FREP Quality Assurance Framework

(*Forest and Range Practice Act* Resource Evaluation Program)

Background Paper

For FRPA Resource Evaluation Program

Ministry of Forests and Range (Forest Practices Branch)
Ministry of Environment
Integrated Land Management Bureau

By FREP Quality Assurance Working Group

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Table of Contents

List of Figures

List of Tables

Executive Summary

FREP QAF background

The *Forest and Range Practice Act* (FRPA) Resource Evaluation Program (FREP) is an environmental monitoring program committed to by the Government of British Columbia. FREP assesses whether forest and range practices are achieving the management objectives for the 11 identified resource values under FRPA.

The FREP Quality Assurance Framework (QAF) will "*ensure that the FRPA Resource Evaluation Program and all of its activities and deliverables meet their objectives in an efficient and effective manner."*

Literature review

A review on the current quality management systems and theories literature found that no single approach meets the needs of the FREP QAF. Quality systems and theories such as International Organization for Standardization (ISO), National Quality Institute (NQI), Total Quality Management (TQM), Kaizen, Six Sigma, and Quality Function Deployment (QFD) are examined with their applicability to the FREP. Quality management in the public sector is also examined. The implementation of TQM in the UK public sector provided valuable experience in addition to the NQI's quality criteria for the public sector in Canada. Generally, government cultures, nature of the services offered, and society as customers are considered significant barriers to a successful quality management implementation. Studies in the UK and Denmark indicated that a holistic and integrative quality management framework, such as the Business Excellence Model, is the preferred and successful approach in the European public sector. Some other successful implementation factors include strong leadership, top management commitment, provision of education and training, and the combination of quality criteria into the public sector accountability requirements.

The case studies revealed best practices and the quality management plans that other jurisdictions have developed or adopted. They generally confirm that the FREP QAF is on the right track in the development of the project management plan, quality assurance framework, quality control protocols, and the use of quality tools. In the case studies, components such as Quality Assurance (QA)/Quality Control (QC) project plan, data management, data quality objective, quality criteria, and the Plan-Do-Check-Act (PDCA) cycle are frequently mentioned. The case studies also showed the components such as the safety equipment and training and the quality audits that the FREP QAF might have not addressed.

QA and QC: conceptual framework

The FREP Quality Assurance Model and Criteria form the basis of the FREP QAF. The model explains the general process, linkages, and requirements for the program and the projects. The FREP Quality Assurance Criteria communicate the quality terms that the FREP should develop, monitor, control, and achieve.

Quality Assurance (QA) is generally expressed on the program level. It deals with the design and planning of the entire quality management (the practice), as well as the quality system (framework and structure). A forthcoming implementation strategy will

focus on these aspects of QA.. Quality Control is expressed on the project level and deals mostly with control and execution. Protocols will be developed to monitor and to control quality level on areas of data collection, data management, data analysis, and data reporting. Together, QA and QC will continuously work on the improvements of quality.

To achieve the objective of the FREP QAF, the requirements for quality must be captured. Thus metrics should be developed so that quality level can be understood, communicated, monitored, improved, and controlled. Quality Metrics should be based on the FREP Quality Assurance Criteria and be developed by the Goal/Question/Metric (GQM) method.

Quality tools

Some of the tools identified for quality improvements are:

- Self-assessment
- Check sheet or scorecard
- Affinity diagram
- Systematic diagram
- House of Quality
- Pareto diagram
- Cause-and-effect diagram (Fishbone and Ishikawa)

Report Recommendations

1. Communicate the QA framework and the QC protocols to the FREP staff and stakeholders.
2. Communicate lessons learned in the environmental monitoring quality management plans and in the public sector quality management frameworks.
3. Capture quality requirements – metrics and Acceptable Quality Level (AQL).
4. Train staff in the use the quality improvement tools and techniques.
5. Use this background paper to consider some of the missed program or project QA and QC components.

1. Introduction

1.1 Report Structure

This report is a background paper in a series of documents under the title of FREP Quality Assurance Framework. This report sets the stage for quality assurance, quality management, and quality control in environmental monitoring and evaluation, specifically for the *Forest and Range Practice Act* (FPRA) Resource Evaluation Program (FREP). Following this paper, an implementation strategy report will focus on applying quality assurance to operations. Requirements for quality will be established, measured, and inspected in the implementation strategy. Furthermore, several quality control protocols will establish quality control in areas of checklist design, project planning, data collection, data analysis, reporting, and publications. A Quality Assurance Working Group has been formed to oversee the production of these reports and papers (British Columbia, FREP QA Working Group 2).

This report presents both generic quality management systems and those tools and techniques applicable to environmental monitoring and evaluations. This is the intention, as well as the challenge. The challenge is to describe all of the quality management systems, but not to report in detail the individual theories or systems because no one quality management systems can fulfil FREP requirements. Quality management systems can be too manufacturing-oriented, or can lack external recognition. Therefore, this report surveys the variety of quality management systems, and extracts the essence applicable to our endeavour — ensuring high quality for all aspects of FREP.

The report contains the following sections.

- Section 1 introduces FREP and its requirement for a quality assurance framework. This introduction briefly explains quality definitions and the purpose of a quality assurance framework.
- Section 2 presents quality management system and their key features, limitations, and applicability to FREP (summarized from literature review in Appendix A).
- Section 3 explores best practices and case studies. This report has identified the United States Environmental Protection Agency and the UN/ECE Task Force on Monitoring and Assessment as the most prominent practitioners.
- Section 4 outlines the development of a solid conceptual framework based on the literature review and best practices. The framework wraps around quality management in the context of FREP. The issue of quality requirements is raised, and the total cost of quality is examined in detail. Also, the FREP Quality Assurance Criteria are listed.
- Section 5 introduces the idea of quality metrics and AQL (Acceptable Quality Level). The GQM paradigm (Goal/Question/Metric) proposed in this section will serve as the primary method to arrive at quality metrics.
- Section 6 includes the seven most commonly used quality control tools, based on the literature review and program needs.

Appendix A contains the complete literature review, while Appendix B includes the glossary.

1.2 FREP Background

The FRPA Resource Evaluation Program (FREP) is a long-term commitment by the government of British Columbia to assess whether forest and range practices are achieving the management objectives for 11 resource values[1] identified under the *Forest and Range Practices Act (FRPA)*. The two primary components of FREP are provincial- and regional-level evaluations and district- and regional-level resource stewardship monitoring. These evaluations and resource stewardship monitoring both use science-based indicators and standardized protocols to assess the effects of forest practices on a specific resource value. The types of evaluations conducted under FREP include implementation, effectiveness, and validation of these practices. Evaluation intensities range from routine to extensive to intensive. FREP is linked to the work of several other monitoring and evaluation initiatives in British Columbia. (British Columbia, The FPRA Resource Evaluation Program 1)

British Columbians desire the sustainable use of the forests that they hold in trust for future generations. For the purpose of FREP, sustainable use includes:

- managing forests to meet present needs without compromising the needs of future generations,
- providing stewardship of forests based on respect for the land,
- balancing economic, productive, spiritual, ecological, and recreational values of forests to meet the economic, social, and cultural needs of the province's people and communities,
- conserving the resource values identified under FRPA and associated regulations, namely: biological diversity, cultural heritage, soil, water, fish, forage and associated plant communities, timber, recreation, resource features, visual quality, and wildlife.

(British Columbia, FREP Monitoring and Evaluation Strategy 3)

The *Forest and Range Practices Act*[2] and regulations introduce the transition to a results-based forest practices framework in British Columbia. Under this new approach to forest management, the forest industry is responsible for developing the results and strategies, or using specified defaults, for the sustainable management of resources in an environmentally sound, innovative, and cost-effective manner. The role of government is to ensure compliance with established future results and strategies, and to evaluate the effectiveness of forest and range practices in achieving management objectives.

FREP is a multi-agency program to evaluate whether practices under FRPA are meeting not only the intent of the current FRPA objectives, but to determine whether the practices and the legislation itself are meeting government's broader intent for the sustainable use of resources.

FREP is a long-term commitment designed to:

[1] The resource values are Forest and Environmental Values, Biodiversity, Cultural Heritage, Fish, Forage and Associated Plant Communities, Recreation, Resource Features, Soils, Timber, Visual Quality, Water and Wildlife. See Ministry of Forests (website http://www.for.gov.bc.ca/hfp/frep/2_values.html) for more information. Other provinces have also identified similar elements. In Quebec, for instance, 11 "protection and development objectives" have also been identified. See Ministère des ressources naturelles 3.

[2] For more information on FRPA, regulation, resource values, and objectives see http://www.for.gov.bc.ca/hfp/frep/

- assess the effectiveness of FRPA and its regulations in achieving stewardship objectives.
- determine if forest and range polices and practices are achieving government's objectives, with a priority on environmental parameters, and consideration for social and economic parameters, where appropriate.
- identify issues regarding the implementation of forest policies, practices and legislation as they affect achieving stewardship objectives
- implement continuous improvement of forest management in British Columbia.

To accomplish these objectives, FREP will:
- develop specific monitoring and evaluation questions to be addressed
- evaluate the status or trends of resource values and determine causal factors
- determine whether resource values are being managed in a sustainable manner through proven or alternative forest practices
- communicate the results of evaluations, and
- recommend changes to forest and range policies and legislation, where required.

(British Columbia, FREP Monitoring and Evaluation Strategy 3)

1.3 What Does Quality Mean to FREP? Issue Statement

In various FREP documents the requirement for a quality assurance framework,[3] quality control, or a quality management system is clearly indicated. The requirement for quality assurance is incorporated in the program. Therefore the purpose of the FREP Quality Assurance Framework is to:

Ensure that the FRPA Resource Evaluation Program (FREP) and all of its activities and deliverables meet their objectives in an efficient and effective manner.

On the same token, the operational definition for the above objective is to:

Develop this framework and its requirements for quality using the predetermined quality assurance criteria.[4]

1.3.1 Quality Assurance and FREP

Quality assurance is a basic aspect of any measurement or assessment program. It ensures that resources are not wasted in the collection of meaningless or irrelevant data. In particular, it lays down the protocols for the appropriate collection, storage, and analysis of data. Quality assurance is not specifically addressed in the Act, but is a basic prerequisite for the program. The investment in data collection and maintenance will be substantial. FREP must collect the right information from the outset, and quality assurance will help to achieve this. The success of FREP will depend on a cost-efficient and effective program that maximizes the utility of the information that it collects. The innovative nature of the results-based approach means that it may be subject to challenge, particularly where non-compliance with future results is identified. In such cases, the quality of the information held by FREP will be paramount.

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[3] British Columbia, Evaluating Forest Management in British Columbia 5
British Columbia, FRPA Resource Evaluation Program, Charter 6 &17
British Columbia, Resource Stewardship Monitoring, Project Charter 6 & 12
British Columbia, FREP Monitoring and Evaluation Strategy 10

[4] See page 50 for the complete quality assurance criteria.

The FREP business map shows that quality assurance is located at three separate locations (Figure 1). At location 1, quality assurance and peer review are outside processes that focus on the "implement projects" step. Quality assurance will look at processes such as data collection, analysis, and interpretation with independent process, standards, and guidelines. At location 2, quality assurance is under the direction of the Resource Value Teams (RVTs). Quality assurance is to be designed, planned, and implemented as a project along with others such as project proposals, budget/costs, design/analysis/reporting, and development and test of indicators and data methods. At location 3, the Regional Stewardship Monitoring Teams (RSMTs) are to implement quality assurance for their monitoring projects.

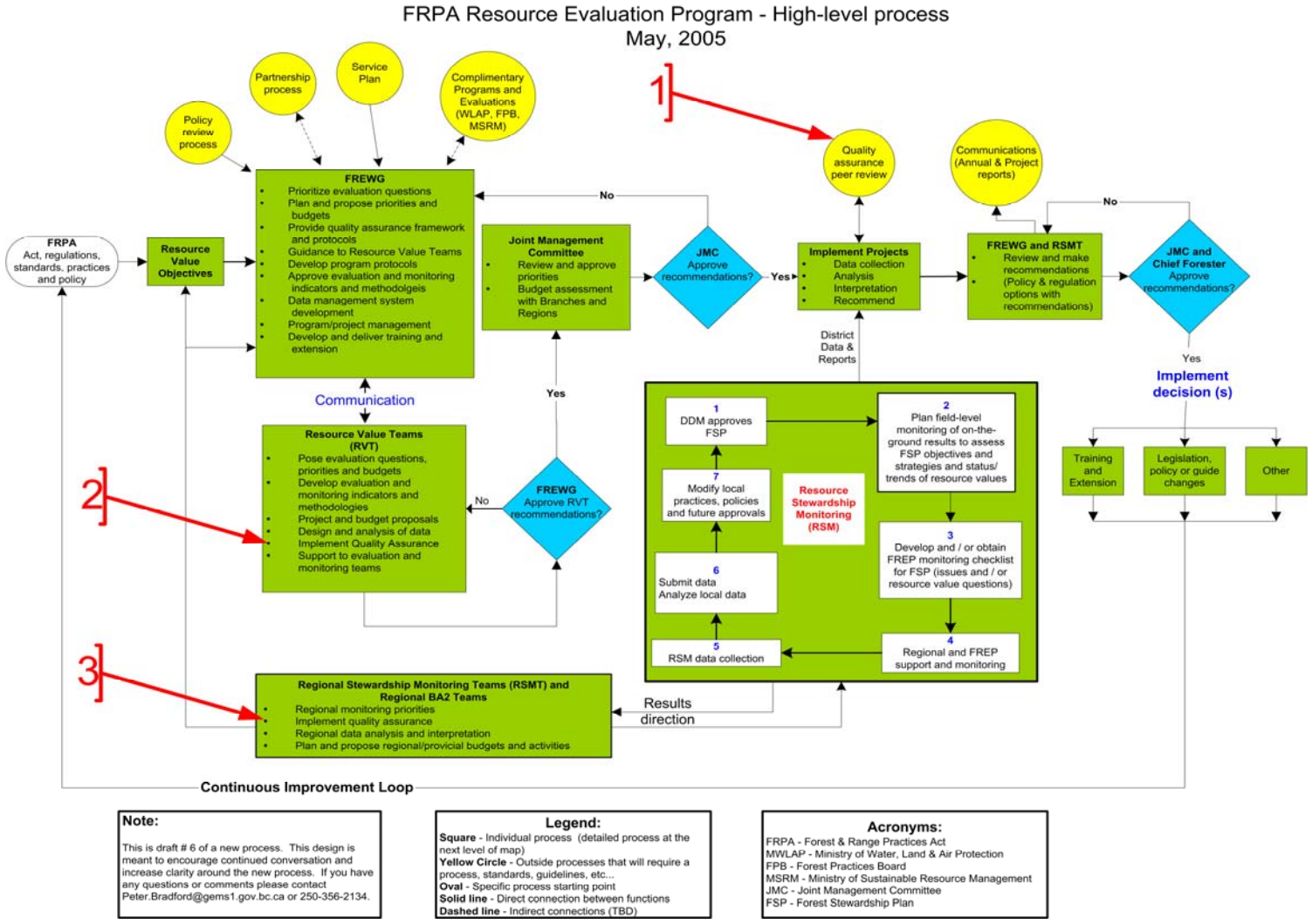

Figure 1. FREP Business Map.[5]

(British Columbia, FRPA Resource Evaluation Program 7)

Quality Assurance has been placed parallel to the measure of program success.[6] QA applies to both the program and the project level.[7] At the program level, the key questions include the following:

[5] British Columbia, Business Process Flow possibilities for the RSMP
[6] British Columbia, FREP Monitoring and Evaluation Strategy 10

- Are the program objectives being met?
- Is the Province receiving value for the resource allocated to FREP?
- Are monitoring and evaluation results valuable and being used?

Quality Assurance at the project level covers all aspects of monitoring and evaluations, including indicator and protocol development; data collection, management, and analysis; and reporting, reviewing and approval processes.

Embedded in the main objective of FREP is the concept of continuous improvement,[8] which forms not only the basis of forest management in British Columbia, but also powers many business processes. Continuous improvement conforms to the ideas of quality management; moreover, it closes the loop by linking evaluation results to the FRPA and its regulations, standards, practices, and policies. Continuous improvement occurs at two levels: district/regional and regional/provincial. At the district/regional level, continuous improvement is practiced by communicating the results of resource stewardship monitoring directly to forest licensees, professionals, consultants, and district managers. This enables the refinement of local practices and the resource value objectives are achieved. On the regional/provincial level, the results of evaluations and resource stewardship monitoring lead to development of recommendations for refining legislation, policies, and guidelines.

1.4 FREP Quality Assurance Framework Deliverables

This background paper, which is the foundation for the FREP Quality Assurance Framework (QAF), reviews the literature, studies the best practices, and provides recommendations to FREP QAF. However, the implementation strategy and quality control protocols make up FREP QAF.

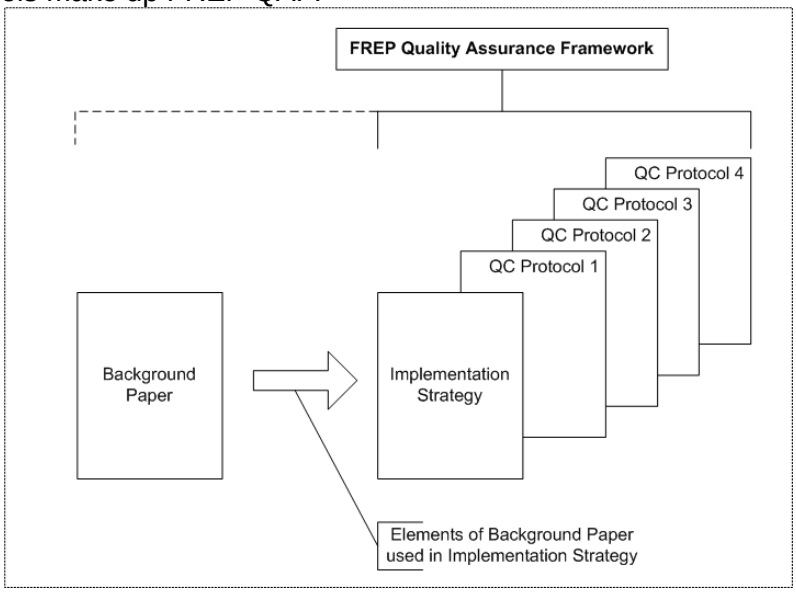

Figure 2. FREP QAF deliverables.

[7] The program level stands for the overall management of the program structure and framework, the project level refers to the individual evaluations and monitorings. Please see Table 1 for detailed program and project components.

[8] British Columbia, The FRPA Resource Evaluation Program 6.
FREP Monitoring and Evaluation Strategy 9.
Activities at the Regional and District Level 7.

Figure 2 shows the deliverables for FREP Quality Assurance Framework. Extracting elements from this background paper, the implementation strategy report will lay out a schedule for the development and implementation of quality requirement, quality metrics, and selection of tools and techniques. Once the requirement and metrics for quality are developed, each quality control protocol will specify the quality control mechanism to achieve or to maintain the desired level of quality.

1.5 What Is Quality?

Quality, according to the International Standard for Quality, is “the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs”(ISO Definition). According to this definition, quality can be seen as follows:

Transcendent
According to the transcendent view, quality is synonymous with “innate excellence.” It is both absolute and universally recognizable, a mark of uncompromising standards and high achievement.

Product-Based
Quality is a precise and measurable variable. Differences in quality thus reflect differences in the quantity of some ingredient or attribute possessed by a product.

User-Based
User-based definitions start from the premise that quality “lies in the eye of the beholder.” Individual consumers are assumed to have different wants or needs, and the goods that best satisfy their preferences are the ones they regard as having the highest quality.

Manufacturing-Based
Manufacturing-based definitions primarily focus on engineering and manufacturing practices, and identify quality as “conformance with requirements.”

Value-Based
Value-based definitions define quality in terms of costs and prices. Thus, a quality product is one that provides performance or conformance at an acceptable price or cost (ISO Definition).

In the context of this report, two “products” are of interest: FREP framework and structure (intermediate products) as well as the products (final products) that are derived from that structure:

- resource value indicators and protocols
- field data collection and analysis
- reports and recommendations

FREP programs, or components, are defined in Table 1. Simply, we want to achieve more than the “user-based” quality in the FRPA Resource Evaluation Program. We want to achieve the “transcendent” quality that makes the program creditable, valid, and recognized externally.

1.6 Purpose of a QA Framework

In the ISO 8402 book, Quality Assurance is "all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality (ISO Definition)." Quality Assurance becomes a management tool for program quality. The term "Quality Assurance" was coined by George Edwards in 1924, who worked in the Inspection Engineering Department as Western Electric's Bell Telephone Laboratories. Edwards stated "…it puts a man at the head of the quality control program in a position to establish and make effective a company-wide policy with respect to quality, to direct the actions to be taken where it is necessary and to place responsibility where it belongs in each instance" (Harrington 8).

The purposes of the FREP Quality Assurance Framework are to:

- ensure reliability and scientific creditability,
- documentation of Quality Metrics[9] and acceptable quality level,
- achieve targets on quality control for each area – design, field, data/analysis, and report,
- ensure program effectiveness and efficiency,
- ensure data accuracy and consistency, and compatibility to other programs,
- enhance accountability to stakeholders,
- protection for the program against uncertain changes in the future.

(British Columbia, FREP QA Working Group 1)

1.6.1 Quality Assurance

Quality Assurance is more than establishing and achieving standards. The functions of a generic Quality Assurance can also include:

Functions	Purpose of FREP QAF[10]
1. Conformance	Increase reliability and scientific credibility
	Identify Quality Metrics and AQL
	Achieve targets on quality control in each project area
	Achieve provincial data consistency or compatibility to other programs
	Enhance accountability to stakeholders and public
2. Improvement	Identify Quality Metrics and AQL
	Achieve targets on quality control in each project area
	Increase effectiveness and efficiency
	Improve performance
	Enhance accountability to stakeholders and public
	Protect the program against uncertain changes in the future
3. Cost or waste reduction	Reduce cost, redundancy, or waste
	Protect the program against uncertain changes in the future
	Maximize the value for resources provided

One basic function of Quality Assurance is to ensure that the final result conforms to the designated specification or meets a specific target. Quality Assurance, however, can also improve upon previous achievements. This continual improvement process is very

[9] An operational definition that specifically describes, what something is and how the quality control process measures it (PMBOK 189). See Section 5, Quality Requirements.

[10] Purposes are modified from the FREP QA Working Group terms of reference.

similar to the methodology employed in Kaizen and in the cycle of PDCA or PDSA. Furthermore, Quality Assurance can also be used to reduce cost, redundancy, and waste. With many internal constraints and external pressures, programs run by the Ministry of Forests and Range are subject to the “do more with less” reality. Using the appropriate tools and techniques of Quality Assurance one can design mechanisms to produce quality result with fewer resources. Many other organizations that compete not only nationally but also internationally face this reality.

1.6.2 Quality Assurance and Quality Management

The term Quality Management and Quality Assurance are used frequently in this report. This report aims to be a comprehensive guiding framework; therefore, elements from Quality Assurance, Quality Management, and Quality System are integrated. Quality Assurance deals specifically with Quality Metrics, standards, and benchmark. Quality Management deals not only with the determination and implementation of Quality Policy, but also with the overall aspects of designing, planning, organizing, and implementing all quality-related matters. To a certain extent, the elements of organizational structure, responsibilities, procedures, and resources for implementing Quality Management are included in this framework, hence the inclusion of a Quality System. This framework synthesizes the most current quality tools and their applicability to FREP.

1.7 FREP Program and Project Components[11]

As previously stated, the purposes of the FREP Quality Assurance Framework operate on multiple levels. The framework encompasses both the program and its projects. By program, we mean the overall FREP program activities such as project management, communication, publication, and all activities and tasks that all FREP teams conduct collectively. On the project level, these are the individual resource value, indicator, and checklists related to each Resource Value team. However, some activities may overlap and require cross-functional quality management. Different types of training are an example that both the program and the projects require. On the program level, training on quality management, and on the project level, checklist methodology, orientation protocols are required. The framework is also multifunctional. Some activities require enhancement, some require maintenance, and some require reduction. As each program or project component spans its functions, the framework attempts to measure the effectiveness and efficiency stand alone or associated. For example, data analysis should be consistent and efficient. Data analysis and reporting would be standardized using templates.

Many components of the FREP under FRPA can benefit from quality assurance. Using clearly established and well-communicated standards, quality can be assured in components such as meeting, field training, data collection, and data custodianship. In addition, the Quality Assurance Working Group has identified the following components:

[11] For a complete program and project level explanation, see FREP Quality Assurance Model in 4.4.

Table 1 - FREP Components in Relation to Quality Assurance[12]

	FREP Components	QA Activities	QC Indicator	QC Metrics	QC Tool(s)
FREP Team	FREP teams	Terms of reference for each team	Terms of reference	• 100% acceptance • Publish on FREP web	Clear roles and responsibilities matrix and process flowchart Template and examples to teams
		Team membership	Representativeness of the target stakeholder(s)		ID Stakeholders
		Lead	Clearly ID Team leader		
FREP Structure and Framework	EE projects	Project plan/charter		Publish on web	FREWG/JMC/Monitoring Team recommendation
		Project management training			
	RSM	Project plan/charter			
		Project management training			
FREP Management	Communication/ Publication	Website	Info & doc update	% of content up to date	Check sheet
			Focus test	# of focus test	"Voice of the customer" & HOQ
		Reports			
		Extension notes			
		Technical notes			
		JMC			
		Executive report (ODMT+CF)			
		Communication to internal stakeholders			
		Public			
		Industry			
		Region, district			
		Executive			
		Protocols			
		Meetings (agenda, minutes, action items, filing and access)			
	Budget	Value for the money			
	Stakeholder involvement	Stakeholder analysis			
		Consultation process			
FREP Outcomes and Results	Evaluation questions (34)	Priority setting			
	Indicators	Peer review			
		Format			
		Testing			
	Checklists	Peer review			
		Design			

[12] This is a partial listing of the program and projects components. FREP Teams will fill out all columns.

		Testing			
	Training	Meta evaluation			
		Skills and competencies			
		QA training			
FREP Operations	Field measurement	Instrument calibration			
		GPS, electronics			
	Data collection	Accuracy and precision			
	Data management	Data entry			
		Data cleaning and validation			
		Data analysis			
		Data storage			
		Data access			
		Data custodianship/ ownership			
		Data maintenance			
		Record (paper) filing			

To have quality assurance on FREP components identified in Table 1, Quality Metrics and Quality management tools and methods should be developed and applied. However, some FREP components and activities can be ambiguous for quality indicator and quantitative quality metrics to be developed. When objective quality metrics cannot be developed directly, alternative quality metrics should be considered. For example, website, budget, checklists, and site selection are all components that can have quality metrics established relatively easy. The “website” can be rated for user friendliness or rated against the Ministry web page publication standard. The quality for website may be the conformance to the standards, but may also incorporate intuitive navigations and convenience features to users. After all, it is designed to communicate information to the stakeholders. But, for a component such as “Stakeholder involvement,” how does one unambiguously and objectively measure the quality of stakeholder involvement? Is it by the number of times a particular stakeholder attends meetings? The level of resources contributed to the program? Or by the quality of feedback and comments from the stakeholders? There is no easy way to establish measures or develop quality metrics for these questions. In addition, Quality Metrics, or what internally have been considered as quality or fair standard, may not be recognized externally. Therefore, to avoid the notion of “user-based” Quality, a valid external standard should align subjective quality metrics to the objective standard; as a result, the program will provide scientifically valid, creditable, and defensible policies.

2. Summary of Literature Review[13]

2.1 Current Quality Management Systems and Theories

All of the literature reviewed represents the most dominant quality management systems in use around the world. Separate individuals or organizations developed each quality management system for various purposes. For example, quality function deployment (QFD) was developed by Dr. Akao, who first applied QFD to ship building.

To present the lengthy review efficiently, the quality management systems have been summarized in the following tables in terms of their key features, nature of quality control, and applicability to FREP Quality Assurance.

Table 2 - Summary of Quality Management System Key Features

Quality Management System	Key Feature	Limitation	Recommended Use
ISO 19011	• Environmental management system • Auditing practices and guideline • External validation	• Potentially expensive • Auditing may require time and sensitive to stakeholders	• Auditing principles and management • Formal external recognition
NQI – PEP	• Canadian version of the US Baldrige Award • Application to public sector	• Require significant investment and commitment if were to be externally recognized	• Excellence framework for public sector
Kaizen	• Extreme continuous improvement • Embedded PDSA	• Cultural adaptation required in implementation	• Continuous improvement principles and practices
Six Sigma	• Statistical process control • DMAIC[14]	• Training required • Collection of data on quality required	• DPMO[15] and analogy for AQL[16]
Quality Function Deployment	• Design and preventive quality management • Matrix table to coordinate external requirement with internal capacity	• Spend more time in the design phase	• Quality Metric prioritization and planning

ISO 19011 is an auditing guideline with an orientation towards environmental management system. It is also internationally recognized. On the other hand, the National Quality Institute's Excellence Framework or its Progressive Excellence Program has both the Canadian and the public sector orientation to quality management.

[13] See Appendix A for complete literature review.
[14] Define-Measure-Analyze-Improve-Control.
[15] Defect per million opportunities.
[16] Acceptable Quality Level.

Table 3 is an attempt to summarize all the quality management systems in terms of their applicability to FREP. A score of 1 represents an "adequate" to the functions listed on the left column. A score of ½ represents a "weaker" match of the function. And a score of 1½ represents a ''very appropriate" match to the function. A score of 1½ means that the quality management system is designed to perform the exact function specified in the matching column.

Table 3 - Comprehensiveness of the Quality Management Systems

Quality Management System/Functionality	ISO 19011	NQI Excellence Framework	TQM and Deming	Six Sigma	Kaizen	QFD House of Quality
Audit	1					
Statistical control		½	½	1		
Process control		½	½	1½	1	½
Environmental management	1					½
Continuous Improvement	½	1	1	½	1½	1
External recognition	1	1		½		½
Preventive approach						1
Total	3½	3	2	3½	2½	3½

The maximum score is 7½: the higher the score, the more comprehensive the quality management system.

Looking at the total scores, we see that no single comprehensive quality management system will cover all the aspects of quality assurance. Each quality management system demonstrates advantages in some areas, weakness in others. For example, QFD's House of Quality stands out prominently as a preventive approach to quality management. ISO 19011, unlike the other examples, audits practices in environmental management. All the quality management systems demonstrate in various degrees the principles of continuous improvement.

Judging by the scores of each quality management system, the requirements of FREP QA call for a different approach and use of quality management systems. Simply picking a quality management system for use in FREP is not feasible. FREP QAF requires an integrated approach and extractions of the essence of different quality management systems.[17] The tools required will also need to meet different processes. Tools used to enhance data quality will vary from those tools used in training. For example, use of a fishbone diagram to attribute problems of data quality, while check sheet or scorecard monitors can serve as preventive tools. Because some of these tools deal with problem identification, and some deal with finding solutions, while some tools control quality using corrective means or preventive approaches. Nonetheless, some tools are used consistently in various quality management systems. These are common tools that can be applied adaptively. The most common tool that can be applied universally or adaptively is the self-assessment.[18] In the case of the stand-level biodiversity, self-assessment is incorporated into the actual checklist. Using four questions the self-assessment ensures data quality by asking evaluators to:

- acknowledge all fields on the checklist;
- calibrate visual estimates with instrumental accuracy, therefore producing consistency;

[17] Navaratnam and Harris 13.
[18] (See Quality Tools and techniques).

- complete all data recording on site; and
- look for often-missed data about invasive plants, innovative forest practices, and ecological anchors when travelling between plots.

2.2 Quality Management in the Public Sector

2.2.1 Total Quality Management (TQM) terminology

Many perceive TQM negatively and misunderstand it. Often TQM is referred as “a fad, label of the month, rain-dance” (Zairi 6). Zairi believes that the misperception and misunderstanding of TQM is due to improper introduction and implementation. He argues that managers have regarded TQM as a results-driven strategy, but it is really a philosophy of process construction that produces benefit in the long run (7). Zairi also believes that for TQM to be succeed, good training and incorporation of the TQM in the education system are necessary (8).

2.2.2 Definitions of TQM

Deming’s concept on quality management system is frequently termed TQM. It is considered the official and orthodox approach (Swiss 357). Definitions of TQM are many; Dewhurst et al. summarized the definitions from four major groups of academics authors in the field of quality management. They concluded that TQM encompasses the dimensions of:

- top management support
- customer relationship
- supplier relationship
- workforce management
- employee attitude and behaviour
- product and/or service design process
- process flow management
- quality data and reporting
- role of the quality department
- benchmarking

(Dewhurst et al. 266)

Each dimension may represent the use of different quality structures and techniques, but TQM should address most of the dimensions using a holistic management approach to satisfy customer needs or requirements. TQM has always placed customers first, because they are the ultimate determiners of quality (Swiss 357).

2.2.3 Barrier in the public sector for TQM

Many authors have also examined the implementation of TQM in the public sector. But there are barriers to implement TQM in the public sector. First, government agencies and not-for-profit organizations are in competition, just like private companies compete domestically and internationally. Only that the public sector organizations compete differently as they compete for funding, for policies, and for programs. Public sector organizations compete within their organizations and with other organizations (Dewhurst et al. 267). Public sector organizations sometimes operate in a monopolistic condition, but still submit to internal constraints (i.e., budget and human resource) and external pressures (i.e., political scrutiny and public expectations). Therefore, the public sector organizations must observe regulations and product/service quality and price. However, in comparison to the practices of quality enhancement, cost reduction and waste elimination are more attractive to public sector organizations because their customers are not just regular customers. They are immediate and internal stakeholders, secondary stakeholders, and most importantly, the public — the whole society (Dewhurst et al. 268; Redman et al. 30; Swiss 358). Their demands are diverse and the public sector organizations tend to meet legal requirements and standards due to this equity issue (Swiss 359).

Second, public sector organizations mostly produce services rather than products. And services are labour intensive. Services are often produced and consumed simultaneously, making uniformity of output and evaluations difficult. At the same time, public sector organizations tend to focus on the inputs and the outputs. Rarely have public sector organizations focused on the process. Swiss argued that government agencies should have performance indicators on how processes are performed in making the products and services, even with the challenge that process control indicators are difficult to develop (359).

Another barrier to a successful TQM implementation in the public sector is the organizational culture. Dewhurst et al. argued that public sector organizations are conservative, employees tend to "play it safe," thus taking less risk and work to a standards, to rules, regulations, and precedent (267). This makes innovation and implementation of TQM challenging. Sinha, on the other hand, argued that despite of quality management effort in the governments within the last 10 years, the true challenge to implementation is to have a leader for quality — organization-wide (417). Swiss argued that typically TQM requires a strong, uniform, and continuous organizational culture (360). TQM favours royalty and aligned business objectives from suppliers and employees, to top management. This "single mind" organizational culture is exactly what the public sector organizations lack.

Some other barriers, claimed Eskildsen et al., include:

- Inability for public sector organizations to make strategic decisions. Politicians set the strategic goals.
- Public sector organizations need to prioritize which customers or users to serve due to limited resources.
- Limited operating room in aspects of human resource management due to collective bargaining. Limited use of incentives and rewards.

(51)

2.2.4 Empirical studies on TQM and other Quality frameworks

Studies on the progress of TQM in the public sector have indicated that the practices have begun to appear in the United States, Canada, the UK, and other European countries. They are itemized as follows:

- streamlining operations and workforce
- recognising citizens as customers
- instituting business process reengineering and benchmarking
- defining vision, mission, and purpose
- using teams and empowering employees
- delegating authorities
- cutting red tape
- doing more with less
- creating partnerships with communities
- managing by results
- using technology for improved communication.

(Sinha 415)

In a study by Redman et al., quality management in the UK public sector in 1995 seems to be blooming. They surveyed 880 private and public organizations and found half of the organizations have formal TQM programs running, while the rest intended to pursuit in the future (24). The sample showed 52% of the public and 53% of the private

organizations having introduced TQM campaign within the past 5 years. They also found more than 30 techniques in use, principally mission statement, customer satisfaction surveys, quality awareness training, customer needs surveys, customer care training, and quality improvement projects. Some of results of quality management claimed are quality awareness, customer satisfaction, teamwork. But the most significant achievements due to TQM, in both the public and private organizations, are the increase in safety of the workplace and the decrease in absenteeism (27). Managers, however, also feel that TQM is putting for demand on their time and more emphasis on teamwork (29). Redman et al. argued that empowerment enables employees to make managerial decisions, thus place their work under greater scrutiny from customers and from subordinates and senior managers (31).

McAdam et al. compared the different types of quality frameworks in the UK public sector. They have identified the frameworks as follows:

- business excellence model[19] (BEM)
- Investor in People[20] (IiP)
- Charter mark[21]
- ISO 9000
- benchmarking
- balanced scorecard

(McAdam et al. 583)

The study showed that in a sample of 266 public organizations in UK, 68% are using Investor in People framework, 47% are using BEM, and 45% are using Charter mark in 2002 (McAdam et al. 585). Obviously more than half of the sample is using more than just one framework. As a result, McAdam et al. found BEM and IiP are most preferred framework amongst the public organizations surveyed. They also found BEM to be an overall integrative quality framework suitable in the public sector context (594). The empirical study by Eskildsen et al. also confirms that public sector organizations in Denmark are more likely to use the “Excellence Model” as a holistic management model (52). They believed, from their study, the quality frameworks can be sustained in UK’s public sector (594).

2.2.5 Solutions and factors for a successful implementation

In light of the barriers for TQM implementation and some of the progress and trends in the public sector, at least in the UK, authors have offered some solutions. Dewhurst et al. argued that top management commitment is one of the major determinants of successful TQM implementation (268). They argued that top management need to accept maximum responsibility for the product or service. Top management need to provide leadership and to create a vision and organizational values. Top management need to motivate employees and align them to the vision and values (Dewhurst et al. 268).

Dewhurst et al. also argued that the supplier chain management in the public sector needs to apply TQM criteria (269). It is still true that suppliers are selected fairly and

[19] BEM has been applied to the public sector since 1996. It shows causal link between enabling and results-based activities with integrated set of performance measures, both qualitative and quantitative, financial and non-financial.

[20] IiP contains a performance measurement framework and links people performance to organizational outputs as listed by the UK Cabinet Office. Key benefits include increased empowerment, planning, and innovation.

[21] Charter mark has a ten point performance measurement system that encourages and rewards improvement on quality of service.

openly in the public sector. This notion of transparency helps to avoid political expediency, economic survival of companies, favouritism, or fraud (Dewhurst et al. 269). However, the idea of quality is omitted in the whole supplier selection process. The idea of the life span of the product to minimize the cost should be considered in comparison of purchasing the cheapest product (Dewhurst et al. 269). TQM criteria can be combined with competitive bidding so that public sector organizations can achieve value for money within accountability requirements (Dewhurst et al. 269).

Public sector organizations have difficulties implementing monetary incentives and other reward systems due to a fixed budget, union opposition, and the fact that organizations reward seniority and not performance. Therefore, a different motivation or incentive scheme is needed. It is not unfashionable to promote the “social service spirit” and “a sense of public service duty” as the motivation behind quality improvement (Dewhurst et al. 270). Swiss called for a reformed TQM approach to implement TQM in government (360). He argued that reformed TQM approach should have client feedback, an emphasis on tracking performance, the principles of continuous improvement, and participation of the workers (Swiss 360). Navaratnam and Harris, however, called for a mixed use of strategies so that a plan can suit each situation (13). They also endorsed the use of a competent consulting firm to support the improvement process. Or within the organization, an internal group can advise, plan, steer, and support the change process (Navaratnam and Harris 13).

Harwick and Russell, in the “Total Quality Performance Consortium,” present a working model named “Quality Criteria for Public Service” in 1992. Harwick and Russell believed that the Baldrige Quality Award Criteria could be adapted and used in the public service (31). They presented the example of the County of Los Angeles and used the Malcolm Baldrige National Quality Award Criteria as a working model that public services in United States can reference (40).

3. Case Studies and Best Practices

In the environmental monitoring or assessment literature,[22] comparison and pre-post effectiveness study are used frequently to determine the following:

- data accuracy,
- resource value or program effectiveness,
- impact assessment,
- and ecological monitoring.

In this report, the literature examples do not directly address, or at length, the issue of quality management or quality assurance. The literature may discuss QA components or one aspect of quality (such as data quality, information needs, and sample validation), but does not provide a holistic approach to quality assurance in environmental monitoring. Some literature provided legal ramifications and the need for a quality management plan, while others address the methodology to validate accuracy.[23] The U.S. Environmental Protection Agency (EPA) is the most prominent pioneer in quality management in environmental assessment and monitoring. No other jurisdiction has emphasized and operationalized the role of quality management like the EPA.

3.1 U.S. Environmental Protection Agency

The EPA has produced many quality-related documents. At the agency level, it has produced mostly manuals, protocols, and guidelines to quality management. [24] Documents produced at the satellite office level are detailed and customized quality management project plans,[25] practical methods,[26] and training programs.[27]

3.1.1 Framework

The quality management manual produced by the EPA generally establishes the following:

- general quality management principles and core elements of a quality system;
- how to develop a quality system that meets the organization's needs;
- an example or case study of a quality system development

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[22] Oregon, Forest Practices Monitoring Program Strategic Plan 7; State of Alaska, Summary of Monitoring Studies of the Effectiveness of Practices under the Alaska and Resource Practices Act 1990-2002 3; U.S. Department of Agriculture, The Strategy and Design of the Effectiveness Monitoring Program for the Northwest Forest Plan 89;
Washington State, Monitoring Design for the Forestry Module of the Governor's Salmon Recovery Plan 31; Busch and Trexler eds., Chapter 8 – Approaches to Quality Assurance and Information Management for Regional Ecological Monitoring Programs 211; U.S. National Research Council, Ecological Indicators for the Nation 59

[23] Addressed data quality and information management (Busch and Trexler 211).
A framework for ecological indicator selection, data quality (U.S. National Research Council 59)
Accuracy Tolerance as quality assurance (Washington State 31)
Legal acceptance and preparation of quality management plan (U.S. Department of Agriculture 89)

[24] U.S. EPA, EPA Quality Manual for Environmental Programs.
U.S. EPA, The Volunteer Monitor's Guide to Quality Assurance Project Plans.
U.S. EPA, Guide to Quality Systems.

[25] U.S. EPA, Guidance on Quality Assurance Project Plans (QA-G5).

[26] U.S. EPA, Guidance Data Quality Assessment, Practical Methods for Data Analysis (QA-G9).

[27] U.S. EPA, Guidance for Developing a Training Program for Quality Systems (QA-G10).

- tools and methodologies that help in the development of quality system

More importantly, the EPA's quality system follows closely the ANSI/ASQ E4-1994 — the American National Standard Institute and American Society for Quality's "Specification and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Program." EPA's quality system has three levels: the policy and regulation level, the organization and program level, and the project level. All three levels aim to produce "Defensible Products and Decisions." (U.S. EPA, Guidance for Developing Quality Systems for Environmental Programs (QA-G1) 6)
In addition, the EPA's internal policy requires their offices to submit to the following specifications:

1. Conform to the minimum specifications of ANSI/ASQ E4-1994.
2. Identify a QA Manager who reports on quality issues to senior executive leadership and ensures that this QA Manager functions independently of direct environmental data generation, model development, or technology development responsibility.
3. Develop and implement a Quality Management Plan following Agency approval.
4. Provide sufficient resources to implement the quality system.
5. Assess the effectiveness of the quality system at least annually and implement corrective actions based on assessment results in a timely manner.
6. Submit a QA Annual Report and Work Plan for the organization that summarizes the previous year's activities and outlines the work proposed for the current year.
7. Use a systematic planning approach to develop acceptance or performance criteria for all work covered by the EPA Quality System.
8. Have approved QA Project Plans, or equivalent documents, for all applicable EPA projects and tasks involving environmental data.
9. Assess existing data when used to support Agency decisions or other secondary purposes to verify that they are of sufficient quantity and adequate quality for their intended use.
10. Implement Agency-wide Quality System requirements in all applicable EPA-funded extramural agreements.
11. Implement corrective actions based on assessment results.
12. Provide appropriate training for all management and staff to assure that QA and QC responsibilities and requirements are understood at every stage of implementation.

(Guidance for Developing Quality Systems for Environmental Programs (QA-G1) 7)

The EPA has also designed a matrix specification for non-EPA organizations to concur with the quality-related regulations and practices. At this point, only the EPA follows closely the ANSI/ASQ E4-1994 specification, while other organizations such as contractors, federal agencies, hospitals, universities, local governments, non-profit organizations, state governments, and tribal governments follow the 48 Code of Federal Regulation 46 (8). But the EPA agency-wide (internal) quality policy is applicable to its contractors, universities, hospitals, non-profit organizations, and other levels of governments by means of grants and agreements.

3.1.2 Tools and techniques

The following are some of the quality control and assurance tools that the EPA's manual identifies:

- standard operating procedures: protocols to implement quality control and to ensure data quality;

- quality policies that communicate throughout the organizations internally and externally their commitment to quality and what they set out to achieve. More specifically, the EPA specified the quality policy to govern different quality requirement;
- requirements, agreement among parties to recognize the quality policy;
- compliance audit — an internal audit that provides administrative reviews;
- training – the EPA suggests an integrated and on-going training in quality systems for both staff and management. They see training being short term (what and how) and long term (why);
- improvements, embedded in each phase are activities that follow the PDCA cycle;

The EPA's manual indicates the following tools for process analysis and improvement:
- process flow charts
- control charts
- cause-and-effect (Fishbone) diagram
- Pareto charts
- benchmarking
- scheduling tools – PERT, CPM

3.1.3 Applicability to FREP
- Conformity with external specifications such as ANSI/ASQ or ISO 9001 that is embedded in ANSI/ASQ E4-1994.
- Use of multiple phases for developing the quality system.
- Dedication to a report for implementation.
- Development of quality systems and policy for non-EPA organizations.
- Integration in quality system of both management and technical activities for planning and assessment of environmental programs.
- Documentation of QA plans internally for all their projects.
- Existence of QA policy and annual reports on QA.
- Budget for targeted QA resources.
- Creation of independent QA managers.
- Training for staff in QA tools and systems.

3.2 The UN/ECE Task Force on Monitoring & Assessment – Quality Assurance

The UN/ECE Task Force on Monitoring & Assessment is mandated under the Convention on the Protection and Use of Transboundary Watercourses and Internal Lake. For the Working program 1994/1995, a group of designated experts produced a report entitled “Volume 4: Quality Assurance” (Timmerman et al. 7).

3.2.1 Framework

The primary focus of the report was on information needs and requirements. Almost entirely the quality assurance report is focuses on the activities of information flow. In the beginning of the report, definitions on “Quality management” are stated in detail. Terms such as quality assurance, quality, quality policy, quality management, quality control, quality system, and quality loop or spiral are explained so that basic assumptions are communicated to everyone. In comparison to the EPA’s quality management manual, these terms are used in a similar manner, but also applied in their different organizational and project contexts. For example, the EPA regards quality policy as the internal (ANSI/ASQ E4) and the external (Federal code and regulation) quality requirement to be met by EPA and their partnering organizations. For the Task Force, they regard quality policy as:

“The overall quality intentions and direction of an organization as regards quality, as formally expressed by top management.”
(Timmerman el al. 13)

Based on the solid understanding of the definitions of quality related terms, the report puts the focuses on information needs. The report argues that the information needs be defined in the following ways:

1. Information needs should reflect the current policy and involve tactic and strategic considerations, thus national and international laws and agreements are the first and major sources for information needs.
2. Decision-makers have the responsibility to define information needs as this links to accountability.
3. Information needs should be quantified so that measures can be linked to management practices in natural resources.

(Timmerman et al. 20)

Some other areas that the Task Force place quality assurance on are areas: monitoring strategy, sample collection, laboratory analysis, data handling, data analysis, reporting, and information utilization.

3.2.2 Tools and techniques

- The report endorses the use of various type of control charts
- Quality assurance follow closely the principle of PDCA/Shewhart cycle
- Quality control in sampling

3.2.3 Applicability to FREP

- Quality assurance – general requirement, organizations and management, quality system, quality audit and review, staff, equipment, measurement traceability and

calibration, methods, accommodation and environment, handling of calibration and test items, records, test reports, contracting, and outside services.

- The nature and sources of analytical errors. For example, systematic errors could be interferences such as extreme weather condition, wildlife presence, and biased calibration on estimates and on instruments.
- Defining analytical requirements – accuracy targets
- Performance testing – systematic error, random error, precision tests
- Statistical considerations – randomization, rounding of data, calculating analytical results, and estimating precisions.

3.3 Principles and Practices for Quality Assurance and Quality Control

The report Principles and Practices for Quality Assurance and Quality Control was prepared by the U.S. Department of the Interior and the U.S. Geological Survey, in cooperation with the Federal Highway Administration. The report stated that QA is more important in environmental sciences than traditional laboratory sciences (Massachusetts 2). The report argued that the cost of providing QA and QC is substantial; however it will be more than repaid by the value added to the data (Massachusetts 2). The report used the terms Quality Management (QM), Quality Assurance (QA), and Quality Control (QC) together to form a quality system for a water-quality monitoring project.

The report also refers the Quality Management Plan (QMP) to the specification of the ANSI/ASQ Standards E-4, 1994. The QMP may be audited so it can be certified with ISO 19000 standards. They argued that certification to ISO 19000 provides public confirmation (Massachusetts 5).

3.3.1 Framework

The report positioned the role of QA in planning and the role of QC in execution. And each of the steps in the project quality assurance cycle is subject to QA and QC. The project quality assurance cycle is as follows:

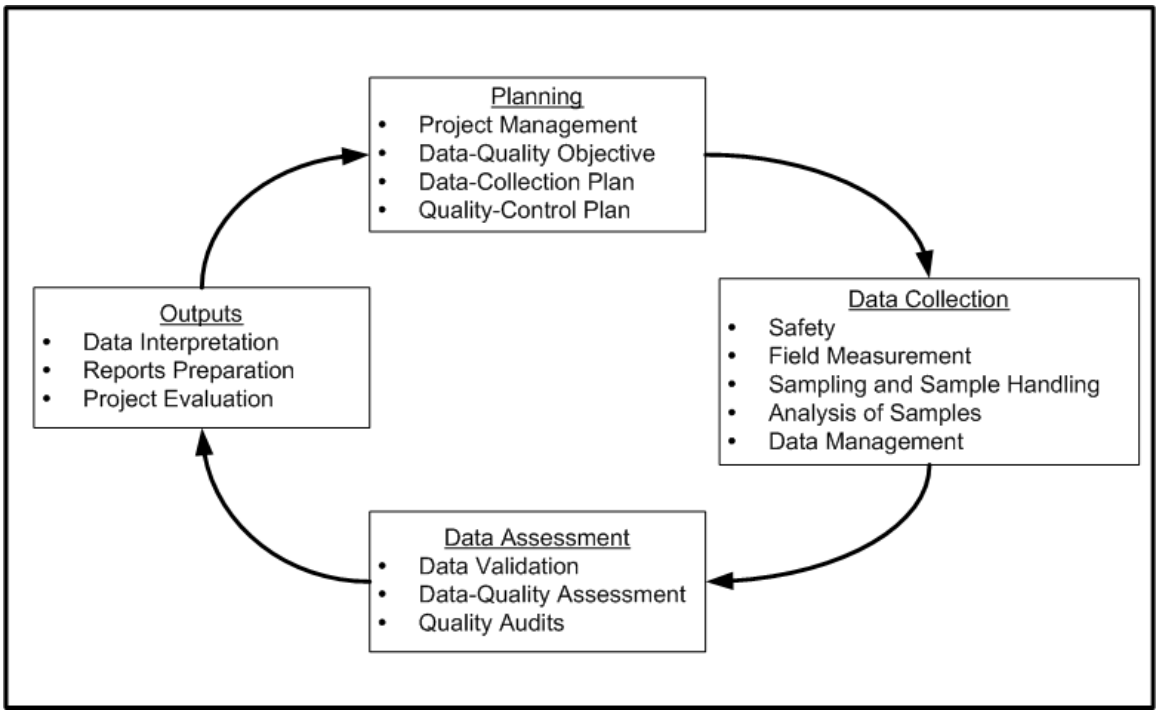


Figure 3 – Project quality assurance cycle.

(Massachusetts 6)

The report also identified five attributes of data quality; they are adapted from the US EPA. They are:

- Precision; the extent of random differences among replica measurement of the same property.

- Accuracy; the degree to which a measured value (or mean of measured values) agrees with the true value of the measured property.
- Representativeness; the extent to which a sample or set of samples possesses the same properties as the body from which it is derived.
- Completeness; the percent of the planned data that was actually obtained.
- Comparability; the degree to which different data sets represent environmental conditions in the same way and, thus, can be compared to determine changes in environmental conditions over space or time.

3.3.2 Tools and techniques

Some of the tools and techniques endorsed by the report are:

- Data collection plan
- Quality control plan (for sample design and handling)
- Data management (storage, maintenance, and retrieval)
- Quality audits
    - Whole-system audits – review that assess the conformance with the project QA plan
    - Data collection process audits in the field
    - Audits of the data, including QC data
- Project evaluation (self-evaluation and used for continuous improvement)

3.3.3 Applicability to FREP

- Data-Quality Objective: goals of the project should be clearly defined, so that the quality, quantity, and the type of data required to fulfill the project goals can be determined (Massachusetts 7).
- Data management: all data entry and validation are logged with date and name(s). There are always back up copies if data set is accidentally erased or altered.
- Safety: Availability of safety equipment, and all personnel must be trained in the equipment use. A plan to organize the responsibilities and implementation of safety should be developed.
- Data quality assessment: The use of 5 data quality attributes to scrutinize data outlier and other reasons for anomalies.

3.4 Minnesota Pollution Control Agency – Quality Management Plan

The Minnesota Pollution Control Agency (MPCA) quality assurance policy is as follows:

'The MPCA promotes an integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that all processes, items, and services are of the type and quality needed and expected by the stakeholder.'

(Minnesota 11)

The MPCA Quality Management Plan believes that "a fundamental component of quality work is the collection of data that are scientifically and legally defensible" (Minnesota 11).

3.4.1 Framework

The Quality System of MPCA can be displayed in diagram below:

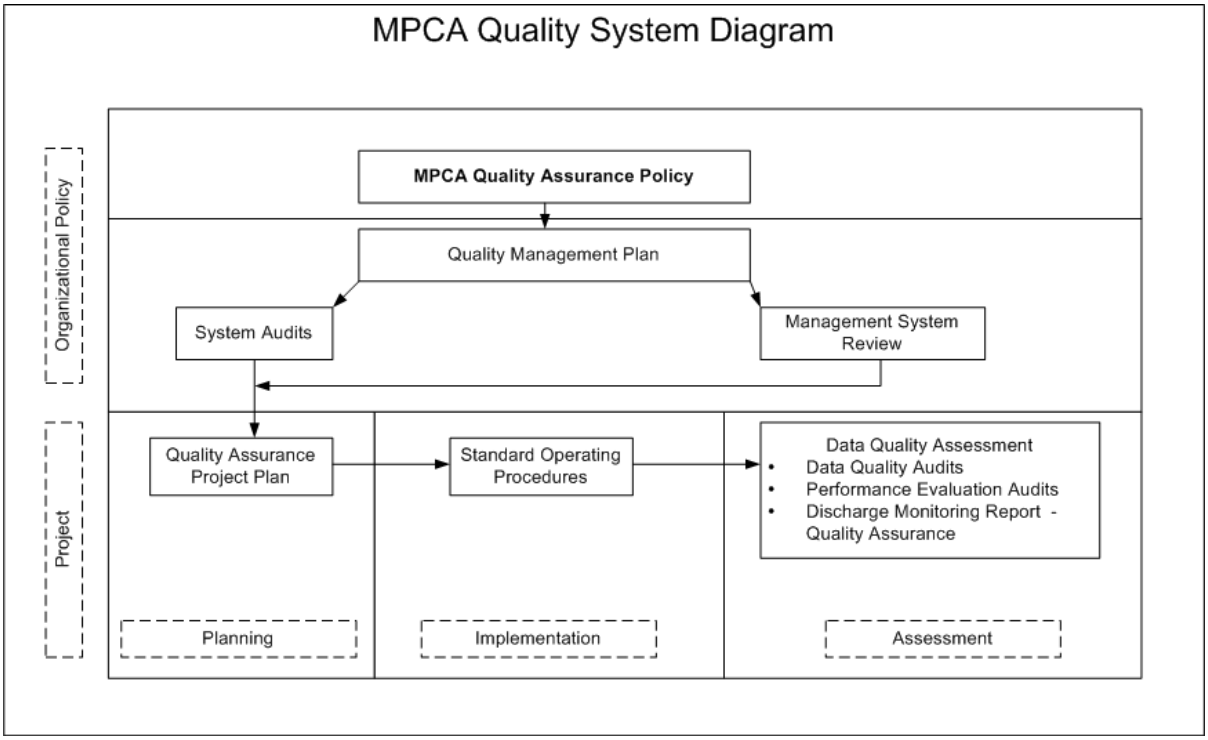


Figure 4 – MPCA Quality System Diagram.

(Minnesota 19)

In addition, MPCA's quality assurance process and documents include:

- Agency Quality Management Plan (QMP)
- Program Quality Assurance Project Plan (QAPPs)
- Sampling and Analysis Plans (SAPs)
- Management System Reviews (MSRs)
- Work Plans (WPs)

- Request for Response Action (RFRA)
- Standard Operating Procedures (SOPs)
- Field Manuals
- Data Quality Objectives (DQOs)
- Technical Assessments
- Data Quality Assessments (DQAs)

3.4.2 Tools and techniques

Some of the tools and techniques identified in the MPCA QMP are:

- Management System Review, it is an internal review by the MPCA Executive Team. Every 5-year cycle of each QMP revision, the internal MSR will evaluate the internal management structure to determine whether the quality system is effectively facilitating the implementation and the achievement of the policies and goals (Minnesota 20).
- System audits, they are corrective actions when a significant problem is identified or suspected. They are mostly used in certified laboratories (Minnesota 21).
- Quality Assurance Project Plan, it is the fundamental quality assurance document to the MPCA. It follows closely the US EPA QA guidelines that every project involving environmental data used for decision making must have an approved QAPP.
- Standard Operating Procedures typically has these basic elements:
  - Scope and application
  - Methods summary
  - Quality control requirements
  - Equipment preparation
  - Calibration procedures
  - Necessary apparatus and materials
  - Safety procedures and precautions
  - Equipment list
  - Stands and reagents
  - Procedures
  - Calculations
  - References
- Personnel Qualification and Training

3.4.3 Applicability to FREP

Two processes that might provide reference to the FREP QAF:

1 “Monitoring – Data – Information” Cycle

This is a process that MPCA follows to identify and to fill the information needs. This information ultimately helps to restore or to protect the integrity of Minnesota’s resources (Minnesota 49).

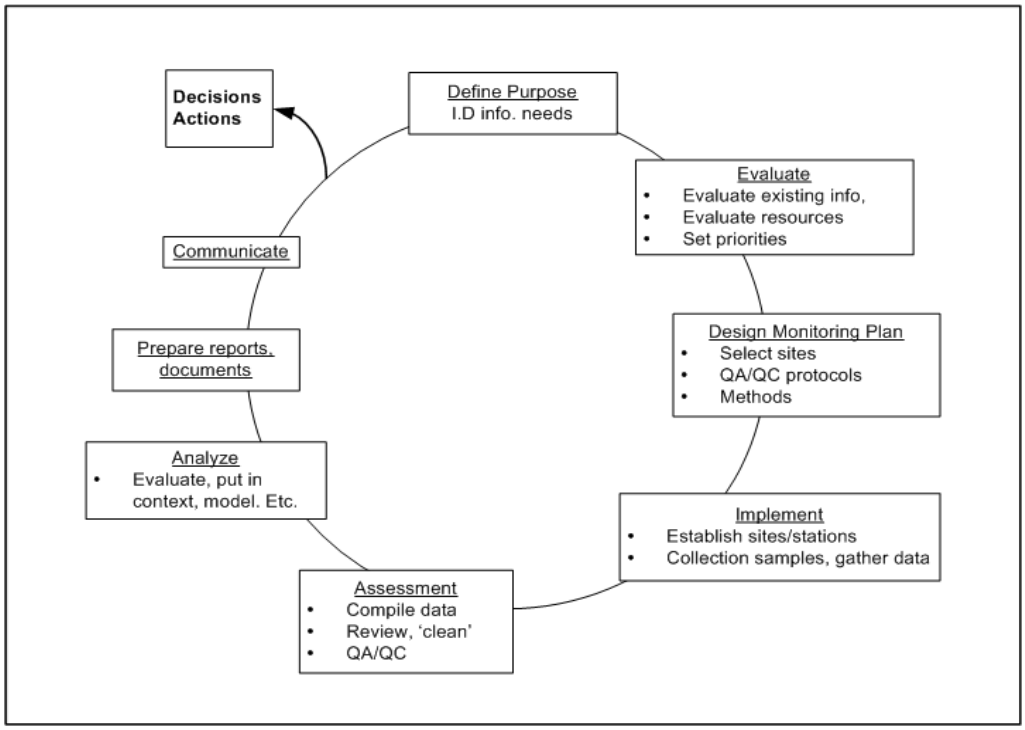


Figure 5 – The MPCA monitoring – data – information cycle

(Minnesota 49).

2 Quality Improvement – process (DMAIC and DMADV Models)

The MPCA uses two Six Sigma processes to improve their quality. They are:

Table 4 – The Two Six Sigma Models

	DMAIC Model (Improvement Project)		**DMADV Model** (Design Project)		
PLAN	Define	-Form the team -Establish the focus	Define	-Form the team -Establish the focus	**PLAN**
	Measure	-Examine the current situation	Measure	-Examine the current situation	
	Analyze	-Analyze the cause	Analyze	-Analyze the cause	
DO	Improve	-Act on the cause	Design	-Ensure that the process is efficient and effective by meeting key customer needs	**DO**
STUDY		-Study the results		-Determine critical quality needs of customers	**STUDY**
ACT	Control	-Standardize the changes -Draw conclusions	Validate	-Verify that the process is performing as desired	**ACT**

(Minnesota 93)

3.5 The State of California Quality Assurance Management Plan for Environmental Monitoring Programs

The Quality Assurance Management Plan of the State of California is a collaborative effort of the Department of Water Resource and the Resources Agency. However, it was mainly developed for the use of the Department of Water Resource (DWR).

3.5.1 Framework

The QAMP addressed the following areas:

- Organization and Management
- Roles and Responsibilities
- Personnel Qualification and Training
- QA/QC Requirement for Contracted Services, Equipment, and Supplies
- Documentation and Records
- Data Reporting, Reduction, Processing, and Storage
- Planning and Implementation of Environmental Monitoring Projects
- Assessment and Response
- Quality Improvement

3.5.2 Tools and techniques

- Quality Control Committee; the committees made up from members of each offices and divisions. It oversees activities such as quality assurance technical documents, QA project plans, sampling and analytical procedures, performance of monitoring equipment, and quality control of data management.
- Quality Assurance Officer is responsible for the overall QA/QC program, who chairs the committee and reports to the director.
- Program Managers are responsible for the environmental monitoring programs. Each Program Manager is in charge of implementing applicable QA/QC practices in their environmental monitoring program.
- Quality Control Coordinators are placed within each environmental monitoring program designated by the Program Manager. Quality Control Coordinators are responsible for the development of data quality objectives and SOPs.

Some of the assessment tools for environmental monitoring programs include:

- Management System Reviews
- Surveillances
- Quality Audits
- Performance Evaluations
- Peer reviews and technical reviews
- Readiness reviews
- Data quality assessments
- Quality Improvement (Prevention in planning and implementation, detection and correction, review and identifying opportunities for improvement)

(California, Quality Assurance 21)

3.5.3 Applicability to FREP

- Quality Objective and Criteria for Measurement Data

Quantitative QA Objective	Qualitative QA Objective
Method Detection Limits[28]	Representativeness
Precision	Comparability
Accuracy	
Completeness	

(California, Guidelines 10)

- Calculation of Data Quality Indicators for quantitative QA Objective

In the appendix of the QAMP are examples of the calculations for Data Quality Indicators. Shown below is an example of 'Completeness':

'Completeness is a measure of all information necessary to validate a scientific study. A useful way to evaluate completeness is to compare the project objectives with the data acquired.'
(California, Guidelines 56)

To use this indicator in the FREP QAF, we can compare the number of sites selected and number of sites actually assessed.

Formula:

%C = (V/T) * 100

Where %C = percent completeness
V = number of measurements judged valid/number of sites assessed
T = total number of measurements/number of sites selected

[28] The lowest possible concentration of an analyte that can be detected in a sample or a blank with a 99 percent confidence level.

4. Conceptual Framework for Quality Assurance

Equipped with the knowledge from a literature review and the experience from the case studies and best practices section, this section puts FREP into the framework of quality assurance. Extracting the appropriate ideas from various quality management systems, the concepts of quality metrics, training and responsibility, and total cost of quality are explored on both the program and project levels. In addition, this section introduces the FREP quality assurance criteria that are to be used in the development of quality requirements and metrics.

4.1 Generic Quality Assurance Model

In section 4.1, the generic Quality Assurance Model is explored on the program and the project level. Each level is assessed for its objectives and specific requirements/needs.

4.1.1 Generic Quality Assurance Model – objective and information need

A model is required to establish general parameter surrounding the concept of Quality Assurance. Below is a generic Quality Assurance model used by most current Quality Assurance programs (Timmerman et al. 16). First, an objective is required. For Quality Assurance, the objectives are mostly related to the derivation of quality results. However, for programs and projects, the objectives can include cost saving, higher performance, better profit, and increasing efficiency. The word “Quality” can be expanded to many levels and many functional meanings. This is one of the key challenges with quality improvement. Nonetheless, once the objectives are clearly defined, identification of the information needs is the next step. Definitions need to be clear, well communicated and understood so that there is no confusion over terminologies. For example, what is water quality? Many experts have different views and standards to define the quality of water, hence the importance of commonly understood and agreed definitions.

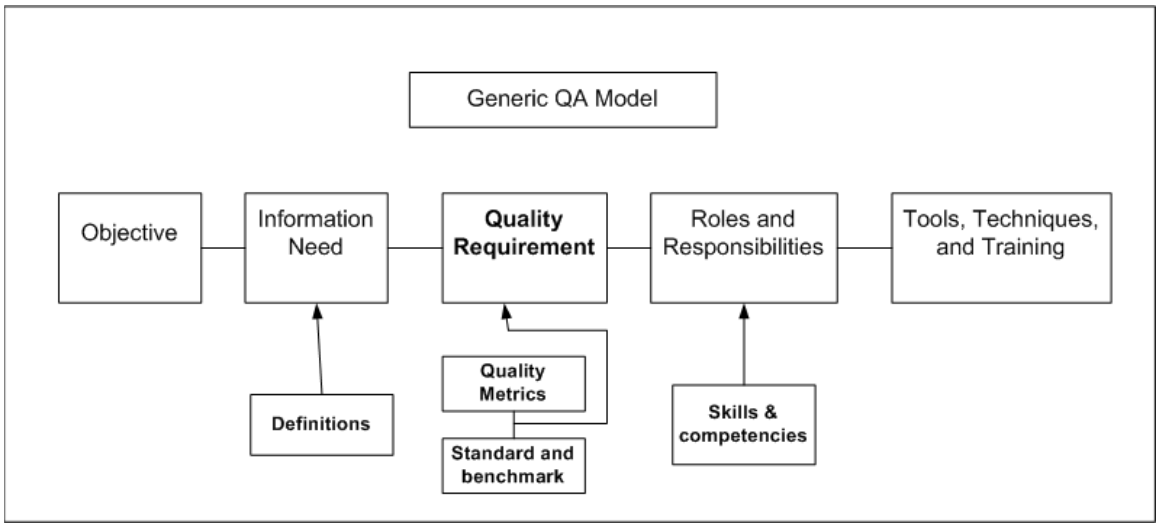


Figure 6 - Generic Quality Assurance model.

(Modified from Timmerman et al. 16)

Information needs should also reflect the current policy and involve tactical and strategic considerations. Most importantly, information needs should be based on Acts or legislation (e.g., FRPA and related legislation). Furthermore, the information needs should be quantified. The UN/ECE Task Force on Monitoring and Assessment considers the following approaches for defining information needs:

- *The effect approach: there can be an adverse effect of some kind that has to be reduced within a certain period. The element of relativity can be used here.*
- *The source approach: there are sources that cause adverse effects. These sources have to reduce their effect, e.g., by reducing their loads on the environment. This is closely related to the effect-approach.*
- *The achievement approach: there is a goal to be achieved within a given time period. This approach gives an impression of how far the intended actions will be after some time. 'The salmon back in the river Rhine' is an example of this approach.*
- *The background approach: "there may be no change in" a given parameter or "the river has to be back in its original state by" a given time. This is usually comparable to the ecological function of a water-system.*
- *The function approach: the water-system has to fulfill a specific function, e.g., be fit for swimming.*

(Timmerman et al. 21)

These approaches to determine information needs are particularly useful for FREP and other environmental monitoring program. For example, resource value team can use an approach so that some predetermining threshold establishes what is environmentally sound and what is not. Riparian evaluation, as one practicing example, uses number of species of invertebrates to determine a stream's functionality. This is the function-approach that the stream system is fit for at least 4 species of invertebrates to live in. In addition, approaches may be interrelated so that different perspectives cover the specification of the information needs.

4.1.2 Generic Quality Assurance Model – Quality requirement

The essence of quality assurance or what defines quality assurance numerically is the quality metrics. Quality metrics specify the standard and benchmark for quality. Without these quantitative measures, we will be wandering in the dark, cluelessly searching for the existence of quality. A section of this report (see Section 5, Quality Requirements) deals with Quality Metrics and Requirements.

4.1.3 Generic Quality Assurance Model – Roles, responsibilities, tools, techniques and training

In a quality system, "functionary"[29] describes roles and responsibilities of each person. In this concept, a formal validation or appraisal system checks the skills and competencies required for each task. For example, Adam is a research officer who meets the skill and competency requirements for "Process mapping." His task, according to the table, is to map the field data collection process within the designated dates.

[29] Functionary – a task, function, or job incumbent.

Table 5 - Example of Functionaries in Quality System

Name	Functionary	Project	Tasks	Start-End Date	Skills Required	Other Tools
Adam Smith	Process mapping	Soil	Field data collection process mapping	April 1 2005 – May 15 2005	Process mapping,	Microsoft Visio
Beth Collins	Internal audit	Riparian	Internal process audit	May 23 2005 – Dec 1 2005	ISO 9000:2001 auditing certified	

However, this is a simplified presentation of a functionary's role and responsibilities. A set of tools and techniques should be identified for tasks and projects in advance. Training, used as a complement to other work, can improve the use of the tools and techniques. For Adam, the tool he needs is Microsoft Visio, the techniques and perhaps the training he requires is process mapping. He may be disciplined in Six Sigma's SIPOC[30] and embedded in the map are the specific quality and work measures. He can use the process map to run simulations so that improvements can be made (iSix Sigma)

4.2 Cost of Quality and Cost of Quality Management

One fundamental question that the quality program needs to answer is the justification for cost: Does the benefit of quality program outweighing the cost of poor quality? When does the program determine that we have achieved the quality level we can afford?[31] Or can we even achieve higher quality and at the same time reduce costs? By weighing the economic efficiency on quality, the program should consider the following:

[30] SIPOC – Supplier – Input – Process – Output – Customer. See http://www.isixsigma.com/library/content/c010429a.asp for more information.

[31] In Gryna's opinion, optimum point of the total quality cost curve is at the 'zone of indifference' where failure cost is about 50% and prevention is about 10% of the quality costs. Projects in this situation are worthy of pursuing (Juran and Gryna19).
Rust et al. justify the optimum expenditure level on quality improvement by studies on company's market share, customer satisfaction, managerial judgement, and other internal data (67). They termed this approach the "return on quality" (ROQ) (59).
Dow et al. argue that TQM does not have a complete positive relationship with quality outcome. They argue that only with combination of 'soft' quality management practices will result in better corporate performance (23). "'Soft" means human resources related management practices, such as executive commitment, open organization, and employee empowerment.
Wilson, in *Examination of the Economic Benefits of ISO 9000 and the Baldrige Award to Manufacturing Firms*, discovers the financial gains from organizational improvements. He argues that financial gains come from a long-term quality improvement effort, rather than immediate monetary benefits (45).

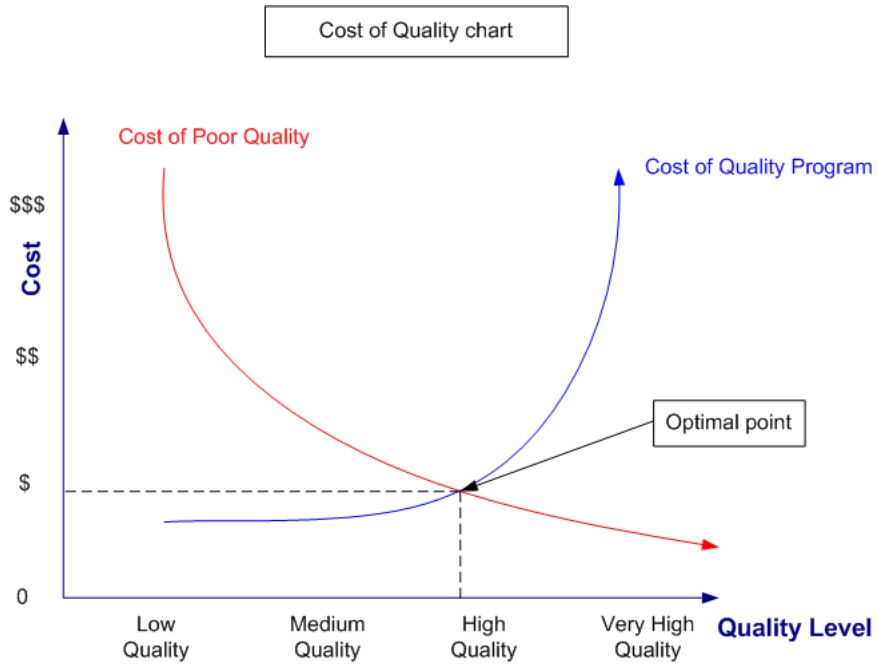


Figure 7 – Balancing cost of quality program and of poor quality.[32]

The "cost of quality deficiencies" is at highest when quality is low. The steepness of the curve is due to the cumulative effect of the cost of poor quality, that is, low quality easily leads to very low quality and creates higher poor quality cost as time passes (without intervention of the quality program). As the "cost of the quality program" achieves very high quality, the cost is much higher than the cost of the previous quality level. The case may well be that an organization can no longer afford to achieve higher quality results because it is not generating enough economic returns. The law of diminishing returns applies here, hence the steep curve at the end. The optimal point represents our target. We should have the ability to achieve high quality and at relatively low cost. In return, "cost of poor quality" will also be minimized.

Similar to the "do more with less"[33] motto, our target is to be effective and efficient with a limited amount of resources so we can achieve the highest quality level possible. Using many resources while achieving low quality is ineffective, but so can the use of many resources to achieve high quality. Using few resources to achieve a low quality level contradicts the purpose of the quality program. As a result, the quality improvement effort is wasted (see Figure 5).

[32] This is a theoretical justification for the appropriate use of resources in the minimization of the cost of poor quality.
[33] Navaratnam and Harris 11; Sinha 414; Leslie and Tilley 1.

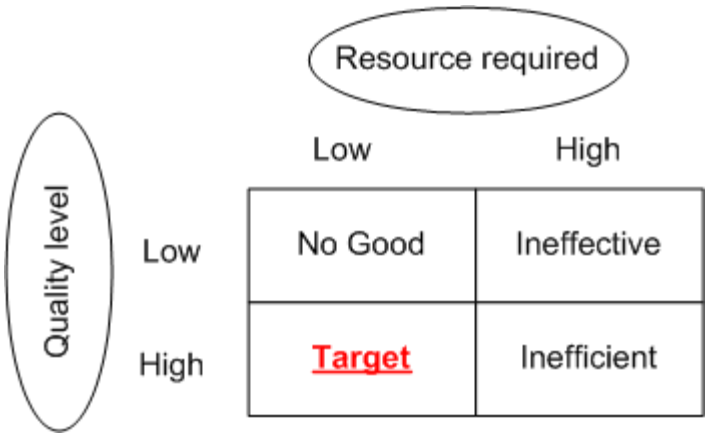


Figure 8 - Resource vs. quality level.

Sometimes, cost of quality (COQ) is confused with cost of poor quality.[34] According to Philip B. Crosby's definition, cost of quality is the "price of conformance and non-conformance," whereas "cost of poor quality" only refers to the "failure" costs. Therefore cost of quality is the sum of prevention, inspection, and failure[35] costs.

The total cost of quality can be summarized as:

Cost of quality = All costs incurred to achieve quality
Cost of quality = Prevention + inspection + failure

Where prevention and inspection are known as the costs of conformance, they are the costs of "making sure." Inspection and failure, on the other hand, are the costs of non-conformance; they are the costs of "getting it wrong" (NQI, Quest for Quality 7).

[34] Harrington 1.
[35] Beecroft 4; NQI 7; Kaner 3; Juran and Gryna 4.

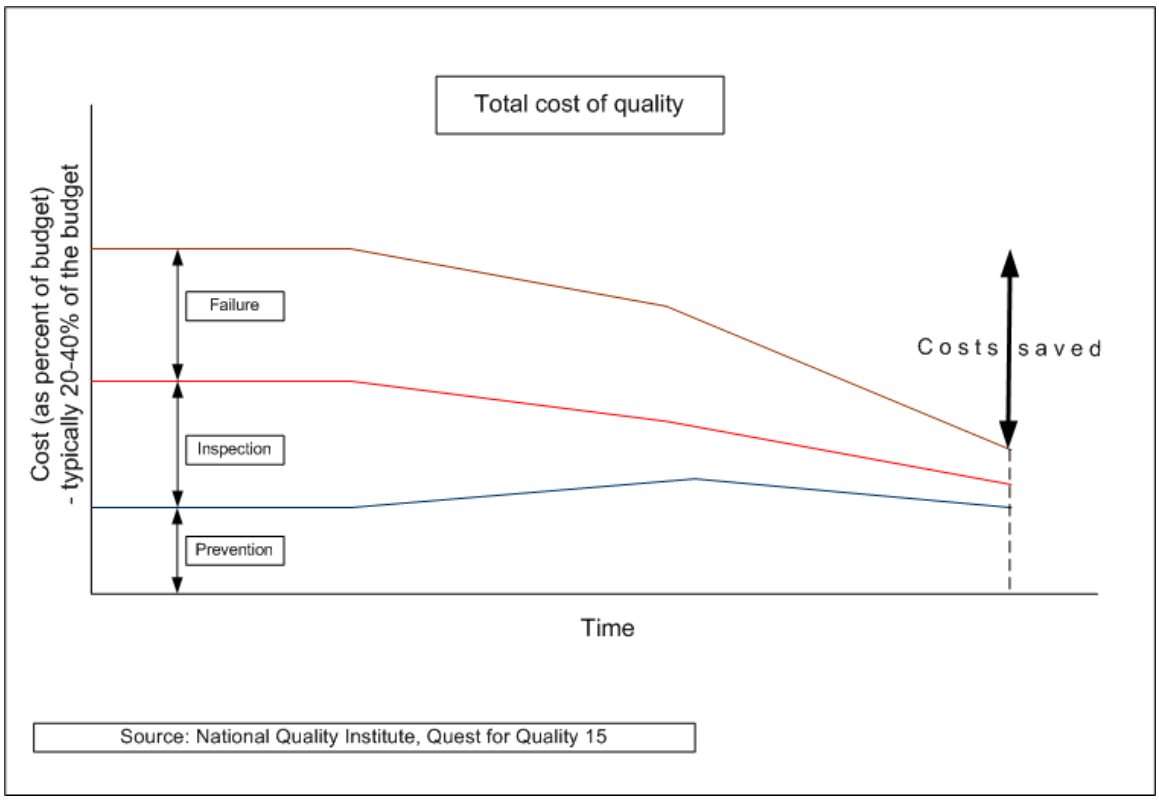


Figure 9 – The cost of quality[36].

Figure 9 is a graphical presentation of the total cost of quality. In the beginning, most of the organizations start with a higher cost proportion for failure and inspection. The costs of failure and inspection constitute the cost of bad quality or non-conformance costs. Almost all organizations devote less effort in the prevention cost, and as the organizations begin to realize the importance of preventive approach to quality, they make this prevention investment, which causes the prevention cost to rise. At the same time, failure and inspection costs will drop significantly. Finally as the quality level or target has been achieved, prevention cost will drop incrementally to only maintain the level of quality achieved. Meanwhile, the failure and inspection costs will continue to decline. The costs saved will be the decreases in both failure and inspection costs plus the increase in prevention cost. Therefore the formula can be written as:

△ (↓) Failure + △ (↓) Inspection + △ (↑) Prevention
= Costs saved

[36] For more detail see www.nqi.ca

4.3 Program-Level Model – Quality Assurance

The highest priority and goals relate to the business map of the FRPA Resource Evaluation Program, Legislation, and the Act. The program objectives are to improve forest management, and the vehicle is improved policy, practices, and subsequent legislation. For this purpose, Quality Requirements should aim to accomplish this important objective. In the program level QA model, almost every aspect of the program, ranging from the project plan, budget, training, communication, stakeholder involvement, framework and structure, to the publications should meet or exceed the Quality Requirements. For example, time management is critical to the project plans. Of the many Quality Criteria, timeliness is about the ability to carry out activities within an appropriate and agreed to time frame. Quality Requirements, however, apply to the program level with different perspectives – that is, not only to use the quantitative Quality Metrics, but also to use techniques of process control to continuously improve. Publications, for example, should go through a series of credible peer reviews and the format should follow the program guidelines and standards while maintaining user-friendliness and accessibility.

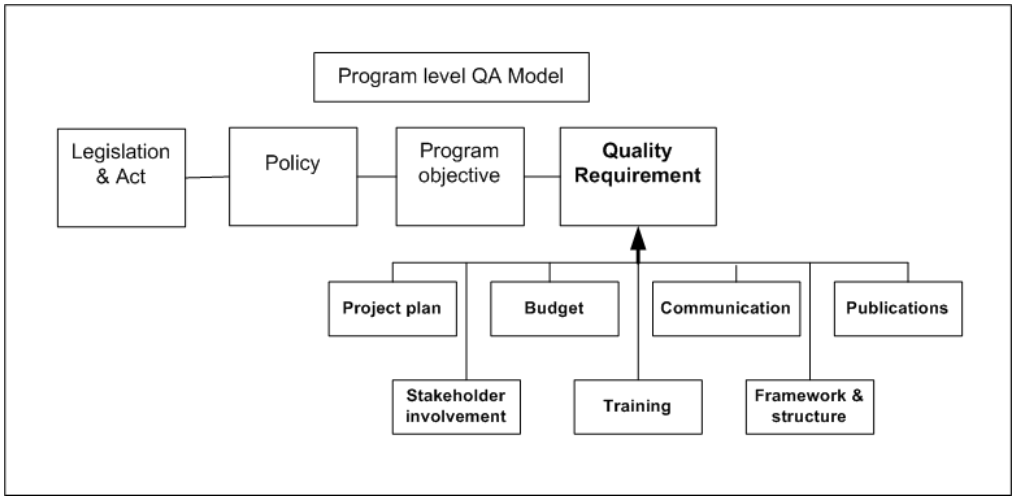


Figure 10 - Program level QA model.

4.4 The FREP Quality Assurance Model

If we inspect closely Quality Assurance at the program and at the project levels, we can observe the linkages and process flow shown in Figure 10. Under the overall program management, Quality Assurance is placed on the program level. Quality Assurance checks on the overall program management for its quality, whereas the Quality Control Protocols check on the project level. At this stage, Quality Control Protocols focus on four major operational areas: design/project, training, data/analysis, and report/publication. FREP QA framework refers to this background paper and the implementation strategy, and QC protocols refer to similar documents such as manuals or standard operating procedures (SOPs).

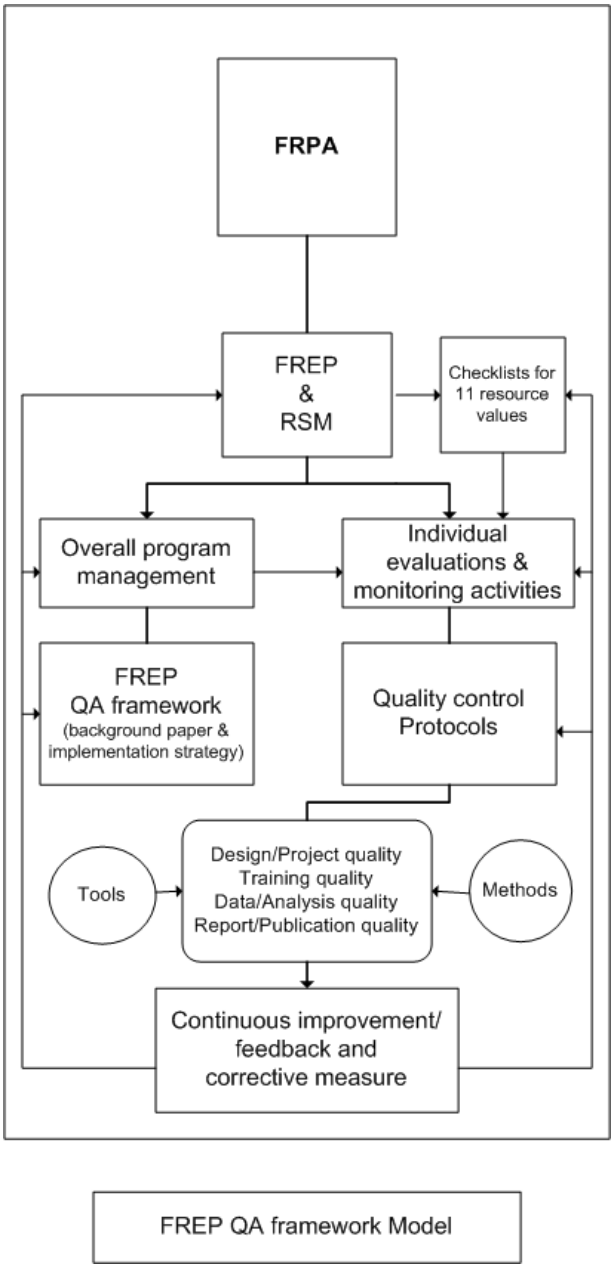


Figure 11 - FREP Quality Assurance Model

4.5 Project-level Model – Quality Control

On the Project level, Quality Assurance is very much involved in the operational and implementation phases.[37] All the processes and activities would conform to a consistent and comprehensive suite of Quality Requirements.

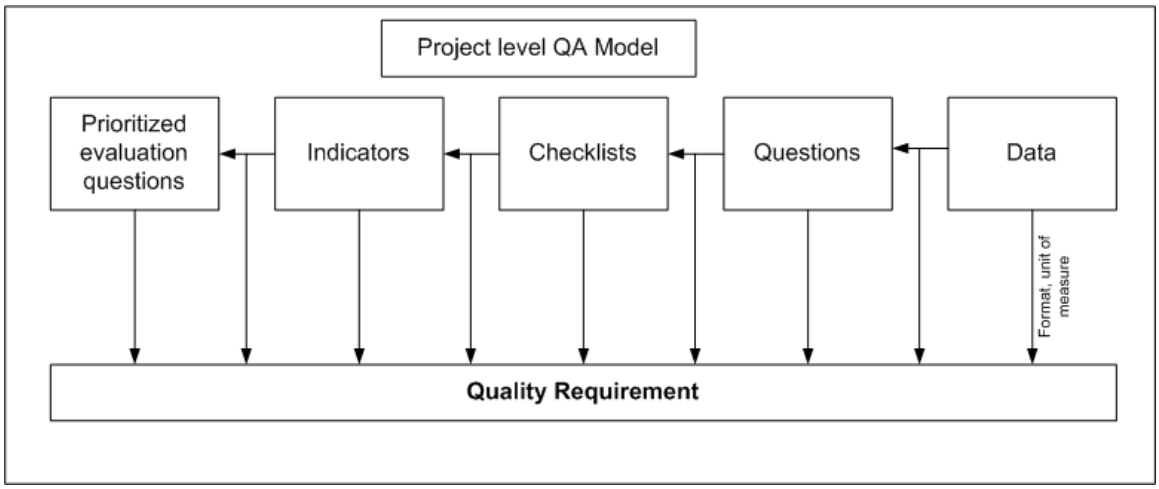


Figure 12 – Project-level QA model.

For example, data should have a consistent format (length, character, etc.) and agreed units of measure. Only when they are internally consistent can that data be used for long-term studies and in cooperation with other Ministries' research and programs. Furthermore, data should be derived from objective measurements. Answer to questions should be recorded objectively. Questions themselves should be subject to Quality Requirements. The number of questions, number of repeated questions (duplicated between checklists), the structure of the question, the design for the answers and responses, and the neutrality of the question itself are all Quality Metrics that measure the quality of the questions.

4.6 FREP Quality Assurance Criteria

Based on a review of the literature including case studies and international best practices, FREP has modified Statistics Canada's QA framework pre-determined hybrid criteria to derive seven Quality Assurance Criteria/principles upon which we will base the development of a QA implementation strategy and the FREP monitoring and evaluation protocols. The seven FREP Quality Assurance Criteria[38] are:

1. Timeliness – the ability to carry out evaluation and monitoring activities, conduct analyses, and produce recommendations and reports within an appropriate (agreed to) time frame.

[37] Hence the term "Quality Assurance" used on the project level is often referred as "Quality Control" so that the annotations of operations are embedded.

[38] Pre-determined hybrid criteria. (Canada, Statistics Canada's Quality Assurance Framework 3; UK, National Statistics – Code of Practice, Protocol on Quality Management 14).

2. Accuracy – the degree to which monitoring and evaluation data, analysis, and results address the questions they are designed to answer.

3. Consistency – the degree to which FREP products and other information conform to standard monitoring and evaluation concepts, including scientific validity and data integrity.

4. Accessibility – the degree to which FREP data, documents, and other publications are accessible and/or easily obtained by identified stakeholders.

5. Interpretability – the usability of FREP information by stakeholders.

6. Value for Money – the degree to which program deliverables, and their contribution to the policy decision-making, are good value for the resources allocated.

7. Fairness and Equity – the degree of fairness in the allocation of FREP resources and in providing opportunities for stakeholders to participate in the consultation and decision-making process.

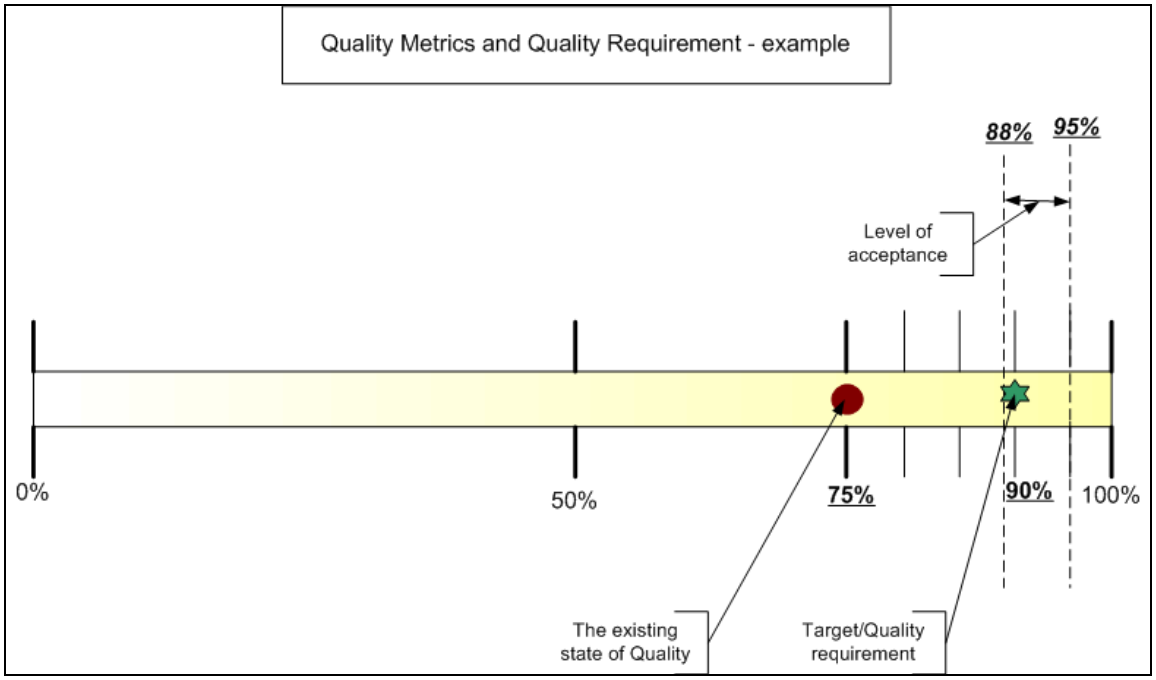
Each Quality Criterion can be expressed in quantitative terms and in the process of continuous improvement. To illustrate, let us look at the example of timeliness. Time is almost always expressed by date or hours. Naturally, the ability to complete assigned tasks on time becomes the legitimate metric. On the program level, we can measure how many times each program activity meets the deadline, as well as how many times the activities met the deadlines. What are the activities that did not meet the deadlines, and are there content similarities in these activities? How far off (hours or days) are these activities from the deadlines? Are there internal and external factors we can control or reduce so that we can meet deadlines? These are all the quantitative metrics and process-oriented questions posing as Quality Requirements on timeliness. In the Section 5 (Quality Requirement) of this report, we will adopt the Goal/Question/Metric paradigm for the development of Quality Metrics. The FREP Quality Assurance Criteria will serve as the preliminary goal and as the basis for metrics development.

5. Quality Requirements

5.1 Components

- Quality Metrics
- AQL – Acceptable Quality Level

Quality Metrics are defined as “An operational definition that describes, in very specific terms, what something is and how the quality control process measures it” (PMBOK Guide 189). Serving as the foundation in Quality Assurance, Quality Metrics exhibit the state of the Quality. The task of Quality Requirements is to establish targets and set parameters called “level of acceptance” or AQL – Acceptable Quality Level.



(A very relaxed Quality Requirement is shown @ 90% Quality Level)

Figure 13 - Quality Metrics and Quality Requirement.

Using a Quality scale ranging from 0 to 100%, 0 being the lowest quality level and 100 being the highest quality level, our state of the quality lies at 75%. Using a checklist as an example, where 25% of the questions on the checklist may be incorrectly completed. They may miss the format, unit of measure, or just be left blank and unacknowledged. As a result, the data are incomplete and their reliability is questionable. To resolve this, the quality team has set a target of 90% quality level as the first attempt to improve. By using quality concept training, self-assessment on the checklist, audits, and other tools, data can be recorded on the checklist consistently. Measuring again the level of quality, we find a 13% increase in quality level, making a final 88%[39] quality level. However, we

[39] 75% + 13% = 88%

are still not meeting the 90% target. Therefore, we will identify the cause and problems so that we can approach a higher quality level.

To illustrate further using a practical example:
We have a total of 120 samples. Out of the 120 samples, 90 are filled out correctly, so we have a quality rating (90/120 = 0.75) of 75%. However, our target is to achieve 90% defect free from the samples. Also, if we were to set 90% as the benchmark, we could establish a level of acceptance; in this case, it ranges from a lower level of 88% to an upper level of 95% (see Figure 11). The level of acceptance is designed to tolerate quality rating due to constraints such as lack of resource, time pressure, and difficulties accessing to field data and other unforeseeable circumstances. This flexibility allows anomalies originating from design, data collection method, or ambiguous and uncontrollable factors. However, a level of acceptance that is too wide and/or too relaxed the quality requirement could easily compromise the continuous improvement effort. It is the maximization of limited resources to the point where quality is best achieved.[40] Setting the level of acceptance towards the higher quality rating as demonstrated above will promote higher quality.[41] But our current state of 75% quality is far from the 90% target. Therefore we need to use techniques such as training, root and cause analysis, self-assessment, audits, etc. to narrow the gap between the state and the target. This pursuit for higher quality also conforms to the idea of continuous improvement. Kaizen and many Continuous Improvement techniques result in the scenario in Figure 11.

The next section discusses the concept of continuous improvement. Level of quality can be expressed by many criteria. Accuracy, consistency, and timeliness are criteria of data quality. The Quality Metrics identify, measure, and present the results of our efforts so that improvement can be continuous.
Figure 11 consists of four Quality targets. Continuously seeking then correcting the errors produces higher quality every time. For example, using self-assessment to review the checklist by the very evaluator helps to increase the quality of the data. Thus by using the simple technique of self-assessment, the Quality Metrics reach a rating of 85%. By using integrated tools and techniques, a higher level of quality can be achieved, thus arriving at the third and the fourth targets. However, higher quality usually requires more time and resources.[42] From a Quality Assurance perspective, the conformance to the target and the improvements to the next target are being achieved.

[40] See page 47 of this document for more information on “Cost of quality.”
[41] Thus we have 5% upper level as oppose to only 2% lower quality level, with a mid target level of 90%. This helps to achieve higher quality by leaving more wiggle room for higher quality and less room for lower quality.
[42] See page 44 for cost of quality management.

5.2 Quality Requirement and Continuous Improvement

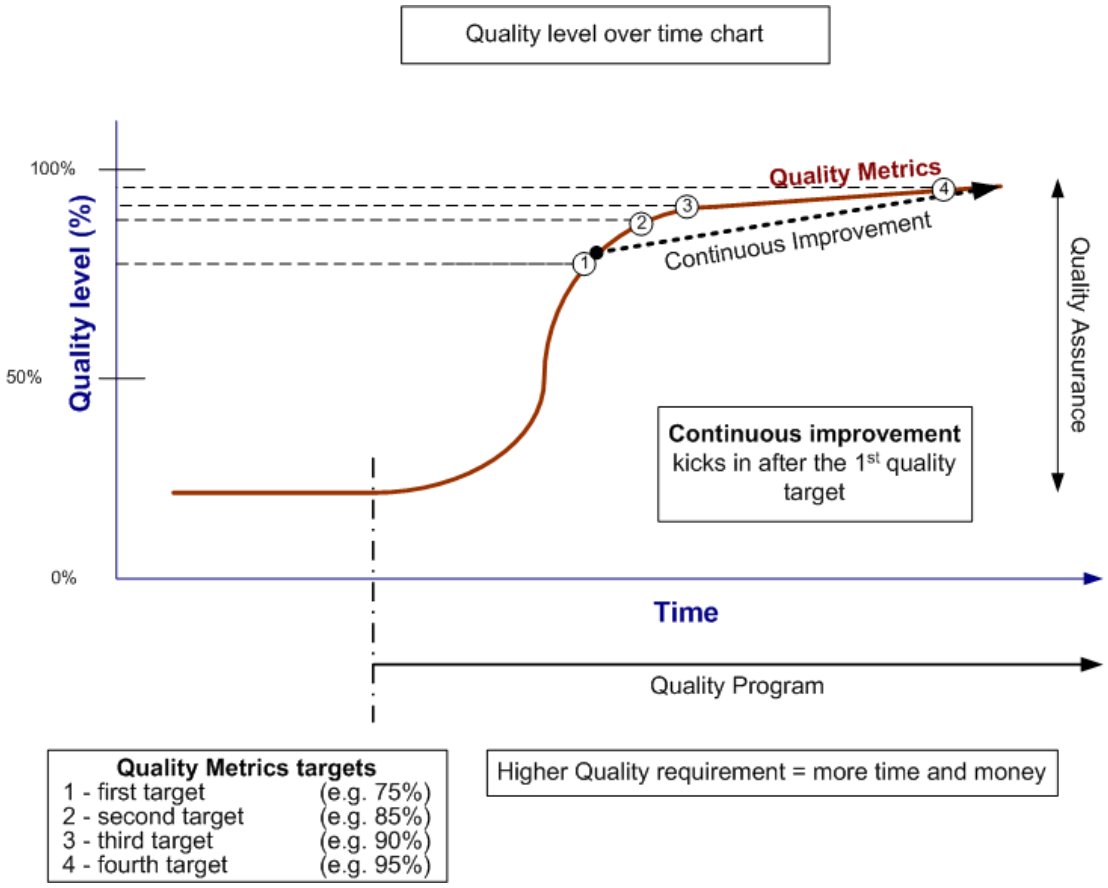


Figure 14 - Quality level and continuous improvement.

Continuous improvement is a never-ending endeavour towards one or multiple goals. In the FREP quality program, our goal is to strive for the highest quality possible.[43] However, as with other projects, we are bounded by time and money. Therefore, an approach to this quality movement is “Incrementalism” – a marginal increase or small change upon the previous achievements. Still, there is a challenge in this incremental improvement effort. Once the target has been achieved, there should also be an effort to sustain the level of quality. Only with the ability to maintain the quality level can the next phase of improvement be targeted. Also according to the idea of continuous improvement, improvement on quality should be never ending, thus there is always a new target. But resources are limited, therefore while a perfect state of quality is ideal, but it is rarely possible. Moreover, second target is more likely to cost more than achieving the first target. The reason for these increasing difficulties (time and complexity) is illustrated in Figure 28 – the ramp of improvement, continuously.

[43] Highest Quality Possible – with the constraint of time, money and other resources. The goal is to produce the best product using limited resources (see pages 45 and 46).

5.3 Quality Criteria and Quality Metrics Development

Using the FREP Quality Assurance Criteria – Timeliness, Accuracy, Consistency, Accessibility, Interpretability, Value for Money, and Fairness and Equity, we can use the Goal/Question/Metric Paradigm to develop our Quality Metrics.
In applying quality criteria to the protocols of data collection, criteria such as Timeliness, Accuracy, Consistency, and Interpretability should be considered. Criteria should be selected appropriately for different components of FREP and for its projects.

5.4 Goal/Question/Metric Paradigm

Developed by Dr. Basili at the University of Maryland, GQM is a useful tool for improvement and measurement.[44] GQM has been widely recognized and has been applied to industrial design, operation management, shop floor monitoring, software engineering, management practices, project management, and other metric intensive applications.[45] GQM follows three phases:

1. Generate a set of goals
2. Derive a set of questions
3. Develop a set of metrics

As metrics can be complex and difficult as we attempt to cover comprehensively all aspects of quality, we may require the use of "lean" metrics. We need the metrics to be accurate and effective measures. Metrics should not lose sight of the goal, and metrics should be easily controlled. People in the program must have the ability to influence the metrics so that real progress can be made. Besides the use of metrics, we must also be open-minded, looking for alternative solutions and creative options. While GQM poses a great tool to develop metrics, QFD's House of Quality[46] can help to prioritize and to organize these metrics.[47] Basili et al. argued that for GQM to be effective, the application must be:

1. focused on specific goals;
2. applied to all life-cycle products, processes, and resources; and
3. interpreted based on characterization and understanding of the organizational context, environment, and goals.

(2)

[44] See Solingen and Berghout about GQM method.
[45] See Rosenberg and Hyatt 1; Fehlmann and Hauri 20; Basili et al. 1; Shepperd, 1.
[46] House of Quality is the planning stage in Quality Function Deployment. It is the most widely used tool to sort and prioritize various types of requirements.
[47] The attempt is to have metrics developed using the GQM methodology, and then QFD or HOQ is to plan and to organize these metrics. Hauser and Katz 18.

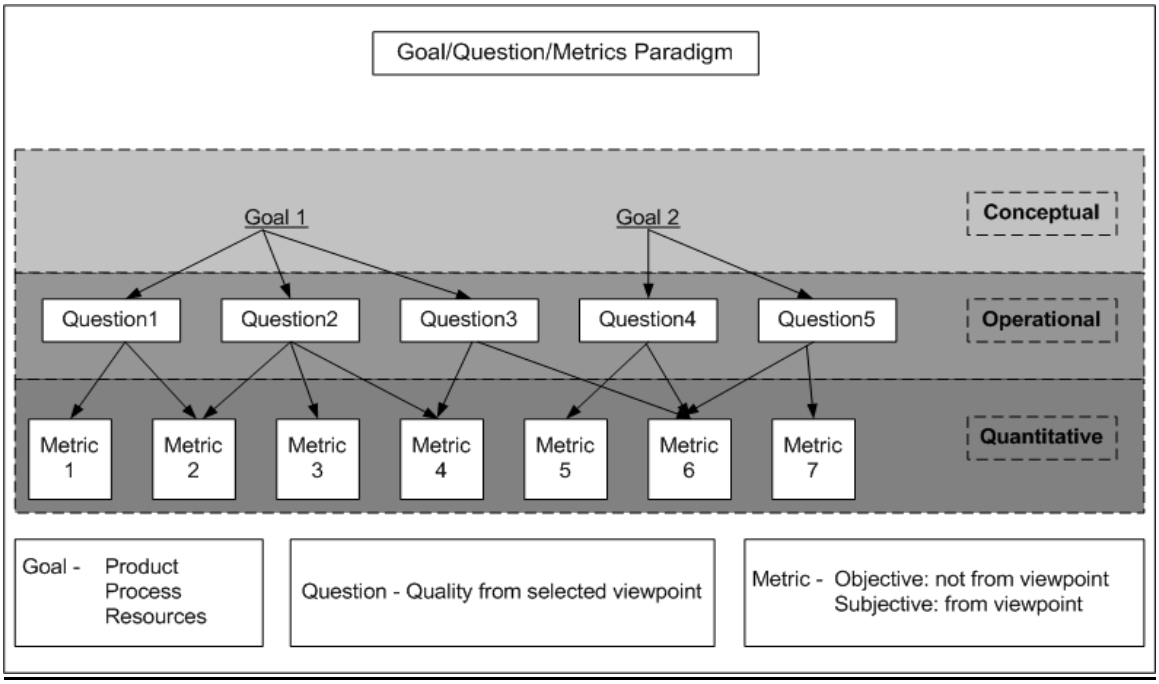


Figure 15 - Goal/Question/Metrics paradigm.

(Basili et al. 3)

The goal is defined at a conceptual level where it is defined for an object, for a variety of reasons, and with respect to various models of quality. From one point of view, the goal is relative to a particular environment (Basili et al. 3). The goal, being defined for an object, can be measured in the following ways.

- Product: artifacts, deliverables and documents that are produced in the system, such as, specifications, designs, programs, and test suites.
- Processes: activities normally related with time; e.g., specifying, designing, testing, interviewing.
- Resources: items used by processes to produce their outputs; e.g., personnel, hardware, software, money.

The question, at the operational level, is used to characterize the way an assessment or achievement of a specific goal is going to be performed based on some characterizing model. Questions try to characterize the objective of measurement, be it a product, process, or resource, with respect to a selected quality issue; and to determine its quality from the selected viewpoint. For example, the questions generated from a resource value team leader tasked with providing data analysis and interpretation are different from those generated by a field staff who collects data.

Metrics are the quantitative measures. There is a set of data that is associated with every question. Data can be objective. The measure is based on the commonly agreed standards. It might be, for example, the amount of the money or the number of hours spent on a task. However, metrics can also be subjective. The measures are taken from viewpoints that “lie in the eyes of the beholder.” For example, subjective metrics are readability of a text or level of user satisfaction.

As a result we can expect the GQM looking like this example.[48]

Table 6 - GQM – Example of Data Collection Metrics Development

Goal Purpose Issue Object (process) Viewpoint	— Improve — the quality of — data collection methodology — from a quality control coordinator's viewpoint
Question 1	• What is the current data collection quality?
Metrics	• Self-assessment score • External audit results • % of blank fields on checklist • % of data error
Question 2	• Is the quality of the data collection improving?
Metrics	• Internal and external score on checklist quality • % of blank and error • # of good quality checklist/total # of checklists X 100

[48] Based on Basili et al. The Goal Question Metric Approach.

We have isolated the “Accuracy” criteria from the FREP Quality Assurance Criteria to demonstrate the GQM paradigm in the following tables. To fairly establish accuracy in the GQM paradigm, we ask the questions on the accuracy criterion about accuracy itself, and on the barriers to accuracy.

Table 7 - GQM, Question and Metrics Matrix

Goal: Accuracy

	Q1 Accuracy criteria	**Q2 Accuracy is? (type)**	**Q3 Barrier to Accuracy**	**Examples**
Format	☑	☑	☑	Length, decimal point e.g., plot number format
Unit	☑	☑	☑	Measurement unit e.g., in metres, inches
Field accuracy[49]	☑	☑	☑	Self-assessed, peer reviewed on site observation and measurement
Data recording[50]	☑	☑	☑	Correct recording of observation and measurement on the checklist
Data entry/presentation	☑	☑	☑	E.g., data are misread by data entry person, symbols or abbreviation not recognized.
Unclear instruction			☑	Confusing and lengthy instruction for questions on the checklist and in the field manual
Lack of training/orientation			☑	E.g., evaluator may be technical expert and possessing experience in field works, but unfamiliarity with checklists inhibits data accuracy.
Human error			☑	E.g., interference in observation and measurement, record the data in wrong field on the checklist.

Examples of incorrect format include decimal point. It is different when evaluator records measures in one decimal point or in three decimal points. For data analysis, “9.1” and “9.188” are different when numbers are summarized in significant figures to derive a conclusion. A decimal point is also related to field measurement where ±10% is

[49] Field accuracy is the ability for evaluator to observe and to measure best the facts in the field.
[50] Data recording is the ability for evaluator to transfer observation and measurements on the checklist accurately.

acceptable. Obviously, the lower the measurement tolerance, the more accurate the data. But this tolerance also decreases the efficiency of data collection. Another example is the date format. One might record 1995 June 10 as 06/10/05 or as 10/06/05. If there was no clear instruction for the date format, analysis using date as a variable (such as time-series) will be incorrect.

5.4.1 Quality Requirement – data collection

Putting all quality criteria applying to data collection into the GQM paradigm, we can exhibit the Goals and Questions interaction in the table below.

Table 8 - GQM, Goal and Question Matrix

	Goal 1 – Timeliness	Goal 2 – Accuracy	Goal 3 – Consistency	Goal 4 – Interpretation
Q1 – time spent on site, getting results to RVTL[51] (# of hours/day)	✓	✓	✓	
Q2 – completion of all assigned sites in time (# of days early or late)	✓	✓	✓	
Q3 – Accuracy criteria, type, and barrier		✓	✓	✓
Q 4 – Design in checklist, question, format, unit…		✓	✓	✓
Q5 – data recording, entry, analysis, presentation	✓	✓	✓	✓

By matching questions 1 to 5 with the goals of quality criteria, we are able to determine what kind and how many of quality metrics needed to be developed for each question. For example, question 5 will require metrics to measure timeliness, accuracy, consistency, and interpretation on data recording, entry, analysis, and presentation.

5.5 Quality Requirement – AQL (Acceptable Quality Level)

Using the concept of Defect Per Million (Six Sigma), one way to express the mandatory quality level can be:

Stringent	*0%*	*-*	*1.25%*
Mild	*1.26%*	*-*	*3%*
Relaxed	*3.1%*	*-*	*5%*

The percentages used here express the number of defects or error per the total number of parts, questions, or amount of data. Therefore, the smaller the percentage is, the better the quality.[52] On the other hand, using a Quality level to express quality:

100%	*-*	*98.75%*	*Stringent*
98.74%	*-*	*97%*	*Mild*
96.9	*-*	*95%*	*Relaxed*

[51] RVTL – Resource Value Team Leader/Specialists.
[52] The measurement and calculation use metrics developed under the GQM paradigm.

This is very similar to the quality requirement diagram (see figure 13). Quality is expressed through achievements using a constructive approach as opposed to a deductive approach. Both approaches can accommodate elements of continuous improvement. And judging by the nature of the metrics, one or both approaches can be applied as AQL.

5.5.1 Example – blank analysis

On one checklist, a blank analysis may look like this:

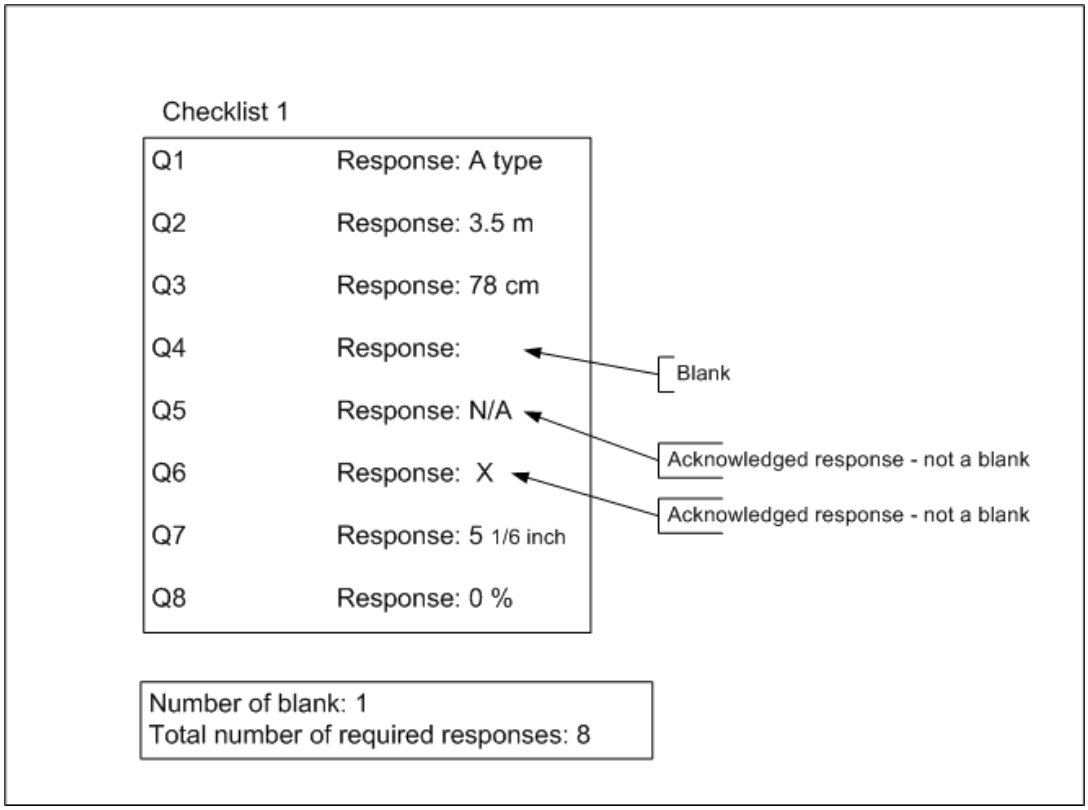


Figure 16 – Example of Blank Analysis.

Calculation of the blank analysis are:

1 / 8 X 100 = 12.5% blank rate per checklist

If we were to set our quality requirement or AQL to 2% or less, this particular checklist will fail miserably. However, if we were not to measure quality level at the individual checklist level, but to monitor the overall quality, the monitoring should be done on all the checklists combined together, thus making the AQL meaningful and lean. Therefore, in a total of 400 checklists and total of 3200 required responses, the calculation may be:

40 (assumed number of blank responses) / 3200[53] *= 0.0125 X 100 = 1.25%*

The total number of blanks will be acceptable in this case. However, we would suggest an even higher AQL for continuous improvement. This is a simplistic representation of the multi-level and complex quality control tasks.

[53] This demonstrates the careful use of the appropriate denominator to arrive at blank rate.

6. Quality Tools and Techniques

This section outlines a number of different tools and techniques that can be used in the pursuit of a quality assurance framework. Each tool or technique is presented with a brief description, the applications and/or applicability to FREP, an example related to FREP, the pros and cons, the weighted cost and time required to deploy the tool or technique, and a short discussion. These tools and techniques may be used in the implementation strategy or incorporated in the quality control protocols.

6.1 Self-Assessment

Cost[54]	$
Time[55]	🕘

Description:
Person who completes the checklist also checks quality using a self-assessment guide or instructions on the checklist.

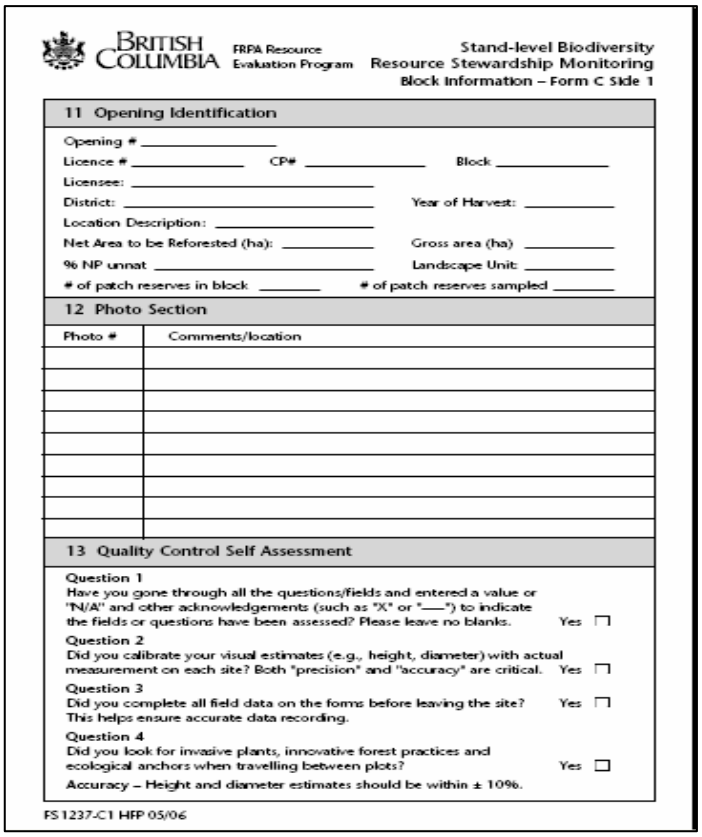
Application:

- Field observation and measurement
- Instrument calibration
- Estimate accuracy and precision
- Data recording
- Data entry
- Data analysis

Example:

[54] Scale: $ - inexpensive, $$ - moderately expensive, $$$ - expensive.

[55] Scale: 🕘 - a little time required, 🕘🕘 - some time required, 🕘🕘🕘 - very time consuming.



BRITISH COLUMBIA FRPA Resource Evaluation Program

Stand-level Biodiversity
Resource Stewardship Monitoring
Block Information – Form C Side 1

11 Opening Identification

Opening # _____
Licence # _____ CP# _____ Block _____
Licensee: _____
District: _____ Year of Harvest: _____
Location Description: _____
Net Area to be Reforested (ha): _____ Gross area (ha) _____
% NP unnat _____ Landscape Unit: _____
# of patch reserves in block _____ # of patch reserves sampled _____

12 Photo Section

Photo #	Comments/location

13 Quality Control Self Assessment

Question 1
Have you gone through all the questions/fields and entered a value or "N/A" and other acknowledgements (such as "X" or "—") to indicate the fields or questions have been assessed? Please leave no blanks. Yes ☐

Question 2
Did you calibrate your visual estimates (e.g., height, diameter) with actual measurement on each site? Both "precision" and "accuracy" are critical. Yes ☐

Question 3
Did you complete all field data on the forms before leaving the site? This helps ensure accurate data recording. Yes ☐

Question 4
Did you look for invasive plants, innovative forest practices and ecological anchors when travelling between plots? Yes ☐

Accuracy – Height and diameter estimates should be within ± 10%.

FS 1237-C1 HFP 05/06

Pros	Cons
Complementary to quality training	More time required in the field
Easy to implement and follow by evaluators	Subjective bias may still be sustained

Discussion:
Evaluators may carry some responsibility for the quality of their work. A self-assessment guideline should be followed closely. Some data validation criteria can be added in the guideline.

6.2 Check Sheet or Scorecard[56]

Cost	$
Time	🕘🕘

Description:
In form, table, or matrix format, to assess and to record the type error and quality level

Application:
- Check results of existing state
- Search for cause
- Check on results of an improvement
- Ensure defect does not recur

Type:
- Defective item
- Defective factor
- Defective position
- Process distribution
- Inspection and validation (scorecard)

Example:

Quality Criteria	Question1	Question2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total
Format	1								1	2
Unit of measure	1			1						2
Blank	1									1
Readability						1				1
Accuracy[57]										0
Total	3	0	0	1	0	1	0	0	1	6

Pros	**Cons**
Different types of check sheet for various type of inspection and validation	Adding one more process to the checklist before data entry
Relatively inexpensive quality control tool	More staff resource and time

Discussion:
Inspection and audit can be undertaken in many levels and ways. There are also implementation details that will likely require a “Quality Control Protocol” itself.

[56] Check sheet, scorecard, affinity diagram, systematic diagram, Pareto diagram, and cause-and-effect diagram are applied for FREP from Ozeki and Asaka 139.
[57] Accuracy is difficult to determine and it has multiple aspects to its meaning. Accuracy is difficult to assess when verification cannot be performed or is costly to perform. The meaning of accuracy in the data collection process ranges from observation, measurement, estimation, to recording.

6.3 Affinity Diagram

Cost	$
Time	🕘🕘

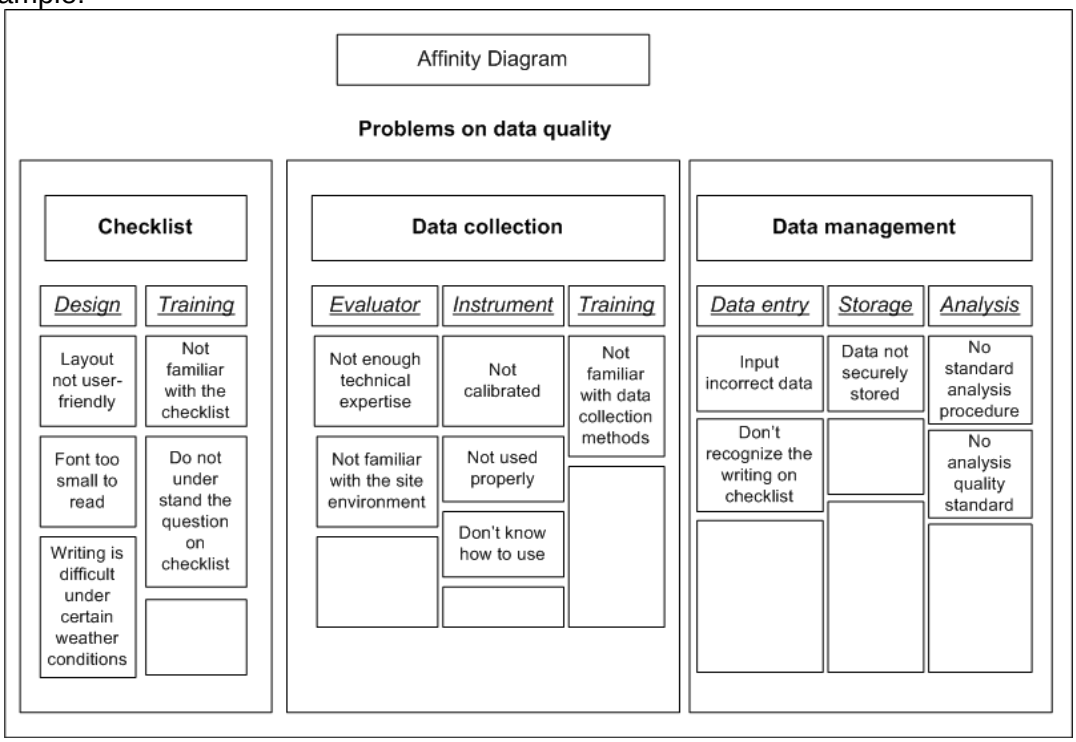
Description:
Organizes data into an understandable diagram that

- Defines the nature of the problem and reveals hidden problems
- Helps to organize and to order fuzzy ideas
- Shows the proper direction to take in solving problems

Application:

- Attack the problem in the right way
- Organize ideas for decision-making
- Reach a solution to problems

Example:



Pros	Cons
Helps to transform fuzzy ideas into a logical order	May require more group input and is potentially time-consuming[58]
Easy and user-friendly to setup	

Discussion:

[58] Time-consuming refers to the issue of efficiency and effectiveness. If the time spent on drafting the diagram cannot be justified by the results, then there is a problem that needs to be resolved. Time-consuming is a major downside and defeating the quality criteria of 'timeliness'.

Fuzzy logic[59] can be applied using the affinity diagram. It transforms facts, predictions, ideas, opinion, and similar expressions to a logically organized framework, thus enables a systematic and straightforward problem-solving strategy.

[59] (Chen and Weng 559) – when affinity diagram combines with QFD's matrix. This creates the best use for a fuzzy model and problem-solving framework.

6.4 Systematic Diagram

Cost	$
Time	🕘🕘

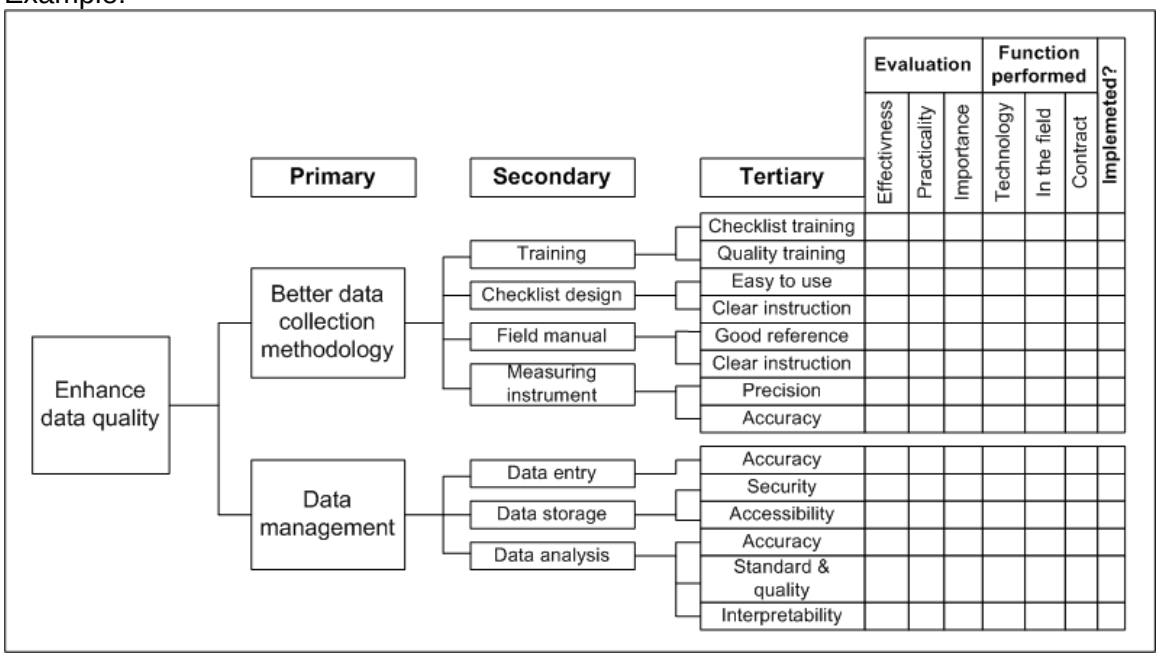
Description:
Systematically organizes aspects of problem-solving techniques or the choice of the optimal method to achieve a particular goal.
There are two type of systematic diagram:

- Plan-development
- Component-development

Application:

- To develop plans
- To evaluate methods and plans

Example:



Pros	Cons
Logical organization of relationships	Time-consuming group efforts
Good method and plan developing tool	
Easy to set up	

Discussion:
The development of a systematic diagram is a group exercise. Often some other group-oriented techniques are required to facilitate the process, such as brainstorming, cluster diagrams, ranking, and sorting.

6.5 Quality Function Deployment – House of Quality and Matrix Diagram

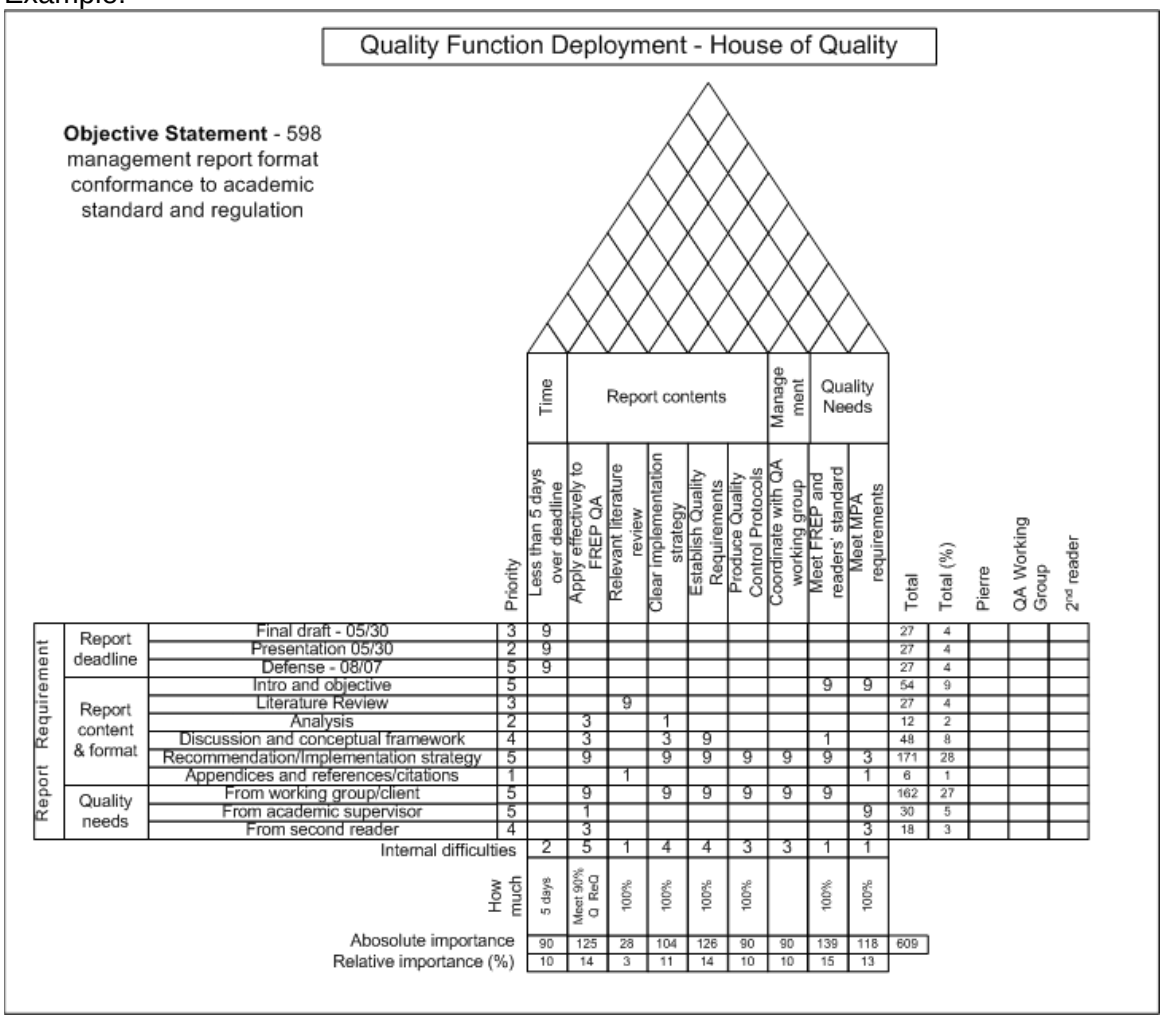
Cost	$
Time	🕘🕘🕘

Description:
Using the "Planning" phase of the Quality Function Deployment methodology, the House of Quality and matrix components describe the relationship between causes and effects, factors and defects, or objectives and methods.

Application:

- Use to clarify relationships
- Evaluate methods and measures
- Sort and rank relationship - prioritization

Example:



Pros	Cons
Effective prioritizing tool	Requires more upfront input and effort in the design stage
Ability to anticipate or incorporate design needs and quality requirements	Identify and listing factors require good group effort, potentially time-consuming

Discussion:
The House of Quality approach is one step further than the matrix diagram. When time is limited or is being carefully planned, the House of Quality is a useful tool to initiate the planning, coordinate the internal capacities, and finally implement the designs. It also provides a snapshot of the existing conditions. It reveals progress made as well as what still needs to be done.

6.6 Pareto Diagram

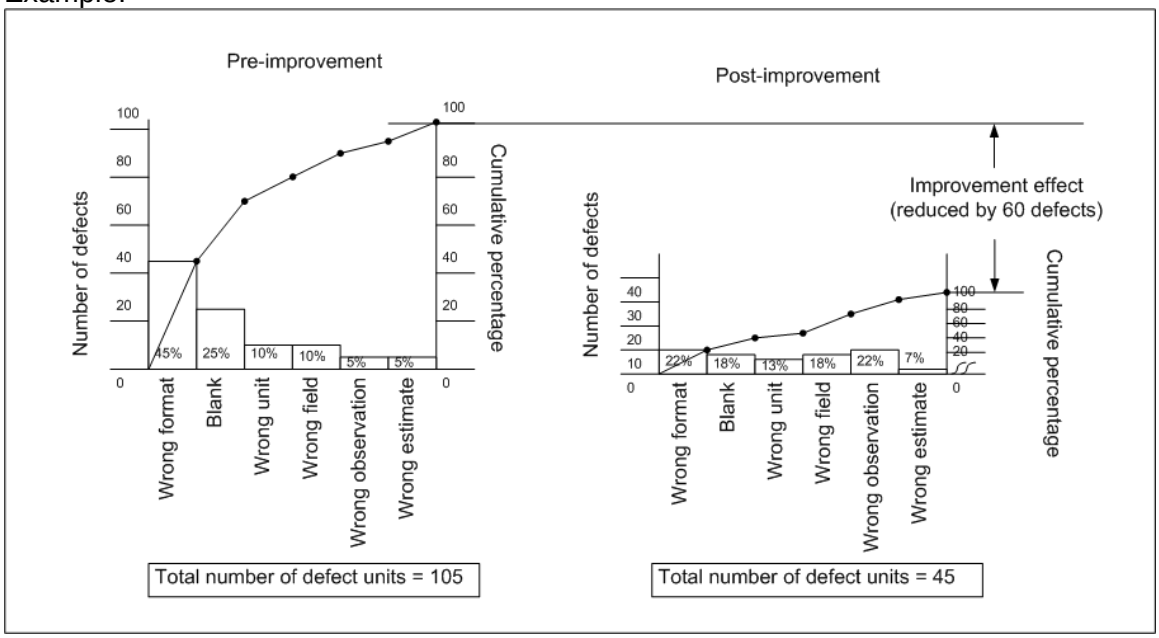
Cost	$
Time	🕘🕘

Description:
The Pareto Diagram is a specialized bar graph to show the relative frequency of events such as bad products, repairs, defects, errors, claims, failures, or accidents.

Application:

- Focus on the principal aspect of a problem
- Decide the objective of your improvements and your improvement items
- Predict the effectiveness of the improvement
- Understand the effectiveness of the improvement
- Make easy improvement right away
- Document explanation and serve a record for improvement

Example:



Pros	Cons
Practical tool to visualize the problem or problems and put in numerical terms	Requires some data collection
Easy to understand and compares pre and post results of an improvement	Depending on the scale of the data, graphing the diagram can be time-consuming

Discussion:
The Pareto diagram is an improvement monitoring tool. It monitors progress as well as pointing out the intensity of the improvement by each defect type. Little effort is required for data collection and the diagram can be customized by linking to monetary terms.

6.7 Cause-and-Effect Diagram (Fishbone or Ishikawa[60])

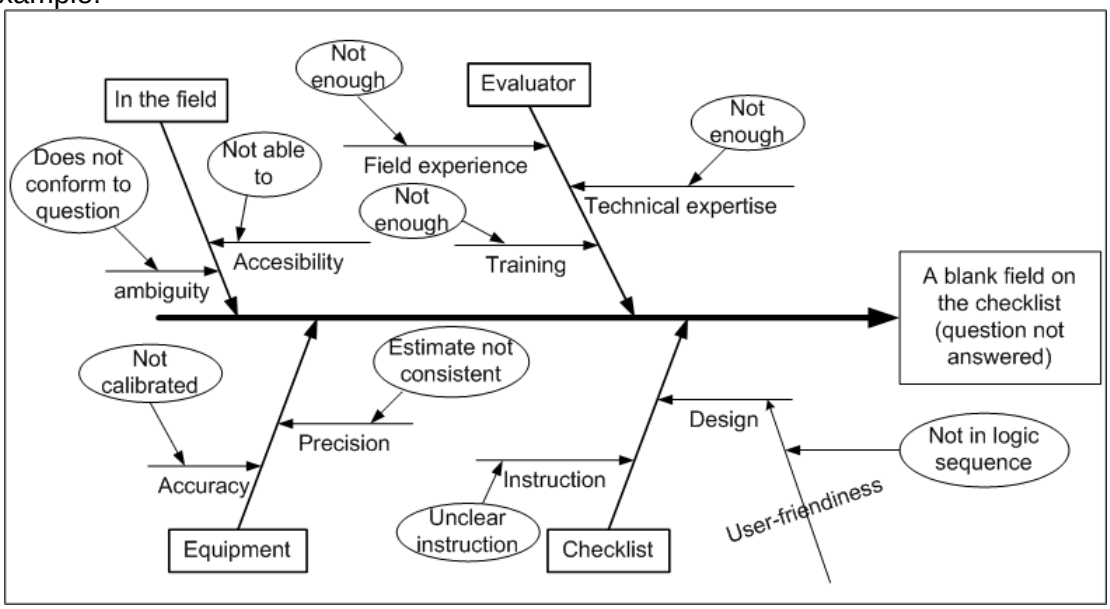
Cost	$
Time	🕘

Description:
The cause-and-effect diagram clarifies the cause of a problem by the classification and indication of the cause-and-effect relationships.

Application:

- Help guide discussion
- Use diagram as a study aid
- Gain a better understanding of the actual situation
- Manage factors
- Serve as technical material when creating and revising quality standards

Example:



Pros	Cons
Easy to set up	May require some data to support the relationship and its significance
Also work on large scale projects due to diagram's effectiveness and efficiency	

Discussion:
There are generally three approaches to the cause-and-effect diagram. There are also some variants that have been arisen since the diagram was first developed.
Approaches:

1. Big branch expansion method
2. Small branch expansion method – similar to brainstorming
3. Small branch expansion method – similar to affinity diagram

[60] Ishikawa 63.

7. Recommendations

1. Communicate the QA/QC framework and the protocols to staff and stakeholders.
The terminology used in quality management can be confusing. The following table clarifies the level in which these terms are used.

Terms	Level	Activities
Quality management	Program or entire organization	Design, plan, and development
Quality assurance	Program	Planning
Quality control	Project	Execution, monitoring, and control
Quality system	Program and project	Combination of QA and QC
Quality management system	Program or entire organization	A management philosophy or systems of practices
Quality framework/model	Program or entire organization	Recognized or institutionalized quality management system such as ISO and BEM
Quality improvement	Any	Any efforts to improve quality using or not using quality control tools and techniques

Ministry staff and stakeholders should understand the basic definitions and premises of the FREP Quality Assurance Framework. This paper is intended for the Quality Assurance Working Group, but understanding basic terminology and quality control tools benefits all staff and helps implementation.

2. Communicate lessons learned in the environmental monitoring quality management plans and in the public sector quality management frameworks.
Some successful quality management practices should be communicated to staff. Some of the experiences from the case studies should be carefully applied to the FREP QAF. We can then use these case studies to identify if our requirements conform to the norms of quality assurance, and what is lacking. The case studies presented best practices in environmental monitoring quality assurance from other jurisdictions and countries. The review of public sector quality management leads to an examination of the contributing success factors and barriers to implementation. In the end, we will have looked at FREP Quality Assurance Framework from three angles: from environmental monitoring QA of other jurisdictions, from existing quality management systems, and from public sector quality management.

3. Capture quality requirements: Metrics and Acceptable Quality Level (AQL)
As in any environmental monitoring program or project, capturing information needs, data requirement, and data-quality objectives are critical. Likewise, we need to capture quality requirements so that we can understand, monitor, and control the level of quality. The recommendation calls for the use of the GQM method to produce quality metrics, which need to be right on target so that we have essential indicators that do not waste resources. Quality metrics will also come from the FREP Quality Assurance Criteria used on both the program and project levels. The FREP Quality Assurance Criteria serve similar functions as the data quality criteria in environmental monitoring.

We also need to some flexibility on the quality metrics. This flexibility or AQL will be the alternative mean to a strict screening and quality validating cut-off point used in quality metrics. The AQL accommodates program and project components that do not meet quality targets. This set-up leaves room for unforeseeable and uncontrollable situations such as poorly designed questions, improper instruction, extreme weather, or presence of grizzly bears. However, outliers will be detected and assessed during the data validation process. The intention is not to allow AQL to interfere with the actual quality level. The achievement of the quality targets continuously is still the ultimate goal. As we approach a very high quality level or target, AQL will become less useful and may need to be abandoned.

4. Selection of tools and techniques for improvements
Section 6 describes some of the popular quality tools and techniques recommended by various authors. These are extracted from different types of quality management systems and are adapted using real FREP quality issues. Some tools are universal and flexible enough to be used in almost every problem-solving scenario. They can be used to identify the real problem(s), to find solutions to the problem, and to sort, rank, and prioritize issues and requirements. These tools are not perfect, but are helpful. With proper training, staff of the FREP may benefit from the use of these tools .

5. Basis for implementation strategy and quality control protocols
This report forms the basis for a future implementation strategy and several quality control protocols. Literature review and case studies revealed some issues that the FREP QAF might consider important and useful. Issues such as the use and the training of the safety equipment make sense; field staff should have access to appropriate resources to ensure their work safety. Quality and/or system audits may also be considered, so that we can recognize our achievements and the level of conformance of our work. The results from audits and evaluation help us to continuously improve.

The paper identified the need for a more formal quality management structure. Other organizations have used an independent quality assurance manager and/or quality control coordinator in addition to a Quality Management Committee that actively oversees all aspects of quality. Our QA working group should be structured so that active involvement and management are possible. Participation and involvement lead to management commitment. This commitment by top management is arguably one of the most important factors contributing to successful quality management implementation. Management commitment also sustains the quality management program within an organization through leadership and the building of a different organizational culture.

Also identified are the linkages between data quality/objectives and information needs, and between monitoring results and data management. The findings suggest a need for

a clearer and more concrete concept on these linkages. The FREP working groups make formal efforts to connect their work to each other. QA is very much related to data management because quality data give valuable information, which in turn helps to produce sound advice and policy.

Therefore, the findings and recommendations from the paper build the foundation for the implementation strategy and the quality control protocols. The concepts of Quality Requirement, the method of GQM, and the quality tools should be applied in the later report and protocols.

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Appendix A – Literature review

The literature on quality management, quality control, quality assurance, and quality systems is very much confined to areas of business, marketing, software development, manufacturing, and engineering processes. Infrequently are quality related tools, techniques and management addressed directly to the public sector or environmental management practices. Quality assurance and quality control in environmental monitoring are studied in Section 3 as case studies and best practices.

The intent of this literature review is to explore the tools, techniques and methods of prominent and externally reputable organizations, such as the International Organization for Standardization (ISO), to assist in guiding the development of an effective quality assurance framework for FREP

1. ISO and NQI

ISO 14000 EMS
The ISO 14000 Environmental Management System (EMS) is designed for organizations to address their environmental practices. The ISO has developed two approaches for meeting the needs of business, industry, governmental authorities, non-profit organizations and consumers (Switzerland, New ISO 14000 37).

In the first approach, ISO offers 350 international standards for sampling and testing methods. Government authorities sometimes use the ISO 14000 series[61] as a guideline for their Quality Plans and related regulations. For example, the Environmental Protection Agency adopts the ANSI[62] and ASQ[63] environmental standards[64] affiliated with ISO 14001 (U.S. EPA, QA/G-1 1).

The second approach of the ISO 14000 is the proactive standards for organizations to manage environmental issues. This proactive approach is meant to be strategic and complementary to the implementation of sustainable development. Within the ISO 14000 series, there are many sub ISO 140XX series that look at different areas within the EMS. For example, ISO 14062 looks at the “design for environment”. In the “Plan” stage of the Plan-Do-Check-Act cycle, the ISO 14062 integrates environmental aspects in design and development, resulting in the improvement of environmental performance of an organization’s products and services. The City of Calgary, for example, is the first municipality in North America to achieve ISO 14001 registration. It took four years to attain their first ISO 14001 registration on one of their business units. As of today, Calgary has all of their 30 business units registered. City council supported EMS implementation from the very beginning; however, the challenge was to structure a management system across 30 business units with varying activities and levels of risk. The City established an Environmental Management business unit employing 15 fulltime staff to support EMS throughout the Corporation (City of Calgary), as well as an environmental network consisting of EMS coordinators from individual business units.

[61] Switzerland, ISO and the environment
[62] ANSI – American National Standard Institute
[63] ASQ – American Society for Quality
[64] ANSI.ASQ E4-1994, Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs

Calgary claims the greatest benefit from ISO 14001 is the communication of environmental performance. Monthly meetings are held to share ideas, provide corporate consistency, and focus on continual improvement of the management system. Some other benefits the City claims include:

- Commitment to the highest international standards for environmental management;
- Achievement of a high level of environmental performance;
- Minimization of the potential environmental damage through continually improvement;
- Reduction of the City's risk and liability for environmental infractions (cost avoidance);
- Achievement of a high level of due diligence and regulatory compliance;
- Management of environmental issues consistently and practically;
- Cost saving through improved resource efficiency;
- Enhancement of citizen perception of the City as an environmental leader and wise manager of public resources;
- Enhancement of the City's image as an employer of choice;
- Improvement of communications throughout the corporation;
- Reduction of redundancies and improved efficiencies across the corporation;
- Identifying roles and accountabilities for managing environmental risk; and
- Provision of a framework for measuring and reporting on environmental performance.

(Brownlie,[65] E-mail exchange)

The ISO 14000 model

The ISO 14001 and 14004 EMS operates through four major functions – Plan, Do, Check and Act. The significant components of the ISO 14000 model, i.e., those that we can borrow for the FREP framework are the ISO 14030 series and ISO 19011 – monitoring environmental and system performance. Since the ISO 14000 model is very much geared towards the setting of environmental practice standards for organizations, some of the ISO series are not relevant to FREP.

Most organizations adopt ISO certification to maintain their business relationships or enhance their general corporate image. Nevertheless, the stringent standard and auditing processes are valuable experience for FREP. It is worthy to note that we are not duplicating the evaluation process for FREP, but rather we are attempting to mirror the standardized process and criteria for consistency to achieve quality control and assurance. More importantly, ISO 19011 is a hybrid of ISO 9000 and ISO 14000 systems providing an audit system for Environmental Management system

[65] Brownlie, Amanda. Environmental Specialist, City of Calgary.

ISO 19011 – a unique auditing standard for ISO 9000 and ISO 14000 systems
ISO 19011 is a systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which audit criteria are fulfilled (Switzerland, ISO develops 42). ISO 19011 merges the principles of auditing [ISO 9000] and environmental management [ISO 14000] together. Of all the ISO auditing series, ISO 19011 has the most merit for FREP due to its auditing of environmental management, aside from the evaluation standards of the ISO 14030 series. Auditing not only checks on performance, but also verifies control mechanisms. The following flowchart explains the process and components of the auditing process.

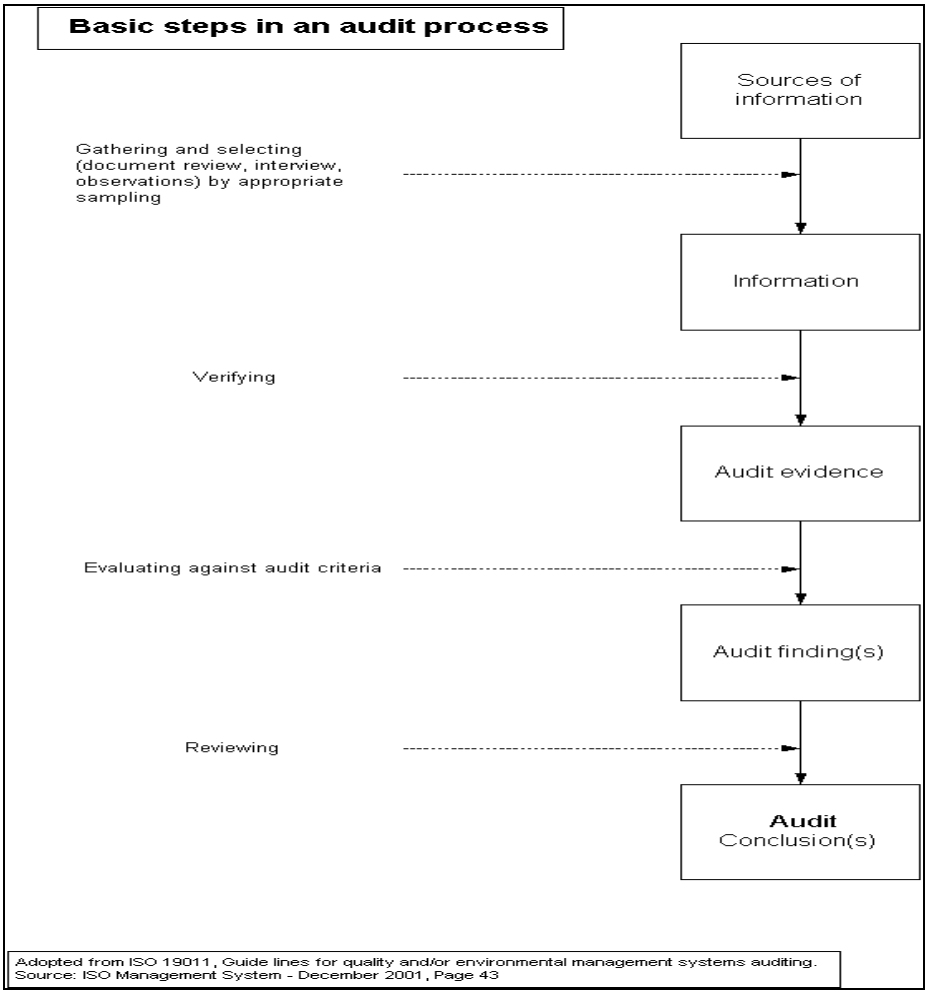


Figure 17 – Auditing steps.

Most audits follow the basic steps of a generic process that emphasizes the use of evidence and review procedures. The ISO 19011 auditing process is unlike other audits such as financial or tax audits, and focuses on auditor competence and environmental evaluation standards borrowed from the ISO 14000 model.

Auditing activities
The breakdown of each auditing step can be translated into activities. Some auditing activities begin in a group process and in an office setting. The auditor needs to

determine the feasibility of the audit and clearly define the objectives, criteria and scope. Once these preliminary tasks are completed, the auditor will visit the site and conduct the on-site portion of the audit. On-site auditing includes tasks such as meetings, communications; the auditor should communicate clearly their duties and agreed expectations. Most importantly, the auditor will collect and verify information to generate audit findings. After completing the audit, it is optional to have an audit follow-up. The follow-up may include a formal review on audit findings, evaluations of the auditors, or a review of the auditing process.

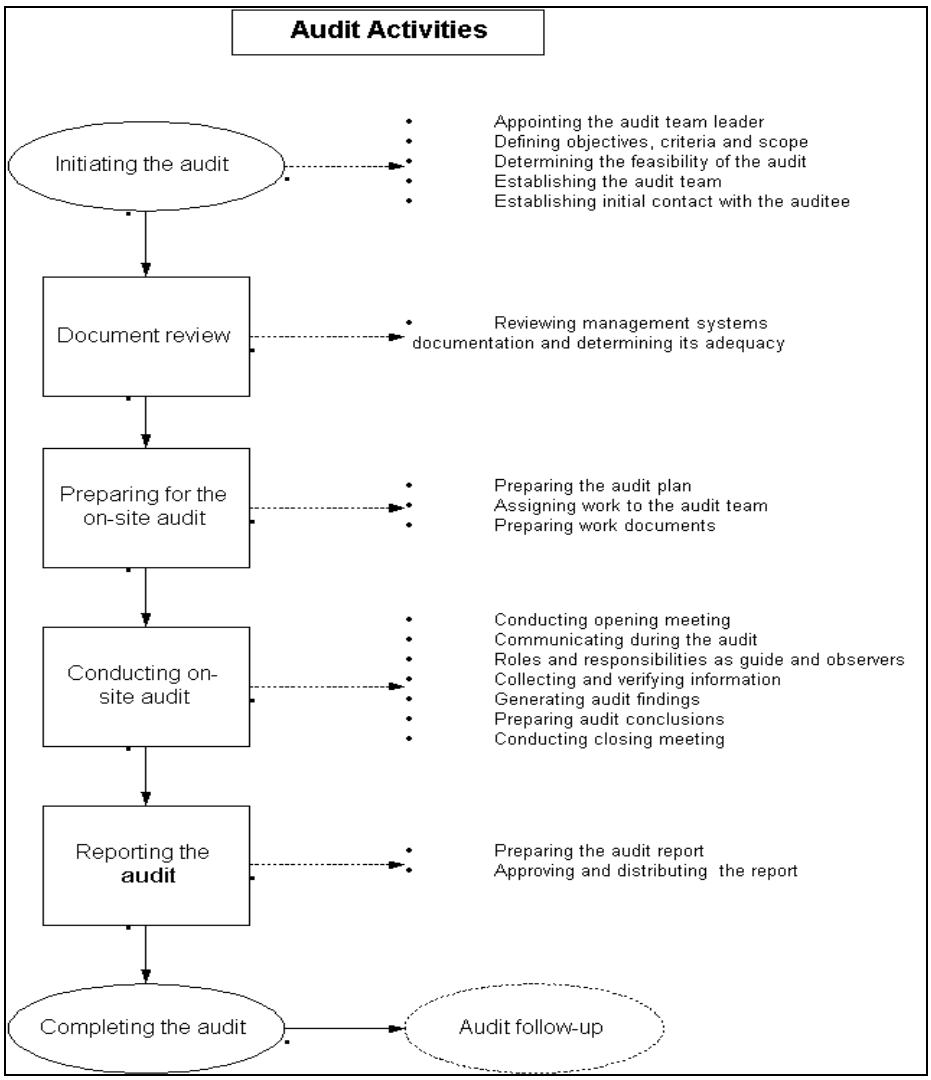


Figure 18 – Audit activities.

Auditing principles
ISO is only responsible for developing, maintaining and publishing the ISO standards. Implementation and certification are carried out by 750 certification bodies world wide. Therefore, ISO 19011, like other ISO standards, has a set of principles developed by ISO. As described in the ISO management Systems (Switzerland, ISO develops 43), the auditing principles are:

- Ethical conduct – the foundation of professionalism;
- Fair presentation – the obligation to report truthfully and accurately;
- Due professional care – the application of diligence and judgement to auditing;
- Independence – the basis for impartiality and objectivity of the audit conclusions; and
- Evidence – the rationale for reaching reliable and reproducible audit conclusions in a systematic audit process.

Three of the principles are related to the auditors, while the other two are related to the audit process.

Auditing program
ISO 19011 defines an audit program as ‘a set of one or more audits planned for a specific time frame and directed towards a specific purpose’ (Switzerland, ISO develops 43). This auditing program conforms to the ISO 14001 and 14004 Environmental Management System where Plan-Do-Check-Act defines the audit program.

In the ‘Plan’ part of the program, the authority for the audit program develops auditing management plans for different type of audits. The management plan is a generic auditing strategy guide so that each individual audit can follow but also allowing each audit team to develop their own audit activities. The most important guide that audit teams need to follow from the general strategy is the ‘Competence of auditor’ and ‘Basic audit steps’. Individual audit team dominates the implementation of the audit program – ‘Do’. However, each team’s can review and monitor on their own audit program, feedback from the audit improves the program, thus closing the cycle through ‘Check’ and ‘Act’.

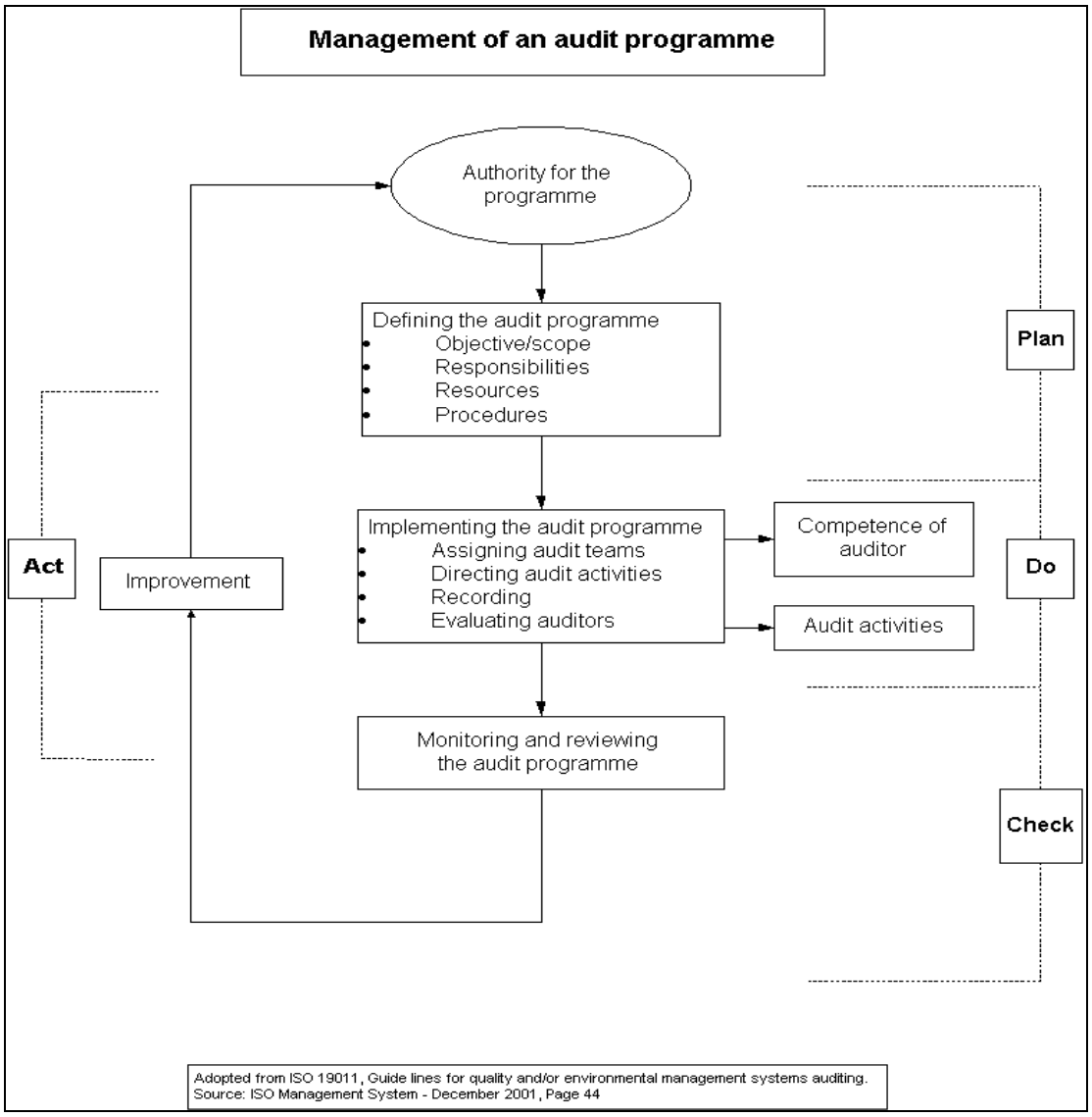


Figure 19 – Management of an audit program.

Auditing parties

In the auditing management plan and/or within the individual audit teams, roles and responsibilities should be clearly defined and described. Organizations being audited should provide access, data and other information to the audit team, and are involved in the audit process through meetings, interviews or other communications. The client and the audit team need to agree on the objectives, scope and criteria of the audit; and more importantly, need to work together under the audit program to achieve the intended objectives.

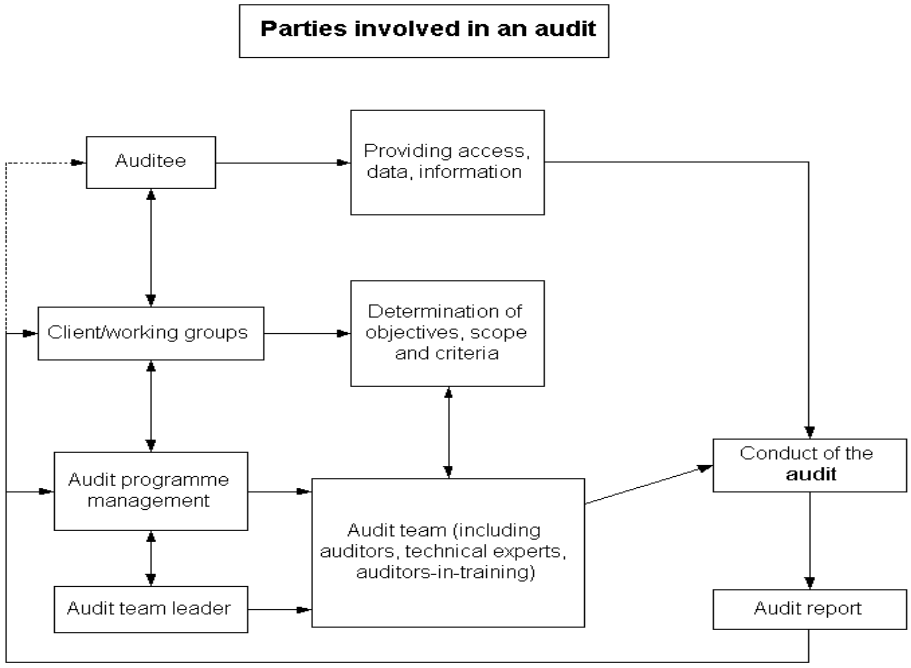


Figure 20 – Parties involved in an audit.

Auditor competence
ISO 19011 is not complete without the incorporation of standards for auditor. Unlike ISO 10011-2 and ISO 14012, ISO 19011 places an emphasis on the auditors' competence. The competence of auditors is assessed not lonely in relation to minimum level of education, number of years of work experience, and hours of auditor training, but also on multidimensional skills, knowledge and personal attributes. The competencies of an ISO 19011 auditor are divided by management systems - one being the general management system, and the others being the environmental and quality management systems. The generic knowledge and skills required under the general management system are:

- Audit principles, procedures and techniques;
- Management systems and reference documents;
- Organizational situations; and
- Applicable laws, regulations and other relevant requirements.

The environmental management system auditor should have:

- Environmental management methods and techniques;
- Environmental science and technology; and
- Technical and environmental aspects of operations.

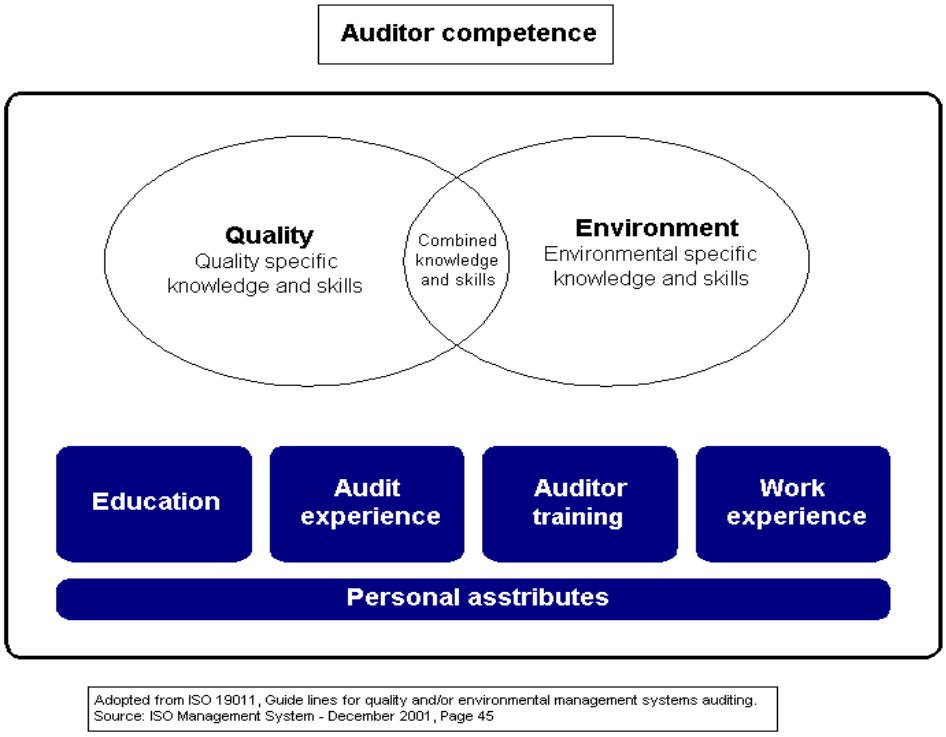


Figure 21 – Auditor competence.

The quality related knowledge and skills required by auditors are:

- Quality-related methods and techniques; and
- Environment – knowledge and skills on environmental monitoring

(Switzerland, ISO develops 45)

NQI – Canada Award for Excellence

ISO does not implement or certify the ISO standards, the most prominent certifying and training body for quality in Canada is the National Quality Institute (NQI). More importantly, NQI also applies to the public sector with an award called "Canada Award for Excellence." This award is equivalent to the Baldrige Award in the U.S., which recognizes excellence in quality. NQI criteria focus more on the process (approach and methods), while the U.S. criteria focus more on outcomes (NQI, Comparison 1). For example, a Plan-Do-Check-Act approach is taken in each section of the NQI criteria, which conforms to ISO's 14000 model.

The NQI Quality Principles for the Public Sector are (NQI, Canadian Quality Criteria For Public Sector 2):

- Leadership through involvement and by example;
- Primary focus on client/stakeholders;
- Cooperation, teamwork and partnering;
- Process oriented and prevention-based strategy;
- Factual approach to decision making;
- Contribution of each and every individual;
- Continuous improvement of methods and outcomes;
- Obligation to stakeholders, including a concern for responsibility to society; and
- Respect for the individual and encouragement for people to develop their full potential.

Comparison between the Canadian and US Quality Awards

The Canadian Award for Excellence uses seven quality criteria to score the award. A comparison to the US model is presented in the following table:

Table 9 – Comparison of Canadian and US model for Quality Award

Canadian Model	
Quality Criteria	**Points**
Leadership	100
Planning	80
Customer Focus	90
People Focus	140
Process Management	110
Supplier/Partner Focus	60
Business Results	420
Total	1000

US model	
Quality Criteria	**Points**
Leadership	120
Strategic Planning	85
Customer & Market Focus	85
Human Resource Focus	85
Process Management	85
Business Results	450
Measurement, Analysis & Knowledge Management	90
Total	1000

Source: National Quality Institute, Comparison of the Canadian and US Framework for Business Excellence 6.

Progressive Excellence Program
Another implementation criterion that NQI possesses is the Progressive Excellence Program (PEP). Each level the quality achievement is certified or recognized so that organizations can progress to the desired level of quality management. Ethical leadership is embedded in the leadership section where it specifically applies to the public sector for responsibility and accountability. (NQI, ISO Standard & NQI PEP)

ISO and NQI for external validation
Internationally recognized, the ISO standard is an important external validation for organizations' environmental management practices. The organizations may be private business, local governments, non-profit organizations, and even the education sector. The motivations for ISO 14000 range from cost reductions to customer pressures. However, the more prominent drivers behind the adoption of ISO standards are usually quality improvements, relations with authorities, marketing advantage, and corporate image (Switzerland, New ISO 14000 35). Local governments certified by ISO 14000 in Japan, for example, are far ahead of the local governments in North America both in numbers and standards (Switzerland, Leading by example 23). ISO 19011 presents a unique auditing opportunity by combining the audit experiences in ISO 9000 and the environmental management practices in ISO 14000. NQI's quality criteria for public sector excellence also closely follow ISO principles. As a leading certification and training body of ISO in Canada, the NQI's PEP complements the Canada Treasury Board Secretariat's "Management Accountability Framework" (NQI, The Treasury Board 1)

2. TQM - Deming

Quality Management originated from industrial operations. Over the years, Total Quality Management (TQM) became a well-studied, documented, and practised management technique in engineering, software development, education, health care, and in the public sector. However, very little of this well-developed management technique has been applied to environmental assessment and monitoring. Most of the literature documents quality management in areas of management practices and operational control. TQM, however, drawing experience from business and industry sectors, offers insights to Quality Management in areas more than management and operations. Nonetheless, TQM philosophy is based on a customer-focused management practice. Under TQM, organizations systematically manage improvements by efforts of all employees across functional and hierarchical boundaries (Schlenker 2). However, managers and experts of TQM have not agreed on the different implementation methodology to apply TQM. Some believe customer satisfaction is the ultimate driver for quality improvement. Others suggest that quality is achieved by internal productivity or cost improvement programs. Also, in many organizations, TQM is considered a means to introduce participative management (Schlenker 3).

Many of the TQM concepts originated from the work of Dr. W. Edwards Deming – an American statistician who guided Japanese industry to recovery (Schlenker 4; Deming 1). Deming introduced the use of statistical methods to improve the quality of Japanese products. Now the Deming Prize is the most prestigious award for quality in Japan. Deming urged the Japanese industry to find out the needs of their customers, then study these needs and use the results to improve the design and production processes until the desired quality is achieved. Deming also urged a change of management style to focus on quality not profits. He argued that employees should learn how to monitor, control and continuously improve their work processes and interdependencies so that they produce products that meet customer expectations (Schlenker 4).

Deming also critiqued the “MBO” – Managed by Objective approach. He pointed out that the traditional model emphasized a chain of command in which objectives are translated into work standards or quotas. Therefore, MBO guides employees and their performance with numerical goals. As a result, workers, managers and supervisors are protective of themselves. Employees have narrow focuses of their own and the organization’s long-term success is placed second. The strategic focus is buried under the employees’ desperate attempt to meet quotas. There is no coordination internally for better performance. In response, Dr. Deming developed the following famous 14 points on management (Tribus, Putting 14 Points to Work):

1."Create constancy of purpose towards improvement." Replace short-term reaction with long-term planning.

2."Adopt the new philosophy." The implication is that management should actually adopt his philosophy, rather than merely expect the workforce to do so.

3."Cease dependence on inspection." If variation is reduced, there is no need to inspect manufactured items for defects because there won't be any.

4."Move towards a single supplier for any one item." Multiple suppliers mean variation

between feedstocks.

5."Improve constantly and forever." Constantly strive to reduce variation.

6."Institute training on the job." If people are inadequately trained, they will not all work the same way, and this will introduce variation.

7."Institute leadership." Deming makes a distinction between leadership and mere supervision. The latter is quota- and target-based.

8."Drive out fear." Deming sees management by fear as counter-productive in the long term because it prevents workers from acting in the organisation's best interests.

9."Break down barriers between departments." Another idea central to TQM is the concept of the 'internal customer', that each department serves not management, but the other departments that use its outputs.

10."Eliminate slogans." Another central TQM idea is that it's not people who make most mistakes - it's the process they are working in. Harassing the workforce without improving the processes they use is counter-productive.

11."Eliminate management by objectives." Deming saw production targets as encouraging the delivery of poor-quality goods.

12."Remove barriers to pride of workmanship." Many of the other problems outlined reduce worker satisfaction.

13."Institute education and self-improvement."

14."The transformation is everyone's job."

In Deming's conception of a quality system, the TQM approach assumes the following (Schlenker 6):

1. Work can be broken down into a series of related steps and tasks.
2. People completing a series of related tasks have interdependent roles in the organization.
3. A group of related processes is a system.
4. The practice of defining the steps and outcomes in their processes and systems by employees' results in a common language and understanding of what their jobs should be and how they fit into the larger picture.
5. With the application of the scientific approach using flow charts, work-flow diagrams, deployment charts, Pareto charts and cause-and-effect diagrams, people can see their interdependence and that the quality of what comes out is in measure determined by the quality that goes into a process.

PDCA or PDSA Cycle

Figure 22 is the Shewhart's PDCA Cycle – controlling factors for quality. Walter Shewhart, the pioneering statistician who developed statistical process control, promoted very effectively the quality control and continuous improvement efforts in the 1950s. Deming has adopted the cycle but changed the "Check" into a "Study" controlling factor.

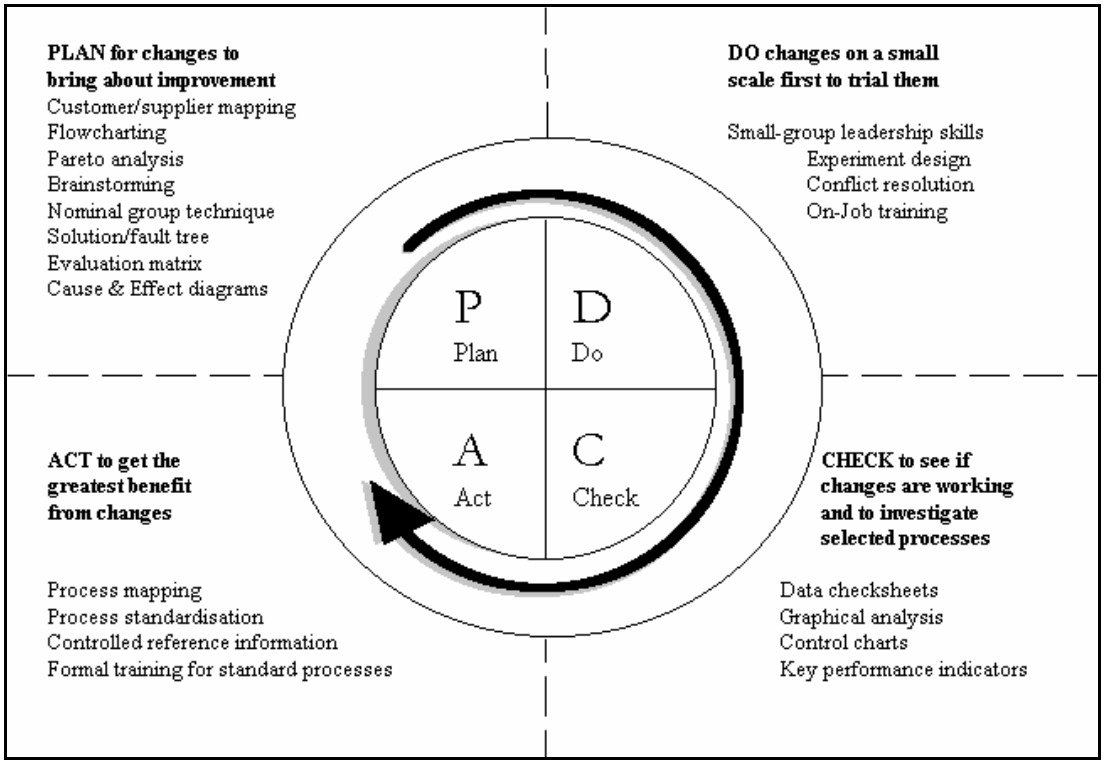


Figure 22 – PDCA cycle.

(Realisation)

"Plan" – This is the first step that identifies where the problem or error is. Then using techniques, such as flowcharting or cause & effect diagrams, the problem is clearly defined. Other techniques can then be applied to generate ideas to solve the problem.
"Do" – In a small experiment or trial, the proposed change is tested without disruption to routine activities.
"Check" and "Study" – Examine whether the changes in the small experiment achieve desirable results. In this stage, the problem and results are investigated in depth. The measurement is monitored continuously, tests reviewed, results analyzed, and learning identified (ASQ, PDCA Cycle).
"Act" – Decide on the results. Either abandon or loop the cycle again, or implement the standardization solution in large scale. This is the decision-making and implementation stage. Implementation may include large-scale implementation, another experiment in a different area, or increasing the complexity of the experiment (Dartmouth Medical School, The PDCA Cycle).

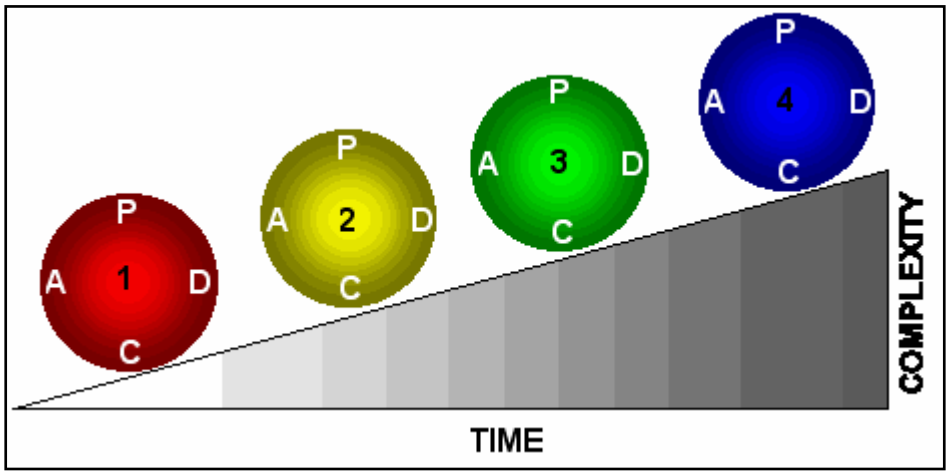


Figure 23 - The ramp of improvement – continuously.

(Dartmouth Medical School)

With one full cycle completed, another cycle can be undertaken in a different area or with more complexity. Moreover, the cycles will become more time consuming as the complexity increases. The rolling from cycle 1 to cycle 4 represents the continual improvement process that is the integral part of the PDCA cycle.

PDCA and strategic application

Arveson from the Balanced Scorecard Institute elaborated further on the use of the PDCA Cycle. He argued that Deming's PDCA Cycle focuses on industrial production processes, and the level of improvement is confined to the level of production. However, strategic initiatives can and should be placed in the PDCA loop, complete with measurements and planning. To illustrate the relationship of business unit processes to strategic processes, a construction of two nested PDCA cycles is presented below:

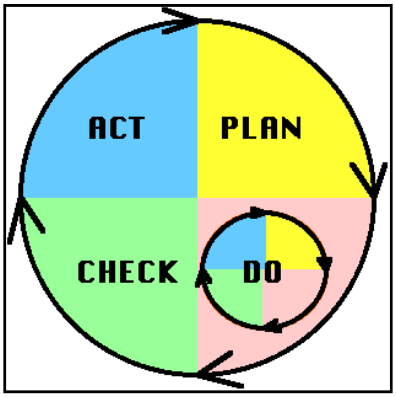


Figure 24 – PDCA Cycle within PDCA.

This “cycle within a cycle” describes the relationship between strategic management and business unit management in a large organization. There are actually several separate business units, each with its own set of metrics, goals, targets and initiatives. This figure illustrates the idea that business activities constitute the “Do” part of the overall strategic effort (Arveson, Balanced Scorecard Institute).

Deming never used the term TQM, as he said “the trouble with total quality management, the failure of TQM, you can call it, is that there is no such thing. It is a buzzword. I have never used the term, as it carries no meaning” (22). Deming criticized TQM to consider quality as a method. Deming thinks quality is the outcome of a method (Latzko, Notes 5). Nonetheless, the ISO 8402 (Quality management and quality assurance – terminology) defines TQM as the “management approach of an organization, centred on quality, based on the participation of all its members, and aiming at long-run success through customer satisfaction, and benefits to all members of the organization and to society.”. Hellsten and Klefsjo in their studies considered TQM as a management system (239). Their idea on TQM’s core value, techniques and tools can be illustrated as:

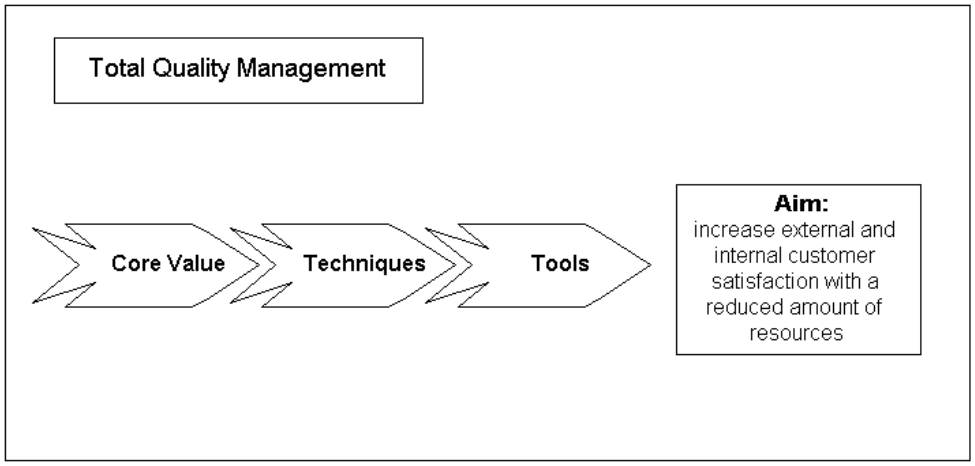


Figure 25 – Basics of TQM.

(Adapted from Hellsten and Klefsjo 242)

Starting with the core value of the organization, determine which core values best characterize the organization. Once the core values are identified, a set of techniques should be isolated from the “pool of techniques” and used to support the core values. Finally, tools should be selected to support the techniques previously isolated. Tools should be suitable to support the techniques in an efficient manner. For example, benchmarking should not be used if it does not support or efficiently measure the techniques. Also, control charts should not be used if the core values behind this choice of this tool are not supported. However, one technique can support different core values, and the same tools can be useful within many techniques.
(Hellsten and Klefsjo 242)

If we were to adapt the above TQM model to FREP, the model should display as:

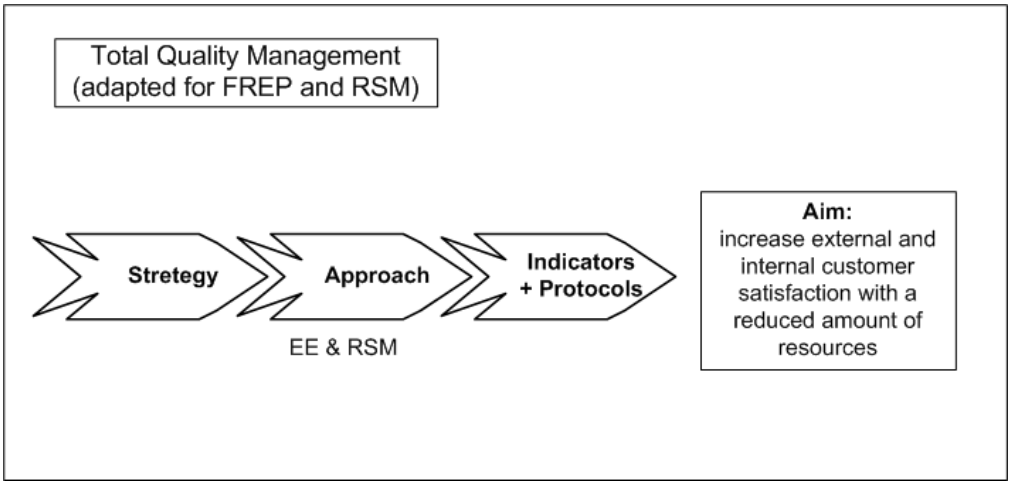


Figure 26 – TQM in FREP.

3. Kaizen – Continuous Improvement

Originating from Japanese, Kaizen is a process-oriented and never-ending continuous improvement concept. The focus is placed on small scale, incremental, and daily changes and upgrades. Kaizen is very much a team-based, across functions, and distribution of power type of discipline. Some scholars have argued that Kaizen has ways to increase empowerment, work ethics and morale (Malloch 109, 118; Styhre 800).

Some of the Kaizen practices and principles are presented in the following table:

Table 10 – Kaizen Summary Table

<table>
<tr><th colspan="2">Kaizen's Starting Point:
Setting the Right Mindset & Business Environment</th></tr>
<tr><td colspan="2">• Not a single day should go by without some kind of improvement being made somewhere in the company.
• Customer-driven strategy for improvement - any management activity should eventually lead to increased customer satisfaction.
• Quality first, not profit first - an enterprise can prosper only if customers who purchase its products or services are satisfied.
• Recognizing that any corporation has problems and establishing a corporate culture where everyone can freely admit these problems and suggest improvement.
• Problem solving is seen as a cross-functional systemic and collaborative approach.
• Emphasis on process - establishing a way of thinking aimed at improving processes and a management system that supports and acknowledges people's process-oriented efforts for improvement.</td></tr>
<tr><th colspan="2">Key Kaizen Practices</th></tr>
<tr><td>Mindset & Culture
• customer orientation
• quality control (QC) circles
• suggestion system
• discipline in the workplace
• small group activities
• cooperative labour-management relations
• total quality control (TQC)
• quality improvement</td><td>Production Process
• automation & robotics
• zero defects
• total productive maintenance (TPM)
• kamban
• just-in-time (JIT)
• productivity improvement
• new product development</td></tr>
</table>

(Kotelnikov)

Kaizen management entails two major components – maintenance and improvement. In maintenance, management should establish policies, rules, directives and SOPs (Standard Operating Procedures) so that changes can be attained in a disciplined manner. In improvement, works on improvement is continuous. Once the current standard has been revised, efforts are expended to achieve that standard until all tasks have been mastered. Then a higher standard can be established for further endeavour. Kaizen is not only obsessed with continual improvement techniques, but also focuses on communication and team building. In the original Japanese practice, managers and shop workers used “Kamban” – a label or signing board to communicate progress, schedules

and new ideas for improvement. Although Kaizen mostly deals with reduction of waste, cost savings, or “do more with less”, Kaizen’s process can be applied to quality control and improvement. In the mindset and culture of Kaizen, the quality circle is the frequent used as a tool for quality control. Based on a team approach, quality circles enhance the safety of the work environment, reduce costs, and increase productivity.

Some Scandinavian managers have criticized the Kaizen lack of cultural considerations. The traditional and fundamental management principles vary greatly between the two cultures. The Swedish and Scandinavia management tradition was thought to rest upon the ability and will of the employees to contribute to the company as individual and creative beings. This contrasts with the Japanese industry, which treats their shop workers as some kind of “human robots”. Styhre, on the other hand, recognizes that Swedish management has been practicing this type of small scale improvement; however, Kaizen has “harmonized” the efforts (803).

In Styhre’s words:

“Japanese management technique was naturalized and constructed as being fair, sound, rational, and desirable.” (803)

Imai in his book “Kaizen: The Key to Japan’s Competitive Success” mentioned the following:

"Japanese management practices succeed simply because they are good management practices. This success has little to do with cultural factors. And the lack of cultural bias means that these practices can be - and are - just as successfully employed elsewhere." (3)

Kaizen is not limited to small scale and incremental changes. However, drastic improvements should not be introduced by the shop floor and by the workers. Imai believed that the top management is responsible for such large-scale change in current processes. The following table illustrates the job functions in Kaizen as perceived by Japanese managers.

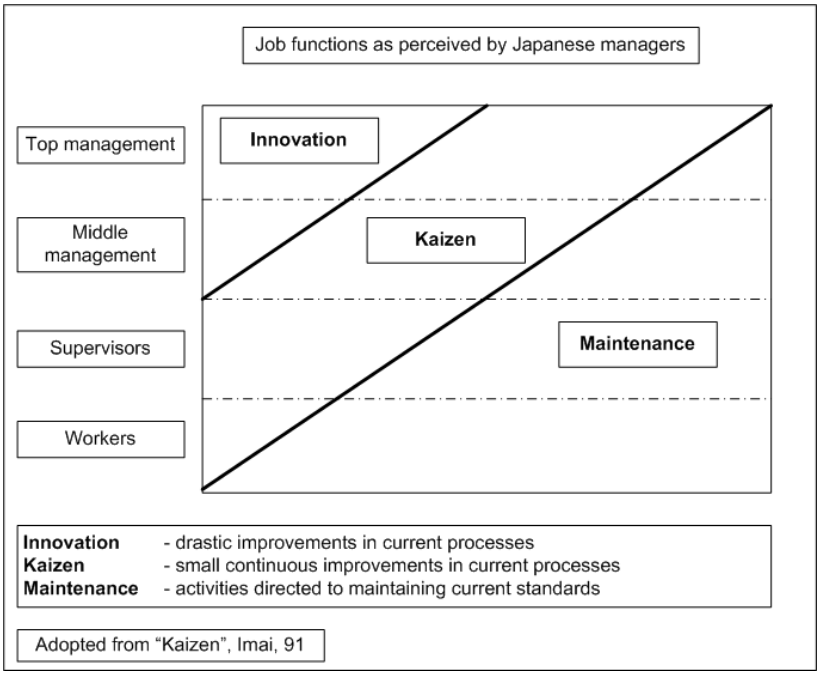


Figure 27 – Kaizen Concept of Roles and Responsibilities.

(Kotelnikov)

Kaizen, continuous improvement in the Japanese way, is useful when implemented appropriately. Not only production processes or product development can use Kaizen, but also quality control. Kaizen's small team and quality circle approach presented a new structure to quality control to the PDCA Cycle. Kaizen enables empowerment, across function effort, and most importantly, communications.

4. Six Sigma and SPC (Statistical Process Control)

Six Sigma is one of the many statistical tools used in quality control. However, over the years, it has evolved into a rather comprehensive quality improvement methodology rather than just a simple statistical control on quality. In statistical terms, Six Sigma stands for 3.4 defects per million opportunities. With six standard deviations between the process mean and the specification limit - the variation can be reduced to a desirable level as demonstrated below.

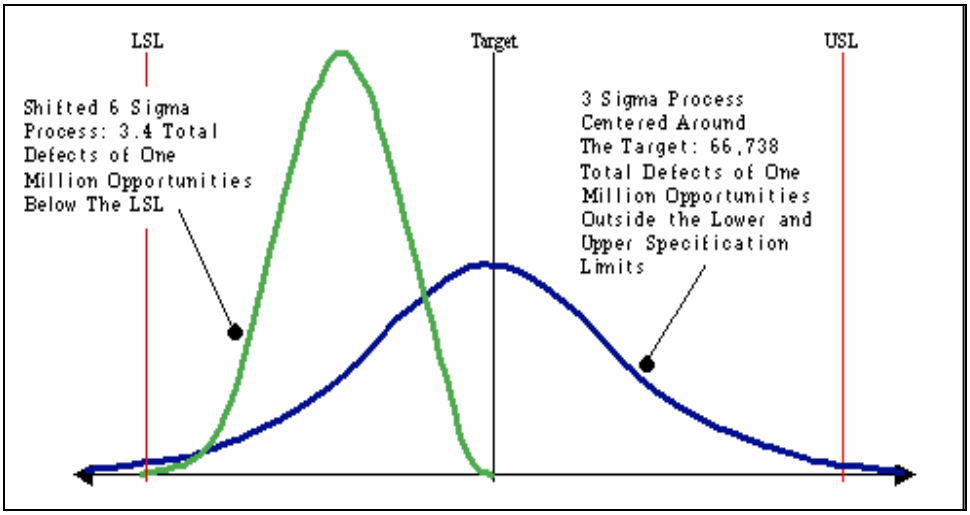


Figure 28 – Six Sigma and Upper/Lower Specification Limits.

(iSix Sigma)

Six Sigma employs a variety of tools, methods and related statistical processes to help a business process improve. More than a reactive solution to process improvement, Six Sigma can be used in identifying and planning, thus prevent poor quality. Six Sigma is both statistics and quality management (Pfeifer et al. 242). Six Sigma is:

"a rigorous and a systematic methodology that utilizes information (management by facts) and statistical analysis to measure and improve a company's operational performance, practices and systems by identifying and preventing 'defects' in manufacturing and service-related processes in order to anticipate and exceed expectations of all stakeholders to accomplish effectiveness."
(iSix Sigma)

Furthermore, Six Sigma can be understood or perceived at these three levels:

- **Metric**: 3.4 Defects Per Million Opportunities (allows the user to take complexity of product/process into account).
- **Methodology**: DMAIC/DFSS (design for Six Sigma) structured problem solving diagram and tools (see Table 9).
- **Philosophy**: Reduce variations in process and make customer-focused, data driven decisions.

DMAIC

Within the Six Sigma methodology, DMAIC is designed for problem solving and process improvement. This table explains the processes and tools in DMAIC.

Table 11 – Six Sigma and the DMAIC process

DMAIC Phase Steps	Tools Used
D - Define Phase: Define the project goals and customer (internal and external) deliverables.	
• Define Customers and Requirements (CTQs) – Critical To Quality. • Develop Problem Statement, Goals and Benefits • Identify Champion, Process Owner and Team • Define Resources • Evaluate Key Organizational Support • Develop Project Plan and Milestones • Develop High Level Process Map	• Project Charter • Process Flowchart • SIPOC Diagram • Stakeholder Analysis • DMAIC Work Breakdown Structure • CTQ Definitions • Voice of the Customer Gathering
M - Measure Phase: Measure the process to determine current performance; quantify the problem.	
• Define Defect, Opportunity, Unit and Metrics • Detailed Process Map of Appropriate Areas • Develop Data Collection Plan • Validate the Measurement System • Collect the Data • Begin Developing Y=f(x) Relationship • Determine Process Capability and Sigma Baseline	• Process Flowchart • Data Collection Plan/Example • Benchmarking • Measurement System Analysis/Gage R&R • Voice of the Customer Gathering • Process Sigma Calculation
A - Analyze Phase: Analyze and determine the root cause(s) of the defects.	
• Define Performance Objectives • Identify Value/Non-Value Added Process Steps • Identify Sources of Variation • Determine Root Cause(s) • Determine Vital Few x's, Y=f(x) Relationship	• Histogram • Pareto Chart • Time Series/Run Chart • Scatter Plot • Regression Analysis • Cause-and-Effect/Fishbone Diagram • 5 Whys • Process Map Review and Analysis • Statistical Analysis • Hypothesis Testing (Continuous and Discrete) • Non-Normal Data Analysis

I - Improve Phase: Improve the process by eliminating defects.

- Perform Design of Experiments
- Develop Potential Solutions
- Define Operating Tolerances of Potential System
- Assess Failure Modes of Potential Solutions
- Validate Potential Improvement by Pilot Studies
- Correct/Re-Evaluate Potential Solution

- Brainstorming
- Mistake Proofing
- Design of Experiments
- Pugh Matrix
- House of Quality
- Failure Modes and Effects Analysis (FMEA)
- Simulation Software

C - Control Phase: Control future process performance.

- Define and Validate Monitoring and Control System
- Develop Standards and Procedures
- Implement Statistical Process Control
- Determine Process Capability
- Develop Transfer Plan, Handoff to Process Owner
- Verify Benefits, Cost Savings/Avoidance, Profit Growth
- Close Project, Finalize Documentation
- Communicate to Business, Celebrate

- Process Sigma Calculation
- Control Charts (Variable and Attribute)
- Cost Savings Calculations
- Control Plan

(iSix Sigma)

Each higher sigma represents a significant decrease in defects. Using the most identified case of study; Motorola makes the centre (0 standard deviation) to shift 1.5 sigma. This is done so that the process can overlap the tolerance limits (Latzko 1). Therefore the shift of1.5 sigma makes the normal curve assumed in the Six Sigma process tolerant and mimics the curve to the actual process distribution.

Table 12 - Theoretical Six Sigma under Normal Curve

Yield %	Sigma	Defects Per Million Opportunities
99.9997	6.00	3.4
99.9770	5.00	230
99.3790	4.00	6210
93.3200	3.00	66800
69.2000	2.00	308000
31.0000	1.00	690000

Latzko argues that the shift of 1.5 sigma is designed to accommodate the normal curve and that all processes are in control. However, if a process becomes unstable and unpredictable, the rationality for the 1.5 sigma shift collapses. The process should undergo re-examination and correct the instability or “special” (Shewhart used the term “assignable”) cause. By means of changing tolerance limit is not a way to correct unstable process (Latzko 2). Therefore, Latzko argues that:

"A far better policy is that of continual, never ending improvement of the process. The continual improvement works on the stabilization of the process and reduction of cost by coming ever closer to the target value and reducing variation (3)."

Table 13 - Six Sigma after 1.5 Sigma Shift from Centre

Shift Value	% Within Curve	Parts per million
-6.0	99.9999999%	0.0
-5.5	99.9999981%	0.0
-5.0	99.9999713%	0.3
-4.5	99.9996599%	3.4
-4.0	99.9968314%	31.7
-3.5	99.9767327%	232.7
-3.0	99.8650033%	1350.0
-2.5	99.3790320%	6209.7
-2.0	97.7249938%	22750.1
-1.5	93.3192771%	66807.2
-1.0	84.1344740%	158655.3
-0.5	69.1462468%	308537.5
0.0	50.0000001%	500000.0
0.5	69.1462468%	308537.5
1.0	84.1344740%	158655.3
1.5	93.3192771%	66807.2
2.0	97.7249938%	22750.1
2.5	99.3790320%	6209.7
3.0	99.8650033%	1350.0
3.5	99.9767327%	232.7
4.0	99.9968314%	31.7
4.5	99.9996599%	3.4
5.0	99.9999713%	0.3
5.5	99.9999981%	0.0
6.0	99.9999999%	0.0

The above table shows the defects after the 1.5 sigma shift. However, the shift is debatable among scholars. The shift may accommodate to anomalies in the normal curve, but some scholars argue that shifting increases the tolerance level, thus decreasing the quality that Six Sigma is designed to improve. As a result, shifting fails to meet the original Six Sigma objective (Latzko 1). However, no sustained conclusion about the shift has been agreed at this point (Latzko 3).

Having discussed Latzko's view on Six Sigma, the benefits and limitations of the process will be examined in further detail.

Benefit of Six Sigma

- A clear focus on achievable, measurable, and quantifiable impacts to the bottom-line on the organization. Expected bottom-line impacts are clearly identified and defined.
- Strong and passionate leadership for strategy deployment.
- Problem solving integrates human elements, change, customer focus, and process elements.

- Six Sigma employs tools and techniques in process in a sequential and disciplined fashion.
- Six Sigma uses a belt system to implement – Champions, master black belt, black belt, and green belt (Hoerl 4).
- Focus on concrete data and evidence for decision-making.
- Emphasis on the use of statistical thinking and techniques to reduce process variability.

Limitations and critiques of Six Sigma

As with other quality management methodologies or systems, there are a few short comings to Six Sigma:

- It is a challenge is to have quality data available. Considering the resources needed to generate data on quality.
- Only a small portion of the solutions get implemented and not all suggested solutions fit all processes.
- The correct selection and prioritization is required at the start of the Six Sigma program. There is often no powerful tool to prioritize projects in Six Sigma or prioritization is fixed to politics.
- The Six Sigma level of 3.4 defects may still be judged poor quality as judged by the end user. Some industries will attempt seven or eight sigma to achieve their quality standard.
- Calculation of Six Sigma is based on the normality assumption. If the cause of defect or error is non-normal, the anomaly cannot be properly addressed using Six Sigma methodology. Six Sigma assumes a stable business process.
- Changes to internal and external environments are high. Critical-to-Quality (CTQ) characteristics and factors may not be valid in the near future due to dynamic and fast changing environments. Multiple CTQs are not thoroughly studied in Six Sigma projects.
- The belt system of Six Sigma consultants lack uniform certification. Not all consultants on the same level posse the same skills and expertise. Certification is highly dependent on the certifying body where no standardization is established (Hoerl 2).
- The relationship between cost of poor quality and process sigma quality level require more justification. The achievement of six sigma may be more costly than the cost of poor quality. (Antony 303)

Another issue with Six Sigma is that when it approaches more than 4.8 sigma, the improvement process starts to become costly and challenging. It takes more time to reach a higher sigma after 4.8, as the strategy is no longer about defect removal, but about the redesign of the system – Design for Six Sigma (DFSS). An exponential reduction of defects calls for an exponential resources. This is especially true when approaching a near-perfect world where the cost of poor quality is less than the Six Sigma project, and further effort to achieve absolute quality cannot be justified under the notion “value-for-the-money”. Cost has outweighed the benefits (Coronado and Anthony 94).

Beyond Six Sigma

Given the demand for quality, and developments in quality education and certification, Six Sigma may not be the ultimate destination for quality. A high tech industry can achieve Seven or even Eight Sigma by means of intelligent tools, migration of quality to

new areas, and commitment of senior management. DeFeo and Janssen argued that quality performance is closely related to the financial performance of the organization (92). Also, ISO continuously revises and adapts sector-specific guidelines to standard. Once only considered in manufacturing, engineering and software development, quality now affects almost every aspect of an organization, and even private life. Quality will become a function of every job, and more importantly, a competitive advantage that everyone seeks. Developing countries, such as South Korea, Mexico, and Asia, will be dependent on quality to compete in the world market (DeFeo and Janssen 94).

Goh and Xie, adding to the benefits of Six Sigma, argued that the merit of both the system and strategic use of Six Sigma. They believe that Six Sigma can be extended from a micro focus to a macro analysis, given the appropriate time and resources (239).

5. Quality Function Deployment – Quality System and the Voice of the Customer

Introduction

Originating in Japan, Quality Function Deployment (QFD) began 30 years ago as a quality system focused on delivering products and services that satisfy customers. The late Dr. Shigeru Mizuno, Dr. Yoji Akao, and other Japanese quality experts developed the tools and techniques used in QFD. Today, the QFD Institute's Akao award recognizes individuals worldwide for the practice and dissemination of QFD (QFD Institute). QFD has shared its success in North America, namely with Florida Power and Light in 1990, AT&T Power Systems in 1994, and the University of Michigan Medical Centre in 1991. Both Florida Power and Light, and AT&T Power Systems are recognized by the Deming Prize. This is especially significant as Florida Power and Light is the first non-Japanese Deming Prize recipient. Still evolving in its application, QFD has been applied in engineering, manufacturing, retail, product design, software development, applied healthcare, food, hospitality, and many other goods and services. QFD has been cited for benefits such as promoting cross-functional teams, improving internal communications, and translating customer requirements into the language and culture of the organization (Bolt and Mazur 3). Furthermore, QFD is a comprehensive quality system that employs tools such as the "House of Quality," achieving quality through design, planning and project management.

The following figure elaborates the concept of customer requirements to capture the essence of QFD.

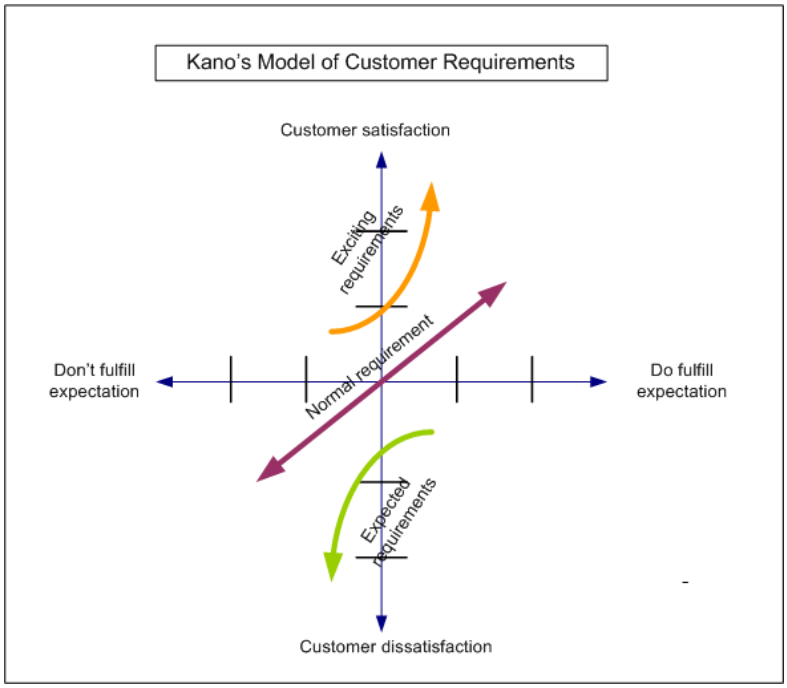


Figure 29 – Kano's model of customer requirements.

(Bolt and Mazur 3)

Normal requirements are typically the information obtained by asking customers what they want. Using the example of a courier service, faster delivery satisfies and fulfills customer expectations. Slower delivery dissatisfies customers and does not fulfill expectations. This is because customer satisfaction and expectation are positively correlated. The fulfillment of customer expectations results in satisfaction, and when expectations are not being fulfilled, dissatisfaction results.

Expected requirements are the very basic customer expectations. These expectations are generated by basic product functionality, social norms, and normally the expectations of the general public. Fulfillment of the expected requirements generates no higher satisfaction. Customers normally do not notice if expected requirements are being met; however, failing to meet expected requirements, will result in customers expressing high dissatisfaction. For example, if a cup of coffee is served hot, the customer will barely notice it, except for being careful not to get burned. If the coffee is served cold, however, the customer will probably be dissatisfied and ask for a new one.

Exciting requirements are challenging to produce or discover. They go beyond customers' expectations. Their absence will not dissatisfy customers, but their presence will be a pleasant surprise.

The Kano model is dynamic. What is exciting today is expected tomorrow. The environments evolve as competition and regulations change or are changed. Business practices in the private sector will argue that due to the changing nature of the business environment, innovation and new product/service development are keys to profitability and survival. To apply the voice of customer analysis to FREP, it implies the development of a program objective, project goals, stakeholder requirements, and the overall long-term planning on the program. Hence, Voices become requirements, and objectives and goals. Customers become stakeholders, committees, working groups, team leaders, and ultimately extend to society or the general public. If we were to adapt the Kano model for FREP, we would aim at the normal requirement as our base standard. Bearing excellence, quality and performance in mind, expected requirements would be met by the positive benefits FREP generates. These would include identifying red flags (high priority and hazardous areas), general trends, and suggest changes to existing policy and regulations.

Phases and components

The most frequently used QFD tool is the "House of Quality." The seven other tools are Affinity diagrams, Relations diagrams, Hierarchy trees, Matrices and tables, Process Decision Program Diagrams (PDPDs), the Analytic Hierarchy Process (AHP), and Blueprinting. The House of Quality (HOQ) is probably the most comprehensive tool that captures the essence of QFD. Authors such as Ouyang et al. believe that QFD is an integral part of Total Quality Management. In their view, QFD controls the quality by the design of "what the customer wants" (4).

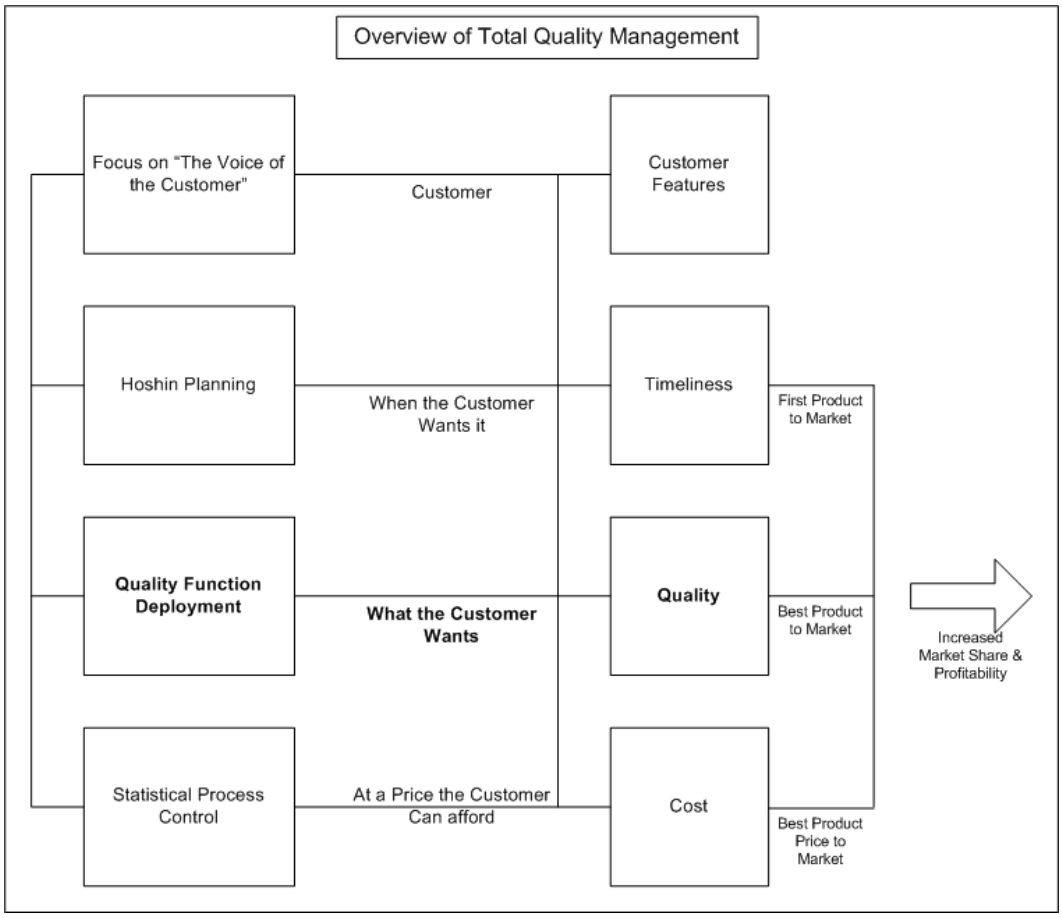


Figure 30 – TQM overview and QFD.

(Ouyang et al. 4)

The typical four phases of the QFD are design, detail, process and production. Adapting this to the FREP context, the four phases will become design, data collection, data analysis and reporting. This can be displayed as:

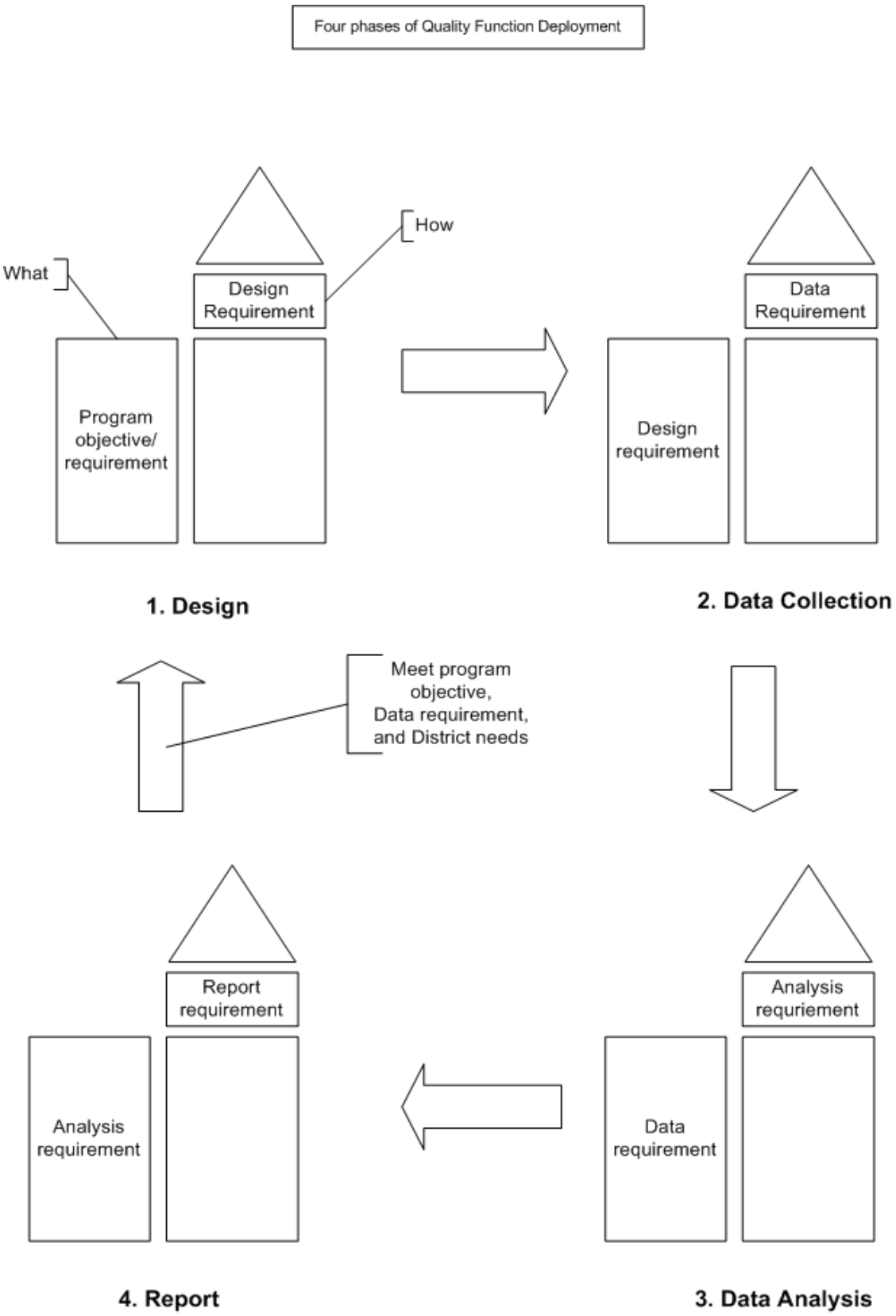


Figure 31 – Four phases of QFD (adapted for FREP).

Note that each succeeding phase is taking the “HOW” requirement from the previous phase and making it the “WHAT” requirement. This process helps to communicate the requirements within the organization, making a thorough and continuous transition from the “voice of the customer” to the final product or service. Participants in the four phases must assess the solutions that will achieve each “WHAT” requirement. All decisions must also be made based on the highest level of requirement[66] satisfaction.

The anatomy of the HOQ is:

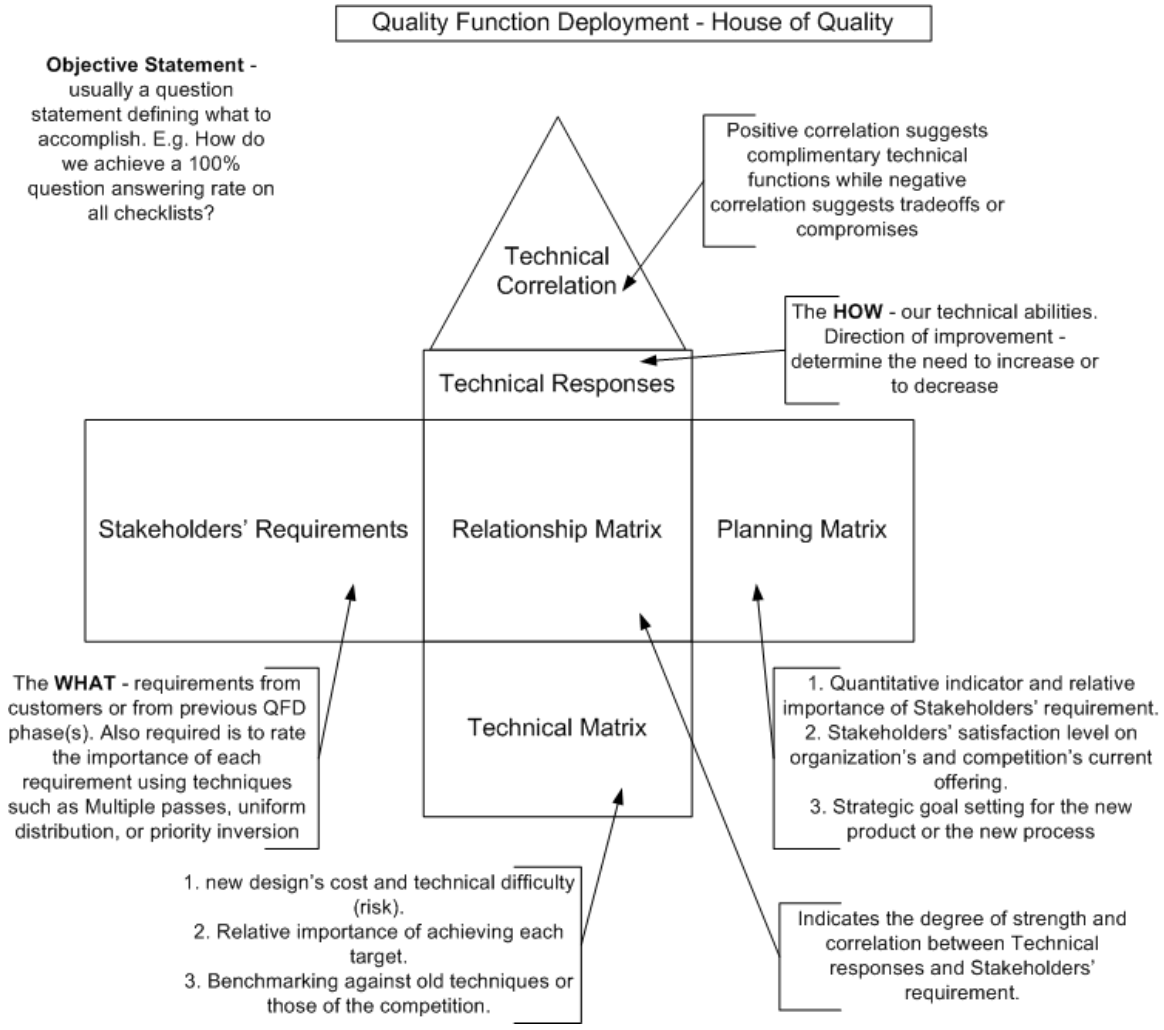


Figure 32 – Anatomy of House of Quality.

An important component of the HOQ is the relationship matrix where correlation builds up the foundation for strength, weakness, priority and the next QFD phase. The objective statement is usually a question that defines what the QFD is trying to accomplish. A good objective should be focused on requirements through a single and manageable task. If there are too many requirements, categorizing them and conducting separate HOQs can help the participants focus and be more efficient. Moreover, a single

[66] Requirement is typically referred to as customer requirements and satisfaction; however, for FREP requirement is referred to as our program and project components, and their objectives.

and manageable task should include both the “HOW” and the “WHAT” requirements. For example, a good objective statement may be “What is the quality of the data collected? The requirements of quality that is important to data analysis?”

Stakeholders’ Requirement

The “voice of the customer” or stakeholder requirements is a list of the requirements. In a typical QFD session, this is referred to as the customer-desired qualities and attributes. These qualities or attributes make up the “WHAT”. Each “WHAT” should represent a single requirement, and each should be limited to five words or less if possible. If not, ten words is the maximum. This length limitation helps to capture and communicate the true requirements without losing the true meaning when paraphrased. When the “voice of the customer” analysis is applied to new product development, a focus group or study panel is often used to generate the customer requirements.

After the requirements are captured and organized, they go through an importance rating or prioritization in a scale of 1 to 5. The rating or prioritization gives a weighting factor to each requirement and a multiplier for other numbers in the relationship matrix (see figure 33). The rating will also affect certain statistical conclusions; therefore, techniques to derive appropriate ratings are critical. Methods, such as multiple passes, uniform distribution, and priority inversion, are popular to review the “WHAT” list and rank them by degree of importance. Using multiple passes as an example, the facilitator takes the importance rating team through the list several times. By comparing the ratings against the requirements on the list, the team can refine the ratings. Uniform distribution, on the other hand, might be an appropriate tool to start the rating allocation. For example, in a six member team which attempts to rating six requirements, there will be four votes allocated to each member. Each vote can only go to one requirement once, and each member must cast all their votes. Member will cast the vote to the requirements they feel are important. As a result, a preliminary rating of the importance of each requirement is established. In this case, multiple passes might be a good tool to adjust the ratings.

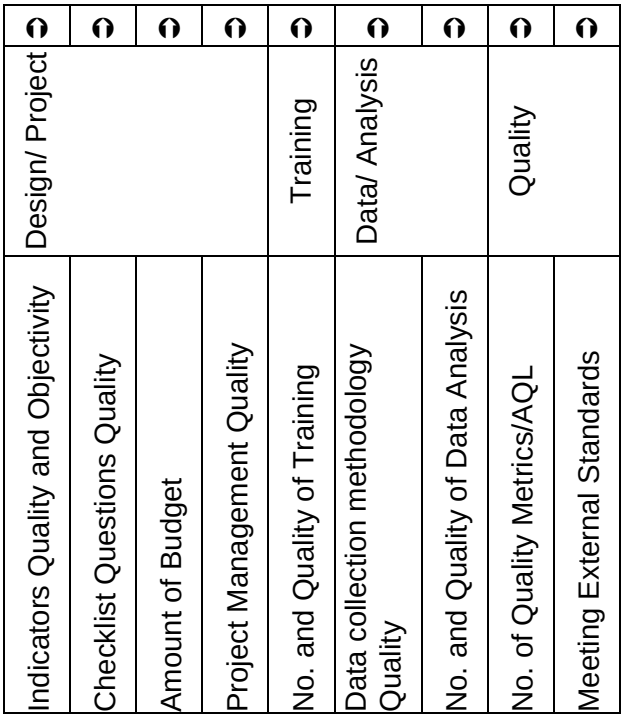
Figure 33 - Example of the requirement – “WHATs”

Program Requirement	**Data/information requirement**	Consistent format	5
		Unit of analysis	5
		Accuracy	5
	District office needs	Field applicability	5
		Identify trend	4
		Plan future research	4
	Policy recommendation	Generate options	5
		Prioritize monitoring and evaluation	5
		Canned and custom reports	4
	Quality	External recognition	3
		Value for money	5
		International standard	4

Technical Responses

The responses capture the “HOWs.” These are the internal technical abilities and capacities that we are able to achieve. The “HOWs” are ways of achieving the “WHATs.” They can consist of processes, facilities, equipment and methods as the emphasis shifts away from problem identification to problem solving. A typical way to capture the “HOWs” is through a brainstorming session with team members from both technical and non-technical backgrounds. This provides an opportunity for all team members to offer possible solutions to the “WHATs.” (Figure 34 in the context of FREP)

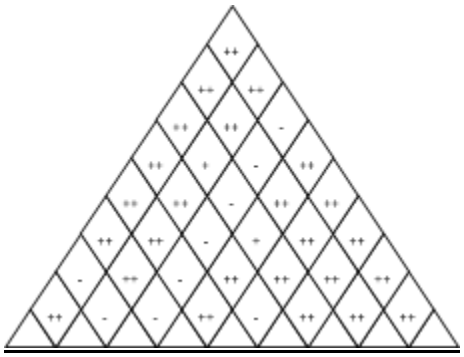
Figure 34 - Example of the technical responses – “HOWs.”



Technical Correlation

This is the “roof” of the House of Quality. The correlation shows the positive and negative relationships among the “HOWs.” If one “HOW” supports or compliments another “HOW,” a positive relationship is established and vice versa (if a conflict occurs, there is a negative relationship). Usually the number of positive and negative symbols indicates the strength of the relationship. The purpose of the correlation is to help identify the resource for overlapping relationships (see Figure 35). The correlation matrix also helps to indicate where additional resources are needed to be allocated and where conflict needs to be minimized or resolved. As a result, the “HOWs” can satisfy the “WHATs” with their full potentials.

Figure 35 - Example of the “Roof” – technical correlations.



The Relationship Matrix

The relationship matrix is the central component of the House of Quality. Team members must identify if a particular “HOW” is solving or fulfilling a “WHAT.” If the “HOW” does not achieve the “WHAT,” a score of zero is recorded in the joined cell. If the “HOW” achieves the “WHAT,” then the team must indicate the relationship using strong, medium or weak scores. The typical attribution of the relationship scores are:

Figure 36 – Strength indicator for the relationship matrix.

Relationship

Symbol	Strength	Score
⊙	Strong	9
○	Medium	3
△	Weak	1

Planning Matrix

The planning matrix summarizes the calculation from the relationship matrix for stakeholder requirements. Using the importance rating of each stakeholder requirements (the WHAT) and multiply the score of the relationship matrix, we can summarize the absolute and relative importance of each requirement. We can also assess the survey, panel study, expert opinion, and other requirement capture methods completed in addition to the stakeholder requirements. Therefore, we are verifying the stakeholder requirements using this matrix and assessing the strength and the weaknesses of the work. Often comparison tables or charts are inserted here so that ratings can be displayed.

Figure 37 - Example of the planning matrix.

Total (Absolute importance)	**Total (%)** (Relative importance)	**Survey**	**Team leader 1**	**Team leader 2**
335	12%			
185	7%			
335	14%			
215	4%			
225	5%			
270	6%			
165	4%			
220	6%			
215	6%			
285	8%			
180	6%			
225	7%			

Technical Matrix

The technical matrix draws conclusions from the technical responses. It assesses the technical difficulties and associated costs. Some QFD teams put risks in this matrix so that they are associated with technicalities. Using the same methodology as the importance rating, technical difficulty is also rated from a scale of 1 to 5, which is used to calculate the absolute and relative importance.

Figure 38 - Example of the technical matrix.

Organization difficulties	1	3	3	1	3	4	3	5	5
How much	100%	100%	$?	95-100%	# And 95%	95% accuracy	100% on time	5 each	Certification
Absolute importance	309	276	230	96	291	356	401	370	225
Relative importance (%)	12%	11%	9%	4%	11%	14%	16%	14%	9%

The values established in the technical matrix are also used for a benchmark. The results can be used to compare against old and new methods, as it provides quantitative measures enabling quality control and monitoring. Therefore, the technical matrix can be used in conjunction with Quality Metrics and Quality Requirements.

Appendix B – Glossary

Quality
The totality of features and characteristics of a product or services that bear on its ability to satisfy stated or implied needs. [Switzerland, Quality management].

Quality assurance
All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality [ISO Definition].

Quality control
The operational techniques and activities that are used to fulfill requirements for quality [ISO Definition].

Quality policy
The overall quality intentions and direction of an organization as regards quality, as formally expressed by top management [ISO Definition].

Quality management
That aspect of the overall management function that determines and implements the quality policy [ISO Definition].

Quality metrics
An operational definition that describes, in very specific terms, what something is and how the quality control process measures it [PMBOK 189].

Quality system
The organizational structure, responsibilities, procedures and resources for implementing quality management [ISO Definition].

Quality spiral; quality loop
Conceptual model of interacting activities that influence the quality of a product or service in the various stages ranging from the identification of needs to the assessment of whether these needs have been satisfied.

Critical Success Factors
Factors deemed necessary in order for FREP to be successful in meeting its objectives.

Compliance audits
Assess compliance with legislated requirements (e.g., FRPA regulations). Conformance with strategies for achieving the desired results is also subject to compliance inspections.

Effectiveness evaluations
Used to determine whether implemented plans or practices actually meet resource value objectives. Monitoring is a component of effectiveness evaluations.

Extensive evaluations
Evaluations involving the collection of categorical data using visual estimates or relatively simple measurements.

FREWG
FRPA Resource Evaluation Working Group – the main working group that oversees the development and implementation of the FRPA Resource Evaluation Program.

FRPA
Forest and Range Practices Act.

FSP
Forest Stewardship Plan.

Implementation monitoring
Undertaken to determine the rate of progress towards a specific goal, including the adoption of new practices, and whether the practices were implemented as planned.

Intensive evaluations
In-depth evaluations involving detailed quantitative data collection and analysis with comparison to controls.

JSC
Joint Steering Committee.

Monitoring
Observing, checking, or keeping a continuous record of a process or quantity over a period of time.

PAC
The Minister of Forests' Practices Advisory Council – a council of external stakeholders providing input into the *Forest and Range Practices Act* and regulations.

Protocols
Methodologies and standards (e.g., data collection and analysis).

Refinement monitoring
Also known as improvement monitoring, refinement monitoring evaluates a range of alternative practices to provide a range of comparisons.

Routine evaluations
Low intensity overview evaluations (lower rigor as compared to extensive and intensive evaluations) consisting of rapid data collection such as visual estimates and yes/no answers). Useful for identifying management trends or issues that may require more detailed evaluations.

Sustainability
A state or process that can be maintained indefinitely. The principles of sustainability integrate three closely intertwined elements – the environment, the economy and the social system.

Validation monitoring
An assessment or verification of the basic assumptions under which a specific management direction was developed.