Inter-industry generic Lean Six Sigma project definitions

Bart A. Lameijer, Ronald J.M.M. Does and Jeroen De Mast
Department of Operations Management, University of Amsterdam, Amsterdam, The Netherlands

Received 6 November 2015
Revised 12 February 2016
Accepted 6 March 2016

Abstract

Purpose – The objective of this research is to provide practitioners with inter-industry applicable rules and guidelines for the Lean Six Sigma (LSS) project definition phase. This research resulted in 13 inter-industry generic project definitions that are divided by four performance dimensions: quality, dependability, speed and cost efficiency.

Design/methodology/approach – A total of 312 previously executed LSS improvement projects in a broad variety of industries at black belt or master black belt level are analyzed. All these projects have followed the LSS methodology and are characterized by the use of critical to quality (CTQ) measurements and the structured improvement method of define, measure, analyse, improve and control for operations improvement.

Findings – This research resulted in 13 inter-industry generic project definitions that are divided by four performance dimensions: quality, dependability, speed and cost efficiency. Three factors that have stood out in this research are; the difficulty to capture the performance dimension flexibility in LSS project definitions, the strong focus on internal organizational benefits in defining CTQs for LSS project definitions and the unclear alignment of LSS project definitions to existing strategic objectives of the company.

Originality/value – This research established useable generic LSS project definitions including generic CTQ's measures, applicable to multiple industries. These generic LSS project definitions provide useful guidance in the initial LSS project phase, helping to decompose strategic focal points into clear and measurable project objectives.

Keywords Lean Six Sigma, Generic, CTQ, Multiple industries, Project definition

Paper type Research paper

1. Introduction

Operations improvement is a scientific discipline that is manifesting in various forms, such as total quality management (TQM), business process reengineering, lean management, business process management, Six Sigma, theory of constraints and Lean Six Sigma (LSS). In this research, we focus on the LSS discipline. The Lean concept has been coupled with Six Sigma methodology and project organization in recent years. Although the LSS method has its origins in manufacturing, it is increasingly used in service organizations. Hence, LSS is a methodology focussed on improving operational efficiency and effectiveness for service and manufacturing companies (George, 2003). As such, LSS has evolved into a widely studied and applied robust business

The authors are very grateful to the referees and the editor. Their comments and suggestions have improved the content and readability of the paper.

Declaration of conflicting interests: The authors declare no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding: The authors did not receive financial support for the research, authorship and/or publication of this article.

International Journal of Lean Six Sigma
Vol. 7 No. 4, 2016
pp. 369-393

2040-4166
DOI 10.1108/IJLSS-11-2015-0044

improvement initiative (Schroeder *et al.*, 2008). The LSS project methodology follows a project-by-project structure, aiming to establish certain improvement objectives. These projects are managed according to the five-phased define, measure, analyze, improve and control (DMAIC) cycle (de Mast and Lokkerbol, 2012).

Despite this clear DMAIC structure, not all LSS projects meet their prior set objectives for various reasons (Arumugam *et al.*, 2014). Scholars have started investigating key determining factors that are impeding successful LSS project execution and adoption. The clarity of the project definition is highlighted as one of the most important factors for project failure (Lynch *et al.*, 2003; Linderman *et al.*, 2003). Unclear project definitions can result in diverging views of the same project by the project leaders (green belts or black belts) and project sponsors (champions), which will lead to different views of what entails a successful project. Missed deadlines or even project termination may be the outcome.

The objective of this research is to enhance the quality of the LSS project definition phase by establishing well-defined and useable generic LSS project definitions including generic critical to quality (CTQ) measures, applicable in multiple industries.

This paper is structured as follows. Section 2 provides a discussion on the literature concerning generic project definitions. In Section 3, the research methodology is elaborated, after which in Section 4 the data are discussed. Section 5 presents the generic LSS project definitions, and Section 6 is finalized with a discussion and conclusions.

2. Literature review

2.1 Determinants of Lean Six Sigma project success

The notion of Juran (1986) that LSS or related operations improvement initiatives are universally applicable has not been agreed upon. As a result, a contingency perspective started to emerge; industry or organizational conditions, under which the uses of different aspects of operations improvement initiatives are effective, were studied (Sitkin *et al.*, 1994). Addressing the culture of an organization became recognized as a key variable in the success of operations improvement initiatives (Detert *et al.*, 2000). In the deployment of operations improvement initiatives, interacting aspects of organizations such as processes, people and machines became acknowledged as important success factors (Foster, 2008). Empirical as well as case studies have been conducted to find critical success factors (CSF) for operations improvement projects (Coronado and Antony, 2002; Brun, 2011). A total of nine most important CSFs for LSS project success are found in earlier literature (Arumugam *et al.*, 2014) and these are:

(1) management commitment and support for projects, training and prioritization of projects;
(2) involvement of improvement specialists in projects;
(3) structured approaches to project execution;
(4) customer focus in project objectives;
(5) usage of tools and techniques;
(6) the link of LSS to business strategy;
(7) a focus on metrics;
(8) the link of LSS to human resource management (HRM); and
(9) data-based decision-making.

Subsequently, scholars have started investigating key determining factors that are impeding successful LSS project execution and adoption. Amongst others, a lack of management commitment (McAdams and Lafferty, 2004), inadequate involvement of management in project selection and involvement during the project life cycle (Nonthaleerak and Hendry, 2008) and poor resource allocation are important factors that adversely affect LSS project success. A substantial part of the key determinants that have a negative effect on LSS project success is most likely to emerge in the project definition phase. The correct definition or sequencing of LSS projects and activities (Chakravorty, 2009), vague definitions of LSS project expectations (Szeto and Tsang, 2012) and finally LSS coach availability for LSS projects (Nonthaleerak and Hendry, 2008) are known determinants that impede successful LSS project definition. This observation about the definition phase is corroborated by findings from the project management literature, in which the clarity of the project definition is highlighted as one of the most important factors for project failure (Lynch *et al.*, 2003; Linderman *et al.*, 2003).

Project definitions, whereby strategic objectives are translated into operational project goals, can be operationalized with, amongst others, a balanced scorecard (Kaplan and Norton, 1992) or a CTQ flow down (de Koning and de Mast, 2007). The CTQ flow down relates high-level strategic focal points to project objectives, and in their turn, project objectives are related to and decomposed into CTQs. The CTQs are made operational in the form of measurements, as displayed in Figure 1.

The CTQ flow down has several objectives. Besides providing a clear project definition, it clarifies the business rational of an improvement project (e.g. "what needs to be improved"). CTQ flow downs help to focus on the vital few real business drivers and thereby facilitates optimal problem-solving. For LSS, the CTQ flow down has emerged as a more widely applied LSS project definition method, being project-specific and less holistic than the balanced scorecard. Hence, the CTQ flow down relates organizational strategic focal points to one-dimensional and well-defined metrics that need to be improved (de Koning and de Mast, 2007; Zu *et al.*, 2008).

2.2 Generic LSS performance dimensions

Because the use of CTQ flow downs by practitioners has evolved, researchers have started to define generic LSS project definitions. Scholars have compared CTQ flow

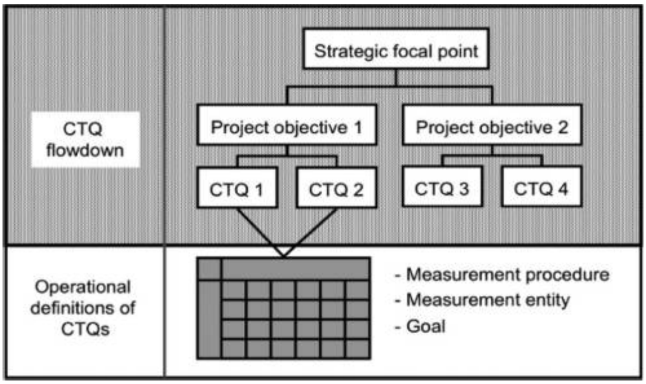


Figure 1.
LSS CTQ flow down and operational definitions

downs from separate industries. In each of these industries, the generic CTQ templates are emphasizing several performance dimensions. To distinguish the different performance dimensions, we specifically draw upon the cumulative capability model by Ferdows and de Meyer (1990). The cumulative capability or the "sand cone" model has been central in the academic debate on the effect of performance dimensions on business results. For a comprehensive review on the cumulative capability model, see Schroeder *et al.* (2011) and for previous performance dimensions categories, see Smith (2000). The central thesis of the cumulative capability model is that business results follow an accumulation of performance dimensions, of which quality is the foundation. The cumulative capability model distinguishes five generic performance dimensions (Ferdows and de Meyer, 1990):

(1) *Quality*: Meeting the needs and wishes of customer; effectiveness and suitability of the services; courtesy, expertise and skills of the supplier; quality of the service; etc.
(2) *Dependability and safety*: Failures, mistakes, rework, punctuality and keeping promises.
(3) *Speed*: Throughput time, waiting time, time of service and admission times.
(4) *Flexibility*: Ability to adapt the process to changes in demand (fluctuations in workload, specific needs of customers and range and customizability of services offered).
(5) *Cost efficiency*: Efficient use of man-hours, facilities and material.

Here, the five performance dimensions serve as a framework for further exploration on the existent generic CTQ flow downs. Examining per industry which performance dimensions are addressed by generic CTQ flow downs is the basis for further research into generic CTQ flow downs applicable to multiple industries.

By comparing project definitions of LSS projects, previous scholars have been able to generate classifications of projects that serve a common performance dimension. In the finance industry, initial research has found eight generic categories of project definitions that correspond to three of the five performance dimensions of the cumulative capability model (de Koning *et al.*, 2008; Lokkerbol *et al.*, 2012a, 2012b). For the healthcare industry, nine categories have been identified (Does *et al.*, 2006; Niemeijer *et al.*, 2011). The identified project definitions correspond to four out of the five performance dimensions. The primary focus in healthcare seems to be on the cost-efficiency performance dimension. The publishing industry has been subject to similar research into generic project definitions as in finance and healthcare. Seven generic project definitions are identified, and three out of the five performance dimensions are addressed by this research (de Koning *et al.*, 2010). Studies in the construction industry have generated seven project definitions, thereby addressing four out of the five performance dimensions (van den Bos *et al.*, 2014). Comparing these four industries reveals a similar pattern in performance dimensions that are addressed by the generic LSS project definitions. The focus of LSS generic project definitions to date is mainly on the performance dimensions quality and cost efficiency Table I. Differences in generic LSS project definitions and underlying CTQs appear to be more semantic than substantial, such as "improving process efficiency" by optimizing man-hour utilization and "improving productivity of personnel" (Table I).

Table I. Generic LSS project definitions addressed in previous research

No.	Generic category of project definitions	Quality	Dependability/safety	Speed	Flexibility	Cost efficiency
Finance industry						
1	Decreasing operational cost by improving processing efficiency					X
2	Decreasing operational cost by using cheaper channels (automation)					X
3	Improving revenue by increasing customer satisfaction	X				
4	Improving revenue by servicing more customers	X				
5	Decreasing operational losses		X			
6	Improving business decision-making	X				
7	Increasing customer satisfaction and improving processing efficiency	X				X
8	Increasing revenue by increasing timeliness of received payments			X		
Healthcare industry						
1	Reduce costs by improving productivity of personnel					X
2	Reduce costs by improving utilization of equipment/facilities					X
3	Reduce costs by improving purchasing processes					X
4	Reduce costs by reducing unnecessary use of resources					X
5	Reduce costs by reducing inventory					X
6	Improve safety by reducing complications and incidents		X			
7	Increase revenue by improving registration		X			
8	Increase revenue by increasing the number of admissions			X		
9	Increase revenue by increasing capacity					X

(*continued*)

Table I.

No.	Generic category of project definitions	Quality	Dependability/ safety	Speed	Flexibility	Cost efficiency
Publishing industry						
1	Revenue improvement by servicing more customers	X				
2	Cost reduction by improving efficiency of processes					X
3	Improvement of customer satisfaction and processing efficiency	X				X
4	EBIT improvement by reducing discounts and cost of sales channel					X
5	Cost reduction by improving efficiency of internal processes and sourcing effective suppliers	X				X
6	Cost reduction by improving forecasting					X
7	Working capital reduction by improving cash management and fast delivery			X		X
Construction industry						
1	Increase profitability of sales by reducing cost of sales					X
2	Reduce operational cost by reducing realized costs					X
3	Increase customer satisfaction (and reduce cost) by reducing the number of defects	X				X
4	Reduce costs by optimizing cost of warranty claims and inspection		X			
5	Reduce costs by reducing purchases and time to handle purchases					X
6	Increase profitability by reducing lost income					X
7	Increase customer satisfaction (and reduce costs) by improving the throughput time of delivery and the quality of complaints handled		X	X		X

Hence, there are similarities in the generic LSS project definitions from the four industries. An academic attempt to integrate the intra-generic project definitions of these four industries into inter-generic project definitions has not been performed to date. In addition, outside of these four industries, no generic project definitions have been researched to date. Exploration into multiple industry project definitions is considered to be a promising avenue for further research (de Koning *et al.*, 2008; van den Bos *et al.*, 2014). The objective of this research is to establish inter-industry generic project definitions applicable for LSS practitioners in multiple industries.

3. Methodology

The objective of this research is to provide practitioners with rules and guidelines for the LSS project definition phase. These rules and guidelines can be discovered through analysis of previous LSS project definitions (Niemeijer *et al.*, 2011). However, project definition is generally an ill-structured task and is hard to capture with rules and guidelines (Lokkerbol *et al.*, 2012a, 2012b). For such ill-structured tasks, an alternative method is provided, by initially artificial intelligence researchers, in the form of case-based reasoning (CBR) (Aamodt and Plaza, 1994). CBR is a paradigm that allows for problem-solving and decision-making that is not based on knowledge framed in rules, guidelines and principles. CBR is a problem-solving paradigm that uses specific knowledge of previously experienced and detailed problem situations. A problem is solved by finding similar past cases to reuse in the new problem situation. Further benefits of the CBR methodology comprise the element of sustained learning. New experiences are retained each time a problem has been solved (e.g. a project definition has been successfully applied) and are thereby made available for future problems (e.g. future project definition phases). CBR originates out of the cognitive sciences, and its classical definition is stated by the notion that a case-based researcher solves problems by using or adapting solutions from old problems (Watson, 1999). CBR is characterized by the CBR cycle, comprising four main activities:

(1) retrieve cases that share a similarity to the problem at hand (e.g. past project definitions);

(2) reuse a solution that is suggested by a similar case;

(3) revise or alter the solution to better fit the problem when necessary; and

(4) retain the newly found solution once its effectiveness is confirmed and validated (Aamodt and Plaza, 1994).

This research applies a CBR approach that consists of a substantial collection of past LSS project definitions (cases). This research does not claim to provide a collectively exhaustive set of generic LSS project definitions. The objective is to provide accessible experience and sustained learning that is structured into inter-industry generic LSS project definition templates by application of the CBR cycle (Figure 2).

4. Data

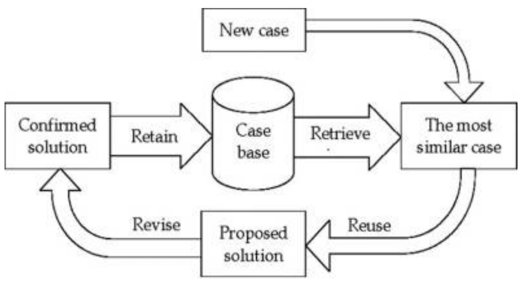
The study sample consists of 312 LSS improvement projects that are executed in a broad variety of industries in The Netherlands. All these projects have followed the LSS methodology and are characterized by the use of CTQs and the structured improvement method of DMAIC for operations improvement (Schroeder *et al.*, 2008). The improvement projects in the sample have been performed by black belt and master black belt LSS practitioners, all trained by the University of Amsterdam. Black belt certification at the university requires the completion of the theoretical course by an exam and finally the execution of two LSS improvement projects, following the DMAIC structure with champions and business controller sign-offs for the realized financial impact. For master black belt certification, there are additional requirements of which two LSS improvement projects is one. From 2005 onwards, the university has certified 312 black belts and master black belts. From each student, the last LSS project that was executed for certification served as an input for the sample of this study. By doing so, struggles in finding the right CTQ flow down in the first project are filtered out. Table II provides an overview of the amount of projects per industry, their total benefit and the time range in which these projects have been executed (Table II).

The projects vary along a range of dimensions, such as industry, the objective of the project and size of the projected benefits. Each of the studied LSS project definitions included at least:

- a business case;
- a (macro level) process map;
- key performance indicators that are to be improved, CTQs in LSS terminology;
- a CTQ flow down (indicating the relation between CTQs and the strategic goals of the company);
- an operational definition for each CTQ; and
- a description of the measurement procedure for each CTQ (de Koning and de Mast 2007).

Table III provides a complete overview of acceptance criteria.

This research aims for analysis at the intermediate level of detail. Project specifics are removed; project objectives are the focus as a distinguishing factor. This organizing principle establishes reusable elements from each project definition. Nevertheless, lessons learned from the transcending strategic objectives in each of the individual LSS project definitions are discussed in Section 6. This research is subsequent to previous research into intra-industry generic project definitions executed by Does *et al.* (2006), de Koning *et al.* (2008, 2010), Niemeijer *et al.* (2011), Lokkerbol *et al.* (2012a, 2012b) and van den Bos *et al.* (2014). By adding



Source: Aamodt and Plaza (1994)

Figure 2.
CBR method

new projects and applying inter-industry research, the retain function general to CBR systems is applied, which enriches the knowledge of generic LSS project definitions to date.

5. Results

The grouping of individual LSS project definitions resulted in generic LSS project definitions in four performance dimensions. Cost efficiency is the dominant performance dimension that was addressed by the individual LSS projects. For the performance dimension flexibility, no individual projects have been identified. For each of the performance dimensions, individual LSS project definitions have been distilled into "general areas of improvement". The areas of improvement are then captured in distinct generic LSS project definitions (Table IV).

In the next sections, each generic LSS project definition and the detailed operational specifics will be presented, stating per which unit the CTQ is measured. Then, a procedure to measure the CTQs is proposed and finally a goal for the value of the CTQs is defined. This is considered helpful for practitioners setting up their LSS project definition and subsequent research strategy. LSS practitioners looking for guidance on the operationalization of the measurement plans are referred to a study by Kemper and de Mast (2013). Combinations of generic project definitions have been observed in the sample. Hence, combinations of generic performance dimensions can be applied by practitioners. For instance, improving the reliability of the process while simultaneously improving the speed of the process can go hand in hand. The practitioner can select the applicable generic project definitions based upon the project scope and objectives and combine these where necessary. As the distribution of performance dimensions is specifically for the sample used in this study, no claims of generalizability can be made. The next sections present the generic LSS project definitions per performance dimension.

5.1 Generic Lean Six Sigma project definitions for performance dimension quality

Two generic LSS project definitions for performance dimension quality are proposed (Table V).

First, for improving perceived quality, a close study revealed that the actual quality is not of primary interest. CTQs of individual project definitions were defined as amount of customer complaints or enquires (as a result of lower than expected quality). These

Industry (SIC)	Amount of projects	Total benefits (in €)	Time range of projects
Agriculture, forestry and fishing	2	670,000	2007-2007
Construction	36	10,778,888	2003-2015
Finance, insurance and real estate	63	10,219,144	2006-2015
Manufacturing	105	36,267,774	2005-2015
Public administration	22	6,003,891	2008-2015
Retail trade	3	524,000	2014-2014
Services (including healthcare)	52	4,020,377	2006-2015
Transportation and public utilities	29	6,911,770	2009-2014
Total	312	75,395,844	2003-2015

Table II. Amount of LSS project definitions of study, sorted by standard industrial classification code (SIC)

Table III. Acceptance criteria for LSS projects in the sample of study, per LSS DMAIC phase

Define	Measure	Analyze	Improve	Control
Project charter	CTQ flowdown	Process behaviour in time	Select important influence factors	Process documentation
SIPOC	Operational definitions	Process capability analysis	Determine effects of influence factors	Control plan
Flowchart	Measurement plan	Value stream map	Summarize your evidence	Roles and responsibilities
Benefit analysis	Validity of the measurements	Updated project objectives	Design improvement actions	SPC and other process controls
Organization (time and review board)	Precision: gauge R&R or kappa coefficient	Brainstorm session/group meetings	Should be process map	Logs, dashboards and Q-reports
Stakeholder analysis	Measurements started	Expert interviews		Mistake proofing
		BOB vs WOW/autopsies		Benefit realization of improvements
		FMEA analysis		Implementation plan and benefit tracking
		Process inefficiencies identified		Project documentation
		Process matrix completed		Follow-ups are scheduled

Performance dimension	General areas of improvement	Generic project definitions
Quality	"Improvement of quality"	"Improving perceived quality"
	"Improvement of customer satisfaction"	"Improving customer satisfaction"
	Reduction of customer complaints	
Dependability and safety	Improving first time right	First time right improvement
	Reducing the amount of rework	Rework reduction
	Reducing operational losses	Operational loss reduction
	Reducing the amount of disturbances	Process reliability improvement
Speed	Reduction of cycle time	Cycle time reduction
	Reduction of idle time (waiting)	
	Improving timeliness of the process	Idle time reduction
Cost efficiency	Improving human capital efficiency	Human resource efficiency
	Reducing FTE	
	Reducing the rate for absence through illness	
	Improve employee satisfaction	
	Reduce processing times	
	Increase the process output	Overall operating efficiency
	Reduction of required resources	
	Improving productivity	
	Reduction of inventory levels	Inventory optimization
	Reduction of selection costs	General cost reduction
	Reduction of general costs	
	Improving the margin	Margin optimization
	Improvement of financial results from business operations	

Table IV. General areas of improvement per performance dimension, captured in generic LSS project definitions

CTQs refer to the perceived quality and subsequent action by the customer (sending in a complaint or enquiry). Second, for improving customer satisfaction, CTQs comprise those elements that are considered valuable for customers. CTQs of the general area "reduction of complaints" have been included in this generic project definition, as logic dictates that a reduction of complaints is followed by improved customer satisfaction.

A remarkable finding in the performance dimension quality is that for both generic project definitions, only internal CTQs for customer satisfaction were defined (complaints or enquiries as a result of non-satisfaction). Hence, when customers do not actively provide their feedback in terms of enquiries or complaints, the level of customer satisfaction would remain unknown. Therefore, we propose an additional CTQ in both generic project definitions, being the actual level of customer satisfaction about the product or service. Example projects from this category may be found in van den Bos *et al.* (2014). Exemplary projects from the sample fitting the generic quality definitions are the following projects:

(1) From the construction industry with the aim to improve quality with CTQs:
   - reduction of warranty claims;
   - cycle time of warranty execution; and
   - number of requests for call back.

Table V.
Generic LSS project definitions for performance dimension quality

Project objective	Generic CTQs	Measurement unit	Measure procedure	Goal
Improving perceived quality	Amount or percentage of warranty cases or claims	Per day/per week	Job tracking system	As little/low as possible
	Amount or percentage of customer enquiries	Per day/per week	Job tracking system	As little as possible
	Cycle time of product or service delivery	Per job (purchase)	Time stamps/job tracking system	As short as possible
	Amount or percentage of satisfied customers	Per customer	Interviews/surveys	As much/high as possible
Improving customer satisfaction	Amount or percentage of complaints or disruptions	Per day/per week	Job tracking system	As little/low as possible
	Timeliness of response	Per product or service	Time stamps/surveys/interviews	As short as possible
	Cycle time of product or service delivery	Per product or service	Time stamps/job tracking system	As short as possible
	Cost of ownership	Per customer	Interviews/surveys	As low as possible
	Amount or percentage of satisfied customers	Per customer	Interviews/surveys	As much/high as possible

(2) From the manufacturing industry with the aim to improve customer satisfaction with CTQs:
   - reduction of amount of days overdue on delivery;
   - amount of defect products; and
   - cost of ownership for the client (for non-defect products).

5.2 Generic Lean Six Sigma project definitions for performance dimension dependability and safety

Four generic LSS project definitions for the performance dimension dependability and safety are proposed (Table VI).

First time right improvement is an integration of first time right improvement and reducing the amount of errors in product or service delivery. The CTQs concern the amount of products or services that are rejected or repaired and subsequently what the costs per repair are. In addition, the amounts of products or services that have not been signalled are of interest, as this indicates the ability to detect poor quality before the final user does.

Rework reduction is about the consequence of not achieving first time right objectives and having to cope with rework. Nevertheless, first time right improvement and rework reduction are not the same. When products or services are not first time right, it is still a managerial decision to rework the product or service. The CTQs for rework reduction specify the amount of rework, the time allocated on rework and the cost per rework.

Operational loss reduction is concerned with two types of loss. The first entails the waste that is incurred in the production process of the product or service. The other is when a product or service is ready for delivery and the full margin on the product or service is not collected because of various reasons, such as claims because of malfunctioning, overdue or non-payment by clients and impaired products or services.

Process reliability improvement is concerned with process deviations from the norms. The previous three generic project definitions are focussing on the variability of the *product or the service*; this generic project definition allows for exact measurements of other than expected *process* metrics. The CTQs percentage deviations to part or case norm and cycle time are focussed on operating the process according to the designed standards and thereby measure operational effectiveness of the process. Test accuracy holds the ability to truly detect deviations. Blockages and accidents cover disruptions in the process, making the process non-operational. The following are the example projects from this category that may be found in Kemper *et al.'s* (2011) and Mooren *et al.'s* (2012) projects from the sample fitting of the generic dependability and safety definitions:

(1) From the manufacturing industry with the aim to improve first time right ratio with CTQs:
   - reducing the amount of errors; and
   - capability of finding defects.

(2) From the public administration industry with the aim to reduce the amount of rework with CTQs:
   - volume of rework; and
   - cost per rework.

Table VI. Generic LSS project definitions for performance dimension dependability and safety

Project objective	Generic CTQs	Measurement unit	Measure procedure	Goal
First time right improvement	Amount or percentage of products or services that are rejected or repaired	Per day/per week	Job tracking system	As little/low as possible
	Amount or percentage of products or services that should be rejected or repaired, but are unnoticed	Per day/per week	Job tracking system	As little/low as possible
	Cost per product or service that is rejected or repaired	Per product or service	From enterprise resource planning (ERP) or other logging system	As little as possible
Rework reduction	Amount or percentage of products or services that are reworked on	Per day/per week	Job tracking system	As little/low as possible
	Time spent per product or service that is reworked on	Per day/per week	From ERP or other logging system	As little as possible
	Costs per product or service that is reworked on	Per product or service	From ERP or other logging system	As little as possible
Operational loss reduction	Amount of products or services	Per day/per week	Job tracking system	As little as possible
	Amount or percentage of waste or loss per product or service	Per day/per week	Job tracking system	As little/low as possible
	Costs of waste or loss per product or service	Per product or service	From ERP or other logging system	As little as possible
Process reliability improvement	Percentage deviation to product or service norm	Per production cycle	Job tracking system	As low as possible
	Percentage deviation to product or service cycle time norm	Per production cycle	Job tracking system	As low as possible
	Percentage of test accuracy norm or test duration norm	Per production cycle	By means of experiments with a sample	As high as possible
	Amount of process disruptions (blockages) or accidents	Per production cycle	From ERP or other logging system	As little as possible

(3) From the finance, insurance and real estate industry with the aim to reduce operational losses with CTQs:
   - costs of occurring problems; and
   - amount of problems.
(4) From the manufacturing industry with the aim to improve reliability of the process with CTQs:
   - Per cent deviations to product norm;
   - Per cent of test accuracy norm; and
   - Number of process disruptions.

5.3 Generic Lean Six Sigma project definitions for performance dimension speed

Two generic LSS project definitions for the performance dimension speed are proposed (Table VII). Delivering a product or service faster to the final user is achieved by first, improving cycle time. The second, idle time reduction makes a process more efficient and/or enjoyable by specifically targeting waiting in the process. By reducing the capacity mismatch, and thereby improving the speed and decreasing the waiting (when the client is part of the process), a reduction of idle time is achieved.

The generic project definition of cycle time reduction focuses on the end-to-end process, meaning from customer demand to customer delivery. The deviation from required cycle time is the first CTQ, stating the actual cycle time performance of the process compared to the desired cycle time. Then, non-value-added and value-added processing time, idle time, amount of errors in the process and time to repair an error are the CTQs that are to be measured. These CTQs are to be improved to achieve an acceptable cycle time.

Idle time reduction is primarily concerned with time waiting (idle time) in the product or service delivery process, because of suboptimal process capacity planning. The CTQs focus on the required capacity to deliver the product or service and compare this to the available capacity. Here, capacity is not just human capital but also non-human capital, such as production line availability and computer processor availability. The last CTQ is concerned with the time spent per unit of production or service. Thereby, it is possible to calculate what the over or under capacity in the process is and what the result for idle time in the process is. Example projects from this category may be found in Schoonhoven *et al.* (2013) and Erdmann *et al.* (2013b). The following are the exemplary projects from the sample fitting of the generic speed definitions:

(1) From the services (healthcare) industry with the aim to improve cycle time of the billing process with CTQs:
   - non-value-adding processing time;
   - number or percentage of products (bills) that are rejected;
   - time spent on rework; and
   - idle time.
(2) From the services (healthcare) industry with the aim to reduce idle time in the process with CTQs:
   - amount of investigations per day;
   - available capacity;

Table VII. Generic LSS project definitions for performance dimension speed

Project objective	Generic CTQs	Measurement unit	Measure procedure	Goal
Cycle time reduction	Amount or percentage overdue cycle time norm	Per day/per week	Time stamps/job tracking system	As little/low as possible
	(Non) value added processing time in the process	Per product or service	Time stamps/job tracking system	As low as possible
	Idle time in the process	Per product or service	Time stamps/job tracking system	As low as possible
	Amount or percentage of products or services that are rejected or repaired	Per day/per week	Job tracking system	As little/low as possible
	Time spent per product or service that is reworked on	Per day/per week	From ERP or other logging system	As little as possible
Idle time reduction	Amount of capacity demand (in unit of production or service)	Per day/per week	From ERP or other logging system	As close to capacity available as possible
	Amount of capacity available (in unit of production or service)	Per day/per week	From ERP or other logging system	As close to capacity demand as possible
	Time spent per unit	Per product or service	Time stamps/job tracking system	As close to norm as possible

- time per investigation; and
- amount of handlings per customer.

5.4 Generic Lean Six Sigma project definitions for performance dimension cost-efficiency

Five generic LSS project definitions for the performance dimension cost-efficiency are proposed (Table VIII). The resulting five generic LSS project definitions are concerned with, the efficient use of human capital and the efficient use of non-human capital.

The generic project definition of human resource efficiency is frequently observed. Here, the aim is to utilize human capital as efficient as possible while maintaining a state of acceptable employee satisfaction. Total cycle time serves as the denominator in the calculation of process efficiency. The sums of non-value-added/value-added processing time and idle time serve as the numerator resulting in the percentage of process efficiency. Capacity mismatch serves to catch the effect of human resource inefficiency on product or service delivery (as explanation for cycle time overrun, when applicable). If the capacity according to existing efficiency standards is not sufficient to keep up product or service demand, backlogs will be the result. When human resource efficiency improves, the capacity mismatch should decrease.

The generic project definition of overall operating efficiency is similar to human resource efficiency and is the non-human resource equivalent. The objective of this generic project definition is to optimize the efficiency of operations. The CTQ cycle time serves as the denominator in the calculation of process efficiency. The CTQs productivity, amounts rejected or repaired and idle time are serving as the numerator in the operations efficiency calculation. Each CTQ is giving an indication of the operations efficiency, especially when compared to (overrun on) cycle times. The CTQ capacity usage serves to catch the effect of operating inefficiency on product or service delivery (as explanation for cycle time overrun, when applicable). If the capacity according to existing efficiency standards is not sufficient to keep up product or service demand, backlogs will be the result. When operating efficiency improves, the capacity mismatch should reduce.

Inventory optimization has the objective to organize inventory as efficient as possible. Turnover time of inventory as CTQ in combination with cost per inventory unit measures the inventory costs per inventory group per time frame. The inventory surplus (in raw, work-in-progress and finished state) which is held should be reduced, just as "losses in inventory" should be. Optimally, turnover time of inventory is as short as possible whereby inventory surplus should not ascend below zero, meaning not being able to deliver.

General cost reduction is defined by those LSS project definitions with no specific cost-reducing objective. Overall cost as CTQ is about reducing the cost level, by investigating the current cost base. Units in use help to specify the search for cost reduction improvements by the amount of costs per unit X or Y and subsequently being able to specify what the surplus in costs per unit X or Y is. This allows for comparison of the cost base (surplus) per unit, making it possible to identify root causes for higher costs. Finally, rejects or repairs incur unnecessary costs, making it an opportunity to reduce costs.

Margin optimization is the first generic LSS project definition that solely focuses on improving income instead of reducing the cost base or delivering more efficiently after

Table VIII. Generic LSS project definitions for performance dimension cost efficiency

Generic LSS project definitions for performance dimension cost efficiency

Project objective	Generic CTQ's	Measurement unit	Measure procedure	Goal
Human resource efficiency	Cycle time	Per day/per week	Time stamps/job tracking system	As low as possible
	Amount or percentage of capacity mismatch	Per day/per week	From ERP or other logging system	As little/low as possible
	(Non) value added processing time in the process	Per day/per week	Time stamps/job tracking system	As low as possible
	Amount or percentage of idle time	Per day/per week	Time stamps/job tracking system	As little/low as possible
	Amount or percentage of satisfied employees	Per employee	Interviews/surveys	As much/high as possible
Overall operating efficiency	Cycle time	Per day/per week	Time stamps/job tracking system	As low/timely as possible
	Amount or percentage of capacity usage	Per day/per week	From ERP or other logging system	As much/high as possible
	Amount or percentage of productivity (units in time)	Per day/per week	From ERP or other logging system	As high/much as possible
	Amount or percentage of products or services that are rejected or repaired	Per day/per week	Job tracking system	As little/low as possible
	Amount or percentage of idle time	Per day/per week	Time stamps/job tracking system	As little/low as possible
Inventory optimization	Turnover time of inventory	Per product/batch	Time stamps/job tracking system	As low/optimal as possible
	Amount or percentage of inventory surplus	Per day/per week	From ERP or other logging system	As little/low as possible
	Amount or percentage of inventory loss	Per day/per week	From ERP or other logging system	As little/low as possible
	Cost per inventory unit	Per product/batch	From ERP or other logging system	As low as possible
General cost reduction	Overall costs	Per day/per week	From ERP or other logging system	As little/low as possible
	Amount or percentage of units in use	Per day/per week	From ERP or other logging system	As little/low as possible
	Amount or percentage of cost surplus per unit	Per day/per week	From ERP or other logging system	As little/low as possible
	Amount or percentage of products or services that are rejected or repaired	Per day/per week	Job tracking system	As little/low as possible
Margin optimization	Amount or percentage of margin on units	Per product/service	From financial systems	As much/high as possible
	Amount or percentage of conversion (per channel)	Per day/per week	From sales database	As much/high as possible

the transaction. Margin optimization consists of the margin on a product or service (unit) and the conversion ratio. Many example projects from this category are available (Erdmann *et al.*, 2013a; Kuiper *et al.*, 2014; Lokkerbol *et al.*, 2012a, 2012b; Zwetsloot and Does, 2015; Zwetsloot *et al.*, 2015). The following are the projects from the sample fitting of the generic cost-efficiency definitions:

(1) From the finance perspective, insurance and real estate industry with the aim to improve human resource efficiency with CTQs:
  - number of calls or consults (generic; number or percentage of capacity mismatch, per unit); and
  - total handling/consulting time (generic; non-value-added/value-added processing time).

(2) From the manufacturing industry with the aim to improve process output with CTQs:
  - encapsulation time (generic; number or percentage of productivity);
  - changeover and start-up time (generic; number or percentage of idle time);
  - machine stops (generic; number or percentage of idle time); and
  - speed loss (generic; number or percentage of capacity usage).

(3) From the agricultural industry with the aim to reduce inventory held with CTQs:
  - inventory costs per product group;
  - safety stock held; and
  - turnover time per product group.

(4) From the public administration industry with the aim to improve client conversion with CTQs:
  - traffic (customer visits); and
  - conversion rate (generic; number or percentage of conversion per channel).

6. Discussion and conclusion

This research resulted in 13 inter-industry LSS generic project definitions that are divided by the four performance dimensions – quality, dependability, speed and cost efficiency. In the process of analyzing the data and presenting the generic project definitions, three factors that have stood out in this research are discussed. The factors are:

(1) the difficulty to capture the performance dimension flexibility in LSS project definitions;

(2) the strong focus on organizational benefits in defining CTQs for LSS project definitions; and

(3) the unclear alignment of LSS project definitions to existing strategic objectives of the company.

6.1 Performance dimension flexibility in LSS project definitions

The analyzed LSS project definitions have corresponded to all performance dimensions but flexibility. For all of the five performance dimensions, a range of LSS project definitions is captured by the meaning of the performance dimension (Neely *et al.*, 2005).

Although the gist of the different LSS project definitions of four performance dimensions lies with an acceptable range to hold meaning as one performance dimension, the variety in project definitions for the performance dimension flexibility is too broad. Flexibility can be about varying production volumes (Weelwright, 1984) or a company's ability to achieve a short time to market in new product development (Tunälv, 1992). In essence, the distinction lies in product flexibility (customization), volume flexibility (adjusting capacity), launch/time to market flexibility, access flexibility (distribution coverage) and responsiveness to target market flexibility (Vickery *et al.*, 1999; Koste and Malhotra, 1999). We believe that in this study, the performance dimension of flexibility is not separately addressed because of the ambiguousness and interrelatedness with other performance dimensions. For example, adjusting human or non-human resource capacity to a change in demand can be categorized as performance dimension flexibility (volume flexibility), though also as cost efficiency (an unwanted increase in cost base by up or down scaling capacity). This would depend on the transcending strategic objective providing the rationale for the project. For performance dimensions – dependability, speed and quality, maintaining or improving process and product or service reliability, speed or quality over time, while demands are changing and flexibility is needed, can be categorized as flexibility or as dependability, speed or quality. This, in our view, depends on the project objective, being internally or externally focussed. When reasoned from the customer (externally), flexibility means receiving a new product or service without without mistakes and promptly while adhering to quality standards. When reasoned from the company, flexibility means delivering a product or service without mistakes (dependability), fast (speed) and with adherence to quality standards (quality). Hence, flexibility is a broad definition and should be made specific in LSS project definitions to provide focus for the LSS practitioner and project stakeholders.

6.2 Strong focus on organizational benefits in Lean Six Sigma project definitions

The generic project definitions in all four performance dimensions have a tendency to adopt internal CTQ measures. The generic project definitions are failing to address CTQs that measure the performance beyond the borders of the organization. For instance, generic project definitions in the performance dimension quality try to capture external (customer) opinions by measuring internal signals of unsatisfied customers (complaints). Perceived quality, or conformance to customer requirements, is measured by the amount of warranty claims and enquiries. The generic project definitions in the performance dimension dependability primarily consist of internally measured CTQs, such as rejects, repairs and deviations to internal norms. This does not address the reliability as experienced by customers or end-users (which would then be labelled as performance dimension quality). For the generic project definitions in the performance dimension speed, focus is on the internal elements that make up cycle time. Cycle time consists of several parts, such as processing time, idle time and time taken to repair rejects. Elements such as time for distribution and transportation to the client are not addressed. Finally, the performance dimension cost-efficiency consists mainly of generic project definitions aiming to improve efficiency that is internally measured. Hence, the generic project definitions have a tendency to focus on internal performance, such as productivity and efficiency, and fail to address external performance indicators such as customer satisfaction and value created. The essence lies in the failure to address CTQs for the end-user in LSS project definitions, and instead focus on internal processes and not on external results. This is a known phenomenon for TQM (Harari, 1993). For the performance dimension quality, we have proposed the CTQ "amount or percentage of satisfied customers" for the project objectives, "improving perceived quality" and "improving customer satisfaction". Hence, we urge LSS practitioners to consider the end-user or customer while setting the project objective and choosing the CTQs to ensure actual improvement instead of problem signal reduction.

6.3 Unclear alignment of Lean Six Sigma project definitions to existing strategic objectives of the company

Each of the LSS project definitions contained transcending strategic focal points, thereby aligning the LSS project objectives to the strategic objectives of the company. Previous literature on TQM addresses the importance of aligning improvement project objectives to existing company strategy. Strategic alignment is considered key to acceptance and even adoption of TQM as a way of working in companies (Lau and Anderson, 1998). Further research suggests that, for TQM programs to succeed, it is necessary that the management accounting system satisfies the need for information that supports a continuous improvement-oriented culture, such as information on quality delivery (Hoque and Alam, 1999; Wruck and Jensen, 1994). In other words, the TQM improvement objectives must be integrated in the objective function of the firm to facilitate:

- mutual understanding and discussions about area's of improvement;
- establishment of improvement goals, feedback on improvement progress and specific improvement results to be forecasted; and
- employee reward and motivational programs for encouragement of improvement potential realization (Lau and Anderson, 1998).

For similarities between TQM and LSS, see Dahlgaard and Dahlgaard-Park (2006). In the sample of LSS project definitions, a wide variety of strategic focal points were identified. The strategic focal points could mostly not be related to general accounting measures.General accounting measures are a good way to break strategic focal points down to measurable indicators. For our analysis, we applied the popularized Dupont scheme (Kaplan, 1984).

The first category of non-relatingness is because of a lack of specificness of the mentioned strategic focal point. Examples of this category are: reducing costs, improving quality, improving turnover/profit and improving efficiency. It is unclear how these focal points contribute to the accounting measures. For instance, reduction in costs can be contributing to the Dupont scheme's accounting measures for total expenses, variable expenses or fixed expenses. The other category of non-relatingness is because of a lack of quantification of the strategic focal point. Examples of this category are: improving customer satisfaction, improving employee satisfaction and reducing cycle time. For these strategic focal points, it is unclear to which accounting measures they contribute. For instance, improving customer satisfaction can contribute to accounting measures for sales, variable expenses (less warranty claims) and profit margin.

Hence, we believe that LSS improvement objectives should be integrated or at least be linked to measurable and existing strategic objectives. This will facilitate the understanding of improvement area selection for LSS projects by project champions and practitioners. In addition, monitoring and discussions on improvement results of LSS projects in terms of contribution to strategic goal realization are facilitated. Finally, employees that engage in LSS project execution can be rewarded for their positive contribution to strategic goal realization.

7. Limitations and further research

The sample size for this research consists of 312 LSS projects, thereby limiting the generalizability of the results. When the generic LSS project definitions are applied, LSS practitioners should carefully validate and tailor the templates to their unique LSS project at hand. We believe we have been able to capture and present valuable knowledge about the LSS project definition phase, allowing practitioners to draw upon previous successful LSS project definitions. Further research avenues should work towards building a stronger empirical foundation of the generic LSS project definitions. This can be done by adding new cases to the sample. In addition, the generic LSS project definitions presented here should be tested and optimized where possible. Another avenue for further research should be the identification of generic improvement actions subsequent to problem indication according to the generic LSS project definition. Mapping successful improvement directions for each of the generic LSS project definitions can help practitioners in selection of the required actions to resolve identified improvement potential adequately.

References

Aamodt, A. and Plaza, E. (1994), "Case based reasoning; foundantional issues, methodological variations, and system approaches", *AI Communications*, Vol. 7 No. 1, pp. 39-59.

Arumugam, V., Antony, J. and Linderman, K. (2014), "A multilevel framework of Six Sigma: a systematic review of the literature, possible extensions and future research", *Quality Management Journal*, Vol. 21 No. 4, pp. 36-61.

Brun, A. (2011), "Critical success factors of Six Sigma implementations in Italian companies", *International Journal of Production Economics*, Vol. 131 No. 1, pp. 158-164.

Chakravorty, S.S. (2009), "Six sigma failures: an escalation model", *Operations Management Research*, Vol. 2 Nos 1/4, pp. 44-55.

Coronado, R.B. and Antony, J. (2002), "Critical success factors for the successful implementation of Six Sigma projects in organizations", *The TQM Magazine*, Vol. 14 No. 2, pp. 92-99.

Dahlgaard, J.J. and Dahlgaard-Park, S.M. (2006), "Lean production, six sigma quality, TQM and company culture", *The TQM Magazine*, Vol. 18 No. 3, pp. 263-281.

de Koning, H. and de Mast, J. (2007), "The CTQ flowdown as a conceptual model of project objectives", *Quality Management Journal*, Vol. 17 No. 3, pp. 19-28.

de Koning, H., de Mast, J., Does, R.J.M.M., Vermaat, T. and Simons, S. (2008), "Generic Lean Six Sigma project definitions in financial services", *Quality Management Journal*, Vol. 15 No. 4, pp. 32-45.

de Koning, H., Does, R.J.M.M., Groen, A. and Kemper, B.P.H.H. (2010), "Generic Lean Six Sigma project definitions in publishing", *International Journal of Lean Six Sigma*, Vol. 1 No. 1, pp. 39-55.

de Mast, J. and Lokkerbol, J. (2012), "An analysis of the Six Sigma DMAIC method from the perspective of problem solving", *International Journal of Production Economics*, Vol. 139 No. 2, pp. 604-614.

Detert, J.R., Schroeder, R.G. and Mauriel, J.J. (2000), "A framework for linking culture and improvement initiatives in organizations", *Academy of Management Review*, Vol. 25 No. 4, pp. 850-863.

Does, R.J.M.M., Vermaat, M.B., de Koning, H., Bisgaard, S. and van den Heuvel, J. (2006), "Standardizing healthcare projects", *Six Sigma Forum Magazine*, Vol. 6 No. 1, pp. 14-23.

Erdmann, T.P., Boessenkool, H., Hogewoning, L. and Does, R.J.M.M. (2013a), "Quality quandaries: reducing work in process at an emergency assistance center", *Quality Engineering*, Vol. 25 No. 1, pp. 78-84.

Erdmann, T.P., Janssen, W.W.L.M. and Does, R.J.M.M. (2013b), "Quality quandaries: streamlining the procurement process at a media and entertainment company", *Quality Engineering*, Vol. 25 No. 4, pp. 455-460.

Ferdows, K. and de Meyer, A. (1990), "Lasting improvements in manufacturing performance: in search of a new theory", *Journal of Operations Management*, Vol. 9 No. 2, pp. 168-184.

Foster, S.T. (2008), "Towards an understanding of supply chain quality management", *Journal of Operations Management*, Vol. 26 No. 4, pp. 461-467.

George, M. (2003), *Lean Six Sigma for Service*, McGraw-Hill, New York, NY.

Harari, O. (1993), "Ten reasons why TQM doesn't work", *Management Review*, Vol. 86 No. 1, p. 33.

Hoque, Z. and Alam, M. (1999), "TQM adoption, institutionalism and changes in management accounting systems: a case study", *Accounting and Business Research*, Vol. 29 No. 3, pp. 199-210.

Juran, J.M. (1986), "The quality trilogy: a universal approach to managing for quality", *Quality Progress*, Vol. 19 No. 8, pp. 19-24.

Kaplan, R.S. (1984), "The evolution of management accounting", *The Accounting Review*, Vol. 114 No. 3, pp. 390-418.

Kaplan, R.S. and Norton, D.P. (1992), "The balanced scorecard - measures that drive performance", *Harvard Business Review*, Vol. 70 No. 1, pp. 71-79.

Kemper, B. and de Mast, J. (2013), "Measurement plans for process flow improvement in services and health care", *Quality Engineering*, Vol. 25 No. 4, pp. 437-450.

Kemper, B.P.H., Koning, S., Luijben, T.C.W. and Does, R.J.M.M. (2011), "Quality quandaries: cost and quality in postal service", *Quality Engineering*, Vol. 23 No. 3, pp. 302-308.

Koste, L.L. and Malhotra, M.K. (1999), "A theoretical framework for analyzing the dimensions of manufacturing flexibility", *Journal of Operations Management*, Vol. 18 No. 1, pp. 75-93.

Kuiper, A., Van Raalte, M. and Does, R.J.M.M. (2014), "Quality quandaries: improving the overall equipment effectiveness at a pharmaceutical company", *Quality Engineering*, Vol. 26 No. 4, pp. 478-483.

Lau, R.S.M. and Anderson, C.A. (1998), "A three dimensional perspective of total quality management", *International Journal of Quality & Reliability Management*, Vol. 15 No. 1, pp. 85-98.

Linderman, K., Schroeder, R.G., Zaheer, S. and Choo, A.S. (2003), "Six Sigma: a goal theoretic perspective", *Journal of Operations Management*, Vol. 21 No. 2, pp. 193-203.

Lokkerbol, J., Schotman, M.A.M. and Does, R.J.M.M. (2012a), "Quality quandaries: personal injuries: a case study", *Quality Engineering*, Vol. 24 No. 1, pp. 102-106.

Lokkerbol, K., Does, R.J.M.M., de Mast, J. and Schoonhoven, M. (2012b), "Improving processes in financial service organizations: where to begin?", *International Journal of Quality and Reliability Management*, Vol. 29 No. 9, pp. 981-999.

Lynch, D., Berolono, S. and Cloutier, E. (2003), "How to scope DMAIC projects", *Quality Progress*, Vol. 36 No. 1, pp. 37-41.

McAdams, R. and Lafferty, B. (2004), "The organizational contextual factors affecting the implementation of six sigma in a high technology mass manufacturing environment", *International Journal of Six Sigma and Competitive Advantage*, Vol. 1 No. 1, pp. 29-43.

Mooren, J., De Mast, J. and Does, R.J.M.M. (2012), "Quality quandaries: the case of premature drill wear out", *Quality Engineering*, Vol. 24 No. 2, pp. 354-359.

Neely, A., Gregory, M. and Platts, K. (2005), "Performance measurement system design; a literature review and research agenda", *International Journal of Operations and Production Management*, Vol. 25 No. 12, pp. 1228-1263.

Niemeijer, G.C., Does, R.J.M.M., De Mast, J., Trip, A. and van den Heuvel, J. (2011), "Generic project definitions for improvement of health care delivery: a case based approach", *Quality Management in Health Care*, Vol. 20 No. 2, pp. 152-164.

Nonthaleerak, P. and Hendry, L. (2008), "Exploring the Six Sigma phenomena using multiple case study evidence", *International Journal of Operations and Production Management*, Vol. 28 No. 3, pp. 279-303.

Schoonhoven, M., Lubbers, C. and Does, R.J.M.M. (2013), "Quality quandaries: shortening the throughput time of a hospital's billing process", *Quality Engineering*, Vol. 25 No. 2, pp. 188-193.

Schroeder, R.G., Linderman, K., Liedtke, C. and Choo, A.S. (2008), "Six Sigma: definition and underlying theory", *Journal of Operations Management*, Vol. 26 No. 4, pp. 536-554.

Schroeder, R.G., Shah, R. and Xiaosong Peng, D. (2011), "The cumulative capability 'sand cone' model revisited: a new perspective for manufacturing strategy", *International Journal of Production Research*, Vol. 49 No. 16, pp. 4879-4901.

Sitkin, S.B., Sutcliffe, K.M. and Schroeder, R.G. (1994), "Distinguishing control from learning in total quality management: a contingency perspective", *The Academy of Management Review*, Vol. 19 No. 3, pp. 537-564.

Smith, G.F. (2000), "Too many types of quality problems", *Quality Progress*, Vol. 33 No. 4, pp. 43-49.

Szeto, A.Y.T. and Tsang, H.C. (2012), "Antecedents to successful implementation of six sigma", *International Journal of Six Sigma and Competitive Advantage*, Vol. 1 No. 3, pp. 437-453.

Tunälv, C. (1992), "Manufacturing strategy - plans and business performance", *International Journal of Operations and Production Management*, Vol. 12 No. 3, pp. 2-24.

van den Bos, A., Kemper, B.P.H.H., Van Dongen, J.P.W. and Krute, M.S. (2014), "Generic Lean Six Sigma project definitions for the construction industry", *International Journal for Six Sigma and Competitive Advantage*, Vol. 8 No. 3, pp. 257-274.

Vickery, S., Calantone, R. and Dröge, C. (1999), "Supply chain flexibility: an empirical study", *The Journal of Supply Chain Management*, Vol. 35 No. 2, pp. 16-24.

Watson, I. (1999), "Case-based reasoning is a methodology not a technology", *Knowledge Based Systems*, Vol. 12 No. 5, pp. 303-308.

Weelwright, S.C. (1984), "Manufacturing strategy – defining the missing link", *Strategic Management Journal*, Vol. 5 No. 1, pp. 77-91.

Wruck, K.H. and Jensen, M.C. (1994), "Science, specific knowledge, and total quality management", *Journal of Accounting and Economics*, Vol. 18 No. 3, pp. 247-287.

Zu, X., Fredendall, L.D. and Douglas, T.J. (2008), "The evolving theory of quality management: the role of Six Sigma", *Journal of Operations Management*, Vol. 26 No. 5, pp. 630-650.

Zwetsloot, I.M. and Does, R.J.M.M. (2015), "Quality quandaries: improving revenue by attracting more clients online", *Quality Engineering*, Vol. 27 No. 1, pp. 130-137.

Zwetsloot, I.M., Buitenhuis, M., Lameijer, B.A. and Does, R.J.M.M. (2015), "Quality quandaries: increasing the first time fix rate in a customer contact center", *Quality Engineering*, Vol. 27 No. 3, pp. 393-400.

Corresponding author
Bart A. Lameijer can be contacted at: B.A.Lameijer@uva.nl