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An analysis of the Six Sigma DMAIC method from the perspective of problem solving

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ABSTRACT

The DMAIC (Define-Measure-Analyze-Improve-Control) method in Six Sigma is often described as an approach for problem solving. This paper compares critically the DMAIC method with insights from scientific theories in the field of problem solving. As a single authoritative account of the DMAIC method does not exist, the study uses a large number of sources, consisting of prescriptive accounts of the method in the practitioner literature. Five themes are selected from the problem solving literature for the analysis of DMAIC—generality versus domain specificity of methods; problem structure; generic problem solving tasks; diagnostic problem solving; and remedial problem solving. The study provides a characterization of the types of problems for which DMAIC is a suitable method, but also identifies problems for which it may be ineffective. An important limitation of the method is its generality, which limits the methodological support it provides, and which fails to exploit task-domain specific knowledge. Domain-specific adaptations of the method partly overcome these weaknesses. Among the method's strengths are the powerful statistical techniques for fact finding and empirical verification of ideas, and the DMAIC stage model, which acts as a problem structuring device. The most prominent limitation identified in this study is Six Sigma's inferior methodology for efficient problem diagnosis. Methodological support for the identification of potential problem causes is offered as an incoherent and poorly structured collection of techniques, without strategic guidance to ensure efficiency of the diagnostic search. Adopters of the method should be aware of its potential limitations.

1. Introduction

Six Sigma is defined by Linderman et al. (2003) as "(…) an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates."

Academic research, such as Zu et al. (2008) and Schroeder et al. (2008), has tried to determine which elements in Six Sigma make it effective. Besides its role structure and focus on metrics, Six Sigma's structured improvement procedure is seen as a novel and effective contribution to quality management. This improvement procedure is generally known under the acronym DMAIC, standing for Define, Measure, Analyze, Improve and Control.

DMAIC is similar in function as its predecessors in manufacturing problem solving, such as Plan-Do-Check-Act and the Seven Step method of Juran and Gryna (Balakrishnan et al., 1995). In the theory of organizational routines, DMAIC is a metaroutine: a routine for changing established routines or for designing new routines (Schroeder et al., 2008). Originally described as a method for variation reduction, DMAIC is applied in practice as a generic problem solving and improvement approach (McAdam and Lafferty, 2004). It is instrumental in the implementation of Six Sigma as a process improvement methodology (Chakravorty, 2009).

Six Sigma and its DMAIC method emerged and developed in practice. It built on insights from the quality engineering field, incorporating ideas from statistical quality control, total quality management and Taguchi's off-line quality control. Their wide adoption in practice warrants a critical scientific analysis. One aspect of a scientific evaluation of Six Sigma is to critically compare its principles with insights from established scientific theories.

This work aims to study the Six Sigma DMAIC method from the perspective of scientific theories in the field of problem solving as published in the operations research and management science (OR/MS) and industrial engineering (IE) literatures. Six Sigma is often described as a problem solving methodology, and for that reason, theoretical insights from the problem solving literature should provide insights on DMAIC. The purpose of the analysis is to identify limitations of the method. These identified limitations may be an inducement for attempts at improving the method. But

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Table 1
Rational reconstruction of the DMAIC procedure, after De Koning and De Mast (2006).

Define: problem selection and benefit analysis
D1. Identify and map relevant processes
D2. Identify stakeholders
D3. Determine and prioritize customer needs and requirements
D4. Make a business case for the project
Measure: translation of the problem into a measurable form, and measurement of the current situation; refined definition of objectives
M1. Select one or more CTQs
M2. Determine operational definitions for CTQs and requirements
M3. Validate measurement systems of the CTQs
M4. Assess the current process capability
M5. Define objectives
Analyze: identification of influence factors and causes that determine the CTQs' behavior
A1. Identify potential influence factors
A2. Select the vital few influence factors
Improve: design and implementation of adjustments to the process to improve the performance of the CTQs
I1. Quantify relationships between Xs and CTQs
I2. Design actions to modify the process or settings of influence factors in such a way that the CTQs are optimized
I3. Conduct pilot test of improvement actions
Control: empirical verification of the project's results and adjustment of the process management and control system in order that improvements are sustainable
C1. Determine the new process capability
C2. Implement control plans

some limitations may be inherent to DMAIC, as it is not plausible that a strong method can be applicable without restrictions in all circumstances. In those cases, the practical value of identified limitations is that they provide a basis for advising users when the DMAIC method is suited.

Since an authoritative or uniform account of the DMAIC method does not exist, we have worked with a large number of sources, varying in degrees of quality, clarity and coverage. In the next section, we describe the sources we have used to obtain a carefully balanced understanding and rendering of the DMAIC procedure. We also outline our approach for studying DMAIC from the perspective of a number of themes in the problem solving literature. The subsequent sections treat these themes, and each formulates a number of conclusions. In Section 8, we seek to integrate the individual conclusions into a comprehensive characterization of DMAIC as a problem solving method.

2. Source material and methods

2.1. Six sigma's DMAIC method

The Six Sigma phenomenon does not refer to a single, clearly delineated method. Rather, it refers to a related collection of practices in organizations, such as Six Sigma courses taught to professionals, textbooks written by consultants, and improvement projects and initiatives undertaken under the flag of Six Sigma. In studying DMAIC, there are essentially two options: to study the method as it is prescribed in courses, textbooks and other instructional media (prescriptive accounts), or to study it as it is factually applied by practitioners in improvement projects (descriptive accounts). Here, we limit ourselves to the first option, leaving descriptive studies of DMAIC applications for further study. Thus, our source material for understanding the DMAIC method consists of prescriptive accounts of the method, such as course manuals, textbooks, and papers.

De Koning and De Mast (2006) make a rational reconstruction of Six Sigma's methodology. Conceiving the Six Sigma method as a system of prescriptions, they discern four classes of elements of the method:

- A model of the function and purpose for which the method applies.
- A stage model (DMAIC) providing a stepwise procedure.
- A collection of techniques.
- Concepts and classifications, such as Critical-to-Quality (CTQ) characteristics and the distinction between the *vital few* and the *trivial many* causes.

Based on an extensive analysis of descriptions of these elements in the practitioners' literature, De Koning and De Mast (2006) conclude that these various accounts have enough commonalities to consider them variations of a single method, thus claiming convergent validity for the method. From a large number of sources, the functions of the DMAIC stages and their steps and prescribed actions are reconstructed as in Table 1. De Koning and De Mast also link techniques and tools to these DMAIC stages. From their analysis of the contents of the method, they arrive at the following characterization of Six Sigma's method:

- The method prescribes that problems are parameterized and quantified.
- Improvement actions are derived from discovered relationships among variables.
- In particular, Six Sigma's method and techniques are largely driven by causal modeling, in which a process's Critical-to-Quality (CTQ) characteristics are regarded as the effects of causal influence factors (the Xs).
- Techniques such as design and analysis of experiments, process capability study, and gage R&R study[1] are iconic for Six Sigma.

[1] This is a statistical technique for evaluating the repeatability and reproducibility of measurement systems.