Analytical Method for the Development of Watershed Plans, Stormwater Programs and Stream Reclamation Projects

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Abstract

While we all acknowledge that the body of knowledge in water resources management is imperfect, a methodological weakness also underlies the relatively poor performance. This paper demonstrates a methodology based on function analysis that uses a six-phase process to improve the value of our efforts.

Despite the best of intentions, talent and energy, many water resource projects are reactive and therefore symptomatic. Developed in response to impending urban growth, a budget crisis or a disaster, the urgency and intensity of the issue *de jour* frequently engenders myopia and accommodation of short-term interests even with experienced professionals. Stormwater programs based on near-term cost benefit ratios often address symptoms and lack serious effort to identify and manage root causes of problems. Commonly efforts that could prevent future degradation by improving systemic stream health languish as lower priorities.

We propose a methodology in which the multidisciplinary team essential to all successful plans identifies the essential project functions and develops alternative ways to achieve those functions. The method includes a disciplined selection process to determine the best solutions for achieving the required functions. These function-based solutions are then combined into workable value alternatives. Here thorny policy, economic, social and technical issues are effectively expressed and integrated. This approach easily accommodates the complexity of water resource issues and provides methods to fully integrate the skills of scientists, engineers, economists, resource managers and public officials. The methodology has been proven worldwide for water resource projects and merits much broader application. The authors will illustrate the application of this methodology in both large and small projects.

Introduction

Many water resource projects are a reaction to a change of conditions either actual or predicted and are therefore symptomatic rather than systemic. The unintended consequences range from poor performance to outright harm to the resource the plan intended to benefit. Too many stream projects are constructed out of context with the watershed and fail to perform as intended.

Discussion

The analytical methods of Value Planning and Value Engineering (SAVE, 1998, 2000) have successfully been applied to water resource projects worldwide. Potential approaches that conventional stormwater management considered off the table are, through this process, demonstrated to be not only possible but often the most efficient, cost effective solutions. This tendency to reveal unconventional but practical solutions is a great benefit of the process. For example, during the Mill Creek Flood Reduction Value Engineering study, the designers stated that they had reviewed retention and detention as a possible solution but rejected these options because the only *open land* was not in locations that would benefit the project. Because there was insufficient open land for detention, the plan was to enlarge the channel to achieve the necessary capacity to convey the flood flows. This enlarged channel required the buyout of 69 businesses, 52 residences, replacement of 10 highway bridges and 9 railroad bridges. One of the tenets of the Value Process is to validate planning and design assumptions. Therefore, the team revisited the concept of retention and detention. Detention was evaluated by placing and sizing it where it would have the greatest flood control benefit within the project reach, regardless of the current land use. This planning condition was not considered because the assumption was that it would be too costly and politically unacceptable to relocate businesses and residences for the purpose of storing flood water. From analysis of the hydraulic model, the team concluded that the majority of the flooding was being caused by a single choke point at the confluence of Mill Creek and a major tributary just upstream of a congested railroad crossing. This is where detention would be of the greatest value. The team concluded that a 900 acre-feet off-line detention basin at this confluence virtually eliminated the need for channel modifications. The detention basin site required the buyout of only 7 businesses. None of the 52 residences, 10 highway bridges, and 9 railroad bridges required relocation. The estimated cost savings was $367.4 million of the original $600 million project. Detention in combination with other interventions proved to be an extremely effective and economical way to achieve flood reduction for this project. It was the analytical discipline of the Value Process that required the team to overcome its resistance to re-evaluating the detention issue.

For larger projects and studies the value process is repeated at discrete stages of the project development, normally the Scoping Meeting, after data collection, reduction and analysis and after the preliminary Action Plan or Design. The Value Process is an intensive session during which the project is analyzed for optimization of value. Value is expressed as the relationship between functions and resources where function is measured by the performance requirements of the stakeholders and resources are measured in materials, labor, price, time, etc. required to accomplish that function. This methodology focuses on improving value by identifying the most resource-efficient way to reliably accomplish a function that meets the performance expectations of the stakeholders. Increasing function or decreasing resources increases value. The best value is achieved by increasing function while decreasing required resources. The method also allows a better understanding of the effect on resources for minor increases in function. This is expressed in Figure 1 below:

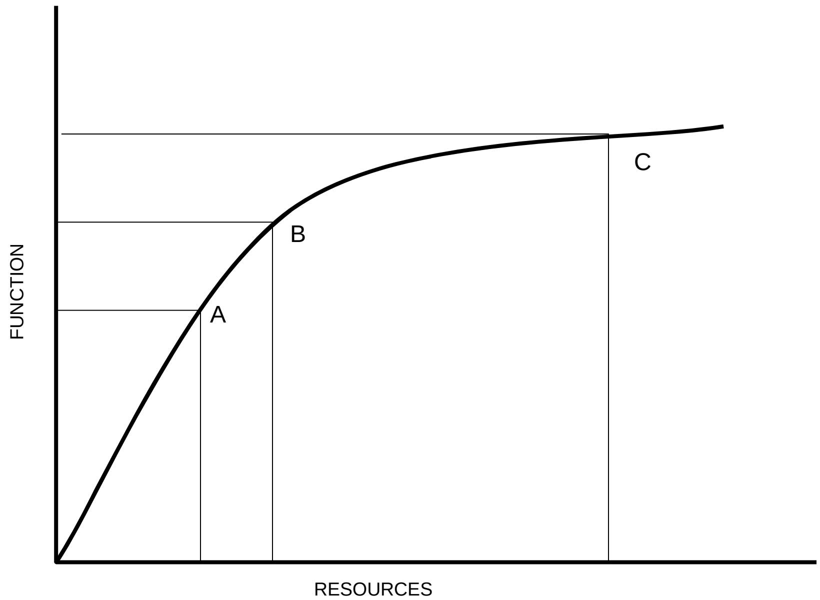

Figure 1. Function-Resources relationship

Expending resources to increase the function from point A to B increases the value. However, expending the additional resources to move from Point B to C decreases the value since the incremental increase in resources is disproportional to the increase in function. This is often not evaluated in conventional projects and is therefore not understood by decision makers.

This approach easily accommodates the complexity of water resource issues and provides methods to fully integrate the skills of scientists, engineers, economists, resource managers and bureaucrats. The Value Process provides an organized approach to identify targets of opportunity for value improvement and develops trust and understanding of the project participants. A typical team is comprised of the professional performing the project, the owner and agency representatives and other stakeholders.

The Value Process is comprised of six phases.

- Information Phase
- Function Analysis Phase
- Creative Phase
- Evaluation Phase
- Development Phase

- Presentation Phase

Information Phase

At each phase of a project, it is important to understand the background of the project from which it was developed. Background includes:

- Reasons for the phase of the project
- Reasons for proposed configuration
- Explanation of features, criteria, and assumptions
- Constraints
- Resources cost

The background provides the team with an overview of the goals, issues, and expectations.

Function Analysis Phase

The Value Team uses function analysis techniques to analyze the project. This process helps the team confirm its understanding of the project objectives and analyzes the functions of key project elements. We are all familiar with projects that are driven by an unstated or understated purpose. This purpose may be perfectly legitimate but social or political tensions often hinder frank discussion. As designers and planners we are seriously hindered by project goals that are unclear or misstated. The Value Team Leader leads the team through an in-depth discussion of the possible functions of each key project element to clearly and precisely identify the purposes of each.

In addition to identifying the essential project functions, this phase of the process is also used for achieving two other goals:

- the unification of the individual Value Team members and stakeholders into a synergistic, cohesive team able to discuss issues frankly, and
- the stimulation of creative ideas prior to beginning the subsequent creative phase.

Function Determination

Defining functional requirements for the project allows the owner to be sure that the project, as conceived, will fulfill needed purposes. The entire project is analyzed to determine what functions are being accomplished. Required functions are retained and other functions become candidates for deletion.

Function analysis is a tool to help the team to think in terms of specific project functions and their costs. It provides a function-based structure for a comprehensive analysis of the project design. This analysis is the catalyst for generating alternative ways these functions could be accomplished.

Function Analysis defines each function of the project with an action verb and definitive noun. The relationships of functions are expressed by the development of a Function Analysis System Technique (FAST) diagram. In this process functions are classified as higher order, primary or secondary. The relationship between functions is determined by asking two questions: How and Why. In a typical FAST diagram a function that answers why is to the left of a function that answers How. As an example of the relationship between functions, three typical functions, “limit flooding”, “increase capacity” and “retain runoff”, are compared. The question “How to limit flooding” is answered by “increase capacity” and “retain runoff”. The question “Why increase capacity or retain runoff” is answered by “limit flooding”. A simple FAST diagram is in Figure 2 presented below:

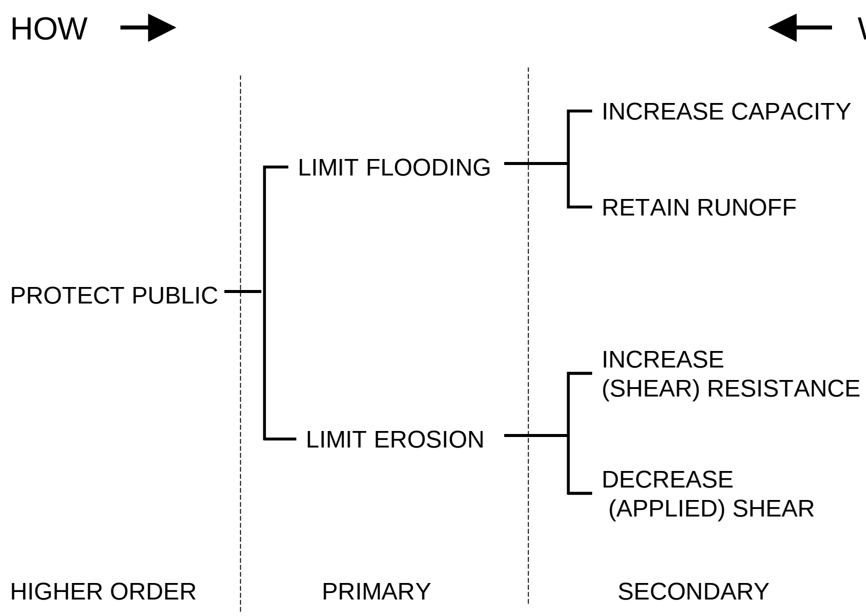

Figure 2. A simple FAST Diagram

Higher order functions are those functions that define the mission of the project and often include public safety or ecological restoration. Altering these functions is generally beyond the scope of the Value Team. Primary functions are those that absolutely must be accomplished in order to achieve the project mission (higher order function). Failure to achieve a primary function results in a failed project. Secondary functions are the methods that the planners or designers have chosen to accomplish the primary functions. Functions become more specific to the solution moving to the right in a FAST diagram. Moving to the left becomes more abstract and defines the project objectives.

Creative Phase

This step in the VE process involves generating ideas using creativity techniques. All ideas are recorded regardless of their feasibility, as evaluation of the ideas is not allowed during the creative phase. The team's effort is directed toward a large quantity of ideas. These ideas are later screened in the Evaluation Phase.

The creative ideas generated by the team are recorded for later review as the project progresses

Evaluation Phase

In this phase of the workshop, the team selects the ideas with the most merit for further development. After an initial vote, the ideas are discussed collectively by the Value Team to reassess whether all those selected by the vote should be developed, and whether any not selected for development should be reconsidered. The criteria used for selection are:

1. the inherent value, benefit and technical appropriateness of the idea

2. the expected magnitude of the potential life cycle cost savings

3. the potential for the acceptance of the idea

Ideas are selected for development as value alternatives based on all three criteria.

Other ideas are selected for development as design suggestions based primarily on the first and third criteria rather than for value improvement. Some design suggestions may save costs, others may increase costs, and the cost impact of some may not be predicted adequately with information and time available to the team. Life cycle cost evaluation is a critical element. By more clearly revealing the complete cost of a suite of actions, resource managers are better able to make the case to budget authorities for a more far reaching, sustainable solution.

Development Phase

During the Development Phase, each selected idea is expanded into a workable alternative. Team members prepare a description of the value alternative comparing it to the original concept, determine life cycle cost and evaluate the advantages and disadvantages of each in the context of meeting the project's primary function. Sketches and rough calculations further illustrate the proposed concept.

Presentation Phase

The last phase of this process is the compilation and documentation of alternatives to help make decisions regarding the acceptance of the value alternatives. As the project progresses this documentation becomes the deliverable of the project such as a watershed master plan, project recommendations or construction documents.

Applications

Strecker Road Emergency Repair

Strecker Road in Wildwood, Missouri parallels Caulks Creek and is threatened by undercutting and slope failures Figure 3. Caulk's Creek is now a flashy, potentially dangerous channel resembling a desert arroyo more than the healthy, beautiful Ozark stream it was a few years ago. Wildwood residents understand that poor land planning caused the destruction of this stream and any management action taken is understandably contentious. Since 1990, many observers have noted changes in the channel morphology of Caulks Creek. Much of Caulks Creek has effectively been cut off from groundwater recharge. Flash-flood hydrology and dramatically increased peak flows gives Caulks Creek the ability to move large bed material and quickly undermine infrastructure. The project reach is bounded by straight, bedrock-controlled reaches upstream and downstream of the meandering section between Clayton Road and Strecker Road crossings.

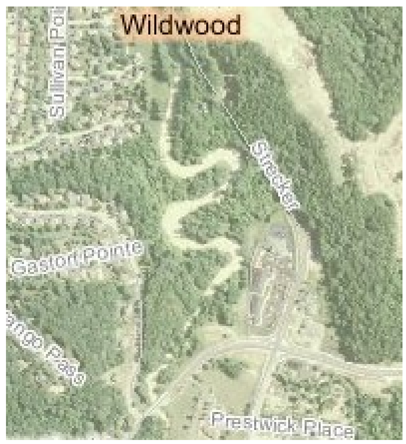

Figure 3. Caulk's Creek at Strecker Road

There had been at least two previous proposals to stabilize the creek bank where it threatened Strecker Road. Several factors including, public skepticism, the lack of funds and a pervasive sense that Caulks Creek is so damaged that it is impossible to manage have played into the inaction on previous proposals. The city is aware that watershed-scale management is necessary; however, fear that one of the city's busiest roads is subject to imminent failure drove the decision to address this problem on its own.

Knowing the history of this site, we integrated the Value Process into the standard design activities that included surveying, geotechnical and fluvial geomorphology investigation followed by a design charrette and final design. The design charrette included the value phases discussed previously. Following the charrette, the design was developed and reviewed by the independent team members. The project is being constructed as this paper is composed.

The main reason for using the value process was to address the contentious nature of any Caulks Creek project. There were a host of competing ideas regarding what Caulks Creek would do next and a larger group of competing and often contradictory ideas of what to do about it. Influential voices advised the city that engineers had caused the problems in Caulks Creek and they could not be trusted to devise a solution. Paralysis ensued. The value process allowed us to unify the individual design charrette members into a synergistic, cohesive team, to stimulate creative ideas and develop acceptance of the proposed solution. The Design Charette Team included the designers of record, Intuition & Logic, independent reviewers from Wright Water Engineering, the city engineer and planner and a consultant to the city who had studied Caulks Creek. The breakthrough for this project came in the Information Phase when all of the stakeholders were compelled to agree upon a single set of data and interpretation of stream process.

After the City stated their goals and the presentation of the data by the various consultants, Function Analysis was used to develop the following FAST diagram, Figure 4.

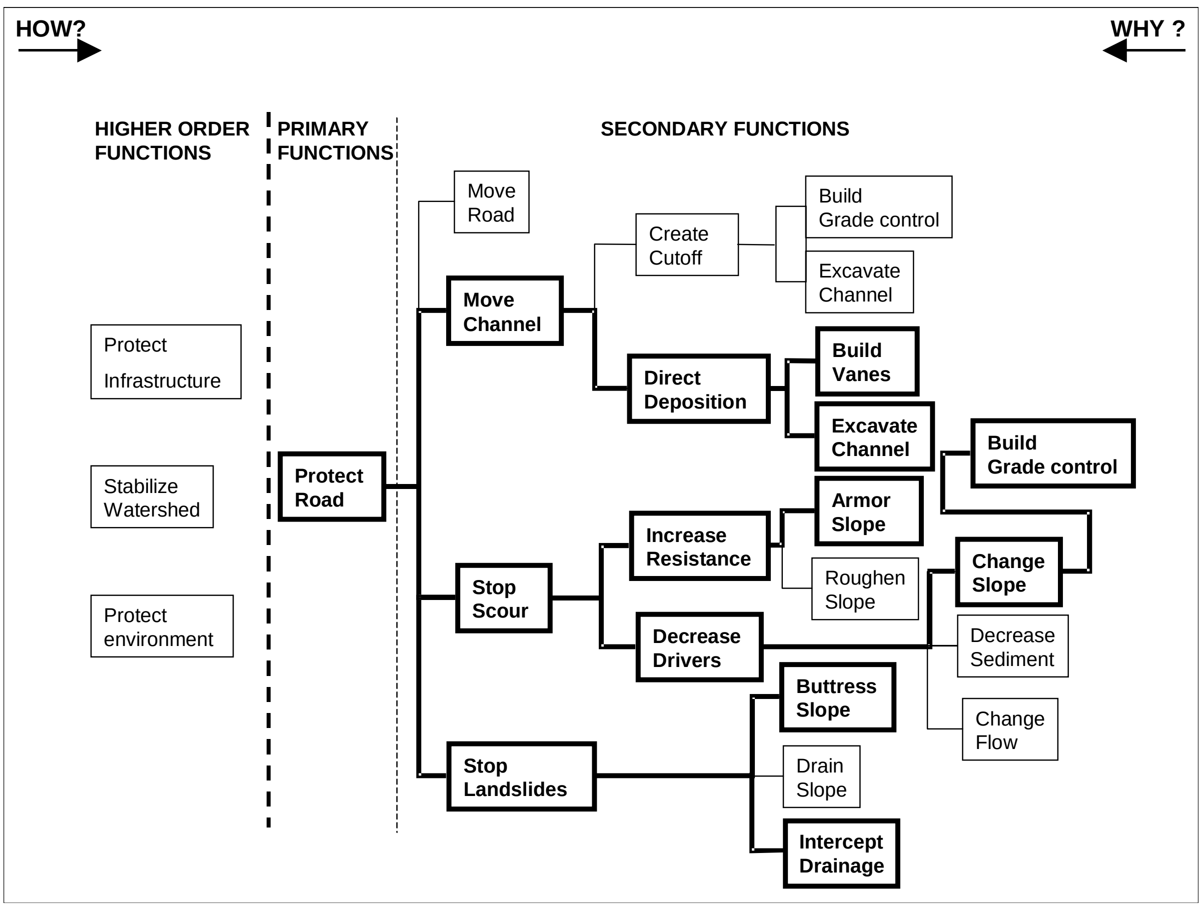

Figure 4. FAST diagram, Strecker Road Protection

After much discussion it was agreed that the primary function of this project is to protect Strecker Road. Part of the discussion during the function analysis concerned the higher order functions. All participants agreed that whatever methods were used to protect

Strecker Road, the interventions must not cause problems elsewhere in the watershed. The bold text, boxes and lines in the FAST diagram are the functions that the team chose to use to protect Strecker Road.

During the creative phase many ideas were presented. These were combined into five possible alternatives for the evaluation phase. These are presented below.

ALTERNATIVE #1: Excavate a cutoff channel from Station 19+00 to Station 32+00
This option assumes that the channel is trending toward a natural cutoff.
Large grade stabilization measures would be necessary to maintain existing bed slope. The straightened channel could effectively impose a braided channel morphology on this reach of Caulks Creek. There is little evidence to predict how the channel will move in the future in response to this intervention. The dominant process for the reach would still be meandering.

ALTERNATIVE #2: Construct a retaining wall at the high bank. This was not accepted because a continuous retaining is an expensive alternative. It would be difficult to permit the plan.

ALTERNATIVE #3: Construct a stepped retaining wall. This was not accepted due to cost and long-term maintenance issues as vegetation grew in and along the stepped wall surface. It would be difficult to permit the plan.

ALTERNATIVE #4: Regrade slope to 3 horizontal: 1 vertical or flatter, install erosion control fabric and plants along with a regraded bank toe to a steeper 2 horizontal:1 vertical and armor. This was not acceptable due to the armor requirements of the tall 2 horizontal: 1 vertical or steeper slope

ALTERNATIVE #5: Regrade the slope to a 3 horizontal:1 vertical or flatter and armor the toe with a vegetated composite revetment and turning vanes. Armor the bends immediately upstream and downstream of the high bank using turning vanes.
This alternative addresses the energy of the system, removes stress from the bank toe by deflecting high shear with the rock vanes, increases resistance to shear by armoring the bank, and prevents landslides by buttressing the slope and grade controlling the reach. This is the selected alternative.

Water Quality Wetland, Tianjin China

China's frenetic pace of construction and environmental imperatives are beginning to converge. One of China's largest developers Vanke, is building a new city near Tianjin that incorporates new water quality regulations. Built on the shores of Dongli Lake, the new development must incorporate wetland treatment of its stormwater. The idea of integrating environmental protection into quality of life and aesthetic elements of residential design is not yet common. While the design team considered the requirements important, they were also a burden with the potential to detract from the market appeal and profitability of the design. The value process revealed that beautiful, high performance wetlands could be integral to the success and profitability of the project.

The breakthrough came in the function analysis. The designers articulated what they wanted to accomplish, a profitable, socially responsible development. Through the construction of the FAST diagram depicted in Figure 5 below, it became apparent that creating beauty, a showcase rich with educational and recreational opportunities was key to meeting the primary objectives. This utterly changed the conversations about the wetlands. No longer were they a regulatory requirement; they were central to the success of the project.

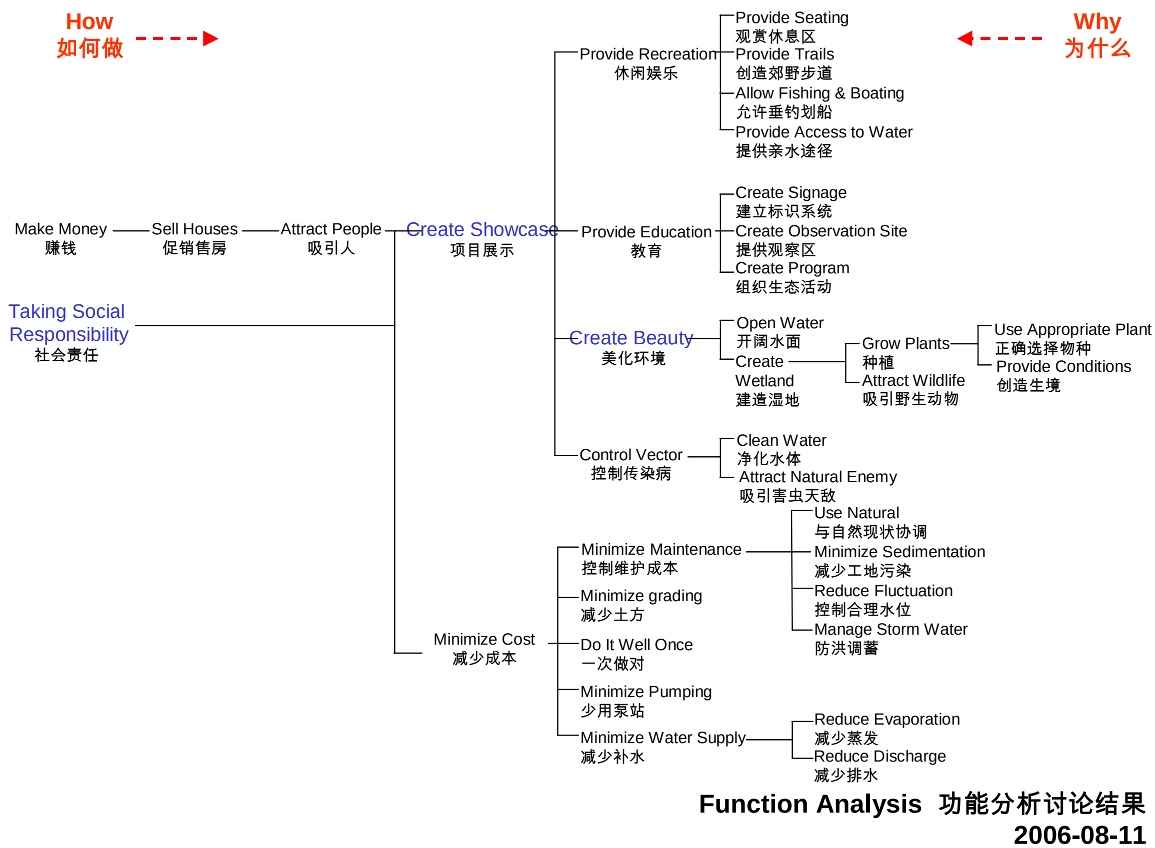

Figure 5. FAST diagram, Water quality wetland

The decision to include both terrestrial and wildlife habitat in a development for human habitation made sense only in the context of this value process. By graphically depicting the relationship between human and wetland health as well as that between architectural and natural beauty, the project changed at a fundamental level and has resulted in a far more sustainable development.

References

1. SAVE International (1998), Value Methodology Standard, (http://www.value-eng.org/about_vmstandard.php)
2. SAVE International website (2007), (http://www.value-eng.org)