A Process Quality Model for the Analysis, Improvement, and Control of Supply Chain Systems

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Abstract

A manufacturing supply chain is an integrated set of business functions, encompassing all activities from raw material acquisition to final customer delivery. Delivering the right product at the right time in the right amount are essential objectives of efficient and effective supply chain systems. Thus, measures must be taken to ensure that all operational components of the supply chain system are operating efficiently. This research examines quality measurement in a supply chain process by developing the Process Quality Model (PQM) to be used in the assessment, improvement and control of a manufacturing supply chain system.

Keywords: supply chain, quality, performance

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1 Introduction

A manufacturing supply chain is an integrated set of business functions, encompassing all activities from raw material acquisition to final customer delivery. Today's changing industry dynamics have influenced the design, operation and objectives of supply chain systems by increasing emphasis on: (1) improved customer service levels, (2) reduced cycle time, (3) improved quality of products and services, (4) reduced costs, (5) integrated information technology and process flows, (6) planned and managed movement, and (7) flexibility of product customization to meet customer needs [3]. Effective management of supply chain systems is achieved by identifying customer service requirements, determining inventory placement and levels, and creating effective policies and procedures for the coordination of supply chain activities [1]. The coordination of logistics functions into integrated supply chain systems has increased the need for improved process quality. Improving the quality of all supply chain processes results in reduced costs, improved resource utilization, and improved process efficiency.

2 Literature Review

Much of the research in supply chain process quality measurement has explored the question of how to assess the performance of individual supply chain functions. In 1978 and 1984, A.T. Kearney, Inc. established four stages of organizational sophistication in performance measurement of physical distribution activities. More specifically, this study established the following four-stage classification scheme:

(1). Stage I organizations: inactive; use simple measures (e.g., total cost) to assess system performance.

(2). Stage II organizations: reactive; use measures of productivity to measure performance.

(3). Stage III organizations: proactive; have meaningful goals; most use engineered standards to measure performance.

(4). Stage IV organizations: exhibit completely integrated information, production, storage, transportation, and distribution systems, allowing for seamless communication across all supply chain functions.

This work established a basis for subsequent work in the performance of supply chain functions.

Konrad & Mentzer (1991) propose that the evaluation of supply chain functions be divided into three areas: productivity, utilization, and performance. The authors define productivity as the ratio of real output to real input. Real output is defined as the number of products being delivered, and

real input refers to the amount of raw material, sub-assemblies, etc. brought into the system. They define utilization as follows:

$$\text{Utilization} = \frac{\text{capacity used}}{\text{available capacity}}$$

Consequently, system performance is defined as:

$$\text{System Performance} = \frac{\text{actual output}}{\text{standard output}}$$

Miller and Read (1991) examine the state of quality in supply chain systems. The results of a survey of 225 international businesses showed that only 40% of all companies have a satisfactory supply chain quality program in place. The authors conclude that the greatest stumbling block to quality programs in supply chain systems is in determining what to measure and then developing appropriate information systems to support this measurement.

DeToro and Tenner (1997) provide a step-by-step approach to process improvement. Their model is based on the principles established by Crosby, Deming, Juran and Feigenbaum. The steps involved in their continuous improvement process are:

1. *Understand the customer*. Understand the requirements of the end customer and assess the organization's ability to meet these requirements.

2. *Assess efficiency*. Gather data on internal process measures and determine whether the process is meeting such demands as cost, cycle time or variability.

3. *Analyze the process*. Determine the efficiency and effectiveness of the process. at this step, the appropriate improvement path must be identified: continuous improvement, benchmarking, or reengineering. If continuous improvement is the appropriate path then step four is performed.

4. *Improve the process*. Plan-Do-Study-Act is used as an approach to improve the process.

5. *Implement changes*. Make necessary adjustments.

6. *Standardize and monitor*. Track performance, monitor process and continually improve.

The majority of previous research provides insight into measuring supply chain systems. Research in supply chain process quality, however, has been very limited. The objective of this research is to bridge the gap between supply chain systems analysis and quality control by developing a Process Quality Model (PQM) for the assessment, improvement and control of quality in supply chain systems.

3 Problem Description

Much of the research in the measurement of supply chain processes has focused on the development and application of productivity, utilization, efficiency, and/or effectiveness equations. However, a model that provides a procedural approach to assessing, improving, and controlling the quality of the supply chain process has not been found in the literature. This research develops a Process Quality Model (PQM) that can be used to assess the performance of a supply chain system and its sub-systems, assist in identifying problem areas, and provide a framework for continuous improvement of supply chain systems. In particular, PQM addresses the following questions:

1. What aspects of quality should be measured?

2. How should these aspects of quality be measured?

3. How can these measures be used to evaluate, improve and control the overall quality of the supply chain system?

4 The Process Quality Model (PQM)

The basic framework of the PQM is given below in Figure 1. The PQM consists of seven integrated modules. The details and procedural steps associated with each module follow.

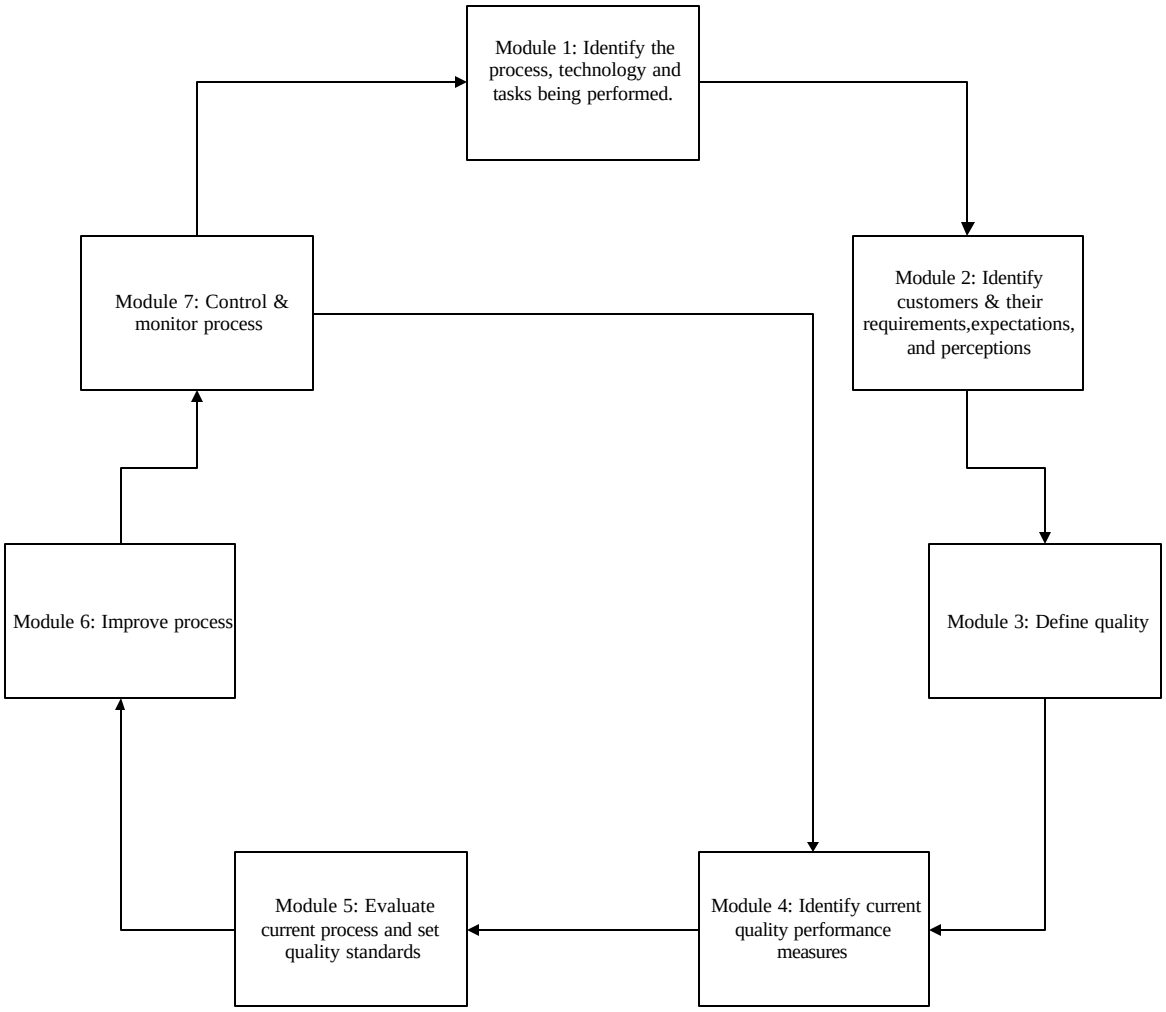

Figure 1. Process Quality Model (PQM)

4.1 Module 1: Define the process and activities being performed

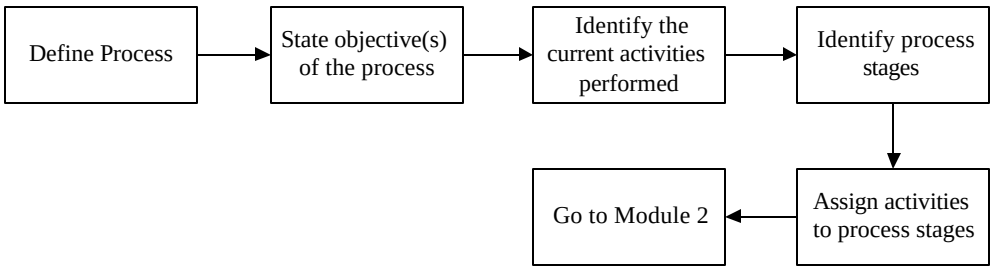

Figure 2. Module 1

Objective: The purpose of Module 1 is to define the process and all required activities.

The first module in the PQM is to define the current system and all activities that are currently being performed. There are a number of graphical tools that are useful in determining the tasks performed in the supply chain process, such as flowcharts, flow process charts, Gantt charts, and relations diagrams. For information regarding how these tools are applied, the interested reader is referred to Straker (1995). After the activities have been identified, then the activities are assigned to process stages. These stages may include inbound and outbound transport, warehousing, production planning/inventory control and customer service.

4.2 Module 2: Identify customers and their requirements, expectations, and perceptions

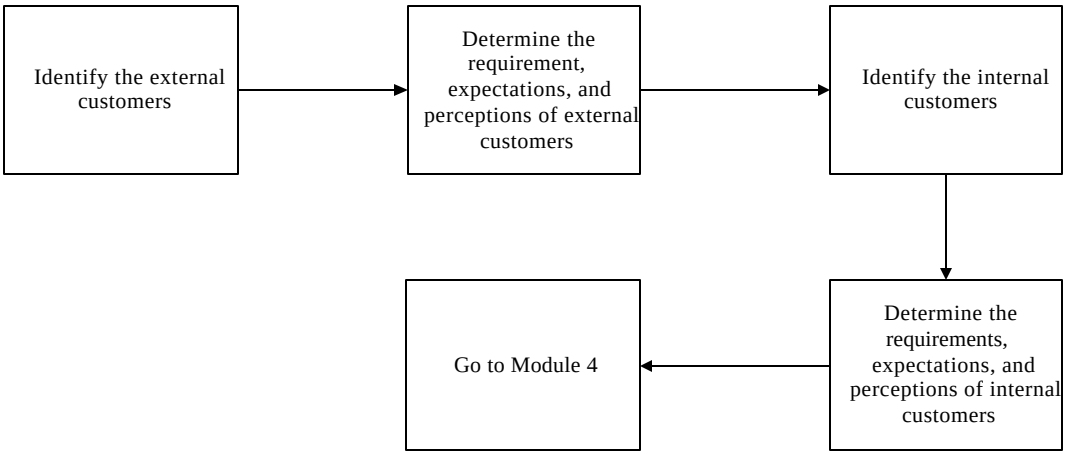

Figure 3. Module 2

Objective: The purpose of Module 2 is to identify customer requirements, expectations, and perceptions in order to continuously improve customer service performance.

Module 2 of PQM is to identify the external and internal customers and their requirements, expectations, and perceptions. The external customer(s) are the consumer(s) of the end product. The internal customer(s) are the department(s) that require goods/services from another department within the organizational boundaries.

4.3 Module 3: Define Quality

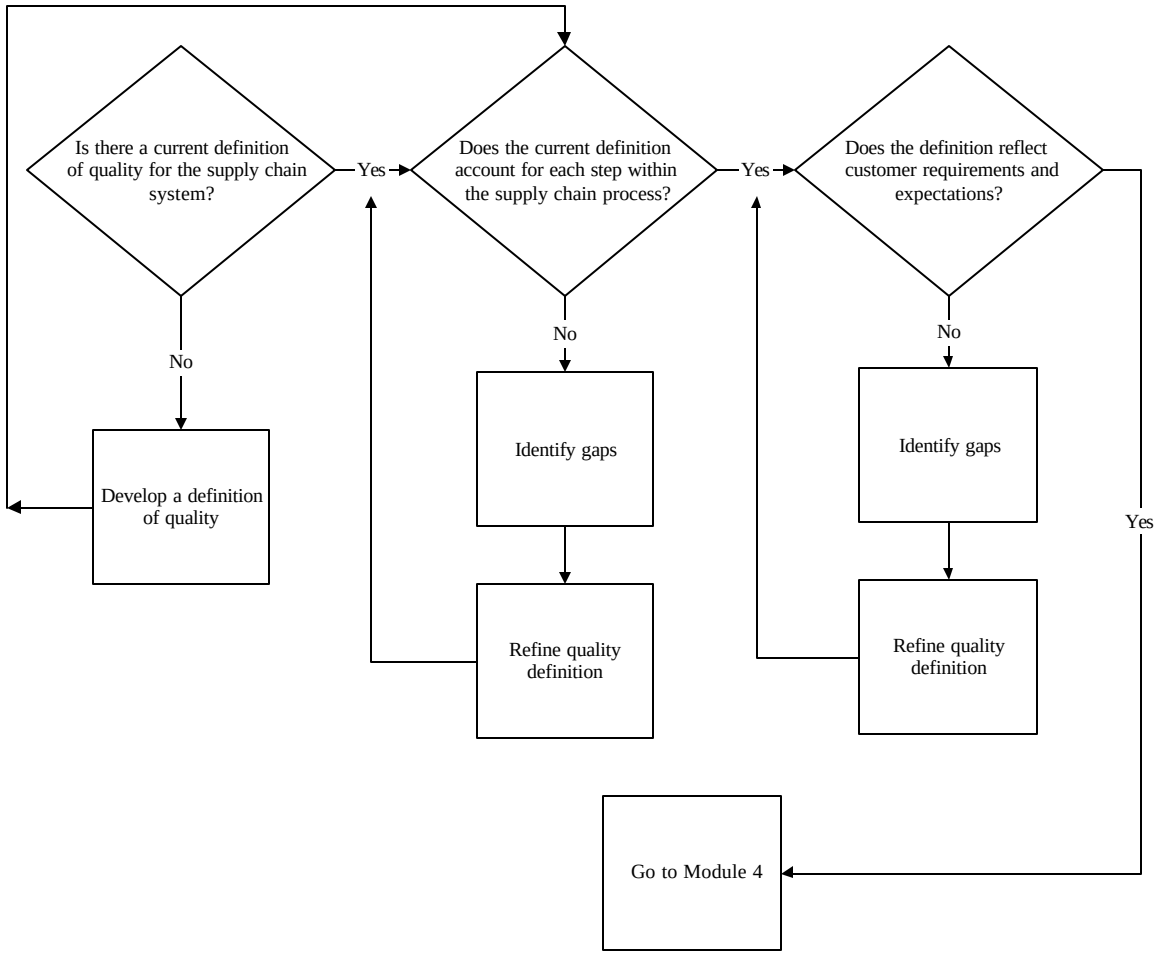

Figure 4. Module 3

Objective: The purpose of Module 3 is to establish and refine the definition of quality in the supply chain system.

There are numerous definitions of quality. For example, W. Edwards Deming defines quality as a product or service "…[that] helps somebody and enjoys a good and sustainable market" [6]. Joseph Juran coined the phrase "fitness for use by the customer" as a definition of quality [9]. Philip B. Crosby bases his approach to quality on four absolutes: (1) "Quality is conformance to requirements", (2) "Quality is caused by prevention", (3) "The performance standard is no defects", and (4) "The measure of quality is the price of nonconformance" [4]. Feigenbaum defines quality as "the total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which the product and service in use will meet the expectations of the customer" [8]. Each definition maintains at its core that quality is defined by the customer. Therefore, each organization should create a quality definition based on the requirements of its customer. The definition should be a reflection of the types of tasks involved and the requirements and expectations of the customers.

When developing a system definition of quality, the following questions must be answered:

(1). What are the goals of the supply chain process? [Objectives]

(2). What are the internal and external customer requirements/expectations from the supply chain process? [Customer requirements]

(3). What are our competitors definition of quality? [Benchmarking]

These questions should be used to formulate objectives for the tasks and processes involved [2]. The goals of the supply chain process should be consistent with and supportive of organizational goals. If the current supply chain process has a definition of quality that does not reflect the stages of the process and the needs of the customers, then the gaps should be identified and the definition refined. The definition of quality should encompass the customer requirements and expectations for each stage in the process.

4.4 Module 4: Identify current quality performance measures

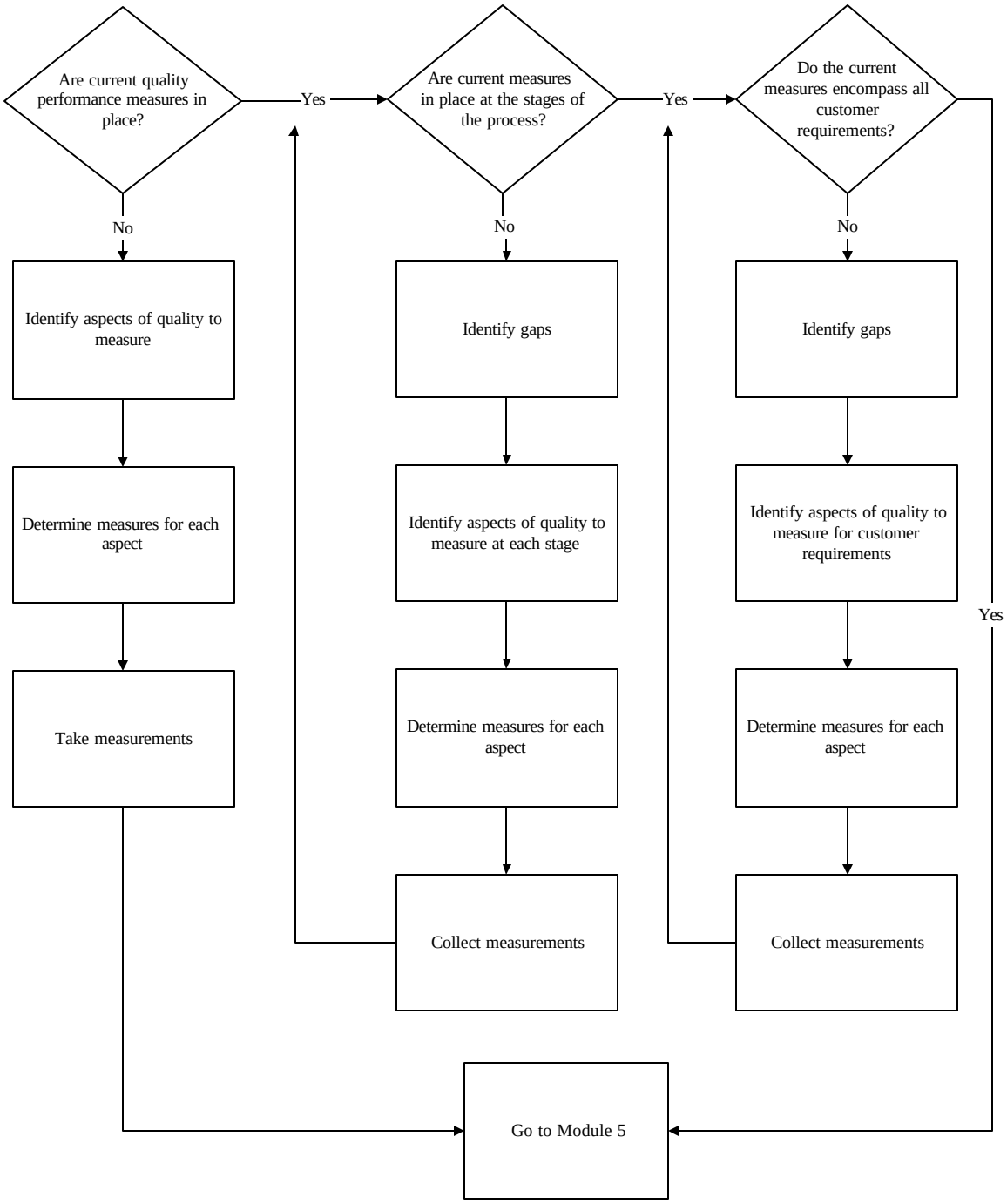

Figure 5. Module 4

Objective: The purpose of Module 4 is to identify current cost, productivity and service measures and identify gaps in current measurements.

This Module facilitates an understanding of the types of process quality measures that are currently being employed. First, the gaps associated with the various supply chain stages and customer requirements are identified. Next, these gaps must be translated into measurements, and then the aspects of quality for the process may be identified. There are numerous aspects of quality that may be measured in a supply chain process. Some examples are provided below [1]:

- reliability - concerns the time between failed delivery of products
- order accuracy - concerns the probability the correct orders is taken, arrives or departs from the warehouse on time
- worker standards - the engineered standards for workers inside the warehouse
- customer satisfaction - concerns whether the internal or external customers are satisfied with his/her service.
- worker quality - concerns safety issues, damaged goods, etc.
- cost - the resulting cost incurred in a supply chain system by stages or throughout the entire system.

After the appropriate quality measures are identified, then procedures must be developed to capture these measurements. Finally, measurements are collected for all supply chain stages and for all customer requirements. Possible measurements for each step of the supply chain process can be found in A.T. Kearney (1978) and Novack (1992).

4.5 Module 5: Evaluate current processes and set quality standards

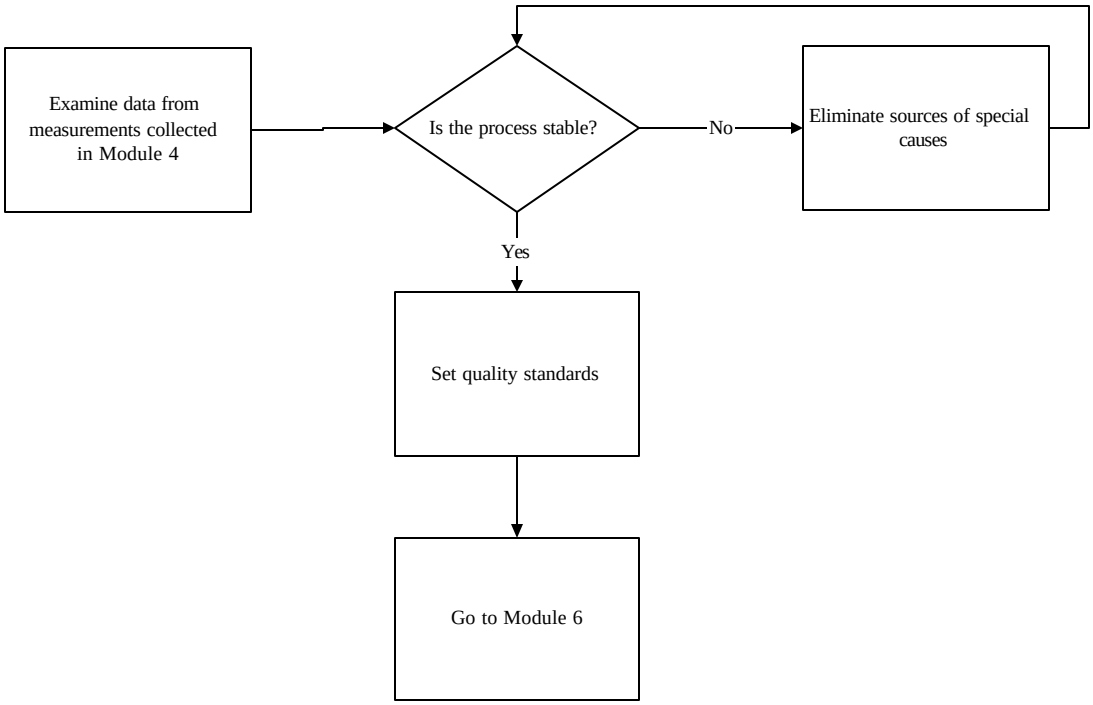

Figure 6. Module 5

Objective: The purpose of Module 5 is to evaluate current performance and set standards for cost, productivity, and service objectives.

In Module 4, the gaps in the measurement process were identified. In Module 5, quantitative quality standards are developed. The first step is to examine the representative data (measurements) collected in Module 4. Before the standards are established, the process must be in control. A process is considered in control when there are no occurrences of special causes. Special causes are assignable causes of variation [13]. An example of a special variation in a supply chain process is a truck arriving late due to inclement weather. The sources of special causes are assignable to a cause that usually does not occur often within a process. The other type of variation present in a process is common causes. These are chance causes that processes experience every day. When only this type of variation is present, the process is said to be in control [13]. Therefore, all special variation should be eliminated before quality standards are established. There are several advantages, stated by Deming (1986), associated with a process in control:

(1). The process performance is predictable.
(2). Costs are predictable.
(3). Output is predictable.
(4). The process has reached its maximum productivity.
(5). Supplier relation are simplified.
(6). Changes in the process can be detected more quickly.

Once the process is in control, current data may be used to develop quantitative process standards.

4.6 Module 6 : Improve Process

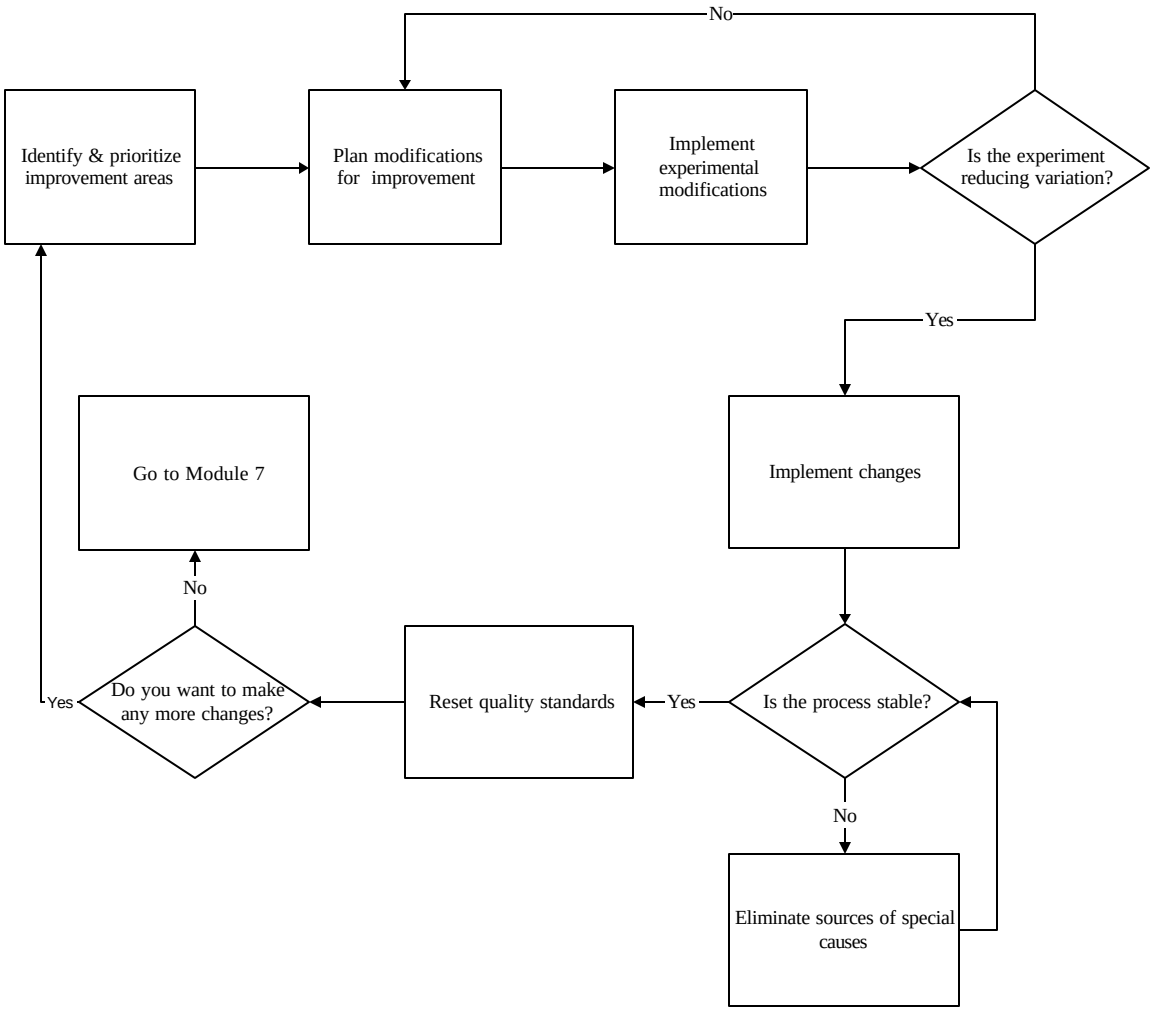

Figure 7. Module 6

Objective: The purpose of Module 6 is to identify and implement changes to improve overall supply chain process performance.

Module 6 of PQM is to improve the processes. The first step within this module consists of identifying and prioritizing improvement areas. Once these areas have been prioritized, then the areas that must receive immediate attention are identified, considering time and cost restrictions.

The purpose of continuous improvement is to reduce the amount of common cause variation present in the process. In planning the improvement, hypotheses must be made concerning the causes of variation. Once the causes have been identified, then a plan should be implemented to eliminate the cause. Next, these causes should be tested to determine whether the solution reduces variation. After the experiment has been tested, the improvement should be implemented throughout the process. The process should be tested again to determine whether it is in control; after the process is in control, then the quality standards are reset for the improved process.

4.7 Module 7: Control & Monitor Process

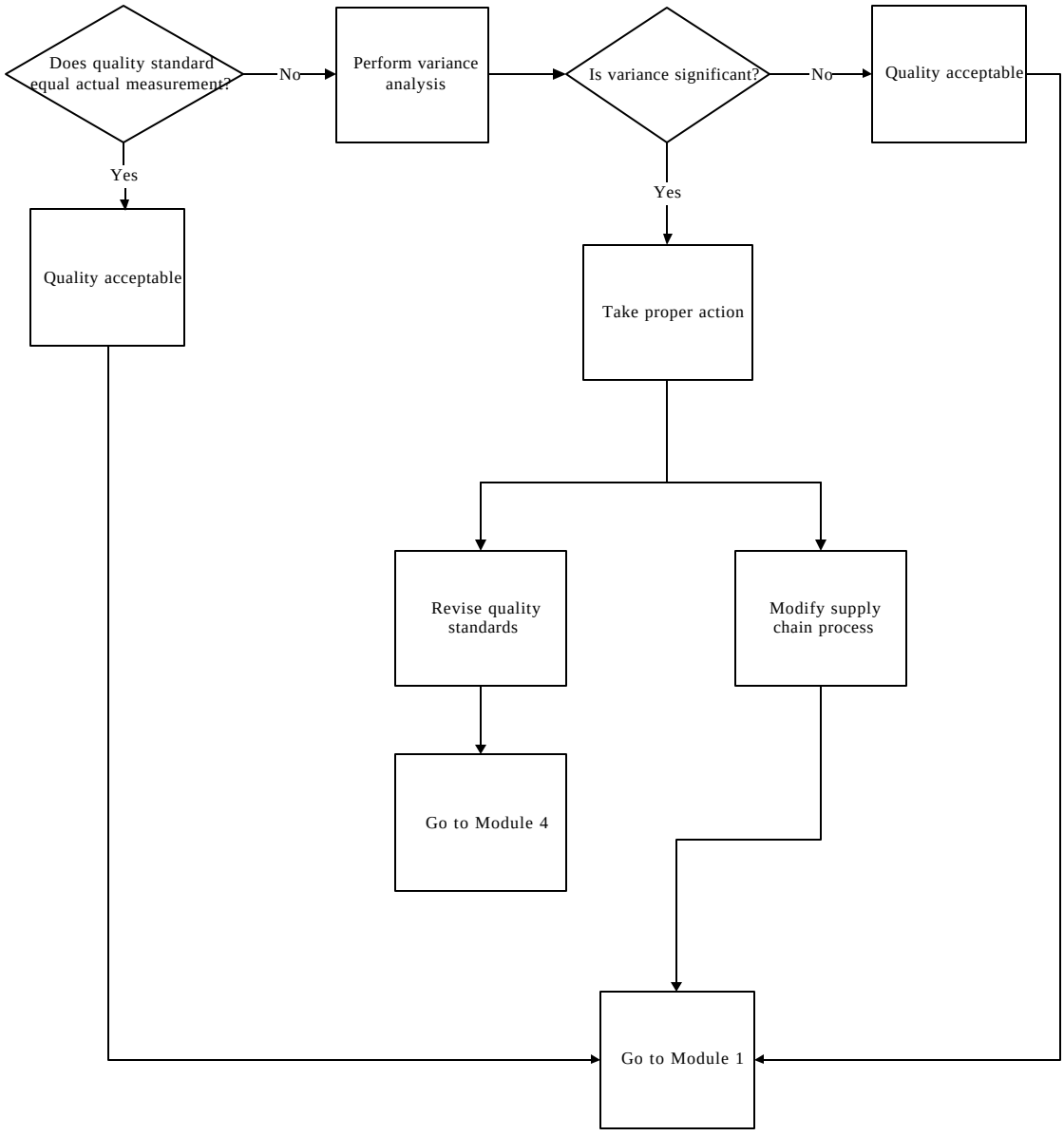

Figure 8. Module 7 (adapted from [15])

Objective: The purpose of Module 7 is to control and monitor productivity and service performance to ensure that the process meets standards.

The final step in the PQM is to control and monitor the process. There are numerous quality tools that can be used in this step. Some examples of these tools are given below, in Table 1.

Tool	**Purpose**
Control Chart	Process variability analysis
Cause and Effect Diagram	Process troubleshooting analysis
Histogram	Process variable frequency analysis
Scatter Diagram	Process variable relationship analysis
Run Chart	Process trend analysis

Table 1. Quality Tools

5 Summary

The Process Quality Model (PQM) provides a methodology for implementing a quality program or improving an existing one. The PQM applies and extends the traditional principles of Total Quality Management (TQM) for use in a manufacturing supply chain. From an implementation standpoint, each of the seven modules of the PQM falls into one of two categories: initialization or continuous improvement. That is, the first three steps are initialization steps that are designed to be executed infrequently (i.e., only if the process changes dramatically):

(1). Identify process, technology, and tasks being performed.
(2). Identify the customers and their requirements, expectations, and perceptions.
(3). Define quality as it pertains to the process of interest.

The last four steps of the PQM are designed to facilitate continuous improvement and process control, and thus will be executed frequently:

(4). Identify quality performance measures.
(5). Evaluate the current process and setting quality standards.
(6). Improve the process.
(7). Control and monitoring.

Thus, through a series of modules, the model provides a method for process identification, measurement, and control. Moreover, PQM is a systematic methodology that prescribes: (1) the specific aspects of quality that should be measured, (2) a method for measuring these aspects of quality, and (3) a method for using such measures to evaluate, improve, and control the overall quality of the supply chain system. Additionally, the PQM represents a shift in supply chain philosophy. That is, previous emphasis has been placed on static models and/or localized study of various supply chain components. In contrast, PQM emphasizes continuous improvement of the entire supply chain process.

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