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Benjamin P. H. Kemper^a; Mariël Koopmans^b; Ronald J. M. M. Does^a

^a Institute for Business and Industrial Statistics (IBIS UvA), University of Amsterdam, The Netherlands ^b Medical Spectrum Twente, Enschede, The Netherlands

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Quality Quandaries*: The Availability of Infusion Pumps in a Hospital

**Benjamin P. H. Kemper¹,
Mariël Koopmans²,
Ronald J. M. M. Does¹**

¹Institute for Business and Industrial Statistics (IBIS UvA), University of Amsterdam, The Netherlands

²Medical Spectrum Twente, Enschede, The Netherlands

INTRODUCTION

In January 2006, a new healthcare system was introduced in The Netherlands, to strengthen incentives for efficiency. It allows insured persons to make a switch in their health insurer at least once a year, whereas health insurers can negotiate more freely with hospitals and other care providers about the prices. In a strongly dictated market frame, these changes lead to a so-called regulated competition among insurers and among hospitals due to free choice of the policyholders and the insurers, respectively (cf. Arrow, 1963; Mot, 2003). Due to this competition, the insurers are encouraged to negotiate good-value contracts with the hospitals. The objective is to create incentives that will reduce total care expenditure by enhancing efficiency in both care insurance and care provision markets. Hence, the care providers are more or less forced to organize and to adopt improvement programs such as total quality management, business process redesign, lean thinking, and Six Sigma.

In this column we provide an example of the application of Lean Six Sigma to healthcare (for an introduction, see De Mast et al., 2006). The specific case study is about reducing operational costs of infusion pumps in a top-ten general (i.e., nonacademic) hospital in The Netherlands. First, we provide a brief background for the case study. We then highlight some of the statistical aspects. This study is interesting because, unlike the common assumption, it shows that there are no trade-offs between quality and cost; i.e., we can improve quality and reduce costs at the same time.

BACKGROUND

The peripheral hospital Medical Spectrum Twente is located in Enschede and it serves about 264,000 people in the eastern region of The Netherlands. It has about 750 beds for about 29,500 long-term stays and about 24,000 day-long stay intakes. Overall it employs 4,000 persons who facilitate 211,000 nursing days and 439,000 outpatient clinic visits per year. The annual budget is about 200 million euros.

With the assistance of an external consultancy firm, in this case the Institute for Business and Industrial Statistics of the University of Amsterdam,

*Edited by Søren Bisgaard.

Address correspondence to Ronald J. M. M. Does, IBIS UvA, Plantage Muidergracht 12, 1018 TV Amsterdam, The Netherlands. E-mail: r.j.m.does@uva.nl

Project description:	Pump use and maintenance
Main benefit:	Reduce pump investment and operational cost.
Additional benefits:	Monitoring pump maintenance
Financial savings:	At least 20,000 euro
Champion:	Mr. A. Gehring, manager MT & ICT

FIGURE 1 Infusion pump project summary.

a Lean Six Sigma (LSS) Green Belt project started in September 2008. The project followed the DMAIC steps:

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

While executing the project, the project leader (i.e., Green Belt, GB) was trained in the LSS method for structured process improvement. The training of the GB was provided through the large-scale LSS program within the University Medical Center Groningen, as described in more detail in Wijna et al. (2009). The training consisted of four modules: a module of one day for the define phase, a module of three days for the measure and analyze phases, a module of three days to complete the analyze phase and for the improve phase, and a final module of one day for the control phase.

The GB project was carefully supported so that the expected lead time of a project was about the same as the period of training and therefore February 1, 2009, was chosen as a deadline for the project.

CASE STUDY

The study focuses on the reduction of total costs in the process of ordering and maintaining infusion pumps, given the legal restrictions for safety and quality. The scope of the process is about 200,000 euros (153,000 euros yearly depreciation; i.e., 10% of the total investment of infusion pumps and 45,000 euros due to maintenance). The financial target of the infusion pump project is to reduce this amount by at least 20,000 euros. The project description is given in Figure 1.

In this case study, the process in which the pumps are used is generic with respect to the type of healthcare that is offered by the hospital. Therefore, we do not take into account a certain specialism or department. The macro process description is given in Figure 2.

The patient and the infusion pump are considered as the input of the process. During the healthcare process the pump is used to infuse fluids, medication, or nutrients into the patient's circulatory system.

The process of managing infusion pump use and maintenance faces a high level of operational cost. It is known that in most departments a large number of infusion pumps are in storage. Further, infusion pumps are rarely exchanged between departments. When storage levels are low, employees spend time tracing pumps, because the hospital lacks a track-and-trace system for infusion pumps. The maintenance of infusion pumps is not monitored at all. Therefore, it is unclear whether the current maintenance level meets the infusion pump maintenance regulations (based on more general patient safety regulations).

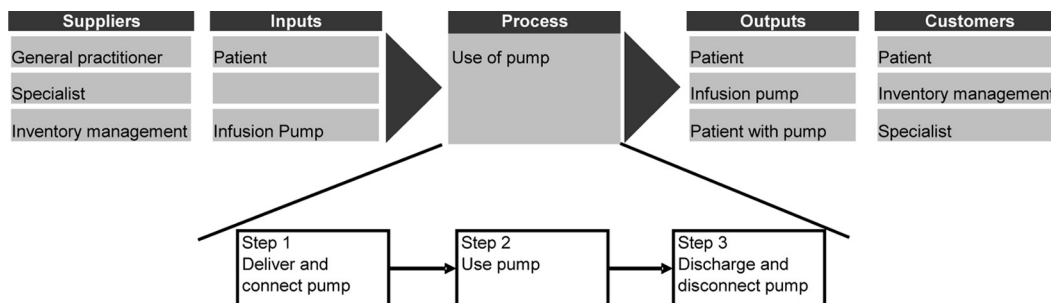


FIGURE 2 The macro process description of the generic healthcare process in which an infusion pump is used.

DMAIC STEP-BY-STEP: THE INFUSION PUMP PROJECT

Define

The infusion pump project covers the process as described in Figure 2. The define phase provided a project summary as in Figure 1. A clear overview of the project scope is provided with help of a Supplier-Input-Process-Output-Client (SIPOC) analysis; see, for example, Wijna et al. (2009). Figure 2 depicts the SIPOC used in the infusion pump project.

The process deals with the investment and maintenance of the infusion pumps. For example, an old pump that needs to be replaced, a broken pump that needs to be repaired, or a pump that is up for a periodic check (maintenance). An important precondition was that the pump maintenance regulations should be fully respected in any outcome of the project. Because one of the expected (additional) benefits was a maintenance monitoring system, this precondition can be easily checked.

In the define phase, the GB provided a stakeholders analysis and she also formed a project team consisting of people with knowledge about the process.

Measure

The measure phase of the DMAIC methodology starts with a critical to quality (CTQ) flowdown (see de Koning and de Mast, 2007). The idea behind the flowdown is to unravel performance indicators that are aggregate process metrics into so called CTQ parameters. The resulting breakdown helps to rationally reconstruct the influence factors that relate to the project objective defined by the champion. The project's CTQ flowdown is depicted in Figure 3.

For each CTQ we need an operational definition. An operational definition per CTQ includes:

- The CTQ: what component will be measured?
- The measurement procedure: how will the CTQ be measured?
- The experimental unit: per what is the CTQ measured?
- Requirement: what is the desired or specified level of the CTQ?

The operational definition serves as an input for the measurement plan for each CTQ. Further, the

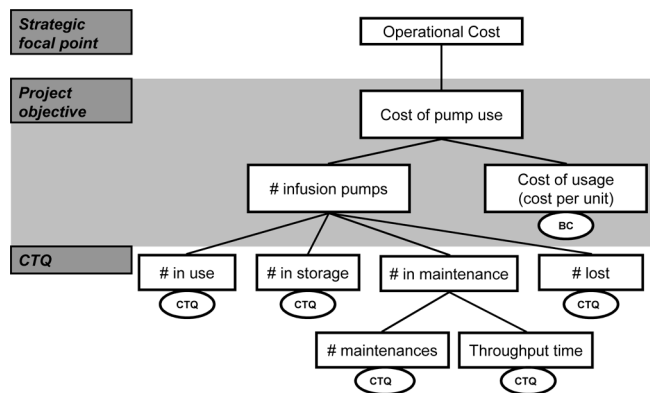


FIGURE 3 The CTQ flowdown of the infusion pump project.

measurement plan includes a schedule, when and for how long the CTQ is measured, an operator or employee, who is going to measure, and a database in which the data are recorded.

The CTQs in this project are total number of patients who use a pump, number of pumps in storage per department, number of untraceable pumps, number of times maintenance was performed during the life cycle of a pump, and throughput time of the maintenance; see Figure 4.

During the measure phase the project leader also decided to measure the number of times maintenance was performed per pump for all infusion pumps and the number of different types of pumps for all pumps. The CTQs “number in storage” and “number lost” are based on the seven departments that had complete data. The CTQ “throughput time of the pump maintenance” is based on a sample of 559 pumps from log data of the registration system. Regarding the number of pumps in use, the project leader decided to measure these data over eight departments during one year from the registration system. Further, the project leader decided to do some additional measurements, such as “number of pump types in use” and “number of pumps in a department that are from another department” (the last characteristic indicates the level of exchangeability or standardization level of the pumps).

Analyze

To get a “feeling” for the data, the project leader summarized the data and plotted a time series of the number of pumps in use from July 1, 2007, through October 31, 2008. The data were collected from eight departments that had complete data

CTQ	# in use	# in storage	# lost	# maintenances	Throughput time maintenance
Experimental unit	Department per day	Department per day	Department	Infusion pump	Maintenance
Measurement procedure	Sampling	Sampling	Sampling	Registration system	Registration system
Requirement	As small as possible	As small as possible	As small as possible	As stated in procedures	As small as possible

FIGURE 4 The operational definitions of the CTQs in the project.

regarding pump use in this period. The eight departments had registered a total number of 101 infusion pumps. A summary of the data is given in Table 1; the time series plot of the data may be found in Figure 5.

From Figure 5 it follows that during the measurement period of 489 days at least 19 of the available 101 pumps were not used! The price of a pump is around 1,800 euros. Hence, with respect to cost avoidance, this is equivalent to 34,200 euros. Note that the data in Figure 5 do not cover the CTQs “number of pumps in storage” and “number of pumps lost,” because the measurement does not take into account the reason a pump is not in use.

Due to the decentralized system of pump use, some departments faced a shortage, whereas others faced a huge surplus of infusion pumps during the sample period.

As mentioned, in the define and measure phase, several types of pumps were used in the hospital. See Figure 6 for an overview of the pump types.

Note that some of the pump types have up to six configurations. Type and configuration are not easily seen from the outside. This complexity prevents infusion pump exchange among the departments.

The CTQs “number of pumps in storage” and “number of pumps lost” were measured with a one-day sample. This sample included seven

departments and a total of 177 infusion pumps registered. An infusion pump that is not in use can be either in storage or lost. Table 2 shows the result of the investigation.

We expected that fluctuations in pump use were mainly due to the number of pumps in use and the number of pumps in storage and that the investigation resulted in a good estimation of the percentage of infusion pumps lost. Hence, one out of eight pumps is estimated to be lost.

The CTQ “number of times maintenance was performed per infusion pump” was collected from the database of the medical technology (MT) department, which is responsible for the infusion pump maintenance. Based on the data, the project leader compared the actual number of times maintenance was performed per infusion pump with the required number of times set according to the equipment maintenance regulations and the pump’s lifetime. An infusion pump is up for a periodic maintenance

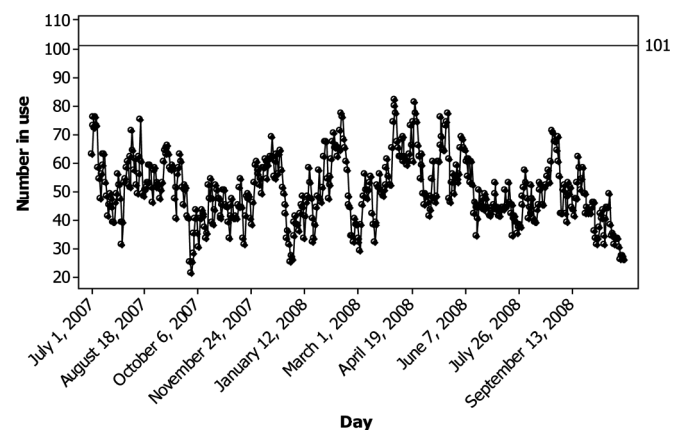


FIGURE 5 Time series plot of total number of infusion pumps in use.

TABLE 1 Descriptive Statistics of the Number of Infusion Pumps in Use

Variable	N	Mean	StDev	Min	Median	Max
# In use	489	50.016	11.423	21.000	49.000	82.000

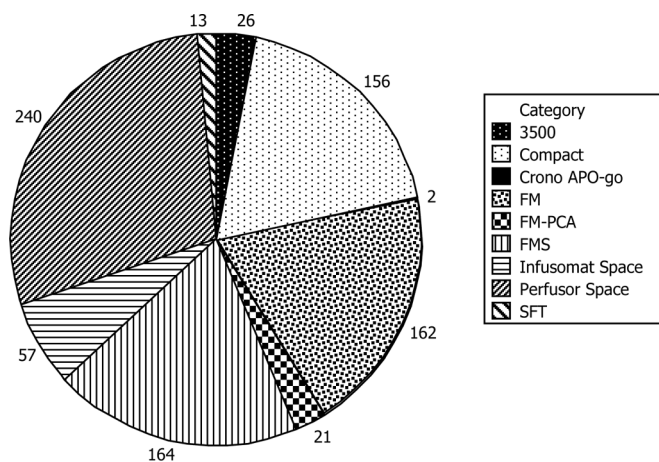


FIGURE 6 A pie chart of the different types (categories) of registered infusion pumps.

check at least once a year. Table 3 displays the results of the investigation.

The first column indicates the prescribed number of times for maintenance based on the pump's lifetime (i.e., if the prescribed number is 4, the lifetime of an infusion pump is 4 years). Columns 2–8 indicate the actual number of times maintenance was performed per row of pump lifetime. The ninth column indicates the number of infusion pumps that had fewer actual times that maintenance was performed than prescribed. It follows from Table 3 that about 88% of the infusion pumps are not in line with the prescribed maintenance.

The throughput time of the maintenance process is measured with the help of log data from the MT department. The throughput time of the maintenance process is on average 90.4 hours, of which 1.4 hours is used for maintenance. This means that about 98% of the process's throughput time refers to business non-value-added time and non-value-added time; the so-called type 1 *muda* and type 2 *muda* (cf. Womack and Jones, 2003). The processing time per maintenance performed is of less interest to the rest of the project, but the project leader strongly

TABLE 2 Descriptive Statistics of the Number of Infusion Pumps in Use, in Storage, and Lost Based on a One-Day Sample

Variable	N	Percentage
Registered	177	100.00
# In use	77	43.50
# In storage	78	44.07
# Lost	22	12.43

recommended that the organization define a project on the reduction of the throughput time of the maintenance process.

The analyze phase concluded with a list of influence factors that have a potential influence of the project's CTQs and are within the control of the organization.

The influence factors are listed as follows:

- Track-and-trace: about 12.5% cannot be traced and are considered lost.
- Exchangeability: corrected for lost infusion pumps standardization may lead to a reduction of at least 8% of the pumps. It is expected that this percentage will increase if more departments participate in a centralized infusion pump system.
- Maintenance process's capacity: about 88% of the infusion pumps were found to be under-maintained.
- Maintenance process's efficiency and productivity: the throughput of the maintenance process is poor.

In the improve phase the effects of the influence factors were investigated and improvement actions were defined.

Improve

The project leader and the project team listed a few vital influence factors. The number of pumps in use depends on the number of patients, which could not be controlled in this project. Therefore, all improvement actions are related to influence factors regarding the CTQs: "number in storage," "number of times maintenances was performed," "throughput time of maintenance," and "number lost."

The level of exchangeability of infusion pumps among departments may be increased through standardization of the infusion pumps. This creates a large pool of pumps for all departments. It is expected that this will reduce the number of infusion pumps by 10%, and there is a potential reduction of almost 20%. This results in a yearly reduction of depreciation of about 15,300 euros and a potential of about 30,600 euros yearly.

To facilitate the infusion pump pool, the hospital needs to invest in a barcode and scan system for

TABLE 3 The Prescribed and Actual Number of Times Maintenance was Required for the Infusion Pumps

Number of times maintenance is prescribed Prescribed maintenances	Actual number of times maintenance was performed								Total	
	0	1	2	3	4	5	6	Undermnt.		
1	14	37							14	51
2	3	52	1						55	56
3	1	193	94	6					188	294
4	2	10	5	2	1				19	20
5		2	12	34	5				53	53
6		12	38	60	73	43	16		226	242
Total	20	306	150	102	79	43	16		555	716

the infusion pumps so that all pumps can be tracked and traced and the hospital is able to plan the infusion pump use more efficient. Investment in a scan system costs about 55,000 euros. The scan system will also have an impact on the number of lost pumps. It is expected that the number of lost pumps can be reduced by 100%. This results in an extra reduction of depreciation of about 16,000 euros yearly.

An additional benefit of the scan system is that employees are expected to spend less time on tracking and tracing infusion pumps themselves. Based on an LSS project in the University Medical Center Groningen, these track and traces cost up to 175,000 euros in personnel cost on average. It is noted that this is not a hard benefit, but the time used to track and trace infusion pumps (which is considered as a non-value-added time) is eliminated.

Finally, to improve infusion pump maintenance, the hospital needs to hire a part-time technical employee at a cost of 20,000 euros. However, these costs could be temporary, because the project leader showed the potential improvements in the throughput of the maintenance process (see De Koning et al., 2006 for an LSS project on maintenance in healthcare).

Control

In healthcare the most important Control phase deliverable is often the design of a dashboard that facilitates performance indicator monitoring and that serves management. In this case the project leader chooses to monitor the total number of registered pumps and pumps in use on a quarterly basis. The dashboard also includes the number of times maintenance was performed and average throughput time per maintenance.

The project leader documented the new working procedures and assigned new roles and responsibilities in the process, including the persons responsible for dashboard data collection. Further, an out-of-control action plan (OCAP) was defined that prescribes the action to undertake in case the infusion pump pool runs out of stock.

The project closure consisted of a discharge form that was signed by the champion and a controller.

CONCLUSION

Results-oriented approaches, such as LSS, have shown to result in improved quality and reduced costs on both the clinical and operational sides of healthcare. This approach to quality benefits the patients, the healthcare providers, and the bottom line.

This study provides an application of LSS to healthcare. Core principles of the LSS approach are a scientific approach to diagnosing problems, deliberate analysis, and obtaining effective solutions based on data. The principles are facilitated by tools and techniques and by the DMAIC roadmap.

The LSS approach was used in a project that focused on the reduction of operational costs of infusion pump use in a hospital. In this case study, quality improvement was measured in terms of number of pumps in use, number of pumps in storage, number of pumps lost, the throughput time of pump maintenance, and the number of times maintenance was performed per pump. The latter is particularly important with respect to patient safety. The project's investigation shows a potential reduction of 20% of the infusion pumps through standardization. Additional improvements will result in a track-and-trace scan system. The project clearly

shows that it is possible to reduce costs while increasing quality.

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