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Control and Recovery of Environment after the Construction

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The Taiwan Strait Tunnel Project will bring very deep, far, and long lasting influence on the environment inevitably. This article focuses on what shall be done considering environmental issues after the construction. Herein an environmental protection program with a four-step procedure is particularly illustrated, including setting environmental objectives, formulation of environment protection program, plan of environmental survey, and management of environmental event. This procedure based on the outcome of environmental impact assessment formulates an environment protection program to control and recover environmental problems after the project completed. Two case studies will illustrate the special design and considerations adopted that make the project coexist with the environment successfully, peacefully, and friendly.

Keywords environment protection program, impact assessment, control, recovery

The concept of "sustainable construction" or "green construction," which looks for the best solution for a construction project to balance economic development, environment protection, or natural resources preservation, has become a global issue and development trend. Based on this concept, developing a construction project must meet the following objectives:

- make social progress fit the needs of the public,
- pursue economic development to promote the quality of life,
- protect environment effectively to preserve natural environment, and
- utilize resources efficiently to achieve sustainable utilization of finite resources that we have.

A railway transportation system, compared with the transportation by sea or by air, has less impact on the environment. This impact can be further reduced if a tunnel is introduced such as the Taiwan Strait Tunnel (TST) Project. However, this project has some unusual characteristics including large scale (the shortest length of is about 144 km, among which the undersea section is about 125 km), extensive scope

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(the average width across the Taiwan Strait is more than one hundred kilometers to link two lands), complex contents (it comprises various engineering works and multiform actions), and special geographic/geological conditions (it is located within the Circum-Pacific seismic zone, and situated at the vicinity of the collision zone of the Eurasia continent plate and the Philippines sea plate) (Fang 2000). Inevitably, this giant project will bring very deep, far, and long lasting influence on the environment. From the environmental viewpoint, the TST Project has the following characteristics.

- On the space aspect: Its scale is huge and crosses over various patterns of environment on land and in sea. Therefore, it will confront complex and varied environmental situations that make the impact deep and extensive.
- On the time aspect: The entire assessment-design-construction procedure will take a long time over several decades, and the operation stage will take even longer. Therefore, the impact on the environment will be a long-term effect.
- On the content of the project: It comprises various engineering works (roads, tunnels, bridges, foundations, retaining structures, etc.) and multiform actions (excavations, cuttings, fillings, grouting, water resistance, etc.). As a result, there will be many work interfaces to be dealt with. Consequently, the construction technology will be very difficult and complicated. That will make the environment impact wider and more serious.

This article focuses on the impact and the effect upon the environment after the construction, including the scope, extent, and corresponding strategy. Then fundamental thoughts and opinions are proposed. It is hoped to provide a direction to further thoughts on controlling and recovery of the environment after the construction.

Environment Impact Assessment

The purpose of the environment impact assessment (EIA) of the TST Project during operation stage is to carry out an extensively detailed investigation and assessment on what environmental situation along the route is and how it will be affected. Then the outcome will form the basis to map out the planning and design, and to program the environment protection plan. As previously mentioned, the TST Project will have very deep and far impact on the environment regarding space, time, and contents, therefore the EIA should be detailed and deep.

The categories and items emphasized on the EIA of the TST Project during operation stage are listed in Table 1.

Environment Protection Program

An environment protection program (EPP) is developed on the base of the outcome of EIA to solve the impact and to manage and protect the environment after the project completed. By processing the four-step procedure (Figure 1), including setting environmental objectives, formulation of environment protection program, execution of environmental survey, and management of environmental event, we can not only minimize the impact on the surrounding environment to achieve a harmony between the structure and the environment, but also establish a sustaining, developed living space for both mankind and fauna/flora.

Table 1
The categories and items emphasized on the environment impact assessment of the TST Project during operation stage

	Category	Item of Emphasis on
1	Ecosystem	• Category, population, and distribution of local species (fauna and flora), especially the dangerous species and hazardous species. • Impact factor of environment and the effect upon local species (live space, lift pattern, habitual behavior, sphere of activities, population growth and decline, etc.). • Effect upon habitat (woodland, river, wetland, vegetable, etc.), especially the nature reserve and sensitive environment area.
2	Landscape	• Local situation of vegetable and plant (type, population, distribution, etc.). • Landscape pattern along the route (forest, open space, hilly area, river, etc.). • Effect upon harmony of local landscape (tunnel opening, embankment, bridge, etc.). • Condition and rate of recovery of local environment. • Category and distribution of historic spots and remains.
3	Aquatic environment	• Condition of surface hydrological system (type, distribution, regional drain, etc.). • Situation of groundwater (depth, pressure, water quality, etc.). • Influence on the ocean circumstance (navigation condition, flow status, silt deposit, etc.).
4	Land use	• Patten of land use along the route (open space, farmland, pastureland, nature plant, residential area, industrial and commercial area, special building, etc.). • Effect upon land use by project development (land value, utility pattern, etc.).
5	Quality of environment	• Pattern of region (urban, outskirts, nature environment, etc.). • Extent and effect of noise pollution. • Magnitude and effect of vibration. • Quantity and effect of dust pollution.

Setting Environmental Objectives

The purpose of setting environmental objectives is to limit the environmental impact extent of construction behavior to tally with the expectation, and to protect ecological environment. A committee can be formed, in which the members can be

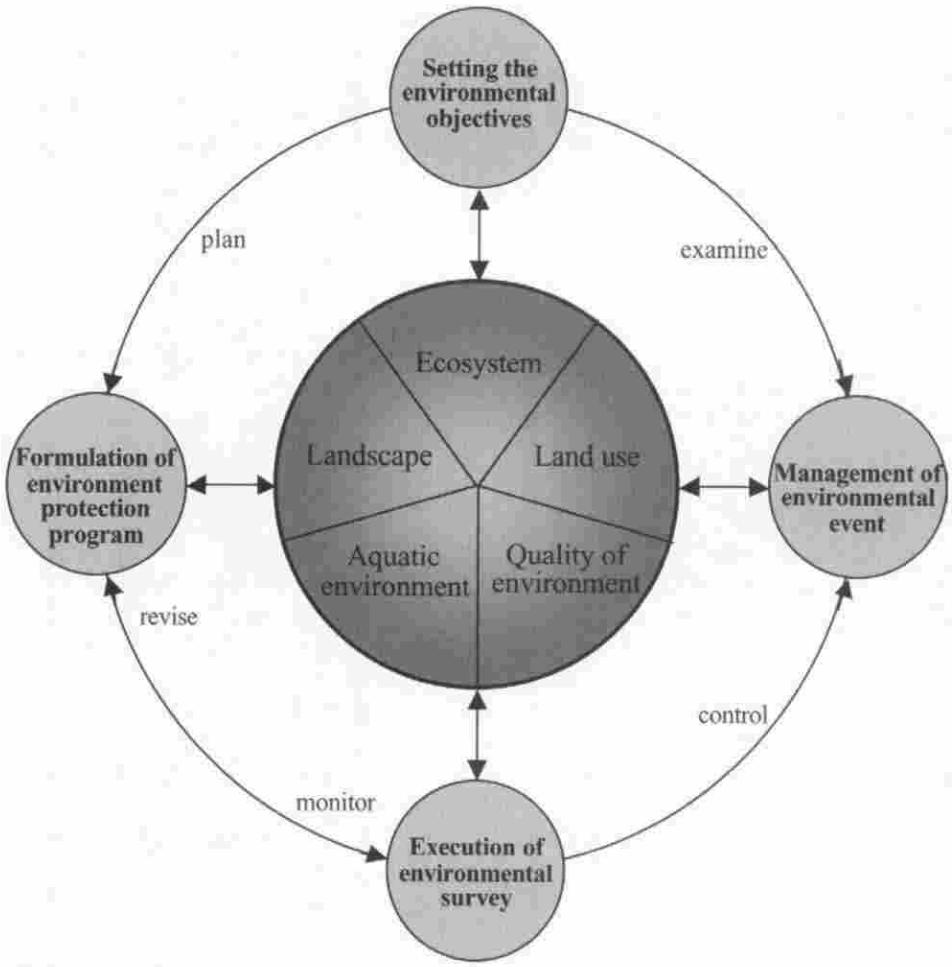

Figure 1. The procedure of environment protection program of the TST Project after the construction.

experts, scholars, officials from correlated government departments, and residents, to draw up minimum environmental requirements (or standards) which consider local environment situations (including ecosystem, landscape, aquatic environment, land use, quality of environment) and meet further development in the future. Then the environmental objectives and standards will be set up according to the minimum environmental requirements.

Formulation of Environment Protection Program

According to the environmental objectives, experts and engineers can formulate a series of plans and measures that transform vague objectives into real plans, via the confirmation by correlated government departments and residents. The environment protection program will thus be formed. This program can be implemented into all stages of design, construction, and maintenance, to make the environment fit with the environmental objectives.

Herein the environment protection program of the TST Project is presented briefly and listed in Table 2. It is hoped that it can provide a guide to thoughts on the relation between the environment and the construction.

Table 2
The environment protection program of the TST Project

Category	Objective	Measure
Ecosystem	• To preserve and establish wildlife habitats. • To protect species of fauna and flora (especially the dangerous and rare ones). • To maintain and enhance the biodiversity.	• Build biopassage (such as tunnel, land bridge, etc.) to connect the separated habitat, and to maintain activity and migration of wildlife. • Establish artificial habitat (such as reef, net, cave, wetland, wood-land, etc.) to enrich species and populations. • Set up fence or barrier to keep animals from intrusion. • Carry out special measures to protect nature reserve and sensitive environment area. • Introduce local or new species that can adapt well to local environ-ment, to enhance the biodiversity. • Move out the invasive and hazardous species to maintain balance of the ecosystem.
Landscape	• To conserve natural landscape and minimize interference. • To make man-made structure blend with surrounding environment. • To conserve listed buildings, heritages, and remains.	• Accommodate to the local geography instead of large-scale excavation and fill. • Harmonize landscape design with surroundings and resident's expectation. • Appropriate planting (tree, shrubs, grass, wildflowers, etc.). • Conserve or move (dismantle and recombine) the listed buildings, heritages, and remains.
Aquatic environment	• To protect surface water body. • To remain regional draining function. • To maintain navigation condition, and flow status.	• Use tunnel to cross surface water body instead of alternatives with embankment or bridge. • Design with minimal change on terrain. • Make use of natural drainage way to drain runoff.

(*Continued*)

Table 2 Continued

Category	Objective	Measure
Land use	• Maximum environmental benefits to use the lands. • Sustainable development of land.	• Undertake the life-cycle cost/benefit analysis that is based on environment, to assess the best use pattern. • Transform low-benefit land use (unirrigated farmland, grassland, etc.) into high-value use pattern (sports park, outdoor recreation field) which consider both environment and practicality.
Quality of environment	• Fit the minimum requirement of environmental quality (noise, vibration, dust, etc.).	• Diminish vehicle noise by using natural buffer (such as woodland, terrain), embankment, reinforced retaining wall. • Reduce vibration and noise via effective shock absorber or cushion design on the rails and bridges. • Appropriate planting to cut down soil washout and dust formation, as well as for a noise buffer.

Execution of Environmental Survey

This procedure aims concerns at the changeable and important conditions of the environment protection program to survey and control the latest situation or variation immediately. It is the basis for executing the management of an environmental event and/or to modifying the environment protection program when an unusual situation happens. There are two ways to execute the environmental survey

1. By specific personnel going into the field to investigate and assess periodically environment situations such as:
   - Populations, distribution and activities of species (especially the dangerous and rare ones);
   - Whether the species, which dispersed or moved out owing to disturbance of construction, are recovered or move back;
   - Habitats situation (condition of inner ecosystem, area size);
   - Growth condition of new planting;
   - The population condition of introduced species;
   - The condition of man-made installations (such as biopassage, fence, railing, reef, net, cave, etc.).

2. By installing the monitor system or monitor instrument to continuously survey the environment, so we can understand and master the environment all the time and record automatically related environmental data such as:
   - Monitoring of noise, air quality, vibration, etc.;
   - The image monitoring (periodical or continuous) of the habitats of dangerous and rare species;
   - The image monitoring of significant location.

Management of Environmental Event

The purpose of this procedure is to react in a timely manner to the adverse situation, either when the environmental situation does not conform to the environmental objectives (standard) or when an environmental event occurs and endangers the environment situation. Appropriate reactions and measures can be adopted to (1) investigate the cause which changes the environmental situation, (2) control the extent of impact or pollution and eliminate adverse situation, and/or (3) recover the environmental situation to conform to environmental objectives.

There are two occasions to execute the management of an environmental event:

(1) The outcome or data of environmental survey does not conform to the environmental objectives, such as:
   - The populations of species (especially important, dangerous and rare) are gradually or suddenly decreasing caused by death or migration,
   - Vehicle noise, vibration or dust is out of allowance standard, and
   - The populations of new planting or introduced new species are unbalanced;

(2) An environmental event occurred and is endangering environment situation, such as:
   - The pollution event (leakage of chemical compound or oil, fire, uncontrolled cut down trees or reclaim lands, etc.),
   - Natural disaster (hurricane, floods, forest fire, etc.),
   - Serious blight or infectious disease that causes a great number deal of deaths of plants or animals.

If the above-mentioned situation occurred, then a meeting will be held by a responsible team (the members including ecologists, scholars, government personnel and residents) to assess the damaged situation and to discuss a corresponding strategy. The resolution of the meeting will be executed to deal with the event to recover the environmental condition. If the ecological environment is obviously varied or damaged, an ecological compensation plan can be carried out. The ecological compensation plan is an appropriate measure that substitutes for the function or value of the ecological environment which has been damaged by a construction project. It can actively compensate for the damage of the environment, and then recover the environment situation and maintain it well. After the execution of an action or measure, the new environment situation will be examined again to see whether it conforms to the environmental objectives. Thus we can ensure that the procedure is proper and effective. The flow chart of managing in environmental event is shown on Figure 2. The joint point A in the figure represents this management work will continually to sustain and manage the environment.

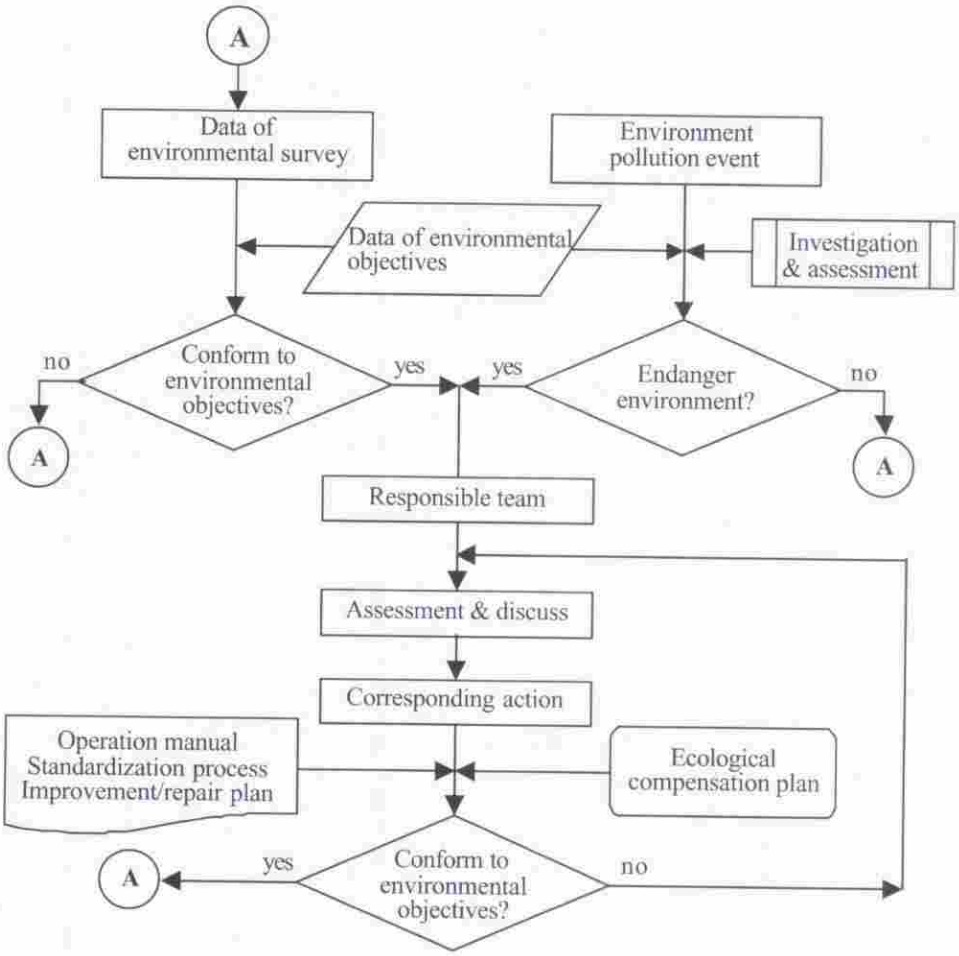

Figure 2. The flow chart of management of environmental event.

Case Studies

The environmental standard is very strict in Europe and the United States. Giant projects, such as strait or marine tunnel construction projects, have very detailed consideration and design on environment issues. They are expected not only to minimize the impact on the environment, but also to enhance and enrich the environment to chase a unity between construction and environment. In the following, the special design and consideration on the environment of two cases are illustrated. Their successful experiences can set a model for future development of the TST project.

The Channel Tunnel Rail Link

The Channel Tunnel Rail Link, that links England and continental Europe for the first time since the Ice Ages, is one of Europe's biggest infrastructure projects to date.

The 31-mile (of which 23 miles are underwater) tunnel was constructed in 1994, and will be completed in 2007 (Rail Link Engineering 2001).

The Channel Tunnel Rail Link was designed to high environmental standards, with about 85% of the route in tunnel or within existing transport corridors. The environmental standards adopted in the design are at the forefront of those commonly applied to major infrastructure projects. Account is taken on environmental impacts during construction as well as operation stages.

A set of Environmental Minimum Requirements was established and a sophisticated Environmental Management System was implemented to ensure that environmental issues were addressed and managed effectively during design and construction as well as operation.

Their ecologist's team has undertaken an extensive program to relocate protected species and create new habitats. The following have been undertaken:

- 255 hectares of mixed broadleaved woodland, of which about 26 hectares will be on translocated ancient woodland soils.
- 240 hectares of grassland seeding, including 46 hectares of wildflower grassland, has been carefully designed not only to match local soil and environment conditions, but also to provide ecological diversity and abundant species.
- In three locations, innovative land bridges have been constructed to allow movement of species between areas of established ancient woodlands.
- Many habitats have been created for amphibians, badger, bat, water vole, rare flower, etc.
- Reintroduction of over 100 Hazel Dormice from Kent in two other UK woodlands was part of the species recovery program.
- An annual ecological survey, including surveys of amphibians, dormice, rare and scarce plants, breeding birds, reptiles and plant communities was conducted.
- A surface water quality and fisheries survey program on all major watercourses was performed.

In addition extensive and sophisticated archaeological works have been undertaken to recover some important English heritages, including the Anglo-Saxon burial site and the Late Mesolithic to Roman Period remains, along with a following further preservation.

The Big Dig

Boston, Massachusetts has a world-class traffic problem: an elevated six-lane highway called the Central Artery on which traffic crawls for more than 10 hours each day. The accident rate on this deteriorating elevated highway is four times the national average for urban Interstates. The same problem has tormented the two tunnels under Boston Harbor between downtown Boston and East Boston/Logan Airport.

The solution called the Central Artery/Tunnel Project (CA/T), now under construction by the Massachusetts Turnpike Authority. This project is known as one of the largest, most technically difficult and environmentally challenging infrastructure projects ever undertaken in the United States. The project includes an underground expressway directly beneath the existing road, two bridges across the Charles River, and a tunnel beneath South Boston and Boston Harbor to Logan Airport (http://www.bigdig.com).

The environmental mitigation program has been implemented to control and minimize as much as possible the disturbance on urban life and ecological environment. This program includes:

- Use of project dirt to cap an old landfill on an island in Boston Harbor, stopping leaching of toxic materials into the harbor and converting the island into a public park.
- Sending clay excavated from downtown Boston to cap area landfills, preventing more costly disposal at distant sites, and saving municipal governments millions of dollars.
- Reclaiming an intertidal wetland area at Rumney Marsh. A total of 300,000 cubic yards of sand was removed to restore the 18-acre Rumney Marsh site. Some of the sand hauled from the site was reused on the CA/T Project, and some was used on other construction projects. The newly restored intertidal habitat is being colonized by salt-marsh vegetation as well as by various species of fish, shellfish and migratory birds.
- Creating an artificial reef system in Boston Harbor. The reef was designed to create a new ecosystem in the harbor, primarily as a habitat for blue mussels and other shellfish. It will also become the home for a variety of other sea creatures, such as lobsters, crabs, and finfish, which are attracted to the shelter of the reef structures, and to the algae and other food sources living on the reef complex.
- Creating more than 260 acres of land open to the public, including 30 acres on which the existing Central Artery now stands, more than 100 acres at Spectacle Island in Boston Harbor, and 40 more acres of new parks in and around downtown Boston.

Conclusion

There is no doubt that any construction behavior has various impacts on the surrounding environment. This is especially true of the Taiwan Strait Tunnel Project which possesses unusual characteristics including large scale, extensive scope, complex contents, and special geographic/geological conditions. Inevitably, this giant project will bring very deep, far, leading and long lasting influences on the environment.

Herein an environmental protection program that has a four-step procedure is illustrated, including setting environmental objectives, formulation of an environment protection program, execution of an environmental survey, and management of an environmental event.

The Taiwan Strait Tunnel Project can be built more environmentally friendly via a detailed and appropriate design and an effective environmental program. This program can not only minimize the impact on surrounding environment to achieve a harmony between structures and environment, but also establish a sustainable developed living space for both mankind and fauna/flora.

Additionally, two case studies illustrating special design and considerations are introduced to show how to make the project coexist with the environment successfully, peacefully, and on a friendly basis. These successful experiences can set a model for the future TST project.

References

Annual Environmental Report 2001 of Channel Tunnel Rail Link. *Rail Link Engineering*, 000-RMA-RLEVC-00045-AA.

Celik, A. P. 1996. The challenge of sustaining our habitat in the twenty-first century. *Tunneling and Underground Space Technology* 11(4):377–379.

Fang, H. Y. 2000. A feasibility study on taiwan strait tunnel project (a Multi-Purpose project): A regionalization stage approach. Proceedings of the Symposium on Feasibility Study of the Taiwan Strain Tunnel Project, Xiamen, Fujian, pp. 11–44.

Guertin, J. D. 1996. Tunneling and underground space for sustainable development. *Tunneling and Underground Space Technology* 11(1):3–4.

Jorges Roxo, M. C. 2003. Tunnels as a sustainable environmental solution. Pp. 139–144 in (*Re*)*claiming the underground space*, Saveur (ed.). Lisse:Swets & Zeitlinger.

Parker, H. W. 1996. Tunneling, urbanization and sustainable development: The infrastructure connection. *Tunneling and Underground Space Technology* 11(2):133–134.

Sellberg, B. 1996. Environmental benefits: A key to increased underground space use in urban planning. *Tunneling and Underground Space Technology* 11(4):369–371.

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