, 80K+100, Spreading Grass Seeds to Cover the Slope

Figure 5. Provincial Highway No. 3, 80K+100, One Year after Construction

Figure 6. Public Construction Commission Issued Citations for Encouragement

Figure 7. Piling and Fencing at Provincial Highway No. 21, 119K

Figure 8. Highway No. 149 A, 28K+120, Before Construction

Figure 9. Highway No. 149A, 28K+120, Piling, Fencing, and Plant-cultivation

Figure 10. Status of Highway No. 149 A, 28K+120, After Construction

(2) Plant-cultivation

Figure 11. Provincial Highway No. 11, 154K, Stabilizing the Side Span with Plant-cultivation

Figure 12. Status of Highway No. 110, 32K+700 under Construction

Figure 13. Status of Highway No. 110, 32K+700 after Construction

(3) Retaining Walls with Dry-stone Masonry

Figure 14. Highway No. 149, 54K, Side Slopes with Dry-stone Masonry

Figures 15-16. Route 169, 10K-12K A Ladder-style Slope with Dry-Stone Masonry

Figure 17. Route No. 172, Dry-stone Masonry at the Headstream of Chong Chong Bridge

(4) Gabion Slope Protection

Figure 18. Provincial Highway No. 18, 28K, Construction for Gabion Slope Protection

Huge Span of the Bridge over Water Habitats

Figure 19. Provincial Highway No. 4, Kanjin Bridge

Tunnels--Minimum Excavation of Tunnel Entrance, replacing road-chasm digging with tunnel Construction

Figure 20. Provincial Highway No. 78, Sketch Map of the Tunnel Entrance at the Bagua Mountain

Box (Tube) Culvert--Box (Tube) Culvert with Courses for Living Beings

Figure 21. Provincial Highway No. 78, Taixi-Kuken Section, Box (Tube) Culvert with Courses for Living Beings

Balusters

(1) Landscape Balusters or Barriers

Figure 22. Provincial Highway No. 8 141K+300, Barriers and Adornment outside the Region

Figure 23. Provincial Highway No. 8, 182K+200, Side Slopes Piles with Bricks; Structural Height is Lowered; Vines and Colorful Bushes beautify the road

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(2) Barriers to prevent animals from entering the course

Figure 24-25. Provincial Highway No. 78, Ku-Ken Line

Figure 26-27. Provincial Highway No. 88 Wan-Dan Interchange, Street lights equipped with lampshades to avoid affecting growth of crops

<u>Illumination--Street Lights should be Equipped with Lampshades to Avoid Affecting Growth of Crops</u>

The examples explained above show that the highway authorities have followed point for point the Ecological Engineering Principles of Road Construction proposed by Mr. Kuo to meet the needs of traffic by employing software and hardware facilities, reducing interference to the environment and ecosystem, avoiding over-excavations that make unstable mountain slopes, preventing roads in the mountains from changing river courses during rainfalls, satisfy traffic demands with the least number of lanes for vehicles, and stabilizing side slopes with Eco-technology. In order to avoid making the mistakes of the past, it is indispensable to reduce unnecessary and improper excavations and adopt piling and fencing, plant-cultivation, dry-stone masonry, gabion slope protection, huge spans of bridges, landscape engineering at tunnel entrances, penetrable barriers, drainage with courses for living beings, fences to restrain animals, and lampshades of illumination equipment. Thereupon, the goal of making all-around Eco-technology in road construction take root will be achieved step by step in coordination with domestic research on Ecological Engineering, technical developments, and regulation amendments.

Primary Considerations in Promoting Eco-Technology in Road Constructions in Taiwan

Application of ecological engineering in road construction is still new in Taiwan. However, it appears that government officials are well-aware of the consequences when ecological engineering considerations are not made. Therefore, the government must promote ecological engineering and ensure that research and analysis can be accomplished with objective and prospective notions and if proper promotion strategies can be figured out based on the real key problems. In addition to what Mr. Kuo has proposed, this paper also seeks to advance some new ideas about how to promote ecological engineering in Taiwan.

Apply Best-Suited Ecological Engineering Techniques

Due to the high frequency of typhoons, earthquakes, and sudden cloudbursts in Taiwan, related techniques should be modified to suit the hydrographic environment of Taiwan. In order to know what kind of related techniques to apply, ecological engineers in Taiwan must study related techniques (such as soil-drainage, used broadly in foreign countries) and modify the same before applying it to domestic cases. Moreover, such related techniques require a sufficiently broad ecological database, which is still insufficient in Taiwan. As a result, further development of domestic techniques of ecological engineering should be processed as soon as possible and basic research and regulations of related techniques also need to be established.

Restructure Current Management of Engineering System

The present engineering systems in Taiwan, ranging from budget, contract-issuing to construction, acceptance criterion, maintenance and management, should be restructured and amended in coordination with promotions of Ecological Engineering.

1. Budget System: The planning of budget, investigation analysis, involvement of citizens, layouts, designs, constructions, and examining procedures of Ecological Engineering are often different from those of the traditional engineering. Deficient time investment will influence the impact of ecological engineering cases.
2. Contract-Issuing System: The service charges for layouts and designs for the time being still discourage people from adopting Ecological Engineering. Contract issuing is often taken because of lower charges, and the companies with abundant experience will not necessarily win the bid; therefore, it is difficult to take advantage of Ecological Engineering effectively under the consideration of costs and gaining.
3. Acceptance Criterion: Prof. Ju-jiang Hung once said, “The ultimate goal of Eco-technology or Ecological Engineering lies in that constructions are invisible to human beings and wildlife and even no technical marks can be seen except for the ecosystem that is suitable for existing and living.” Nevertheless, general construction in our country is usually undertaken with the blueprint, and estimation is made based on reality, which has a conflict with Ecological Engineering’s emphasis on changing plans according to different situations and employing on-site materials. But, the engineering staff often has no choice but to follow the original acceptance criterion in order to avoid violating the law.
4. Maintenance and Management System: Ecological Engineering requires more initial maintenance and investigation analysis before and after construction. However, so far this system still lacks such a unit.
5. Decision-making System: When a conflict between safety and ecology considerations takes place, safety in a populous area is often given priority. There is no definite regulation of decision-making for the time being if ecological demands conflict with purposes of road construction (such as safety or convenience, etc.)

Increase Number of Ecological Specialists

A great number of specialists are needed to for collect and classify of the domestic ecological information, develop native engineering technologies, conduct basic research, and even test the principles of related techniques. However, according to the statistics, before 1970, there were less than 10 persons engaging in investigations of biological resources and ecological research; till through 1990, the number had been gradually increased to 200 or so, most of whom were expert in biology; and few had mastered eco-environment. Furthermore, Talent Cultivation for Ecological Engineering in the normal educational system or examination programs for talent screening in our country still lacks concrete measures. Disappointedly, only few educational institutions in Taiwan provide ecological engineering program such as National Taipei University of Technology, National Taiwan University and National

Chung-Hsing University. This serious deficiency of talents will be another problem in the future. In addition, it is a hard task to combine ecology and engineering; however, Eco-technology contains the two professional fields of Eco-biology and Engineering. If the specialists in ecology know nothing about engineering, and engineers bear no ecological background, development of Ecological Engineering will be hindered undoubtedly.

So far, there are still doubts the minds of the engineers in our country: Is it possible to calculate the safety coefficient of Ecological Engineering? How much time does it require for piling and plant-cultivation to grip soil? What responsibilities should engineers bear if Ecological Engineering does not work? The answers are no doubt related to immaturity of domestic information on the ecosystem, engineering techniques, basic research, and principles for techniques mentioned above. However, the supervision institute and the judicial system in our country still offer no space for engineers to experiment with. Thus, prevented from bearing juristic responsibilities, the staff of road construction prefers traditional engineering with lower risk rather than attempt ecological engineering.

Promote Private Public Ecological Awareness and Dialogue

A certain proportion of the citizens and representatives, or even local governments, still bear the incorrect idea that “a wider road is better.” The engineering staff has to run the negotiations with the public, related organizations, specialists, and scholars for the balance of Ecosystem Protections and Transportation Construction, but the process is often lengthy and it is hard to reach an agreement.

Strategies in the Promotion of Ecological Engineering to Road Construction in Taiwan

To order to encourage Taiwan’s consistent application of ecological engineering to road and highway construction, I present the following strategies for future consideration.

Strategies in Applying Best-Suited Ecological Engineering Techniques

1. Establish domestic information on ecosystem investigation.
2. Build the database and information platform for Ecological Engineering.
3. Take encouraging actions to spur research in each field.
4. Develop domestic techniques for Ecological Engineering to set up principles of applied techniques of Ecological Engineering.

Strategies in Restructuring Current Management of Engineering System

1. Draft (or adjust) overall plans to promote Ecological Engineering.
2. Plan strategies for development, and amend related regulations for purchases on the basis of Ecological Engineering.
3. Modify the budget systems of construction and accounting, methods of contract-issuing and contract-taking, and acceptance criterion of constructions on the basis of Ecological Engineering.
4. Set up construction executing modes corresponding to Ecological Engineering, and follow-up managing systems for monitoring and maintaining.
5. It is necessary to set up a standard of decision-making system, so the rules will be followed easily if there is a conflict with ecology, safety, convenience, and so on.
6. Establish ecological evaluation standards and procedures to offer the rules for designs and management of Eco-technology. To avoid impact on landscape, land-using control should be emphasized.
7. Establish official procedures of Eco-technology and units in charge of management to make contact with other departments.

Strategies in Increasing Number of Ecological Specialists

1. Basic education--firstly in National Education, and combine with community operations to promote it as family education and social education, then to each class in society.
2. Accelerate planning complete professional education, such as teacher training, setups of related professional subjects and programs, to cultivate talents in Eco-Technology.
3. Setup related categories in priority, such as ecology or landscape engineering, in National Examinations, which enables the authorities to employ specialists in ecology and promote Ecological Engineering.
4. Engineering crew should participate in seminars

and discuss Ecological Engineering.

5. Hold retraining of related technicians and engineering staff, and experts in ecology should also study engineering principles and contributing their professional information.
6. Suggest Public Construction Communication to organize a consulting team that provides advice, guidance, and service about related plans on Ecological Engineering.
7. Upgrade the skills of engineering and controlling staff to maintain the quality of Ecological Engineering.
8. Communicate with the judicial units and combine the regulation amendments mentioned previously to free the engineering staff from bearing unlimited responsibilities.
9. Suggest Public Construction Commission to organize a consulting team providing advice, guidance, and service, set up the Committee of Ecological Engineering Techniques responsible for examining methods of Ecological Engineering to reduce responsibility ascription of the engineering staff, and reinforce confidence in executing Ecological Engineering.

Strategies in Promoting Public and Private Ecological Awareness and Dialogue

1. Increase opportunities to inspire the public to get involved, especially for the NGOs (Non-Governmental Organization), which enables the plans on Ecological Engineering to incorporate the opinions from the public and professional organizations.
2. Every citizen is a supervisor during the construction, participating in maintaining and managing afterward.

Conclusion

To understand the dilemmas in the endorsement of ecological engineering in the construction of roads, several examples are addressed in the content of this article. The strategies proposed in this article suggest some ideas in the promotion of construction of roads in ecological engineering. The ultimate value of ecological engineering is taking the systems, educational purposes and practice of road engineering all together in consideration.

To apply sustainable development into ecological engineering, the first step is to make engineers have extensive knowledge about the ecological environment. According to the investigation and analysis of construction processes and ecosystem, it all of us in each field must continue to learn and make efforts to purchase the maximum benefit, reduce the impact that road construction will make on nature, build up an environment with variety of habit at and species, and thus achieve the idea of “harmony of nature and humanity” in traditional Chinese philosophy.

References

[1] Chinese Institute of Civil and Hydraulic Engineering, 2003 Civil and Hydraulic Engineering, Vol.30-6.
[2] Chiu, M.Y., 2002, Study of National Highway Construction Applying Principles of Eco-technology.
[3] Construction News Record, 2004, “Will Eco-technology is the Next Educational Reformation?”
[4] Endemic Species Research Institute, Executive Yuan, 2003, Seminar of Masonry in Ecological Engineering－Theories and Calculation of Metered System.
[5] Endemic Species Research Institute, Executive Yuan, 2003, Seminar of Masonry in Ecological Engineering－Near Natural Masonry.
[6] Forman, R.T.T., 1995, Land Mosaics-The Ecology of Landscapes and Regions, Cambridge University Press.
[7] Forman, R.T.T., 1998, Road and Their major Ecological Effects, Annual Review. Ecol. Syst., 29:207-231.
[8] Forman, R.T.T., 1998, Road Ecology: A Solution for the Giant Embracing Us, Landscape Ecology, 13:3-5.
[9] Forman, R.T.T., 2003, Road Ecology: Science and Solution, Island Press, Washington.
[10] Hsieh, J.D., 2002, Ecological Engineering at the Present Stage.
[11] Huang Y.P., 2003, “Ecological Engineering on Transportation Construction－Principles and Practice” Seminar of Ecological Engineering, Directorate General of Highways.
[12] Japan Highway Public Corporation, 1999, Highway Environment Protection and Plant-cultivation.
[13] Japan Road Association, 2001, Design Principles of Ecological Engineering Paving.
[14] Kuo C.J., 2003, “Development Directions and Promotion Systems of Eco-technology－A Brief Report on Road Landscape”
[15] Lin, C.Y. & Chiu, Y.W., 2003, Introduction to Ecological Engineering Methods.
[16] Lin, C.Y. & Chiu, Y.W., 2002, “Ecological and Civil Engineering.”
[17] Mitsch, W.J., S.E. Jorgensen, 1989.Ecological

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Engineering: An Introduction to Ecotechnology, Wiley, New York.
[18] Modern Construction, 2003, “Rough Opinions on the Procedures Applying Eco-technology.”
[19] Randolph, John, 2004, Environmental Land Use Planning and Management, Island Press, Washington.
[20] Rund Cupers, 1999, Guide lines for Ecological Compensation Associated with Highways, Biological Conservation, 90:41-51.
[21] Rund Cupers, 2001, Ecological Compensation in Dutch Highway Planning, Environment Management, 27:75-89.
[22] Tsai, H.N., Chiu, M.Y.& Lu, H.Y., 2003, Ecological Technology for Road Construction.
[23] Wu, S.W., 2004, “Initial Conception of the First Draft about Road Ecological Engineering Plan.”

Educational and Publicity Activities of the Fei-tsuei Reservoir

Date Visited: 5/28/2005 (Saturday)

Location: Fei-tsuei Reservoir and Jr-tan Water Treatment Plant, Taipei

Hosted by: Water Resources Agency, Ministry of Economic Affairs
Water Environment Commitee, The Chinese Institute of Environmental Engineering
Water Environment Research Center, NTUT

Sponsors: Enviroment Engineering Commitee, Chinese Institute of Civil and Hydrolic Engineering
Administration of Fei-tsuei Reservoir, Taipei City Government
Taipei Water Department, Taipei City

Participants: Graduate students, Seniors majored in environment, civil or hydraulic engineering

Announcement of the activities on the website

Educational tour to the Fei-tsuei Reservoir

Educational tour to the Jr-tan water treatment plant

International Special Topic Forum

Date and Time:	10-12 am, 5/20/2005 (Friday)
Location:	Conference Hall, 5F of Civil Engineering building, National Taipei University of Technology
Speaker:	Liu Cheng-chun, Professor of Environment and Civil Engineering Department, University of Hawaii.
Special Topic:	Watershed Conservation and the Protection of Source Water
Chairman:	Li Yeou-fong, Chairman and Professor of the Dept. of Civil Engineering, NTUT
Hosted by:	Water Resources Agency, Ministry of Economic Affairs Water Environment Resource Center and Dept. of Civil Engineering, NTUT
Sponsors:	MWH Global, Inc.

Poster of the International Special Topic Forum.

Professor Li, the chairman, and Professor Liu, the speaker, of the forum.

The talk generated enthusiastic discussion during the forum.

2005 Conference of Sustainable Use of the Hot Spring Water

Conference Date:	5/26/2005 (Thursday)
Location:	No. 25, Chiuan-yuan Rd., Bei-tou area, Taipei city
Purpose:	Researches in laws relative to hot spring water, water qualities of hot spring, humen health and management, etc.
Sponsors:	Health, Welfare and Environment Foundation, HWE Water Environment Research Center, NTUT
Participants:	Citizens concerned with the use of hot spring water, academic or trade associations

Site situation of the conference

Participants had enthusiastic discussions with the speaker

Poster of the 2005 Conference of Sustainable Use of the Hot Spring Resources

Manuscripts Submission Guidelines

Journal Content

The Journal of Ecotechnology will publish (1) academic papers in watershed management or ecological engineering, (2) description of local or international meetings or activities, (3) case studies, (4) technical reports, and (5) review articles. Fields of interest include, but not limited to, hydrology, water and soil conservation, ecology, vegetation engineering, environmental engineering, and civil and hydraulic engineering.

1. **Language**: All manuscripts must be submitted in English. The manuscript title, authors, affiliation, and abstract should also include a Chinese translation.
2. **Format**: Manuscripts shall be typed in Times New Roman, 12-point font. Please submit both a Document (.DOC) file and a Portable Document Format (.PDF) file for editing purposes.
3. **Figures**: Please do NOT reduce the resolution of illustrations. If illustrations were not included in the text files, please send them separately with at least 300 dpi resolution.

Manuscripts Submission

1. Please submit your manuscripts by E-mail if the file size is less than 10 MB.
   E-mail to: jauntysl@gmail.com
2. Please submit your manuscript stored in CD-ROM disks by mail if the file size is larger than 10 MB.
   Mail to: Miss Jaunty Liu
   Water Environment Research Center,
   National Taipei University of Technology
   No. 1, Sec. 3, Chung-hsiao E. Rd. Taipei, Taiwan, R.O.C. 10608

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稿約

稿件內容

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1. 本期刊投稿撰寫一律以全英文稿為限，惟論文題目與作者名、機關名、摘要均請同時並列中英文。
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