Incorporating Stakeholder Values and Needs in National Highway Decision Support System Improvement Planning

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Abstract

National highway investment and performance analyses have provided decision support information to Congress since the early 1970s. Over this thirty year period, the highway investment and performance modeling approach has evolved. These model developments, some major and others minor, have contributed to significant changes in the resultant information product. In this paper, Total Data Quality Management (TDQM) principles are used in developing an integrated and responsive approach for planning decision support system (DSS) improvements. The TDQM methodology may be applied to capture and reconcile the information quality values and needs of highway stakeholders, and to prioritize improvements of various aspects of the decision support system. An infrastructure agency may therefore adopt the TDQM approach for proactively planning improvements in its DSS that respond to the quality needs of infrastructure stakeholders. The benefit of using TDQM for planning DSS improvements is that, at any period in the progression of DSS development, it enables the infrastructure agency to integrate the information values and needs of infrastructure stakeholders with planned changes in the decision support system.

1. Introduction

1.1 National Highway Investment Decision Support Provision

Beginning in 1968, the Federal Highway Administration (FHWA) has been statutorily required to report biennially to the nation's Congress on highway investment needs (US Code, 1965). This requirement has created a need for the infrastructure agency systematically to collect and manage data that captures the condition and performance of the nation's highways, and to develop the analytical means for estimating the nation's future highway investment needs. Collectively, the data, analytic tools and agency processes may be viewed as the agency's decision support system (DSS). In these three decades, the highway investment DSS analysis model and database have been progressively developed to better capture the relationship between national highway investment and performance, and hence to provide improved information for decision-making. The decision support information is made available through the Condition and Performance (C&P) Report to Congress, formerly known as the National Highway Needs Report.

Total Data Quality Management (TDQM) provides a means for identifying and synthesizing the information quality values and needs of an infrastructure agency's information consumers. Consequently, an infrastructure agency may adopt the TDQM approach to reconcile the predominant information needs of its customers with incremental improvements of its DSS. In the sections below, the TDQM methodology is described and applied to develop a logical procedure for extracting the information values and needs of highway stakeholders and information consumers, and integrating these with the infrastructure agency's decision support system improvement process.

1.2 Infrastructure Decision Support Systems

A review of the nation's highway, bridge and transit investment DSSs reveals a generic macro-structure comprising four basic components:

[1] A database management system;
[2] A system of analysis tools;
[3] An infrastructure agency with two main functions of:
  [A] Generating decision support products for its clients;
  [B] Managing the improvement of its DSS to meet agency objectives and client needs;
  and,
[4] Clients with various demands for information products.

Figure 1 depicts the macro structure of a national transportation infrastructure investment DSS. The database management system and the system of analytic tools may collectively be viewed as the *information system*. The DSS could be viewed as a system of interdependent elements and processes. From a general perspective, a DSS consists of *raw data* (inputs) and *information products* (outputs), connected by *agency procedures* and *stakeholder feedback* (processes) that transform the raw data into meaningful information products to satisfy client needs. From an agency perspective, the DSS processes may also be viewed as inputs and outputs. They may be viewed as inputs for creating the final information products, and as outputs of the overall decision support process, as they are the infrastructure agency's *assets* for accomplishing its objectives. Using this construct, we recognize that the agency's processes are progressively shaped by its legal function, the feedback it obtains from its clients, and the resulting priorities it places on developing and managing its assets (i.e. DSS information system and processes). Total Data Quality Management (TDQM) principles may be applied to factor the information values and needs of infrastructure stakeholders in the DSS improvement planning process.

1.3 National Highway Investment Decision Support Modeling

Investment and performance models used at the federal level are policy models. They are used to investigate and provide information on the consequences of alternative investment levels and strategies. Since its inception, highway investment and performance modeling, at the federal level, has been based on a static and deterministic benefit-cost/optimization approach for evaluating highway needs. The highway investment and performance models perform discrete section-by-section analysis that does the following:

[1] Simulates the impact of system usage on system condition and performance over a specified period of time;
[2] Identifies deficient highway sections based on specified engineering and/or economic standards;
[3] Selects appropriate highway improvements to achieve specified condition and performance levels;
and,
[4] Estimates the level of investment required to achieve specified condition and performance levels.

Over the course of three decades, this approach has undergone some major and minor developments, which, taken collectively, imply a significant change in the resultant information product. Major changes in modeling have occurred between the following three approaches:

[1] The *Highway User Investment Study* (HUIS) approach, developed in the early 70s and first used in the 1972 Report to Congress (Gruver, 1974);
[2] The *Highway Performance Monitoring System - Analytic Process* (HPMS-AP) approach, developed in the mid-70s and first used in 1978 (Gruver and Reulein, 1983);
and,
[3] The *Highway Economic Requirements System* (HERS) approach, developed in the late 80s and early 90s and first used in 1995 (USDOT, 1996)

The major changes in the modeling approach have been largely related to: [1] methods used in the determination of highway levels of service; and, [2] the nature and scope of the performance measures used in the benefit-cost calculus. In the 70s and 80s, highway levels of service were determined based purely on engineering standards. Beginning in the 90s, however, a combination of economic and engineering standards have been used in identifying deficient highway sections and in selecting appropriate improvements, reflecting a widespread intent to optimize the use of limited resources relative to civil infrastructure investment needs. In the early 70s and 80s, highway benefits were considered as those realized by the highway user and agency. In the 90s, environmental benefits have been incorporated into the benefit-cost calculus, reflecting a growing intent to internalize the environmental impact costs of highways.

The latter two models use data from the national highway database: the Highway Performance Monitoring System

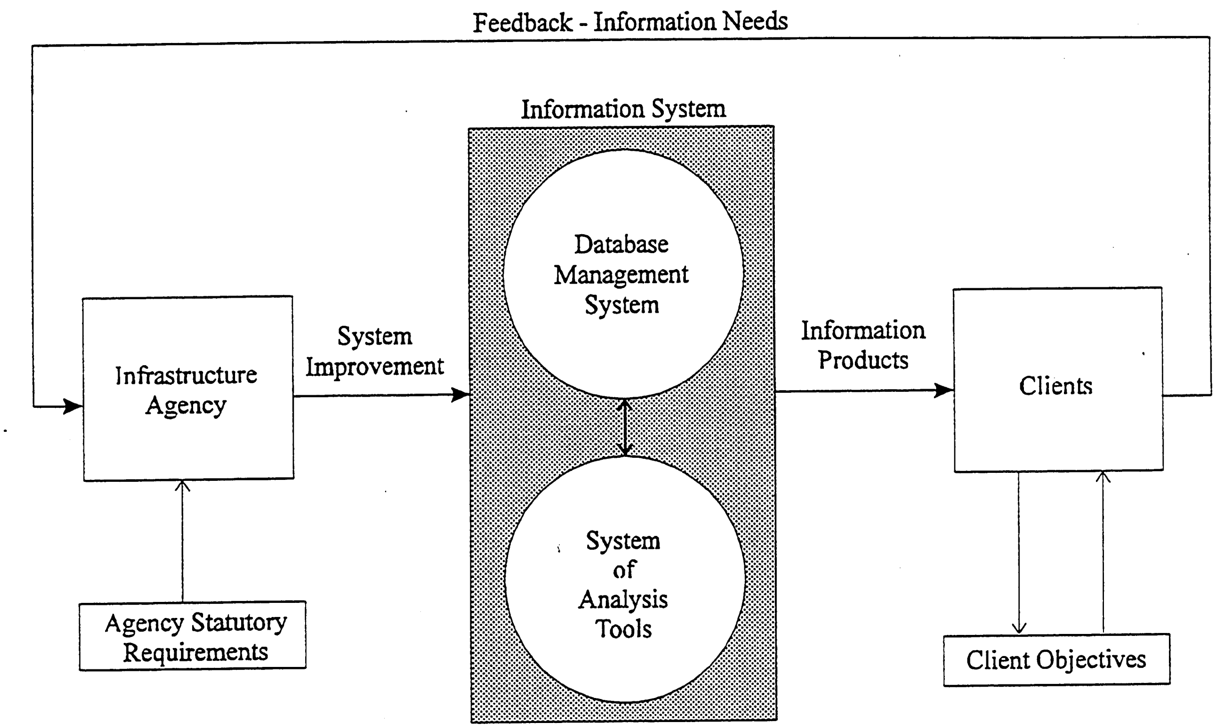


Figure 1: Macro-Structure of a National Transportation Infrastructure Investment Decision Support System

(HPMS). The HPMS database was implemented in 1978 to supply the nation's highway data and information needs (USDOT, 1993). A major change in the data approach occurred in the late 70s. Prior to 1978, highway investment estimates were based on the analysis of numerous, uncoordinated state data reports, as well as biennial studies conducted by each state (USDOT, 1997). Beginning in 1978, however, statistical sampling methods have been used to represent the population of highway sections that collectively constitute the nation's highway system (USDOT, 1993). Currently, the HPMS contains data describing over 100,000 highway sections sampled to represent the nation's highway system (USDOT, 1994).

1.4 Decision Support System Improvement

In the 90s, there have been various efforts, at the federal level, to control quality in government and improve program performance. This is evident in the passage of such legislation as the *Information Technology Management Reform Act* of 1996 and the *Government Performance and Results Act* of 1993. The Information Technology Management Reform Act requires federal agencies to apply the principles of goal setting, performance measurement and reporting to their information technology efforts. Specifically, federal agencies are required to establish performance measures to gauge how well their information technology supports their program efforts. The Government Performance and Results Act is aimed at improving program performance. It requires that federal agencies establish long-term strategic goals, as well as annual goals linked to them, measure their performance against the goals, and report publicly on their progress toward these goals (USGAO, 1996).

Changes in decision support modeling approaches may be considered improvements to the extent that they concretely improve the ability of infrastructure agencies to fulfill *a priori* objectives for which they employ these decision support models. The decision support agency's objectives are affected, either directly or indirectly, by demands infrastructure stakeholders and users of the decision support information. Morgan and Henrion (1990) have described one goal of Policy Analysis as identifying a set of mutually compatible and plausible beliefs, values, decisions and models. This goal is considered valuable for improving national infrastructure decision support systems. It promotes integration among key aspects of the decision support provision process and hence provides opportunities for managing inconsistencies among these aspects. An example of such inconsistency is revealed in the various definitions of "investment need" by different segments of the highway community. The National Council on Public Works Improvement (NCPWI) compares three well known national highway needs studies by three independent organizations: the Associated General Contractors (AGC); the Congressional Budget Office (CBO); and the Joint Economic Committee (JEC). All within a period of a year, these three studies develop the following estimates for the deficit between national transportation infrastructure improvement needs and available revenues: 17.4 billion dollars (CBO, 1983); 24.6 billion dollars (JEC, 1984); and 71.7 billion dollars (AGC, 1983) (NCPWI, 1996). The variation in these estimates reflects that infrastructure investment needs are a strong function of perceived infrastructure needs, which are, in turn, a function of the minimum acceptable levels of highway system performance and infrastructure condition that one adopts. It also reflects the potential usefulness of a forum for periodically understanding and integrating the values of various segments of the highway community, in so far as these values affect the objectives of national highway investment decision-making.

To improve the quality of information being supplied to decision-makers, model improvements must be responsive to the changing expectations and values of decision-makers and other infrastructure stakeholders. To this end, emerging methodologies that provide a means for integrating consumer information values and needs with decision support system improvements are potentially useful for improving the infrastructure DSS planning process. Total Data Quality Management (TDQM) provides a methodology for developing linkages between consumer information values and needs and the decision support system improvement process. In the following sections, we describe TDQM; apply TDQM to develop a framework for planning DSS developments from highway stakeholder and information user perspectives; and discuss the benefits of using this framework for planning infrastructure DSS improvements.

2. Total Data Quality Management

The field of Total Data Quality Management (TDQM) is a branch of the field of Information Quality (IQ). The knowledge created for the field of IQ is based on principles, guidelines and techniques in Total Quality Management (TQM) in the field of Product Manufacturing. IQ theory draws from an analogy between quality issues in Product Manufacturing and those in Information Manufacturing. In Product Manufacturing, the assembly line (processing system) acts on raw materials (inputs) to produce physical products (outputs). Similarly, in Information Manufacturing, we may view the information system (processing system) as acting on raw data (inputs) to produce information products (outputs) (Wang, 1998).

2.1 Information Quality

The term "data quality" is defined as the "fitness for use" of data for its purpose(s). This implies that the concept of data quality is relative and that data considered appropriate for one use may not possess sufficient quality for another use (Tayi and Ballou, 1998). Thus, information quality could be viewed as the "fitness for use" of information for the purpose(s) for which it is generated. Wang (1998) uses the terms *data* and *information* interchangeably, he acknowledges that, in practice, managers intuitively differentiate information from data, and describe information as data that has been processed in some manner. In addressing the quality needs of DSS information consumers, we find it useful to define information as *processed data*, in contrast with *raw data*. We consider as information any raw data that has been processed by some *definite analytical means*, thus introducing analytical tools as a valid component of the DSS for transforming raw data into final information products. Under this construct we are conceptually able to evaluate improvements to the modeling approach, as well as the raw data, based on the potential impacts that these have on the quality of DSS information products.

2.2 The TDQM Cycle and Methodology

The TDQM Cycle is a continuous cycle that defines (i.e. identifies important IQ dimensions and corresponding IQ requirements), measures (i.e. produces IQ metrics) , analyzes (i.e. identifies root causes for IQ problems and calculates impact of poor quality information), and improves (i.e. provides techniques for improving IQ) an information manufacturing system, to ensure high-quality information products. This cycle is depicted in Figure 2. The key points in this process are that information manufacturers, suppliers and product managers must play a proactive role in continuously providing an acceptable quality of information for their clients. This would involve institutionalizing a system that periodically determines how and why consumers use information. The TDQM Methodology implements this cycle (Wang, 1998). The TDQM Methodology involves: [1] defining the information product; [2] measuring the information product quality; [3] analyzing the information product; and, [4] improving the information product. These four tasks are discussed below.

[1] Define Information Product [IP]

Defining the information product (IP) involves defining the following: [A] information manufacturing system; [B] information product characteristics; and, [C] information quality requirements, as is discussed below.

[A] *Define Information Manufacturing System*

Identifying the structure and components of the information manufacturing system (IMS) would provide the information product (IP) team with a basis for assessing the values of the information quality (IQ) dimensions for the IP and studying options for improving the IMS. The IMS is that which produces the information products. The IP is the output from the IMS and has value that is transferable to the customer. The IMS consists of the [I] Data Suppliers; [ii] Information Manufacturers; [iii] Information Product Managers; and [iv] Information Consumers.

[B] *Define IP Characteristics:*

Characteristics for the IP are defined at two levels. At the higher level the IP is conceptualized in terms of its basic functionalities for information consumers. Fully characterizing the information product involves determining the information needed by customers to perform their respective tasks. The functionalities and consumers of the system are identified in an iterative way. Information consumer perceptions of what constitutes important IQ dimensions are captured and reconciled and the process results in a variety of IQ dimensions for the IP. At a lower level, one would identify the IP's basic information unit, components and component relationships. Defining what constitutes a basic unit for an IP is critical as it dictates the way the IP is produced, utilized and managed.

[C] *Define IQ Requirements*

With the characteristics of the IP specified, the next step is to identify IQ requirements from the perspectives of IP suppliers, manufacturers, consumers and managers. This process involves the collection and synthesis of data from the various groups that comprise the information manufacturing system.

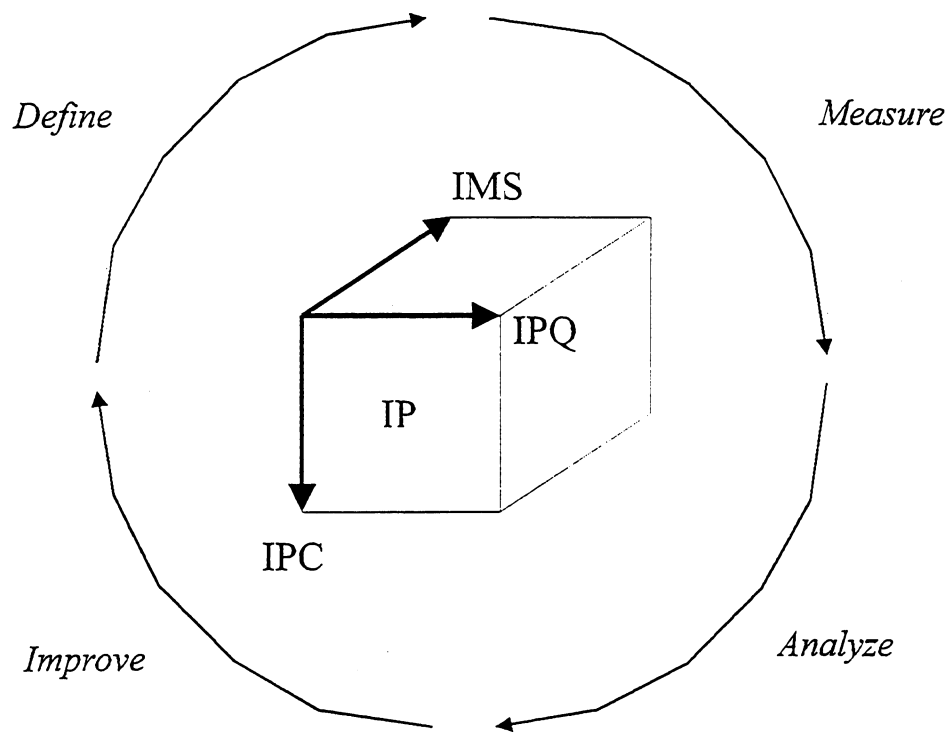
[2] Measure IP Quality

The key to measurement is the development of metrics. Whatever metrics are adopted, they must reflect the IQ requirements developed in the previous stage. The IQ requirements must be broken down into objective, measurable characteristics for the information manufacturing system (IMS).

[3] Analyze IP

Using the measurement results, the IP team can explore the root cause for IQ problems using simple or complex methods or tools.

[4] Improve IP



LEGEND
IP: Information Product
IPC: IP Characteristics
IPQ: IP Quality
IMS: Information Manufacturing System

Figure 2: The Total Data Quality Management Cycle

(Wang, 1998)

Based on the IQ assessment results, an agency can proceed with improvements of its decision support system. There are two alternatives. The organization may develop a new IMS for the IP. The advantage of this approach is that many IQ requirements can be designed into the new IMS, resulting in a quality-information-by-design system with many of the IQ problems of the legacy system corrected. The disadvantage of this approach is that a new system would require more initial investment and significant organizational change. Alternatively, the organization can use the IQ assessment results as guidelines for developing mechanisms to remedy the deficiencies of the legacy system though data (and/or modeling) improvements for the IMS that improve upon the quality of the IP.

3. Application of TDQM to Highway Investment DSS Management

3.1 National Highway Investment Information Manufacturing System

There four components of the national highway investment Information Manufacturing System (IMS) are discussed below:

[1] Data Suppliers

Data Suppliers are those who create or collect data for the information product (IP). Data suppliers for the national highway IMS are the State Highway Agencies, collectively responsible for annually collecting and providing data for the national highway database: the Highway Performance Monitoring System (HPMS). The HPMS is managed by the Federal Highway Administration.

[2] Information Manufacturers

Information Manufacturers are those who design, develop or maintain the data (and analytical) systems infrastructure for the IP. The Information Manufacturers for the national highway IMS consist of a partnership between the Federal Highway Administration's in-house and affiliated professionals: the Highway Needs and Investment Team, the Highway Performance Monitoring Division, Industry Consultants (Public and Private), and Researchers (Academic and Non-Academic).

[3] Information Consumers

Information Consumers are those who use the IP in their work. At the most basic level, highway stakeholders may be viewed as the users and providers (law/policy-makers, financiers, planners, designers, builders, operators, maintainers and managers) of highways. Highway investment information consumers are the subset of highway stakeholders who use the Condition and Performance (C&P) Report to Congress for various purposes.

[4] Information Product Managers

Information Product Managers are those responsible for managing the entire IP production process throughout the IP life cycle. The Federal Highway Administration's Office of Policy is the Information Product Manager for the Condition and Performance Report to Congress.

3.2 Highway Decision Support Information Quality Attributes

Just as a material product has quality dimensions associated with it, an information product has information quality (IQ) dimensions. Traditionally, concerns have centered on the *accuracy* of information. However where there are multiple users of information, fitness for use of information implies that we need to look beyond the traditional concerns with the accuracy of information to other attributes such as *completeness*, *consistency*, and *timeliness* (Tayi and Ballou, 1998).

In the 40s, similar information quality dimensions were recognized as important in the provision of highway decision support information, by the Highway Research Board's Committee on the Uses of Highway Planning Survey Data. This committee was formed to develop plans for more fully utilizing all available highway information and to enhance the value of planning surveys to highway organizations. State contributions to this effort included recommendations for improving the quality of information. Information quality attributes such as *timeliness*, *format*, *consistency* and *accessibility* were recognized as important, as is reflected in the following remarks from state-level agencies (Dimick, 1946):

> "The usefulness of data when collected depends largely on the ease and length of time required to prepare them for any given purpose." [Timeliness]
>
> "It is commonly found that an arrangement of data for one study is unsuited for another so that arrangement becomes necessary." [Format]
>
> "It is frequently necessary to blend data from two or more different studies. Accordingly, it has been found desirable that all basic information should be placed on tabulating cards since control of the work is simplified and consistent answers will be produced at different times from the same data with something approaching a minimum effort." [Format and Consistency]

"One very simple suggestion that was made by several states and which should prove beneficial to all is the advertising of the information stored in the planning survey files by means of indices published periodically, and listing reports, maps, and miscellaneous data available." [Accessibility].

In the 90s, similar information quality attributes have been reiterated as important by various segments of the highway community. The results of the 1994 Highway Statistics Survey on Customer Services indicate that highway information users place a premium on *consistency*, *timeliness*, *accessibility* and *level of detail* the data (USDOT, 1995). The guidelines for implementing the Government Performance and Results Act of 1993 recommend that data collected for evaluating program performance must be sufficiently *complete*, *accurate* and *consistent* (USGAO, 1996). In the Highway Performance Monitoring System (HPMS) strategic reassessment process, one of the four major objectives of the HPMS has been recognized as the provision of a "publicly *accessible*, *consistently* high quality *objective* and *timely* national database" (USDOT, 1998).

There are various other attributes for evaluating information quality. Based on consumer information research, Wang and Strong (1996) have identified fifteen dimensions and four categories of information quality as shown in Table 1. And based on a comprehensive literature review, Wand and Wang (1996) have developed a list of the most often cited data quality dimensions, as shown in Table 2.

Building on the information quality attributes recognized as important by various segments of the highway community for managing decision support information (Dimick, 1946; USDOT, 1995; USGAO, 1996; USDOT, 1998), and drawing upon previous work done by Wang and Strong (1996) and Wand and Wang (1996), we have developed a pool of attributes for evaluating the quality of national highway investment decision support information. These attributes were developed as follows. The literature reveals that eight attributes have been recognized by the highway community as important for evaluating the quality of highway information (Dimick, 1946; USDOT, 1995; USGAO, 1996; USDOT, 1998). In decreasing order of their respective total number of references in the highway information literature, these attributes are listed below:

[1] Consistency [4]
[2] Timeliness [3]
[3] Accessibility [3]
[4] Format [2]
[5] Accuracy [1]
[6] Completeness [1]
[7] Objectivity [1]
[8] Level of Detail [1]

An evaluation of these information quality (IQ) attributes reveals that they are readily classified into the following four categories:

[1] Credibility-related
[2] Accessibility-related
[3] Format-related
[4] Scope related.

Objective and measurable attributes that fall into any one of these categories, and do not completely overlap with the original eight highway IQ attributes, were selected from the comprehensive pool of attributes developed by Wang and Strong (1996) and Wand and Wang (1996), resulting in a total of ten attributes for evaluating highway decision support information. These attributes are listed and classified in Table 3, and may be used to extract and synthesize highway stakeholder and information user values and needs.

4. Future Work

Having set the stage by explaining how the TDQM process is applicable to the national highway investment decision support process, it is clear that this methodology can be used to develop an integrated and responsive approach for planning infrastructure decision support system improvements. The following section describes further steps that are needed to develop the TDQM methodology into a fully functional tool for decision support system improvement planning. To move from the present stage to demonstrating a useful and complete application of TDQM for the national highway decision support system improvement process, we will do the following:

[1] Survey highway stakeholder information values:
Highway stakeholders may be classified on the basis of their organized interaction with the highway system as is

TABLE 1: Information Quality Categories and Dimensions

IQ CATEGORY	IQ DIMENSIONS	NOTES
Intrinsic IQ	Accuracy Objectivity Believability Reputation	Intrinsic IQ captures the fact that information has quality in its own right.
Contextual IQ	Relevancy Value-Added Timeliness Completeness Amount of Data	Contextual IQ highlights the requirement that information quality must be considered within the context of the task at hand.
Accessibility-Related IQ	Access Security	Accessibility-Related IQ emphasizes the role of information systems in providing appropriate information access and security suitable for the context.
Representational IQ	Interpretability Ease of Understanding Concise Representation Consistent Representation	Representational IQ emphasizes the role of information systems in providing a variety of representational attributes that facilitate the use of information by customers.

(Wang and Strong, 1996)

TABLE 2: Most Often Cited Data Quality Dimensions in the Literature

Dimension	# of Times Cited	Dimension	# of Times Cited
Accuracy	25	Importance	3
Reliability	22	Sufficiency	3
Timeliness	19	Usableness	3
Relevance	16	Usefulness	3
Completeness	15	Clarity	2
Currency	9	Comparability	2
Consistency	8	Conciseness	2
Flexibility	5	Freedom from Bias	2
Precision	5	Informativeness	2
Format	4	Level of Detail	2
Interpretability	4	Quantitativeness	2
Content	3	Scope	2
Efficiency	3	Understandability	2

(Wand and Wang, 1996)

TABLE 3: Highway Information Quality Attributes

Categories	Highway Decision Support Information Quality Attributes	Number of Times Referenced in the Highway Information Literature
Credibility-Related	Consistency	4
	Accuracy	1
	Objectivity	1
	Reliability	0
Accessibility-Related	Accessibility	3
	Timeliness	3
Format-Related	Conciseness	1
	Level of Detail	1
	Quantitativeness	0
Scope-Related	Completeness	1

Glossary (Webster, 1988)

Consistent:	Conforming to the same principles
Accurate:	The quality of being in exact conformity to fact
Objective:	Based on observable phenomena
Reliable:	The quality of being dependable
Accessible:	Easily obtained
Timely:	Occurring at a suitable time
Concise:	Short and to the point
Detail:	Particulars considered individually and in relation to a whole
Quantitative:	Of or relating to a number or measurement
Complete:	Having all the necessary elements

illustrated in the *organized-interaction-based* classification in Table 4. They may also be classified according to the roles they play in the creation of decision support information, as illustrated in the *information-manufacturing-system* classification in Table 5. Stakeholders may also be classified according to their organizational affiliations as is depicted in the agency-based classification system in Table 6. Arguably, the interaction of infrastructure stakeholders with the infrastructure system influences their particular information needs. Also, the role played by infrastructure stakeholders in the information development process may influence their evaluation of the quality of information. Thirdly, the organizational affiliation of highway stakeholders may influence their perceptions of the quality of information in the national highway investment decision support product. We will develop a survey to extract highway stakeholder values using these three classifications, together with the pool of information quality attributes assembled in the previous section. The objective of this survey will be to determine the relative value that highway stakeholders and information consumers place on the different information quality attributes for evaluating the Condition and Performance Report, based on the fitness of use of the information contained therein for their various purposes.

[2] Survey highway stakeholder evaluations of the quality of information in the Condition and Performance Report: We will extract highway stakeholder and information user evaluation of the information product based on the different information quality attributes and relative to the purposes for which they use the Condition and Performance Report.

[3] Evaluate the results for the purpose of improving the national highway investment decision support system: By comparing the relative importance ranking of the information quality attributes with the relative quality rating of the information product (IP), based on the different attributes, we will be able to identify *dominant* as well as *preferred* attribute improvements for the information product as is depicted in Table 7. This information will provide an *information consumer/information quality* (IC/IQ) interface. To use this information in prioritizing the improvement of various aspects of the actual DSS requires the development of an *information quality/decision support system* (IQ/DSS) interface; one that identifies principal linkages between various attributes of information quality and aspects of the DSS. A high level IQ/DSS interface is depicted in Table 8. Using these two interfaces, we will be able to identify and make recommendations on dominant and preferred DSS improvements on the basis of information values and needs of highway stakeholders .

5. Summary

Highway investment and performance analysis has been routinely used in providing decision support information for federal-level decision-making on highway investments, since the early 70s. Over the course of this period, the nature of highway investment and performance modeling has progressively evolved, producing information on highway investment requirements with incrementally different approaches. These incremental changes in the modeling approach have contributed to significant changes in the resultant information product, the Condition and Performance Report to Congress. Total Data Quality Management (TDQM) is introduced as an integrated and responsive approach for planning improvements in infrastructure decision support systems. The innovative aspects of using this process in DSS improvements are that [1] information quality values and needs of highway investment information consumers are identified and synthesized; [2] this information is used to proactively plan and implement DSS changes. The approach contributes a systematic process for integrating the national infrastructure decision support system improvement process with the information values and quality needs of infrastructure stakeholders and information consumers; a useful and timely contribution in this era of renewed emphasis on quality assurance in government.

Acknowledgment

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Gruver, James E., and William Reulein. Estimating the Impacts of Changing Highway Conditions, Transportation Research Record, Number 940, 1983, pp. 1-7.

TABLE 4: Organized-Interaction-Based Classification of National Highway Stakeholders

Information Consumers	Categories	Examples
Organized Users	Highways	American Trucking Association [Commercial] American Automobile Association [Non-Commercial]
	Alternative Modes	American Public Transit Association
Organized Highway Providers	Law/Policy Makers	Congressional Decision-Making Committees House Transportation and Infrastructure Committee Senate Environmental and Public Works Committee
	Planners	American Institute of Certified Planners
	Designers	American Consulting Engineers Council
	Financiers	American Truckers Association American Automobile Association
	Constructors	Associated General Contractors
	Operators and Maintainers	Departments of Transportation
	Managers	Highway Administrations
	Researchers	Council of University Transportation Centers.[Academic Institution] Eno Transportation Foundation [Non-Academic Institution] Transportation Research Board [Public Organization] American Society of Civil Engineers [Private Organization]
	Environment Protectors	Rails-to-Trails Conservancy

TABLE 5: Information-Manufacturing-System-Based Classification of National Highway Stakeholders

CATEGORIES	INFORMATION MANUFACTURING SYSTEM
Data Suppliers	**State Highway Agencies**
Information Manufacturers	**Federal Highway Administration** Highway Needs and Investment Team Highway System Performance Division **Industry Consultants** Public Private **Research Community** Academic Non-Academic
Information Consumers	**Highway Users** Non-Commercial Commercial **Highway Providers** Law/Policy-Makers Planners Designers Builders Financiers Operators Maintainers Managers Environment Protectors
Information Product Managers	**Federal Highway Administration** Office of Policy

TABLE 6: Agency-Based Classification of National Highway Stakeholders

Categories	Agencies
Regulatory	Office of Management and Budget General Accounting Office Environmental Protection Agency
Administrative	Federal Highway Administration State Highway Administration
Consulting	Private Consulting Organizations Public Consulting Organizations
Planning	Metropolitan Planning Organizations
Operations	State Department of Transportations
Research	Academic Research Institutions Non-Academic Research Institutions
Advocacy	Organized Lobbies

TABLE 7: Identifying Dominant IQ Improvements from Simultaneous Value and Deficiency Ranking

Rating of Priority	Rating of Deficiency Level
A [Higher Priority]	B [More Deficient]
B	D
C	I
D	H
E	A
F	G
G	E
H	F
I [Lower Priority]	C [Less Deficient]

Explanation of Table
{A .. I} = Information Quality (IQ) Attributes

From the ratings above, we observe that IQ attribute 'B' is of higher priority to the raters than all but one of the IQ attributes, and that the information product is considered to be the most deficient in B. From the perspective of these raters then, a planned change to the DSS that improves upon the quality "B" in the information product is clearly a dominant alternative to changes that improve upon the qualities: "C, D, E, F, G, H, I".

TABLE 8: Decision Support System/Information Quality Interface

IQ Categories	IQ Attributes	Decision Support System Improvement Option			
		Data	Modeling	Information Presentation	Organizational Processes
Credibility-Related	Consistency	✔[1]	✔	✔	
	Accuracy	✔	✔		
	Objectivity	✔			
	Reliability	✔	✔		
Accessibility-Related	Accessibility				✔
	Timeliness				✔
Format-Related	Conciseness			✔	
	Level of Detail	✔	✔	✔	
	Quantitativeness	✔			
Scope-Related	Completeness	✔			

1 Check-marks are used to indicate a direct relationship between the Decision Support System Improvement Options and the Information Quality Attributes.

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