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Quality Quandaries: Streamlining the Path to Optimal Care for Cardiovascular Patients

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INTRODUCTION

In this column, we provide an example of a Lean Six Sigma project in health care. The setting was Deventer Hospital in The Netherlands and the cardiology department in particular. It concerns a project to improve the quality of care for outpatients and at the same time to achieve a more efficient allocation of resources and hence increase the hospital's revenues. The specific process of interest is diagnosing new cardiovascular patients and conducting checkups on existing cardiovascular patients. The hospital's objective to provide faster and easily accessible care was translated into a concrete project objective, namely, to shorten the admission time (for new patients) and the throughput time of the cardiac consultation pathway.

At the time the project was initiated, the cardiology team felt that they were operating in a high-pressure work environment, which was expected to increase as a result of an aging population and earlier recognition as a result of the increasing diagnostic possibilities, for example, for a general practitioner. A more efficient allocation of resources would be needed to improve working conditions and meet the challenge of a higher patient admission rate. These findings fueled the second project objective, namely, to improve the efficiency of resource utilization and, in doing so, increase the number of patients treated and revenue earned.

Before we discuss the project in greater detail, some background information on the project setting and the Lean Six Sigma program is given in the next section. The following five sections apply the Lean Six Sigma methodology to an improvement project in the cardiac outpatient clinic. The final section offers some concluding remarks.

BACKGROUND

The Deventer Hospital in The Netherlands is a 534-bed, medium-size teaching hospital employing a staff of 1,500. In 2009, the Deventer Hospital had 20,368 admissions, performed 23,954 outpatient treatments, and received 295,066 visits to its outpatient clinics, of which 114,339 were first contacts. In 2009, the board of the hospital decided to initiate a Lean Six Sigma program. Under the guidance of the Institute for Business and Industrial Statistics at the University of Amsterdam, Lean Six Sigma kicked off with a one-day executive training course for the board and senior management and a first wave of Green Belt (GB) training. Two more GB rounds followed

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and the fourth wave started in September 2011. Some of the high-potential participants from the first wave followed a Black Belt training, too, and have finished their training for the Master Black Belt role, which means that the hospital itself can now train and coach their own GBs.

The GB program required each participant to complete a project with potential annual benefit of $60,000. On average, a participant worked on his or her project for one or two days per week during in the course of 6 months. To execute their projects all participants followed the DMAIC sequence (cf. De Mast et al. (2006)):

- Define: Specify project objectives.
- Measure: Define and validate measurements.
- Analyze: Analyze the problem and identify influence factors.
- Improve: Establish the impact of influence factors and define actions for improvement.
- Control: Implement improvements, assure quality, and close the project.

In accordance with Lean Six Sigma project management, all participants were carefully monitored and allowed to proceed to the next project phase only after presenting (i.e., the problem owner and coach) the completion of the preceding phases to their champion. This project commenced on May 1, 2009. It received strong support and was expected to take approximately the same amount of time as the period of training. For this reason, November 1, 2009, was chosen as the project deadline.

DEFINE

During the define phase of a Lean Six Sigma project, it is paramount that the project leaders clearly define the process to be improved, state project objectives, analyze potential benefits, create a project organization, and draw up a time schedule.

The process to be improved was that of diagnosing new cardiovascular patients and conducting checkups on existing patients in a cardiac outpatient clinic. The SIPOC model of the process—showing supplier, input, process, output, and customer—is depicted in Figure 1.

A new patient is referred to a specialist by the general practitioner. Existing patients are admitted by a cardiologist who is treating them. When a new patient arrives for consultation at the outpatient clinic, an electrocardiogram (ECG) is administered. During the first consultation, the ECG is discussed by the cardiologist. Based on the outcome of the ECG and the results of the consultation on patient's fitness level and cardiac history, the cardiologist decides which additional diagnostic tests, such as an echocardiogram (echo), a cycling test, or a Holter test (i.e., continuously monitoring heart activity for at least 24 hours), are required. Some specific scans, are performed and analyzed by the radiology department.

At the outset of the project, the cardiology department was staffed by seven cardiologists, who—on top of other tasks such as treatments, research, and teaching—were assigned for a minimum of 15 hours a week for matters concerning the cardiac outpatients (for each patient this includes a first consultation and second consultations to discuss test results). For new patients, 20 minutes were scheduled for the first consultation and 10 minutes for the second consultation; for existing patients also 10 minutes were scheduled.

The cardiologists perceived the total volume of consultations as a high and growing workload. The first project objective was to look for efficiency improvements in the use of available consultation time. By enabling cardiologists to see more patients,

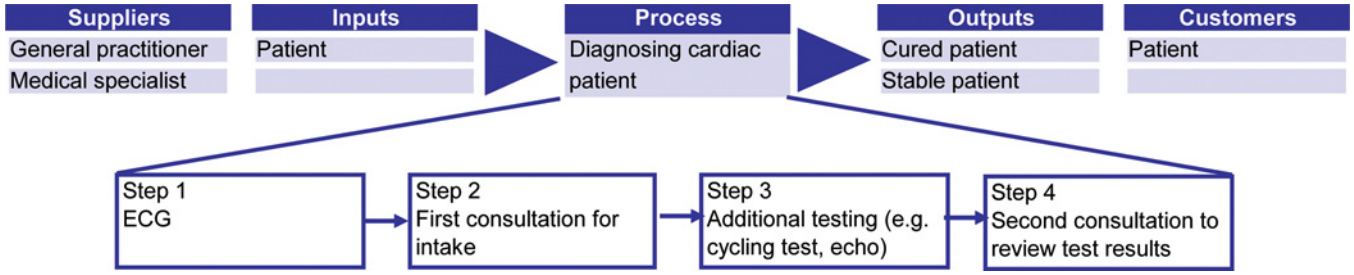

FIGURE 1 SIPOC of the outpatient clinical process. (Color figure available online.)

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the clinic would also generate greater revenues. The project assumed a 5% growth rate in the number of new patients, translating into a $60,000 increase in annual revenue.

Prior to the project, the admission time for new patients was estimated at around 2 weeks and the throughput time—measured from first consultation (initial diagnosis) to the second consultation (review of test results)—was estimated at around 5 weeks. This, however, was considered to be too long for a patient with possible cardiovascular disorders. The second project objective was to have a consultation arranged within 10 days for at least 95% of new patients and to reduce the throughput time needed for additional tests to 2 weeks for 95% of all patients.

To achieve these objectives, a six-member project team was created, with each member drawn from the process under study. The team consisted of three cardiologists, including the head cardiologist; an operations manager; and two clinical assistants. The main tasks of the team were to collect and provide information about the process, to brainstorm influence factors that relate to the objectives, and to generate ideas for improvement.

MEASURE

In the measure stage, project objectives are operationalized in the form of measurable quality characteristics, or *critical-to-quality characteristics* (CTQs) in the terminology of Lean Six Sigma (cf. De Mast et al. (2006)). A procedure is established to measure the CTQs and this procedure is then validated.

Recall that the project objectives were to improve the allocation of resources (thus allowing more new patients and raising revenues), to reduce the admission time to 10 days for at least 95% of patients, and to reduce the throughput time to 2 weeks for at least 95% of patients. These project objectives were translated into the following CTQs: admission time, throughput time workload, throughput, and overall resource efficiency.

We measured the admission and intermediate waiting times to identify where in the process patients had to wait. In addition, we measured the number of new and existing patients scheduled per week (referred to as workload, WL) and the number of patients treated per week (referred to as throughput, TP) in the various stages of the process. The latter metrics would allow us to better understand the relationship between workload and capacity over time and might explain why there were long admission and throughput times: when workload and/or capacity vary strongly, admission and throughput times will increase (see next subsection).

In measuring the resource utilization, the project focused specifically on the use of a cardiologist's available time rather than the use of other resources, such as echo equipment. This was because the work conducted by the cardiologists constituted the main activity in the cardiac outpatient clinic and they were also considered the bottleneck in the consultation process. The overall resource efficiency (ORE) measures how well the total scheduled time is used. To determine the ORE we applied a conceptual framework proposed by De Mast et al. (2011). In the next subsection we explain this framework.

Overall Resource Efficiency

The ORE model includes a system of metrics for calculating the capacities of resources, tasks, and processes, as well as efficiency factors for each. The calculations resemble the framework of overall equipment effectiveness (OEE) in the manufacturing industry; see, for example, Nakajima (1988) and Ljungberg (1998). This framework allows the identification and diagnosis of bottlenecks in the process, the key to improving throughput or reducing waiting times. Further, it allows an assessment of the efficiency of the process, quantifying where resources are wasted. In Table 1 some of the metrics needed are defined.

The overall resource efficiency is defined as the number of patients treated per time unit divided by potential capacity. Potential capacity, in turn, is the total time scheduled (for all cardiologists) divided by the processing time (*PT*) per patient. When the overall resource efficiency is significantly below 100%, capacity is wasted.

We discuss two dimensions for capacity to be wasted. First, capacity may be lost due to distractions or interruptions which reduces the availability (*Av*) of a resource. The number of patients who can be treated when such time losses are taken into account is the effective capacity. Second, there may be idle time in the process resulting from synchronization

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TABLE 1 Metrics to be Measured

Metric		Definition
Potential capacity	*PCap*	The capacity based on the total scheduled time of a resource divided by the mean processing time
Availability	*Av*	The fraction of the total time that a resource is actually available for a task
Effective capacity	*ECap*	$Ecap = Av * PCap$
Idle time	*IT*	The fraction of the available time of a resource that is not spent on tasks
Effective utilization	*EUt*	The percentage of available time that a resource is not idle

losses. Some examples of synchronization losses for an outpatient clinic are as follows:

- Late arrival of patients or staff, no-shows, last-minute scheduling disruptions.
- Conflicting schedules of physicians, rooms, and other facilities.
- Variation in processing times.

Taking the first two as self-evident, the third point follows from a generally known principle in industrial engineering (see, e.g., Hopp and Spearman (2008), chapters 8 and 9), which states that higher variability (in cycle times, interarrival times, outages, quality problems, and other sources) results in more idle time (*IT*) of a resource, unless one buffers against *IT* by keeping work on standby. The fraction of available time that a resource (or process) is not idle is the effective utilization (*EUt*). Given that there is sufficient demand and there is no rework (thus the first time right ratio is 100%), one defines $ORE = EUt * Av$.

The metrics introduced in the above allow the identification of improvement opportunities, which, in the process improvement paradigm, are identified from process diagnosis. If the effective capacity of one of the resources is not sufficient (that is, does not match with the demand), one could increase the processing speed (for example, reduce the standard consultation durations) or increase the availability by limiting interruptions and distractions. If the effective utilization of a limiting (or bottleneck) resource is low, one should implement improvement actions so that the bottleneck resource need not wait for patients or other resources.

De Mast et al.'s (2011) framework was used to determine the relevant process metrics for the project in the cardiac outpatient clinic. To measure potential capacity we measured the total time scheduled for consultation with a cardiologist. To measure the effective capacity we measured the time lost during consultation hours due to interruptions in between patients. Finally, the effective utilization was measured in terms of no-shows and the idle time caused by patients arriving late. Furthermore, hospital finances are arranged in such a way that a follow-up (as opposed to a new) consultation does not necessarily generate more income. For this reason, it was important to understand how many follow-up consultations were scheduled. This was captured in the metric number of follow-up consultations per patient. The CTQs together with their measurements are summarized in Table 2.

The measurements were collected in a 4-week period by a member of the administrative staff. The

TABLE 2 The CTQs Defined in the Cardiac Outpatient Project

CTQs	Metrics
Admission and throughput times	Admission and throughput times
Workload	Number of patients scheduled/week
	Number of follow-up consultations/patient
Throughput	Number of patients treated/week
Overall resource efficiency	Start and end times of consultations
	Interruptions in consultation hours
	Consultation time/patient
	Idle time due to no-shows
	Idle time due to patients arriving late

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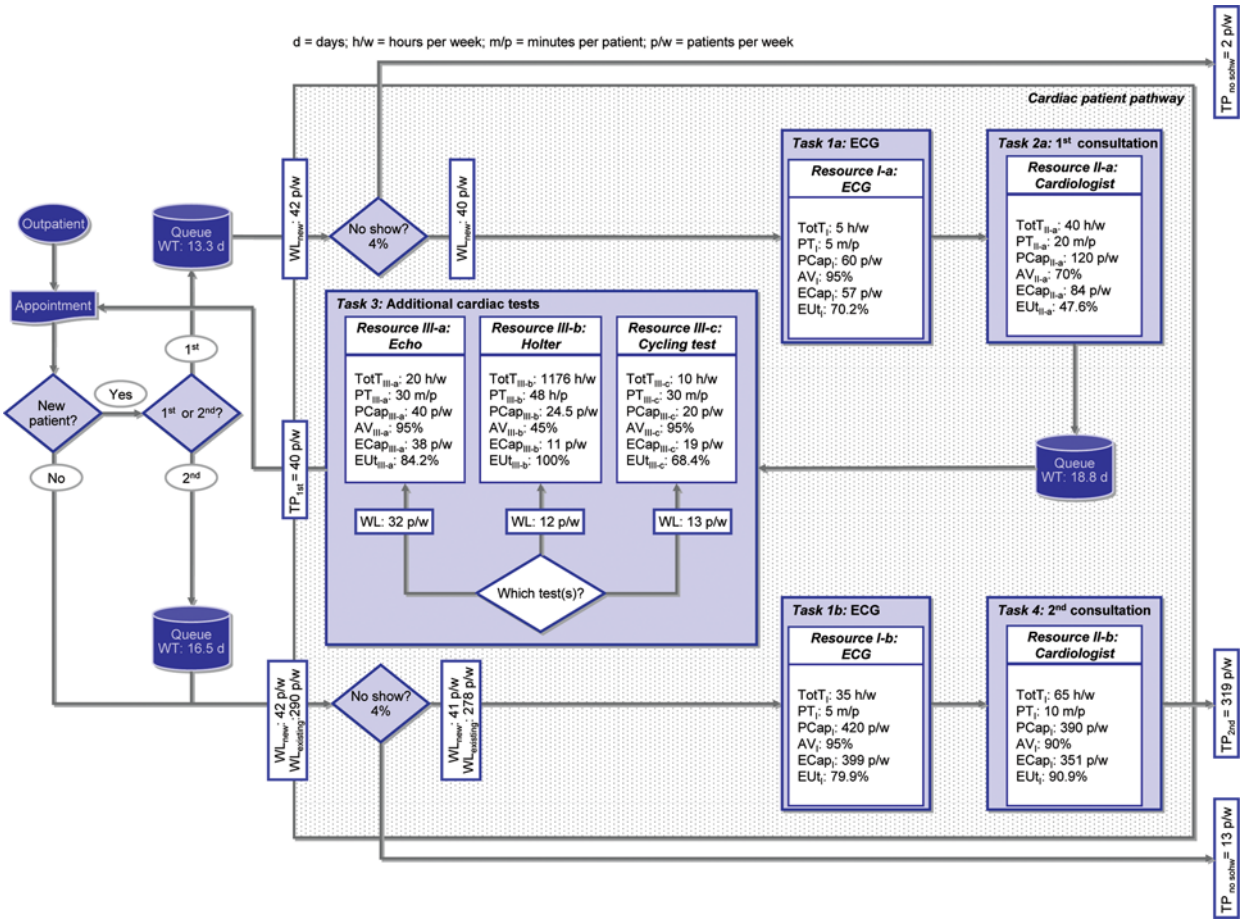

FIGURE 2 **Value stream map of the cardiac outpatient process. (Color figure available online.)**

Black Belt created measurement forms and, to ensure their validity, discussed them with the individuals responsible for collecting measurements. Any definitions were discussed and clarified where necessary. It was not clear, for example, whether the process metric consultation time should include the time the cardiologist spent on patient reporting. Clarifying definitions ensured that measurements would capture information correctly.

ANALYZE

In the analyze phase, the initial levels of the CTQs are determined from the collected data. These values are analyzed in order to diagnose any problems in the process and to produce a list of potential influence factors.

A useful tool for describing the process flow in detail and visualizing any forms of waste is a so-called value stream map (VSM); see Womack and Jones (2003) and Kemper et al. (2010). Here, the value stream map was used primarily to show admission times, the times (in days) between a new patient's first consultation and any additional tests, and, for each conditional (i.e., given the patient's diagnosis) pathway, the percentage of patients following that pathway. The VSM for the cardiac outpatient process is shown in Figure 2.

The VSM shows that the preproject admission time for new patients was 13.3 days on average. To identify the reason behind long admission times, we considered the number of new patients scheduled (workload), the number of patients that can be treated (potential and effective capacity), and the number of patients treated (throughput) on a weekly basis. It turned out that it was mostly the level of capacity that fluctuated considerably. And these large variations in capacity led to longer waiting times.

The variation phenomenon was even more pronounced in the case of additional diagnostic testing. Looking at workload and capacity on a weekly and monthly basis revealed that planned capacity fluctuated significantly. In the case of the Holter tests, it

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even appeared that there were structurally too few such tests scheduled. As a consequence, the waiting time for this test tended to be high.

Another problem underlying long throughput times was the sequential scheduling of tasks: patients were not contacted for a consultation until the secretary had received the test results. From that moment, the waiting time for a consultation was another 2 weeks. The overall resource efficiency, that is, the proportion of total available time effectively used for consultation, proved to be considerably below 100%.

The last step in the analyze phase is to generate factors that influence the CTQs. For the cardiac outpatient process, the project team identified the main influence factors from the analysis of the measurement data, from the process flow, and from conversations with other cardiologists and external departments responsible for additional diagnostic tests. The main influence factors for the CTQs admission and throughput times were as follows:

- Number of available consultation hours/week
- Number of available additional tests (e.g., echo, Holter, and cycling test)
- The procedure to schedule consultations to discuss test results
- Throughput time for processing additional diagnostic tests

Results for the total throughput time per patient were a real eye-opener for the cardiologists. With the new insights acquired, they were far more ready to think about ways of reducing follow-up consultations.

The main influence factors for the CTQ overall resource efficiency were the following:

- Patient arrival time for the ECG (which takes place before the first consultation)
- Number of no-shows
- Unplanned activities during consultations (which could also be done at other times and/or by clinic assistants)

The main influence factors for the CTQ number of follow-up consultations per patient were the following:

- Agreement on a best practice
- Management reporting

IMPROVE

In the improve phase, the influence factors identified during the analyze phase are critically examined, prioritized according to their effect on the CTQs, and serve as input to generate improvement actions that ensure that the CTQs satisfy certain standards.

The most important factor influencing admission times for new patients was the fluctuation in the number of consultation hours available to a cardiologist. Agreements were made with every specialist about available consultation hours per week. To reduce the throughput time from the first to the second consultation, the number of additional tests scheduled was geared more closely to the expected number of tests based on the number of new and existing patients. Moreover, consultations for reviewing results were no longer scheduled at the moment that test results came in but at the same time as the initial consultation and within 14 days. It was also agreed that this would be the time available for diagnostic testing and results to be available. The new procedure is a good example of a so-called critical path analysis: rather than scheduling tasks sequentially, they are carried out in parallel so that waiting times are shorter. To ensure that test results would be available within 14 days, agreements were made with the departments that are responsible for the tests. Finally, the analyze phase revealed a backlog of Holter tests (see Figure 2, $PCap_{III\text{-}b} = 11 < \mathrm{WL} = 12$). To process the backlog, more such tests were scheduled for a limited period of time.

The analyze phase showed several inefficiencies in the use of consultation time: staff did not start consultations on time, cardiologists carried out tasks other than consultation during consultation hours, and patients arrived late because they did not know that an ECG had to be administered before the first consultation. To address the first two issues, the clinic implemented a workflow procedure that facilitated the start of a consultation and reduced time spent on unplanned activities. The appointment letter to patients was changed to state when they should arrive for their first consultation to allow sufficient time for an ECG.

To reduce the CTQ workload per patient, agreements were made with the cardiologists about reducing the number of follow-up consultations per patient.

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CONTROL

The last phase of the DMAIC method is the control phase. The goal of the control stage is twofold. First, actions must be taken to ensure that improvements are permanent. This involves assigning roles and responsibilities as well as regular reporting. Second, the benefits of the project are determined and the Black Belt is discharged.

To maintain the improved admission and throughput times, a new scheduling procedure was implemented for the secretary. The number of consultations scheduled to review test results would equal the number of first consultations and there would be greater attention to the need to schedule a corresponding number of additional tests. The cardiology team made clear agreements to minimize unplanned tasks during consultation hours and to keep down the number of follow-up consultations.

It was also agreed that the operations manager would check admission times, throughput times, the availability of test results, and the number of scheduled consultations. The number of follow-up consultations would be monitored by the head cardiologist.

In 2010, the Black Belt conducted a postproject appraisal. She found that admission times for new patients were shorter: 95% of patients had an appointment for a first consultation within 10 days. Throughput times were all within 14 days in the first 6 months of 2010.

There was a better flow of patients, with physicians spending less time waiting for the next patient, and there was less underutilized consultation time. Part of this time was used to schedule new patients, resulting in extra revenues of $20,000. The remaining underutilized time did not lead to any direct revenues but because physicians could do other revenue-earning tasks, it generated potential revenues of $20,000.

There were fewer follow-up consultations and hence a higher proportion of new patients in the patient population. This generated an additional $30,000 in revenues.

CONCLUDING REMARKS

The project in the cardiac outpatient clinic was a success: reducing admission and throughput times for the patient as well as improving efficiency levels and raising hospital revenues. The project has shown how tools such as Lean Six Sigma, together with the conceptual framework developed by De Mast et al. (2011), can help to diagnose and resolve workflow and efficiency problems. In the case of the cardiac outpatient clinic, they have reduced unacceptable waiting times faced by patients, and they have created a more efficient allocation of valuable hospital resources.

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