A reconsideration of Lean Six Sigma in healthcare after the COVID-19 crisis

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Abstract

Purpose – The purpose of this study is to reflect upon the ramifications of two decades of Lean Six Sigma implementations in Dutch healthcare institutions in the light of the current COVID-19 pandemic.

Design/methodology/approach – The authors provide an evaluation of the impact that Lean Six Sigma implementations have had on the ability of Dutch healthcare institutions to respond adequately to healthcare needs during the COVID-19 crisis.

Findings – Process improvement in healthcare has had a tendency to cut capacity and flexibility which are needed to deal with excessive demand shocks, such as during a pandemic. The main reason for this failure seems to be an overly strong focus on cost reduction instigated by Lean Six Sigma during stable times.

Research limitations/implications – Besides the research method being an inferential procedure, the research focuses on the Netherlands and so the generalizability might be limited. However, using Lean Six Sigma to improve healthcare processes has found broad acceptance, so the implications may well carry over to other countries.

Practical implications – The authors call for a more comprehensive approach of process improvement within healthcare that takes flexibility and buffering in anticipation of excess variability and disruption into greater account. Therefore, this study provides a new perspective on how and to which aim Lean Six Sigma should be applied in healthcare.

Originality/value – An assessment is given of the impact of Lean Six Sigma implementations on the ability to respond to the COVID-19 crisis. This is done by identifying the focus points of improvement projects and considering the impact on the resilience of healthcare operations.

Keywords Lean Six Sigma, Healthcare operations, Process improvement, Lean healthcare, COVID-19 pandemic, Supply chain dependency

Paper type Research paper

1. Introduction

The current global COVID-19 crisis as the result of the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was declared a pandemic by the World Health

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Organization on 11 March 2020 (WHO, 2020a). Its impact on healthcare has been dramatic and far-reaching in every country. It has resulted in many healthcare personnel, processes, facilities and external organizations subordinating themselves to treat COVID-19 patients. A beyond controllable influx of COVID-19 infections led to nationwide lockdowns and border closures (Anderson *et al.*, 2020) across the world.

A real-life example of the sudden consequences was experienced by one of the authors, when he went to a private clinic, specialized in the human musculoskeletal system, on 16 March 2020 for a total knee replacement. Within a day of his surgery he was released because the clinic had to be closed. Its ventilators and personal protective equipment were hastily transferred to surrounding hospitals for treating COVID-19 patients, and the clinic discontinued its operations for more than three months. Regular care was reduced substantially in The Netherlands because the number of patients with COVID-19 in the hospitals was extremely high. Not soon after, on 23 March 2020 the Dutch government invoked a lockdown as the numbers of hospitalizations continued to increase.

In this paper, we study the situation in The Netherlands during the COVID-19 crisis in light of the process improvement efforts that have taken place over the past decades. The crisis has been on-going for more than a year, and although vaccines have been introduced – The Netherlands is lagging behind in distributing these (Holligan, 2021) – The Netherlands is as of 23 March 2021 still subject to lockdown and curfew measures. For The Netherlands we find that Lean Six Sigma has never accounted for the case of such unlikely events as it is focused on improving day-to-day operations that are stable, aligning demand to capacity in an efficient manner. This has led to even further proneness to suffer the ramifications of the COVID-19 crisis.

The outline of the paper is as follows, first, we provide the research method followed. After which we discuss the process improvement efforts in Dutch hospitals. Then we characterize the focus point of these improvements and continue with an analysis of its impact on healthcare operations. We finalize with conclusions and recommendations for the application of Lean Six Sigma in healthcare.

2. Research method

The spread of COVID-19 and the surge of patients requiring hospitalization reveal shortcomings in today's healthcare systems and operations (Leite *et al.*, 2020). These systems have lacked the capacity to cope with the outbreak, for example, insufficient availability of ICU beds, ventilators and personal protective equipment (PPE). The degree and timeliness to which governments have resorted to forceful measures and the impact of COVID-19 on society in general have obviously been affected by the availability of costly buffer capacity in terms of beds, medical personnel and equipment, such as PPE and ventilators to treat severely-ill COVID-19 patients. Seen in this way the outbreak can serve as an opportunity for reflection on the process improvement efforts that have taken place over the past decades.

As a COVID-19 pandemic can be regarded as a single anomaly or case there is too limited a starting point to follow a deductive approach (theory testing), nor an inductive approach (theory generalization). Instead, we follow the method of abductive reasoning, which comes down to inference to the best explanation, introduced as a research method in Pierce (1934) and successfully applied to unravel the success of a Lean implementation in Shah *et al.* (2008). In this research method, the goal is to find the most plausible explanation from a set of observations using existing theory.

As Merton and Merton (1968) formulated the approach, it aims to obtain an explanatory conclusion after the fact, which in our case is the pandemic. Linking the ramifications of the

pandemic to the Lean Six Sigma efforts that have taken place we can infer on the role that Lean Six Sigma has played. Because of the authors' experience with the Dutch healthcare system and the availability of literature that has characterized the application of Lean Six Sigma in Dutch hospitals we have focused our study on The Netherlands.

3. Implementations of process improvement programmes in Dutch hospitals

We will describe how in The Netherlands an environment has been shaped for the emergence of process improvement in healthcare. Many hospitals in The Netherlands felt after the millennium a need to reduce costs and by implementing Lean Six Sigma hospitals tried to become more cost efficient. The Institute for Business and Industrial Statistics of the University of Amsterdam (IBIS UvA) has played a central role by implementing Lean Six Sigma in hospitals throughout The Netherlands. Their work has been documented in several academic works, which we use to shed light on the ability of Lean Six Sigma to achieve this goal.

3.1 Market liberalization instigating process improvement

Starting two decades ago, healthcare institutions in Western countries started riding the wave of market liberalization and engaged in professionalization of healthcare management. Already before 2000 there had been an increasing pressure put on reducing costs in healthcare. The Institute of Medicine (1999, 2001) published two reports demonstrating that healthcare requires a fundamental change. In general, healthcare processes were poorly designed and were characterized by unnecessary duplication of services as well as long waiting times and delays. As a result, healthcare costs exploded and did not satisfy patients' needs. Since 2000, much progress has been made with respect to improving quality and reducing waste (cf. Bisgaard, 2009).

Focusing on The Netherlands, Schut and Van de Ven (2005) report that even before 2000 pressure was put on reducing costs in healthcare and conclude that the goals were a mix of cost-containment policies and efforts to create more competition among healthcare providers. These efforts were market-oriented reforms preconditioned to establish a regulated competition in healthcare which allows equal access to healthcare, while keeping down costs.

The Netherlands is one of the countries which comes close to meeting all the necessary preconditions of a regulated competition as postulated by Van de Ven *et al.* (2013). These preconditions revolve around equality of risk selection, efficiency, safety and affordability of care. Given these long-term goals, reducing costs have been a prominent performance objective in healthcare operations over the past decades, which is also reported in Maarse *et al.* (2016). They criticized further that the overall impact of the reform on healthcare has been unclear and that it also has led to a power conflict between healthcare providers and insurers.

3.2 Improvement in healthcare: Lean Six Sigma

Continuous improvement programs, like Six Sigma and Lean, have been used in industry for many years. Six Sigma was started initially by Motorola in 1987 and was then popularized by General Electric from 1995 (Harry, 1997). It has a strong focus on reducing variation and enables production of high-quality outputs. Six Sigma offers a clear organizational structure with an approach based upon a scientific method of handling problems by executing five consecutive phases: Define, Measure, Analyze, Improve, and Control. This approach, shortened as DMAIC, is carried out by Black and Green Belts to obtain breakthrough improvements. Originating from automotive manufacturing (Ohno, 1988), the term Lean has

been introduced by Krafcik (1988) and further conceptualized in Womack *et al.* (1990). Lean comprises various methods and techniques many of which are centered around the elimination of waste to achieve synchronized processes. Buffers are commonly held by firms to ameliorate the effects of variability in operations (Shah and Ward, 2007). Some manifestations are excess inventory (e.g. supplies, equipment) or excess capacity (e.g. facility time, physician time). Around the turn of the millennium both methodologies started to be used in tandem being called Lean Six Sigma. Since then, it has been embraced by industry and services (George, 2003). Lean Six Sigma has also found broad adoption as a process improvement paradigm in healthcare (De Koning *et al.*, 2006; Langabeer *et al.*, 2009). The popularity of the combination in healthcare is rooted in how Lean offers many practical solutions to logistic problems, and combined with Six Sigma it also allows breakthrough improvements for quality problems.

IBIS UvA supports quality and efficiency improvement initiatives based on its expertise in the field of statistical methodology. IBIS UvA has over 25 years of experience with Lean Six Sigma and has supported Lean Six Sigma initiatives at many companies. The staff members of IBIS UvA have an extensive scientific education and combine their activities (teaching, research and consultancy) at the University of Amsterdam. Since 2001, some of the authors have also had extensive experience in healthcare, starting in the Red Cross Hospital in Beverwijk, The Netherlands. This is a general hospital with an ISO 9001-2000 quality management system. After the initial certification in 2000 the hospital was not satisfied with the existing quality improvement system. Therefore, they started looking for a more advanced quality improvement system that had proven results and was appropriate for a hospital organization. After studying Six Sigma the board decided to "take the risk" and to start, as the first hospital in The Netherlands, the implementation of Six Sigma. The full story has been described in the PhD thesis of Van den Heuvel (2007). In the beginning, the approach was based on Six Sigma, but from 2005 it became common to use Lean Six Sigma.

At least 35 hospitals, but also many other healthcare institutions in The Netherlands adopted the example of the Red Cross Hospital. Most of them followed the Lean Six Sigma approach that is described in De Mast *et al.* (2012): a well-defined organizational structure, a five-phase project management approach with an eight-step activity plan, a set of statistical and Lean tools and techniques and a philosophy which states that decisions are based on facts rather than on feelings and intuition. Usually, implementation begins with a one-day introduction course for the board and management team. Such an introductory course is often followed up by a training of a first group of Belts (i.e. the people who actually run the improvement projects). Projects mainly deal with improving imperfect processes and are only started if a certain amount of cost savings can be achieved. After positive evaluation of the initial results to the board and management teams, subsequent groups are trained. This approach is continued until the hospital has enough experience to continue with their own experts (the so-called Master Black Belts). In practice, this takes two to three years.

We have previously described our experiences in various Dutch hospitals; to mention a few: Van den Heuvel *et al.* (2005, 2006); De Koning *et al.* (2006), Does *et al.* (2010); and Niemeijer *et al.* (2012). We have also written a series of papers about case studies in healthcare. The most frequently cited being: Van den Heuvel *et al.* (2004), Bisgaard and Does (2009); Does *et al.* (2009); Niemeijer *et al.* (2010, 2013); VA Leeuwen and Does (2011); and De Mast *et al.* (2011).

A perfect illustration is provided by the experiences of the University Medical Center Groningen, the second largest hospital in The Netherlands. Lean Six Sigma was introduced in 2007 to create the financial potential to innovate. Niemeijer *et al.* (2012) describe how Lean

Six Sigma was introduced and how it developed in the following years. Until 2011 there had been 163 official projects in nearly all parts of the organization, with an emphasis on the primary process of patient treatment and care. The nursing efficiency and the length of stay of every nursing department have been analyzed. The Finance Department calculated that the financial benefits of all projects amounted to approximately €15m and budgeted for the following year the amount of €40m. In Section 4, we evaluate the type of projects executed and consider their focus.

4. Focus of Lean Six Sigma in healthcare

Since the reforms to create a competitive healthcare system, there has been an urge for hospitals to become more efficient and effective (cf. Schut and Van de Ven, 2005). The trend for improving efficiency has predominantly resulted in large-scale implementations of Lean Six Sigma in healthcare institutions. As Lean Six Sigma offers a paradigm in which these goals can be formulated as a project, we can investigate the type of projects that have taken place. These projects are subsequently linked to generic performance dimensions; see, for example, Ferdows and De Meyer (1990). Finally, other relevant features of improvement in healthcare are also summarized.

4.1 Type of projects

Indeed, focusing on the Lean Six Sigma projects that have taken place in healthcare these can be classified as one of the following generic project definitions which have been reported in the studies of Does *et al.* (2006) and Niemeijer *et al.* (2011), who performed a retrospective analysis on nearly 400 projects as follows (in brackets the percentages of projects adhering to such a project theme):

- reduce costs by improving productivity of personnel (24%);
- reduce costs by improving utilization of equipment/facilities (12%);
- reduce costs by improving purchasing processes (4%);
- reduce costs by reducing unnecessary use of resources (8%);
- reduce costs by reducing inventory (3%);
- improve safety by reducing complications and incidents (4%);
- increase revenue by improving registration (11%);
- increase revenue by increasing the number of admissions (15%); and
- increase revenue by increasing capacity (19%).

To validate their generic project definitions, Niemeijer *et al.* (2011) used this classification on more than 50 beginning projects, all of which fell into one of these categories. Considering these project titles only generic title 6: "Improve safety by reducing complications and incidents" does not have a clear business rationale, and by closer inspection 7: "Increase revenue by improving registration" is the result of reducing the number of mistakes in the registration process. All other project titles aim on either a better use of resources (1, 2, 3 and 4), better inventory management often by (5) or increasing capacity (8 and 9), which reduce costs or increase revenues.

4.2 Focus of the projects

In the cumulative capability "sand cone" model (Ferdows and De Meyer, 1990; Schroeder *et al.*, 2011), different performance dimensions are distinguished. The model illustrates that

business results follow an accumulation of performance dimensions, with quality performance as the foundation and cost efficiency as the accumulated performance. The model distinguishes five generic performance dimensions as follows (Slack *et al.*, 2016):

(1) *quality*: functionality, courtesy, customer needs, durability;
(2) *dependability, reliability and safety*: failures, mistakes, rework, punctuality;
(3) *speed*: throughput time, waiting time, time of service, admission times;
(4) *flexibility*: ability to adapt the process to changes in demand; and
(5) *cost efficiency*: efficient use of resources.

These five performance dimensions serve as a framework for further exploration of the nine generic project definitions in healthcare. One can characterize the generic projects by translating these to the five performance dimensions in operations management. In Lameijer *et al.* (2016), the nine generic project definitions in healthcare are classified according to the five performance indicators (Figure 1).

It turns out that the projects are mostly concerned with cost efficiency (generic categories 1 through 5). Generic projects 6 and 7 focus on dependability by reducing the number of mistakes and required reworking. For handling patients faster (e.g. reducing length of stay) or shortening processing times (e.g. scanning more patients) as in generic projects 8 and 9, the performance dimension of speed is the primary focus.

Of course a hospital cannot focus on all performance dimensions simultaneously and trade-offs must be made, although the capabilities continue to rely upon one another with no single capability taking precedence (Ferdows and De Meyer, 1990; Schroeder *et al.*, 2011), e.g. improving speed result in freed up capacity and more admissions, which in turn via higher utilizations can bring down the unit costs. Interestingly, improving the quality of care or flexibility has never been the key performance dimension of any Lean Six Sigma project referenced in the study by Lameijer *et al.* (2016) (Figure 1). However, a precondition of every project in healthcare has always been that quality of care cannot be infringed upon the Hippocratic oath: "First do no harm."

As reported by Schonberger (2018), when investigating a Lean implementation at The Minneapolis Heart Institute (Shah *et al.*, 2008), the following Lean tools were found to be beneficial to healthcare: quick setups, visual management, 5S, queue limitation (in terms of maximum inventories and patients in the operations), cross training of personnel (maintained by job rotation) and finally the choice of layout, which is either product-focused or customer-focused. These elements align well to achieve a quicker response, which simply translates to flexibility and speed. Schonberger (2018) also concludes that it is imperative to

#	Generic category of project definitions	Performance dimension and focus	
1	Reduce costs by improving productivity of personnel	Cost efficiency	Man-hours
2	Reduce costs by improving utilization of equipment / facilities	Cost efficiency	Man-hours/facilities
3	Reduce costs by improving purchasing processes	Cost efficiency	Man-hours/materials
4	Reduce costs by reducing unnecessary use of resources	Cost efficiency	Man-hours/facilities
5	Reduce costs by reducing inventory	Cost efficiency	Materials
6	Improve safety by reducing complications and incidents	Dependability	Failures/mistakes
7	Increase revenue by improving registration	Dependability	Mistakes/rework
8	Increase revenue by increasing the number of admissions	Speed	Throughput time/waiting
9	Increase revenue by increasing capacity	Speed	Processing time/waiting

Figure 1.
Generic Lean Six Sigma project definitions in healthcare

formulate a long-term healthcare strategy so as not to lose focus in the face of ever-changing regulations, legislations and pressure to reduce costs.

4.3 Environment for process improvement

As noted in a contemporary article (Schonberger, 2018) Lean in healthcare – and thus also Lean Six Sigma – requires a different treatment than traditionally in manufacturing. In manufacturing there is a great distance between production and the customer, whereas in healthcare this is not the case. A patient is the input, who is undergoing the process, and is directly the output and the customer. Processing can obviously not start before the arrival of a patient, which is contradictory to common practice in complex manufacturing systems wherein inventories can be used to ensure smooth and efficient production cycles. Owing to high visibility of healthcare processes, it is also desirable that long waiting lists should be avoided, keeping time to care low, as otherwise medical complications can arise.

Dutch hospitals are paid according to diagnosis-treatment combinations, which are pre-set reimbursement schemes for treatments and diagnoses. As reported in Maarse *et al.* (2016), there is a power struggle between health insurers and providers, and the competition is largely focused on cost and volumes (Krabbe-Alkemade *et al.*, 2017). For a hospital, current practice is that each calendar year, agreements are made with health insurers about production targets, commonly expressed through a maximum on the number of treatments to be billable. As the year passes by, there are three possible outcomes. Firstly, the hospital can experience a too low volume, through smaller influx of patients or decreased capacity at the hospital, causing revenue to be lower than expected and agreed. Secondly, the target is exactly met, which is financially the most preferable and beneficial outcome. Thirdly, demand and thus the number of treatments and diagnoses performed can surpass the pre-set target, which causes hospital costs to rise, but for the hospital it will remain unclear whether these extra expenses will be covered by the insurer.

This compensation system with predefined targets therefore exhibits a strong focus on meeting yearly objectives, causing many of the projects to share a short-time horizon. In fact, losing sight of this objective can result in a bankruptcy, which two cases in 2018 show: Medical Centre Slotervaart in Amsterdam and Medical Centre IJsselmeer in Lelystad (Van Manen *et al.*, 2020). With such a stringent focus and scope, longer-term issues spanning over a one-year time horizon fail to receive attention. This echoes the conclusions by Radnor *et al.* (2012), who found that projects are typically small scale and aimed at reaping local benefits and that healthcare is mainly driven by capacity targets.

5. Consequences of the Lean Six Sigma approach

After describing the characterization of the projects that have taken place in terms of performance dimensions, we describe the consequences thereof. Central is the fact that the focus on cost savings and the application of Lean Six Sigma as done in manufacturing have serious drawbacks if applied to healthcare. Furthermore, Lean Six Sigma can change underlying trade-offs, making continuity of healthcare more prone to catastrophic events, such as a pandemic, which is exacerbated by modern trends in supply chain management. We link these themes to various observations amid this crisis, for which we first proceed to give a general description.

5.1 Ramifications of COVID-19 in hospitals

Amid the ongoing COVID-19 crisis hospitals are taking center stages. From a hospitals' capacity managers viewpoint several key observations can be made during the outbreak. First of all in the early stage it became clear that the number of intensive care beds was too

low, see also Phua *et al.* (2020). These beds are critical to treat the severely ill COVID-19 patients as they are equipped with ventilators to provide the patients with sufficient oxygen to keep them alive. Therefore, many extra ventilators had to be found to expand capacity, see also Ranney *et al.* (2020). Internally this came at the direct cost of other hospital facilities, because the ventilators of the post-anesthesia care unit ward were taken, almost all elective surgeries were cancelled. Furthermore, there was also an external search for extra capacity as the anecdote in the introduction illustrates, which comes at the cost of closures of private clinics.

Much of the regular care offered by hospital was scaled down or halted owing to the lack of qualified medical personnel. Operating ventilators requires specific skills, to be acquired through education and training, which only a small group within the hospital has acquired. On top of that clinical COVID-19 patients need more care than other acute patients, causing bed-to-nurse ratios to halve. Scarcity of nurses led to decreased capacity for non-COVID-19 care. In the meantime, there was little work for other hospital staff, such as polyclinic employees or surgeons.

The availability of personal protective equipment (PPE) was at the time of the first wave limited. The supply that was available went to hospitals instead of to nursing homes which had to deal with the dire consequences, see also Abbasi (2020). One of the key reasons was the dependency on China for production of these materials and at that time global supply chains were disrupted (Ivanov, 2020). Even the World Health Organization released a statement on the rational use of PPE (WHO, 2020b). Soon a national consortium started to procure medical materials nation-wide.

Concerning medical drugs to treat COVID-19 patients, there were, among others, shortages of propofol, morphine, ketamine and remifentanil, leading to rationing, prioritization of patients and forced postponement of treatments, see also Ammar *et al.* (2021). Furthermore, national coordination was set up to exchange drugs between institutes to continue combatting the pandemic. COVID-19 also leads to shortages of other facilities, such as one-person isolation rooms. These rooms are especially useful for awaiting a test outcome for a suspected case of COVID-19. Such rooms are expensive but normally used in case of influenza or methicillin-resistant *Staphylococcus aureus* as these are highly contagious diseases or are resistant to commonly used antibiotics.

Because of the issues described above and the fact that urgent treatments, such as the treating of COVID-19 patients, could not go into backlog while the number of incoming patients continued to increase, countries proceeded with severe countermeasures such as lockdowns to lower the demand for healthcare to levels which the system can bear (Anderson *et al.*, 2020), i.e. flattening the curve. Primarily to make sure that the limited bed capacity and personnel were not completely overloaded by a peak of patients suffering from COVID-19. Undoubtedly, in line with Section 4.3, these restrictions also affect the financial status of the hospital; not meeting the targets set for regular care while having to accept unaccounted COVID-19 patients. Next, we substantiate several underlying tendencies and issues that have had an impact on the emergence of the situation in Dutch hospitals as described above.

5.2 Becoming lean

Considering the trend in the Dutch healthcare system the focus on efficiency and the use of Lean Six Sigma to achieve these goals has resulted in significant improvements. One of the most striking ones, also with respect to COVID-19, is the reduction in the number of beds, see Figure 2, which is based on the data provided by the European Commission database (Eurostat): https://ec.europa.eu/eurostat/. To put this into perspective some neighboring

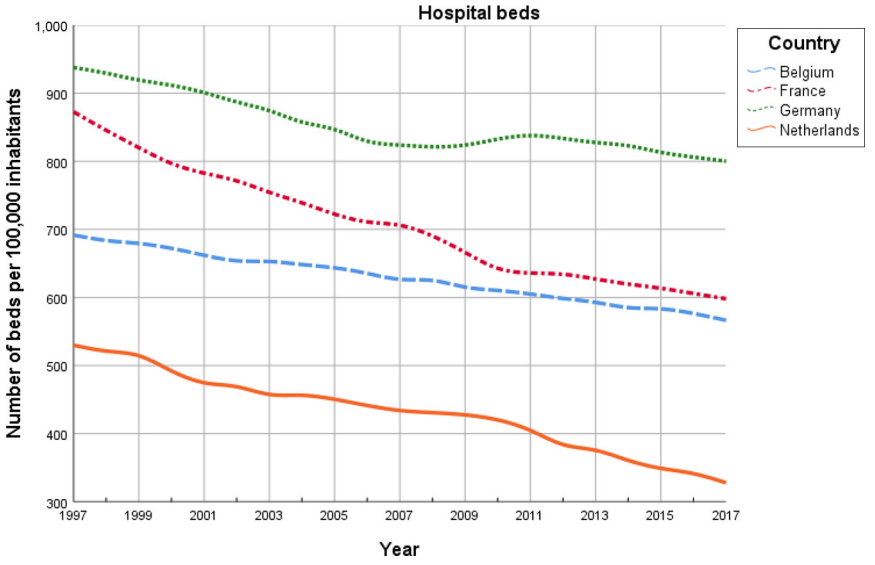

Figure 2.
Total number of beds corrected for size of population (per 100,000 inhabitants) for neighboring countries, as provided by Eurostat

countries are plotted as well. Germany has less market-oriented competition in healthcare and imposes certain governmental standards (Van de Ven *et al.*, 2013), for example, on the number of beds which are to be kept. During the recent COVID-19 pandemic, it was reported that Germany, free of charge, accepted Dutch patients who contracted the virus and required hospitalization, see also Holligan (2021).

Concerning optimality of capacity and resource allocation, Eroglu and Hofer (2011) conclude on a study of the performance of more than 50 large manufacturing companies in the USA that there is a point after which becoming leaner deteriorates performance, as to some degree inventory and slack is required to ensure smooth operations. By over time setting capacity much closer to average demand (i.e. reducing these buffers) healthcare operations become more prone to disruption as they will lose capability to accommodate for surges in the number of patients requiring hospitalization, such as during the current COVID-19 pandemic. A similar line of reasoning is likely to hold for other healthcare resources.

As a matter of fact, comparing the health expenditure as per cent of the gross domestic product we observe that the Dutch healthcare system is relatively cheaper to operate than that of Germany, as supported by Figure 3. In addition, examining this figure shows that there is no relation suggesting that rising health expenditure increases the availability of hospital beds. Even more relevant to the case of COVID-19 is of course ICU bed capacity, but these figures are not available in Eurostat's database. Fortunately, Rhodes *et al.* (2012) performed a comprehensive study on critical care bed capacity in Europe, which largely consist of ICU beds. Although the data might not reflect current practice we find The Netherlands belonging to a group of Western countries that have a relatively low capacity of ICU beds, 6.4 beds per 100,000 inhabitants, and that there are great differences between countries, for example, Germany (29.2 beds per 100,000) has almost seven times more ICU beds than Portugal (4.2); and our neighboring countries Belgium (15.9) and France (11.6). This supports the idea that finding an appropriate balance between healthcare resources is a non-trivial exercise, which will be the subject of Section 5.4.

Considering the application of Lean Six Sigma Radnor *et al.* (2012) found that projects in the public domain typically take place in a rather short-time span, see also Section 4.3 on the context of process improvement in Dutch hospitals. In such a time frame, a great focus lies on the application of tools to address localized issues. This execution lacks a general philosophy of continuous improvement and as the authors also concluded yields short-term, unsustainable, efficiency gains.

5.3 Increased uncertainty and variation

Although healthcare operations have become leaner, there are recent developments which require healthcare to be able to deal with more uncertainty and variation. Further globalization of supply chains creates a myriad of dependencies which leverage variation – meeting the criteria for a bullwhip effect – and at the same times exposes healthcare's inability to adequately deal with various issues raised by the pandemic.

Simultaneously to the implementation of Lean Six Sigma in healthcare scholars have emphasized the importance of supply chain management in healthcare services (Kumar *et al.*, 2008; Mustaffa and Potter, 2009), predominantly to overcome one of healthcare's major challenges: managing costs while meeting patient expectations. Healthcare services consist of extensive, complex buyer–supplier relations for, among others, medical consumables, laundry and cleaning, medical equipment, home care products, information systems, vehicle fleet management and general materials (Gattorna, 1998; De Vries *et al.*, 2011) and globalization does not ease the issue of complexity, e.g. pharmaceuticals, see Shah (2004) and PPE, see the recent article by Cohen and Van der Meulen Rodgers (2020). Healthcare must be efficient, and excessive supply chain dependency must be prevented to respond adequately in crisis situations, such as the current surge faced by hospitals (Bohmer *et al.*, 2020). Such large disruptions created by natural disasters or man-made events are often unaccounted for in supply chain optimization attempts (Govindan *et al.*, 2017).

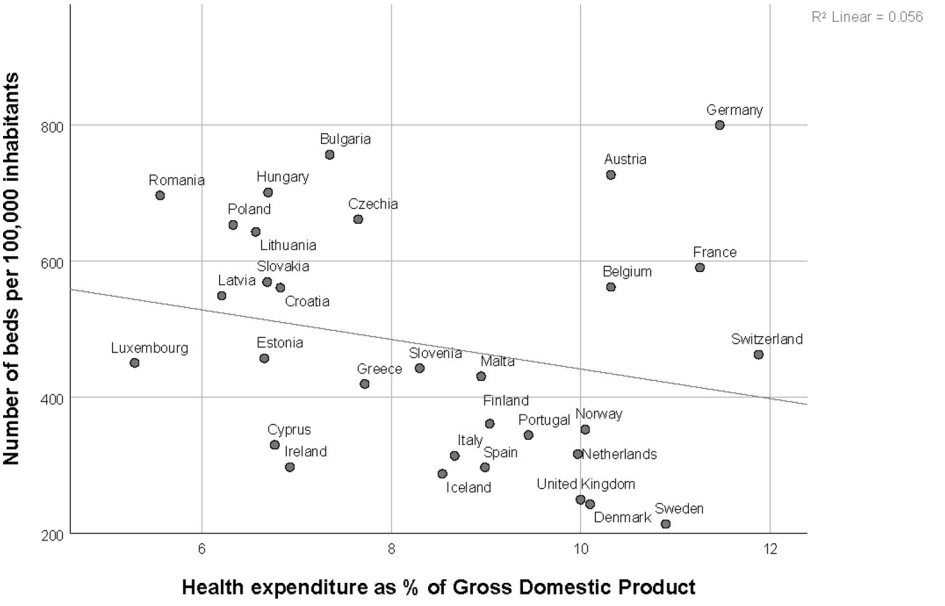

Figure 3.
Comparison of the numbers of beds per 100,000 inhabitants against the proportion of health expenditure as a percentage of gross domestic product for several EU member states. The line represents a linear regression analysis, which is insignificant (p-value > 20%)

A phenomenon which arises even in simple supply chains and is exacerbated in more complex systems is the so-called bullwhip effect (Forrester, 1961), which is also found in healthcare supply chains (Samuel *et al.*, 2010) and which can be described as an upswing in the mismatch between demand and capacity. For information on how this effect can be simulated and triggered via a simple supply chain experiment introduced by Forrester in 1958, we refer to Nienhaus *et al.* (2006). Concerning the bullwhip in practice, Lee *et al.* (1997) distinguish the following four major causes for the phenomenon to occur:

- demand forecast updating;
- order batching;
- price fluctuation; and
- rationing and shortage gaming.

In fact, some features of the COVID-19 pandemic can be identified which would contribute to such a bullwhip effect, see also Cohen and Van der Meulen Rodgers (2020) who identified various problems that triggered a large demand shock in PPE.

Firstly, corresponding to the first major cause, the virus itself sparked a sudden, unanticipated demand for trained personnel, ICU beds, ventilators and PPE. In addition, the incubation time, varying from 2 to 14 days (median 5.1 days) of the virus added even more uncertainty, as reported by Lauer *et al.* (2020) – thus figures shown today are the effect of measures and infections that occurred one or two weeks earlier – and factually during the first wave limited testing took place, see, for example, the Worldometer (2021) when comparing reported cases of the coronavirus versus COVID-19 related deaths for The Netherlands.

Secondly, as supply chains for physical resources, such as PPE, are global, they suffer from large lead times and therefore are ordered in batches, echoing the second cause. As already reported in Ivanov (2020), the forced closures and openings of facilities at different echelons in the supply chain would cause a ripple effect, which itself would further exacerbate the bullwhip effect. Thirdly, as the previous section has shown, healthcare operations have become much leaner; this rationing allows demand shocks to propagate up the supply chain. Furthermore, as there is global competition for limited resources there is a great incentive for shortage gaming (Cohen and Van der Meulen Rodgers, 2020). The bullwhip effect does not lead only to shortages in the short term but also can lead to undesirable surpluses after a while. As an example, currently in the second wave in The Netherlands test capacity far outstrips demand, and whereas there was initially a shortage of PPE and ventilators, hospitals' inventories are now stocked with surplus. For 2021, capacity managers report that hospital warehouses have increased their inventory levels by nearly four times compared to the start of the pandemic in 2020.

Besides stockable resources such as PPE and ventilators, medical personnel and beds are harder to scale up, although they are not the end of a global-oriented supply chain. They require either scarce space or a specialized education and training trajectory. In fact, all hospital personnel that had some acquittance with ICU care were asked for assistance, which in part shows flexibility in operations, which can be attributed to one of the robust principles of Lean, see also Section 5.2. However, aggravating effects also occur here: personnel has become exhausted, working long shifts, while facing extra sources of stress and anxiety resulting in poor mental health among workers (Mehta *et al.*, 2021), which potentially exercabate staff shortages in the face of future surges.

5.4 Shift in trade-offs

The previous sections have shown that there is a trend to make healthcare operations leaner, for example, by the use of Lean Six Sigma, while at the same time relying on more global supply chains. These trends reinforce one another, making healthcare operations more prone to disruption and thereby shifting an underlying trade-off. To understand this interrelation, we rely on a general framework to deal with process variability.

In a general sense, to deal with process variability and variation, Hopp and Spearman (2011) identify three generic directions, which build on top of each other:

(1) Variability should be reduced as much as possible.

(2) Operations can counteract variability by being more flexible to accommodate the encountered variability.

(3) The remaining variability will be absorbed in a balance between various buffers, typically excess inventory, unused resource capacity or waiting jobs.

In healthcare, as already mentioned, excess inventory, except for stockable resources, is rarely an option. In case of products, it is the trade-off between the cost of holding safety stock versus the out-of-stock probability, but for typical healthcare processes the trade-off encompasses capacity versus time to care, as expressed, for example, by the extent of the waiting list. The degree to which these buffers of capacity appear is often the result of an implicit (strategic) choice.

Interestingly, considering the aforementioned buffers, all of them are considered waste in the realm of Lean (Shah and Ward, 2007). Therefore, it is no wonder that the Lean Six Sigma projects studied have displayed a great focus on aligning capacity and inventories to predictable demand; reducing unnecessary buffers and making operations leaner. Furthermore, in this pursuit little focus has been put on developing flexibility to reduce the remaining variability to be dealt with. Furthermore, as discussed earlier, supply chains have become more complex, unknowingly leveraging the variability with which a hospital might be confronted.

According to the third level of the framework, the remaining buffers that a hospital keeps are the result of an implicit trade-off to deal with variability and uncertainty. This trade-off however has shifted at the expense of society as over the years both the buffers at hospitals have been reduced and variability has been leveraged. These developments have therefore worsened healthcare operations' ability to counteract the case of a serious disruption. So while attempts to eliminate "waste" sound attractive and work well in stable times, its changes to the underlying trade-offs go unnoticed.

6. Discussion, conclusions and recommendations

Clearly, the risk of a pandemic had not been figured into Lean Six Sigma projects which were focused primarily on improving stable day-to-day operations. Efforts which resulted in healthcare becoming more efficient could latently have changed the trade-off in which buffers, such as sufficient ICU beds, well-trained personnel and ventilators, are kept in case of immediate need. Furthermore, nowadays many healthcare products are produced abroad and find their way to The Netherlands via complex supply chains. Therefore, hospitals in The Netherlands face greater supply chain dependency which is possibly prone to unwanted effects that aggravate mismatches between demand and supply in case of large unpredictable events, as for example by a pandemic, which have severe and extensive consequences for hospitals and society in general.

In this study, by means of abductive reasoning, we lay groundwork for several directions for future research. As the research method leads to a conjecture, here about the role of Lean Six Sigma, that it worsened healthcare's ability to deal with a disruption, it remains open for further substantiation. We reached this conclusion by means of a consideration of the outbreak's manifestations in healthcare operations and subsequently linked these to operations management theory. This involved a retrospective analysis of Lean Six Sigma projects that took place prior to the event. There may of course also be other clarifications of the role that Lean Six Sigma has played in response to the pandemic, and this research provides a starting point for finding more evidence which can support our interpretations and resulting conclusions.

The focus of our study is on The Netherlands, although we believe that the conclusions extend to other Western countries, since many countries have adopted Lean Six Sigma to improve healthcare operations. Nevertheless, each country has its own healthcare system and the scope of Lean Six Sigma projects that have taken place can differ, therefore the generalizability of this research might be limited.

One might argue that a global pandemic can be regarded as an improbable event and that it therefore does not have to be accounted for. It was, however, likely to happen (Platto *et al.*, 2020), matching the definition of a "Black Swan" (Taleb, 2007). On top of that, COVID-19 will likely become endemic (Veldhoen and Simas, 2021), that means it will be a recurring disease just as influenza. This in itself will likely increase the variation in healthcare demand and the possibility of outbreaks, urging societies to rethink how to account for such events.

Some strategies for becoming less susceptible to supply chain disruption, for example, in the case of a pandemic, are by leveraging flexibility, increasing inventories as well as capacities and reconsidering the topology of the supply chain (Snyder *et al.*, 2016). In The Netherlands, the pandemic itself forced The Netherlands to put a provisional plan into place: buffers of medical drugs and PPE have been greatly extended, a nation-wide procurement and exchange plan has been set up. But to which extent such costly strategies should be kept or further developed is a question to be ultimately answered on a societal level.

The answer would affect the perception of how and to what extent Lean or Lean Six Sigma should be applied in future projects taking place in Dutch healthcare institutions: it should likely be with a broader focus on speed and flexibility increasing the resilience of the operations, instead of waste reduction driven by a pursuit for cost efficiency. Some lean tools that are promising for healthcare revolve around quick response: quick setups, visual management, 5S, queue limitation, cross training and redesign of processes to be customer or product-focused. This echoes the tenth lesson as formulated in Forman *et al.* (2020): "We need to test the responsiveness and resilience of health systems and make changes and improvements based on the results." Therefore, this evaluation calls for a more comprehensive approach of process improvement within healthcare.

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