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Context Sensitive Solutions: The Application of QFD for Developing Public Transportation Projects in the U.S.

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Abstract

For many years, the selection of transportation routes, design of roadway features, etc. were based mostly on engineering considerations. According to the Maryland State Highway Administration, "Context sensitive design asks questions first about the need and purpose of the transportation project, and then equally addresses safety, mobility, and the preservation of scenic, aesthetic, historic, environmental, and other community values. Context sensitive design involves a collaborative, interdisciplinary approach in which citizens are part of the design team." QFD has developed since the 1960s a powerful tool set for new product development that enables engineers to listen to the Voice of the Customer and translate the most important needs into design requirements and then assure their quality in the resulting goods and services. This paper will show how QFD tools can be adapted for Context Sensitive Solutions and Design in road building and other large projects.

Key words

Context Sensitive Solutions (CSS), Context-Sensitive Design (CSD), QFD, Voice of the Customers (VoC), QFD for transportation and civil engineering projects

Introduction

Over the past 40 years, the Federal government has promoted improved decision making on its actions beginning with the broadest, most important environmental law, the National Environmental Policy Act of 1969 (commonly termed NEPA). Since 1969 many laws, presidential orders, and state and Federal policies have been enacted to supplement and enhance NEPA.

Both state and Federal government transportation agencies have sought to better implement NEPA and to promote transportation projects in harmony with communities and the natural environment. The most important of these from a national standpoint are the development of Context Sensitive Design and its overarching successor Context Sensitive Solutions (CSS). These initiatives are relatively new and procedures to apply them are still emerging. Many state transportation agencies have adopted the principles of CSS in their project development processes. This paper will introduce these laws/practices, review the transportation project development process and provide insight on how Quality Function Deployment (QFD) can be applied to yield improved transportation decision making.

NEPA

NEPA was passed by Congress to regulate the environmental/community impacts of Federal actions (including federally funded transportation projects). It required Federal agencies to look beyond the narrow focus of benefits of a proposed action and determine the potential impacts of that action on society, economics and the environment. While NEPA does not preclude environmental/community impacts arising from Federal actions, it was clearly intended to prompt Federal agencies to take potential impacts into consideration and employ avoidance, minimization and/or mitigation where possible (1).

To ensure compliance with this law, Congress mandated that each Federal agency establish an environmental review process that included multi-disciplinary input, environmental reviews, and a balanced decision making process. Each Federal agency has its own NEPA process. For federally funded transportation projects, state highway agencies (SHAs) have to address the Federal Highway Administration NEPA process. All project-related investigations must have approval of the Federal Highway Administration. Those approvals are based upon NEPA review documents (Environmental Assessments, Environmental Impact Statements, FONSIs, and Categorical Exclusions) submitted to the Federal Highway Administration by state transportation agencies.

NEPA had far-ranging effects on federally funded transportation projects. State highway agencies created environmental divisions and rigorously prepared the federally required documentation. The project stakeholders/ public were made more aware of the proposed actions. There was better compliance with environmental regulations of resource agencies.

Despite becoming more environmentally compliant, SHAs encountered growing opposition to transportation projects by the public, interest groups and other stakeholders. Those parties began using litigating to delay or halt projects. Notable examples include US 27 & 68 (Paris Pike) between Lexington and Paris, KY and I 40 at Overton Park in Memphis, TN. The former project was blocked for 26 years (despite several traffic fatalities) and the latter remains uncompleted some 36 years after it was originally halted. In part, this opposition was due to the greater environmental consciousness of the public, concern for adjacent impacts (“not in my back yard” or NIMBY) and past heavy handed dealings of transportation agencies in implementing projects (e.g. I 93 Central Artery through downtown Boston).

Figure 1. Public Demonstrating Concern about a Proposed Highway at a Pre-Scoping Meeting.

Some projects such as the well-known I 40 at Glenwood Canyon in Colorado and US 27 & 68 Paris Pike in Kentucky gained national and international acclaim for balancing transportation, environmental and public interests. Typically, those projects involved state transportation agencies going the "extra mile" in planning and design to ensure that stakeholder/public concerns were addressed. The governor of Maryland issued an official order for state agencies to address stakeholder/public concerns about their actions leading to the Maryland DOT's "Thinking Beyond the Pavement" initiative. Those efforts had a common thread, but there was no formal nationally recognized procedure that instituted or promoted these actions.

Context-Sensitive Design/Context Sensitive Solutions

In the 1990s, Federal Highway Administration (FHWA) recognized that highway planning and design practices could be altered to accommodate public concerns. Some SHAs had developed/adopted/employed those practices, at least on controversial projects with great success. However, the range of practices and their application varied greatly among the SHAs. In an effort to promote a wider, more consistent use of those practices, the FHWA prepared a guidance document *Flexibility in Highway Design* in 1997.

In 1998, a key workshop was held in Baltimore, MD sponsored by the Maryland DOT, the FHWA and AASHTO. Its objective was to assemble all of the beneficial practices employed by transportation agencies into a coherent practice that would make transportation projects fit better into communities and the environment. Transportation agencies also sought to address the sources of contention that had plagued project development early in the NEPA Era.

The meeting participants developed a set of principles with supporting methods and practices that formed the basis for a coherent approach to making transportation projects fit into communities and the natural environment. That approach was termed "Context Sensitive Design" to emphasize the additional efforts needed in stakeholder/public involvement and flexibility in design to identify key issues and provide projects that were sensitive the environment in which they were constructed. Several related key documents include:

1) FHWA Manual-*Guidelines for Flexible Design*
2) AASHTO Manual-*Public Involvement Procedures*
3) AASHTO *A Policy on Geometric Design of Highways and Streets ("the Green Book")*
4) AASHTO *Roadside Design Guide*.

The Conference attendees defined *Design Excellence* as designing projects that balanced transportation objectives with those of communities and the environment. It embodied the use of transportation design to implement the decision-making process originally mandated in NEPA. The attendees termed this new methodology *Context Sensitive Design*. The then-current focus of that initiative was related to project development actions undertaken in the Planning and Design stages to provide projects that were acceptable to the public and other stakeholders based upon 1) public/stakeholder involvement in decision-making (or some elements thereof) and 2) flexible design that balanced environmental and economic issues with transportation requirements.

The term "Context Sensitive" pertains to the circumstances surrounding a transportation project. The "Context" of a project depends upon its location and potential to impact communities and the environment. Each location is different with varying community values and environment. As a consequence, in separate locations the same action can have different impacts. Recognition of the actions/factors needed to address those impacts and the willingness to address them pertain to "Sensitive". To be context sensitive, transportation officials must possess situational awareness of both the proposed project (its purpose & need) and of the human and natural environment in which it is to be placed.

In the early 2000s, the term *Context Sensitive Design* began to be supplanted by *Context Sensitive Solutions* (CSS). The reasoning behind this was that the framers of *Context Sensitive Design* were focused on the early phases of project development (i.e. planning and design) and that other context sensitive activities occurred within the project development process that were vital and needed to be recognized. *Context Sensitive Solutions* was applied to address that perceived shortcoming. The current FHWA definition of CSS is: *Context Sensitive Solutions* — is a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting preserves scenic, aesthetic, historic and environmental resources while maintaining safety and mobility. CSS considers the total context within which a transportation improvement project will exist.

The elements of CSS can be divined from a list of guiding principles that govern its application. In 2006, the Kentucky Transportation Center at the University of Kentucky identified 15 guiding principles:

1. Use interdisciplinary teams
2. Involve all stakeholders
3. Seek broad-based public involvement
4. Use full range of communication methods
5. Achieve consensus on purpose and need
6. Utilize full range of design choices
7. Consider all alternatives and modes
8. Maintain environmental harmony
9. Consider community and social issues
10. Provide aesthetic treatments & enhancements
11. Provide a safe facility for users & community
12. Document project decisions
13. Track and meet all project commitments
14. Create a lasting value for the community
15. Use all resources effectively (time and budget)

Transportation Project Development Process

In the 1960s, the typical highway project development process used by SHAs on Federally funded projects appeared as shown in the following figure:

Figure 2. 1960s FHWA/SHA Project Development Process.

This represents the traditional 5-step process that was initiated for projects placed in the SHA multi-year capital improvement program. It began with planning and then proceeded through location (also termed preliminary design), design (or final design), right of way and construction. Typically, SHAs were functionally organized along those process steps with separate divisions addressing each step (with the exception of preliminary and final design steps that were typically assigned to the SHA design division.) The processes were conducted in a sequential fashion with minimal interaction between divisions. Project actions were completed in each respective division (that operated as a "functional silo") and their products were "thrown over the wall" to be further developed by the next division. At that time, there was little

SHA focus on environmental issues, except on a reactive basis. Opportunities for public involvement were typically limited to two meetings, one during location, and the other during final design.

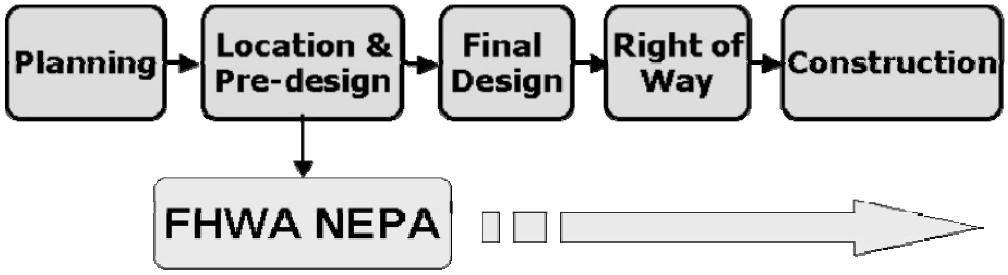

Figure 3. FHWA/SHA Project Development Process Incorporating NEPA.

In the years following the enactment of NEPA, the FHWA worked to better define its requirements and to ensure that the intent of NEPA was implemented. SHA environmental divisions addressed NEPA as an adjunct process that began in location and ended in right of way (Figure 5). The FHWA issued a series of directives and guidance documents that more completely defined necessary NEPA actions and encouraged SHA involvement with the public and other stakeholders. It stressed equal consideration be given to both community and environmental issues and allowed the use of Federal funds as enhancements "to make projects fit better into communities and the natural environment" (2). As SHAs found themselves increasingly unable to proceed with needed projects, they became more receptive to involve the public and develop acceptable projects.

To properly implement CSS for a transportation project, SHA officials must consider the area it will traverse, the people who will live about it, and those who will use it. From a transportation perspective, they must address the project's purpose & need, linkage, access, safety, and mobility. Beyond that, they must also address the preservation of scenic, esthetic, historic, environmental, and other community values. This requires that highway planners and designers better evaluate those criteria as part of determining the purpose, location, and design of a highway. To do that effectively, the public and other stakeholders must be engaged to identify community desires, needs and concerns (i.e., public/stakeholder involvement).

There must also be willingness by highway planners and designers to seek adjustments to the roadway capacity and other highway design factors to provide a facility that not only addresses transportation needs, but also conforms to the community and the environment it traverses. Under CSS, planners and designers do not need to provide theoretically "optimum" transportation facilities (e.g. divided four-lane roads with paved shoulders). The "fit" of a road in its environs becomes as important as the road itself. Flexibility is encouraged in applying national road-building guidelines. The primary guide for highway design is the American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets ("the Green Book")* and the AASHTO *Roadside Design Guide*. The *"Green Book"* presents ranges of roadway design values and suggests that the higher values be used where social, economic, and environmental impacts are not critical. This allows willing highway planners and designers to tailor roads to address all the transportation, community and environmental requirements.

To fully address CSS, SHAs must revise their approach to project development and work in multi-disciplinary teams applying needed expertise (e.g. landscape architecture, archeology, historic preservation, etc.) as necessary. While the bulk of the public/stakeholder involvement is required during planning and design, it needs to be continued through construction and into maintenance & operations. A new

project development model is emerging. The SHA organization framework remains supplemented by constant public/stakeholder involvement and the use of SHA teams from project inception through construction. This structure addresses the precepts of CSS and the guiding principles necessary for its proper application.

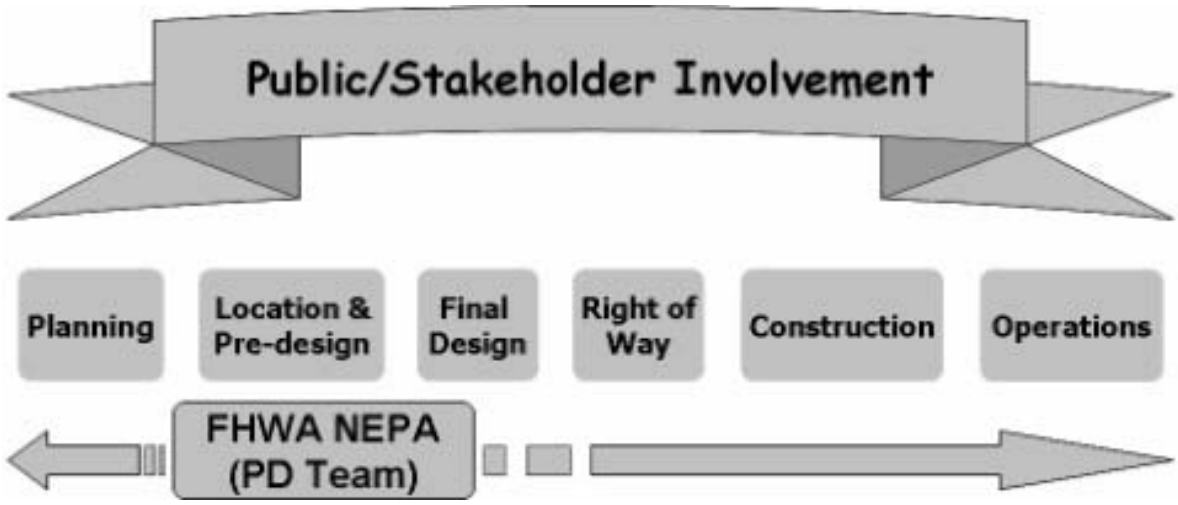

Figure 4. Idealized Project Development Model.

Quality Function Deployment and Context Sensitive Solutions

CSS involves SHAs meeting with the public/stakeholders to obtain their input about the roadway environs and roadway alternatives. The venues for obtaining public/stakeholder input include public meetings, charrettes, surveys and permitting documents provided by stakeholder resource agencies. Techniques for facilitating input are being explored. Some Kentucky projects have used experimental methods of structured public involvement to solicit esthetic design feature preferences. The use of flexible design and multi-disciplinary teams enables SHAs to provide projects that are in harmony to communities and the environment (i.e., locals and stakeholders). Some SHAs have been concerned about project development costs using CSS and have restricted its employment to large projects which pose the potential for controversy and litigation. Other SHAs are employing it on most/all projects. It remains an emerging practice and not all SHAs have adopted it despite encouragement from the FHWA.

In 1999, the Kentucky Transportation Center (KTC) participated in an FHWA initiative by developing CSS training for SHA personnel involved with project development. KTC developed a course that has been presented to 19 SHAs and about 5,000 people nationwide. KTC researchers have also actively participated in state and national research studies related to CSS. Over recent years, they began to take a different view of CSS than most of its users/proponents/ practitioners. In their view, CSS should be considered a business practice that SHAs adopted to facilitate programming and development of highway projects. They began investigating other business practices including continuous improvement methods, value analyses, structured innovation and lean manufacturing to determine their application to CSS and improved project development.

During those investigations, they identified Quality Function Deployment (QFD) as a business tool with remarkable similarities to the intent of CSS. More importantly, they determined that QFD possessed many structured analytical approaches that CSS lacked. It appeared that those approaches could be used to identify public/stakeholder desires and/or concerns that were difficult to characterize in a quantifiable manner or to balance those desires and/or concerns against conflicting ones held by other stakeholders. Those situations are especially problematic for SHA project development officials. KTC researchers eventually contacted the QFD Institute and began a dialogue that lead to the salient point of this paper-the application of QFD practices to CSS transportation projects.

Fundamentals of QFD

Traditional approaches to assuring quality often focus on solving problems within the work process, whether it is manufacturing, service, software, or road building. However, consistency and an absence of problems are often insufficient to create lasting value for the customer, especially when customers are more demanding and have choices. While in a competitive marketplace, this choice among alternative products or suppliers can be called competition, in government funded and controlled projects, constituents make choices when they elect officials. With traditional quality approaches, the best you can get is nothing wrong – but is this good enough? In addition to eliminating negative quality, we must also maximize positive quality end-to-end throughout the organization. This creates value which leads to customer satisfaction.

Quality Function Deployment is the only comprehensive quality system aimed specifically at satisfying the customer. It concentrates on maximizing customer satisfaction (positive quality) by seeking out both spoken and unspoken needs, translating these into actions and designs, and communicating these throughout the organization end-to-end (Figure 5). Further, QFD allows customers to prioritize their requirements, benchmark us against our competitors, and then direct us to optimize those aspects of our product, process, and organization that will bring the greatest competitive advantage. Most projects cannot afford to apply limited financial, time and human resources to low priority issues.

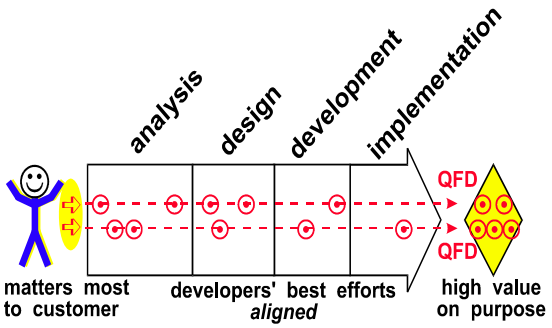

Figure 5. QFD delivers value end-to-end. (3)

With budgets, time, and personnel always limited, QFD helps organization get their biggest bang for the buck by enabling a data driven approach to allocating constrained resources. When priorities are properly derived and proportioned based on sound mathematical principles, they can actually be used to calculate money, man-hours, and staff.

Voice of the Customer

In its earliest uses in the 1960s, QFD concerned itself primarily with end-to-end alignment of requirements throughout the organization.(4) As internal business processes improved, QFD began to look upstream at where the requirements came from and where improvements could be made. As a result, QFD invited the marketing and sales efforts, traditionally the most customer oriented, to join. In the ensuing years, QFD has devised numerous tools to bring this fuzzy front end into clearer focus. The problem is exacerbated because customers are not always able to articulate what outcome they want, especially with regards to something new. Instead, they try to explain what features the product itself should have, in the belief that if they tell designers how to do their job, their outcomes will be met. Successful product devel-

opers know that just doing what the customer asks is no longer sufficient; they must analyze the stated "voice" to understand the underlying outcomes and needs. Modern QFD has several new tools to aid this analysis. These tools are engineer-friendly in that they help parse complex customer problems into discreet elements that can be analyzed more easily.

Cause-and-effect

QFD, as a Total Quality Management approach, builds on the cause-and-effect relationships of customer needs (effect) and design issues (cause). Figure 6 illustrates an example from Bridgestone Tire who published their first use on QFD in 1966 for the design of a tire. Using the fishbone diagram to illustrate the cause and effect relationships, they identified the various design, processing, and handling requirements necessary to assure a "smooth ride."

This concept is especially useful in trying to understand true customer needs that underlie customer verbatims. In other words, if a customer asked for his tires to be trued (a technical process), we could use this fishbone to understand that his real need was for a smooth ride, that tire truing was one way to achieve it, and that there could be others at the design, process, and material handling stage that could be used in combination to make the ride smoother. Cause-and-effect also governs the relationships among the product features, such as the relationship between tire characteristics and molding characteristics, the relationship between molding characteristics and material properties, and so forth.

By parsing complex problems into groupings like customer needs, design characteristics, manufacturing and process characteristics, material properties, etc. and showing their cause-and-effect relationships, technical people can analyze the nature of the design intent and how to achieve it.

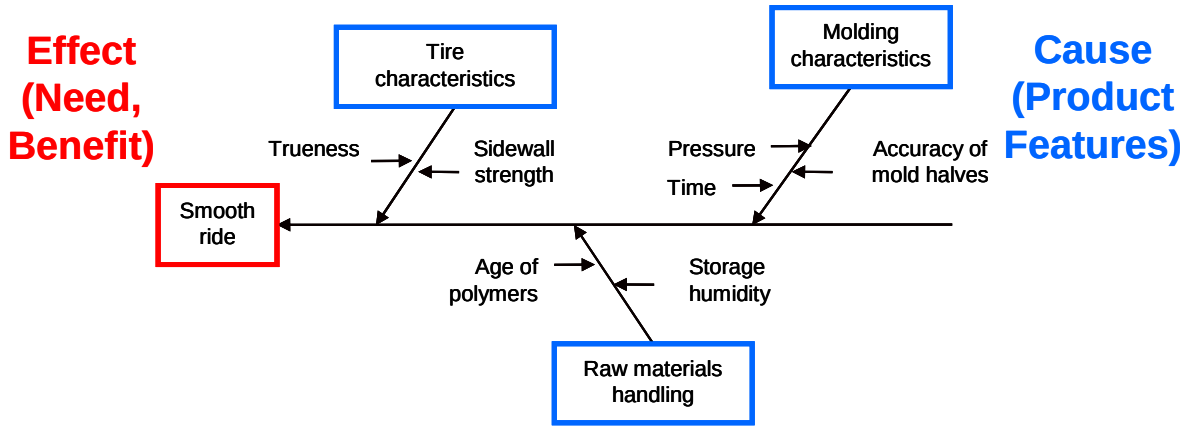

Figure 6. Fishbone diagram shows cause-and-effect relationships between customer need and design features (example from Bridgestone Tire) (5).

Prioritization

Prioritization in multi-criteria decision making was advanced by the research of Dr. Thomas Saaty in the 1970s at the U.S. Department of Defense and later at the Wharton School of Business at the University of Pennsylvania. Saaty found that decision makers facing a multitude of elements in a complex situation innately organized them into groups sharing common properties, and then organized those groups into higher level groups, and so on until a top element or goal was identified. This is called a hierarchy and when making informed judgments to estimate importance, preference, or likelihood, both tangible and intangible factors must be included and measured. The Analytic Hierarchy Process (AHP) was created to

manage this process in a manner that captures the intuitive understanding of the participants and also yield mathematically stable results expressed in a numerical, ratio scale. (6,7) A numerical, ratio scale is preferred for the following reasons.

1) Numerical priorities can be applied to later analyses to derive downstream priorities.
2) Ratio scale priorities show precisely how much more important one issue is than another. Ordinal scales only indicate rank order, but not the degree of importance.
3) Numerical scales can be tested for judgment inconsistency, sensitivity, and other useful properties.

A problem lies in how to get these numerical ratio scale priorities. It seems the human brain can make more accurate comparisons by judging two items at a time, much the way an optometrist tests for prescription lenses – "which is better, A or B?" This pairwise comparison is used to generate the priorities for all the items.

In QFD, we use AHP with customers as a way to understand what outcomes or needs are most important. This method uses a force choice pairwise comparison of the needs and yields precise, mathematically sound ratio scale priorities of the needs. AHP is psychologically friendly and with its hierarchical structure, can be faster and less fatiguing to customers than trying to rate or rank a list of items. AHP can be utilized to prioritize just about anything, and is helpful in other phases of the QFD process, as well.

Application of QFD Principles to Context Sensitive Solutions

There are parallels between the elements of product and transportation design and solutions, as indicated in Table 1. Paramount is delivering solutions to stakeholders that give the biggest benefit for the effort made. Transportation and other civil projects can have more complexity if one product (a road) must serve all constituents, compared to a manufacturing company that can produce a varied product line targeting specific segments. Two QFD models will be discussed. **Model I** is when the voice of the stakeholders is gathered prior to initial planning and is integrated into the formulation of alternative design concepts. This requires starting at the earliest phases of the project, perhaps even before projects are selected, and is recommended for advanced applications. **Model II** is when design concepts have been formed by the planning team and stakeholder input is required to select the best alternative. This requires the least change to current practice and is recommended for first QFD application.

Table 1. Parallels between manufacturing and transportation.

	Manufacturing	Transportation
Team	Planning, Project Management, Marketing, Sales, Engineering, Manufacturing, Production, Quality, Service	Project Manager, Planner, Traffic Engineer, Design Engineer, Environmental Coordinator, Landscape Architect, General Contractor, Trades, Maintenance
Stakeholders	Shareholders, Management, Customers within Market Segments, Labor, Regulators	Local government, Resource Agencies, Users (Residents, Industry, Emergency, Community Associations), Historical Preservation Agencies, Environmental Groups (Federal, State, NGOs), Other Special Interest Groups
Processes	Research, Design, Procure, Build, Distribute, Sell, Service	Planning, Location & Pre-design, Final Design, Right of Way, Construction, Operations

QFD Model I for Stakeholder Input Prior to Initial Planning

The full power of QFD is best realized when it is used from the start of the initial project planning phase. Using the reconstruction of Kentucky Route 234 (Cemetery Road) into the city of Bowling Green, the various QFD tools will be demonstrated. The following flow chart (Figure 7) shows the overall process and is followed by specific examples of the steps.

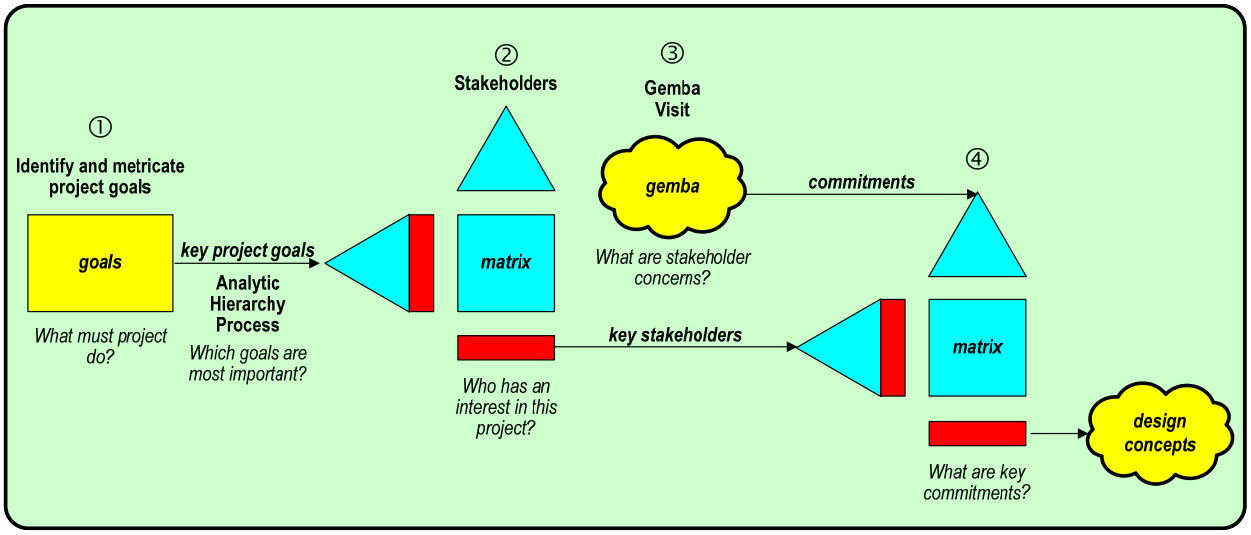

Figure 7. Model I QFD flow chart.

Step 0. Identify Planning Team Membership

Since early decision making relieves rework and problems that can occur later, it is important that the appropriate team members be identified and their roles and responsibilities clarified. The nature of the project will determine who the team members are, but they will usually include those shown in Table 2.

Table 2. QFD Team roles and responsibilities.

Personnel	Role
project manager	lead on road reconstruction
planner	focus on community impact
traffic engineer	determine impact on wider transportation system
environmental coordinator	focus on environmental impact

Step 1. Identify and metricate project goals.

A project is typically started with certain goals, objectives, and outcomes that it must achieve. It is important to identify what these are, how they are measured and by whom, by when they must be achieved, and which ones are most critical. This assures that even when team members interpret the goals according to their role or function, these differences can be discussed in terms of where conditions are today, where they need to be in order for the project to be judged successful, which are most critical, etc. Table 3 shows the goals for the KY 234 project and related details.

Table 3. Project goals.

Goal Statement (inc. current/target)	How measured?	By when?	Who judges success?	Means to achieve it (optional)
Improve access to Bowling Green Central Business District	# cars/hour		Bowling Green CBD Authority	4-lane facility
Relieve traffic congestion	time from I-65 to Main Street		Community	4-lane facility
Improve safety on Cemetery Road	# injury			

According to the project, some goals may be more critical to meet than others. In many cases, these can be easily identified using a verbal, ordinal scale such as "must haves," "nice to haves," etc. However, if the team has difficulty prioritizing the goals, it may be useful to employ more rigorous decision making methods, such as AHP. Table 4 shows the AHP prioritization of the project goals by the planning team, with an acceptable level of judgment inconsistency.

Table 4. Project goals prioritized with AHP.

KEY PROJECT GOALS	Downtown Access	Traffic Congestion	Safety	ratio scale
Downtown Access	1	1/3	1/5	0.106
Traffic Congestion	3	1	1/3	0.260
Safety	5	3	1	0.633
				1.000
			Inconsistency ratio:	**0.03**

Step 2. Identify and prioritize stakeholders.

There are many stakeholders in a large civil project, and it is essential that they are included in the early decisions. Stakeholders whose voices are heard can become champions for the project while those who were overlooked may later raise objections requiring a reconsideration of previous decisions, leading to delay and waste. Table 5 lists the stakeholders and what context sensitive factors concern them. Table 6 uses a QFD matrix to translate project goal priorities into stakeholder priorities (key project goal weights are multiplied by a correlation value; the product is then summed for each stakeholder). While government officials may be concerned it is politically incorrect to weight stakeholders and their voices differently, the stakeholders themselves may find this logical and sensible if the process is transparent.

Table 5. Stakeholders, context sensitive factors.

Who has a stake in the outcome?	Context Sensitive Factors
KYTC Officials - District 3, Central Office, Resident Engrs Office	
Local gov't - City of Bowling Green, Warren County Judge-Executive's Office	
Resource agencies/MPOs - KY Herritage Council, City-County Planning Commission, Greenways Commission, Operation P.R.I.D.E.	
Special Interest Groups - Citizens for Improving Cemetery Rd	
Individuals - Adjacent landowners and businesses (primary stakeholder)	Impact to residents along reconstructed roadway
Others in community - Neighborhood Associations, Western KY University, Warren County 4H Extension Board, Bowling Green Tree Board	Disruption during construction of Interchange of I-65 and KY 234. Utility
SHPO (State Historical Properties Office)	Historic properties

Table 6. Key project goal priorities are translated into stakeholder priorities using a QFD matrix.

Stakeholders / Key Project Goals	1st level	Government				Agencies					Communitiy						
	2nd level	KYTC Officials		Local Gov't		Resource Agencies/MPOs				Quasi-Agencies	SIGs	Individuals		Others			
	3rd level	Central Office	Resident Engineers Office	City of Bowling Green	Warrant County Judge-Executives Office	KY Heritage Council	City-County Planning Commission	Greenways Commission	Operation P.R.I.D.E.	SHPO (State Historic Preservation Office)	Citizens for Improving Cemetery Rd	Adjacent Landowners	Businesses	Neighborhood Associations	Western KY University	Warren County 4H Extension Board	Bowling Green Tree Board
	KPG wt.																
Downtown Access	0.106	-	-	0.52	0.13	0.07	0.27	0.07	0.07	0.13	0.07	0.07	1.00	0.13	0.13	0.07	0.07
Traffic Congestion	0.260	0.07	0.27	0.52	0.13	-	1.00	0.07	0.13	-	1.00	1.00	1.00	1.00	0.13	0.07	-
Safety	0.633	0.13	1.00	1.00	0.27	-	0.27	0.07	0.27	-	1.00	0.52	0.27	1.00	0.27	-	-
Absolute Weight		0.103	0.703	0.823	0.219	0.007	0.458	0.069	0.212	0.014	0.901	0.596	0.536	0.908	0.219	0.025	0.007
Stakeholder Weights		**0.018**	**0.121**	**0.142**	**0.038**	**0.001**	**0.079**	**0.012**	**0.036**	**0.002**	**0.155**	**0.103**	**0.092**	**0.157**	**0.038**	**0.004**	**0.001**
Rank Order (Lowest is most critical)		11	4	3	8	15	7	12	10	14	2	5	6	1	8	13	15

Step 3. Go to gemba.

One of the unique activities in QFD is to go to the *gemba*, a Japanese term equivalent to the scene of the crime in a detective show. Literally, it means where the truth can be learned. In addition to interviews, community gatherings, and focus groups, it includes visiting customers at the site in question to see how they live and work, what their goals and ambitions are, how they live the "jobs" of their life, and how they measure success in their own terms. Input from the *gemba* visits can include observations of behavior, spoken verbatims, documents including photographs, videos, etc. When these inputs are complex, it is sometimes useful to reduce and clarify them into single issue statements. We can also ask customers how they measure their success or satisfaction with these issues. Often their measurements are far less technical than we imagine, but they form the basis of whether the customer will feel satisfied. Table 7 is an example of a Gemba Visit table where verbatims are clarified and measurements derived. Clarified items can be translated into commitments, as shown into in the Customer Voice table in Table 8.

Table 7. Gemba Visit table clarifying customer verbatims and how they measure satisfaction.

Interviewee: John Doe Contact info: jdoe@shpo.org			Interviewer(s) Ted Hopwood Date and Tim 30-Sep-03 Place: Historic Office - Bowling Green		
Interviewee Characteristics (*memorable):					
Environment Discussion of sub-division owner feedback from community meeting.					
Process Step	Observations	Verbatims	Documents	Notes	Clarified Items *(with measures)*
		Berms are 2'			Adequate sound barriers *(reduce road noise so it does not disturb sleep).* Adequate visual separation from road *(cannot see into adjacent homes)*
		Old pine trees will be relocated			"Country" view from lawn and windows maintained *(degree of "surrounded by woods" unchanged)* No unwanted views of activities on Lover's Lane *(degree of "surrounded by woods" unchanged)*
		Sub-division entrances will be wiped out			Ease of entry into sub-division *(can identify where to turn in time)* Easy to identify sub-division *(sub-division name visible in time to turn)* Exclusivity of sub-division maintained *(design*

Table 8. Customer Voice table translates clarified items into commitments.

clarified items	promises/ commitments
Adequate sound barriers (reduce road noise so it does not disturb sleep). Adequate visual separation from road (cannot see into adjacent homes)	Berms and landscaping. Bridge aesthetics. Interchange landscaping. Multipurpose path.
"Country" view from lawn and windows maintained (degree of "surrounded by woods" unchanged) No unwanted views of activities on Lover's Lane (degree of "surrounded by woods" unchanged)	Berms and landscaping. Bridge aesthetics. Interchange landscaping.
Ease of entry into sub-division (can identify where to turn in time) Easy to identify sub-division (sub-division name visible in time to turn) Exclusivity of sub-division maintained (design consistent with home architectures)	Access.
No outages during construction (electricity, phone, water, gas uninterrupted) No future utility failures due to digging, new plantings, etc. (electricity,	Utility work.
No health hazards resulting from construction dust, debris, flowers, weeds, etc. (no new health care issues)	Median landscaping. Interchange landscaping. Develop park.

Step 4. Prioritize Commitments.

While projects try to deliver all commitments to all stakeholders, it is often impossible to fulfill all wishes within the time and budget constraints. The QFD matrices can be used to translate stakeholder priorities into commitment priorities as shown in Table 9. High priority commitments should be designed to accommodate the clarified items in Table 8 in order to assure customer satisfaction. The information derived in the above QFD steps can then be used to fine tune the ongoing context sensitive design concepts.

QFD Model II for Stakeholder Input for Design Concept Selection

First time users of QFD as well as those who begin QFD in the middle of a project may want to integrate its methods into their existing process to reduce resistance to change. In Model II, the concepts are already developed by the project team and they want community input in order to create the best plan. First, stakeholders would be identified and prioritized as in Step 2 above. Then the design concepts would be prioritized in a matrix with prioritized stakeholders as in Step 4 above. Advanced techniques such as budget allocation further require mathematically sound methods such as AHP for prioritization and proportional distribution of matrix relationships.

Conclusions

QFD offers many potential benefits to SHAs in applying CSS to transportation project development. It should improve the effectiveness of the CSS practice and enhance SHA efficiency. The first step in applying QFD to transportation projects is to inform the transportation sector about QFD and how it can be used to facilitate project development. Thereafter, QFD practitioners must pursue opportunities to apply it on CSS projects. The QFD Institute and KTC will pursue educating the transportation sector through technical papers directed at the transportation audience and training to educate SHA officials employing CSS. Opportunities will arise for QFD practitioners as the transportation sector is large and many multi-

million dollar transportation projects are initiated yearly. Beyond this lie the potential to apply QFD to other projects/actions of federal agencies outside transportation that fall under the broad NEPA umbrella.

Table 9. Stakeholder priorities are translated into commitment priorities using a QFD matrix.

Stakeholders / Commitments				1. No impacts to historic/eligible properties including cemetery.	2. Controlled access between Ewing Ford Rd/Cemetery Road intersection and I-65.	3. Berms and landscaping.	4. Median landscaping.	5. Bridge aesthetics.	6. Interchange landscaping.	7. Construct a multi-purpose bicycle/pedestrian path.	8. Develop a 14-acre park on excess property purchased by KYTC.	9. Divert truck traffic entering Cemetery Rd from I-65 onto Lovers Lane.	10. Signalize 5 intersections using mast mounted lights.	11. Minimize 4F takings at Spero Keriakes Park and grade park land.	12. Reconstruct stone wall subdivision entrance at Hayes Lane intersection.	13. Add guardrail along multipurpose path at sinkhole.	14. Provide signing and bollards at end of multipurpose path.	15. Install conduit for
1st level	2nd	3rd	S-H wt															
Government	KYTC Officials	Central Office	0.018															
		Resident Engineers Office	0.121															
	Local Gov't	City of Bowling Green	0.142		0.27			0.07	0.07	0.13	0.27	0.27	0.27	0.13	0.07			0.
		Warrant County Judge-Executives Office	0.038		0.13			0.07	0.07	0.13	0.13	0.13	0.13	0.13				
Agencies	Resource Agencies/ MPOs	KY Heritage Council	0.001															
		City-County Planning Commission	0.079		0.07					0.13	0.27	0.27	0.07			0.07	0.07	
		Greenways Commission	0.012		0.27	0.13	0.13	0.07	0.07	0.52	1.00						0.13	
		Operation P.R.I.D.E.	0.036					0.13		1.00	0.52						0.13	
	Quasi-Agencies	SHPO (State Historic Preservation Office)	0.002	1.00														
Community	SIGs	Citizens for Improving Cemetery Rd	0.155		0.07			0.07		0.13		0.52						
	Individuals	Adjacent Landowners	0.103			0.13	0.13			0.07		0.52						
		Businesses	0.092			0.07	0.07					0.27						
	Others	Neighborhood Associations	0.157	0.27		0.27	0.27			0.07		1.00				0.52		
		Western KY University	0.038	0.13		0.13	0.13			0.27								
		Warren County 4H Extension Board	0.004	0.27		0.13	0.13			0.13	0.13							
		Bowling Green Tree Board	0.001	0.52		0.13	0.13			0.13	0.27							
Absolute Weight				0.051	0.062	0.070	0.070	0.029	0.013	0.127	0.096	0.379	0.048	0.024	0.091	0.005	0.012	0.0
Commitments Weights				0.032	0.039	0.044	0.044	0.018	0.008	0.080	0.061	0.240	0.031	0.015	0.057	0.003	0.008	0.0
Rank Order (Lowest is most critical)				13	12	10	10	16	20	2	5	1	14	17	6	22	21	1

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