Lean beyond waste

Roemeling, Oskar-Paul

CHAPTER 3

This chapter is currently under review at the *International Journal of Operations & Production Management* as: Roemeling, O.P., Land, M.J., & Ahaus, C.T.B. (2016). Does Lean cure variability in healthcare?

Does Lean cure variability in healthcare?

3.1 INTRODUCTION

Lean management has been successful in improving performance in production environments (Fullerton and Wempe, 2009). Later, Lean moved beyond production environments into services, including in health care. This interest is reflected in the growing number of studies focusing on Lean health care (e.g. Chiarini and Bracci, 2013; Papadopoulos, 2011; Papadopoulos, 2012; Poksinska, 2010; Poksinska *et al.*, 2013). Most of these healthcare-oriented studies report successful Lean outcomes (e.g. Breslin *et al.*, 2014; Chiodo *et al.*, 2012; Raab *et al.*, 2006; Yousri *et al.*, 2011). Hence, the adaptation of Lean ideas to healthcare environments seems promising. However, a review by DelliFraine *et al.* (2010) suggests that the evidence that Lean improves healthcare quality is weak. Furthermore, Waring and Bishop (2010) observe that clinicians worry about negative consequences for patients when contemplating changed practices based on Lean principles. In a literature review, Mazzocato *et al.* (2010, p. 376) noted that most of the studies "report narrower technical application with limited organizational reach" of Lean principles. Additionally, Curatolo *et al*. (2014) observed that a structured methodology is often absent, and this hinders study replication and validity. Radnor and Osborne (2013) comment that Lean implementation in the broader public service environment has generally been defective due to a focus on tools without an overarching logic. For both service as well as production environments, Hines et al. (2004) noted that the way Lean deals with demand variability has received particular criticism. Thus, whilst there are positive reports on the effects of Lean in health care, it seems questionable whether Lean is well understood and fully applied in healthcare environments.

In this research, we adopt Hopp and Spearman's (2004, p. 144) definition of Lean: "Production of goods or services is *Lean* if it is accomplished with minimal buffering costs". Reducing variability and buffers are key Lean elements (Hopp and Spearman, 2004; De Treville and Antonakis, 2006; Shah and Ward, 2007; Browning and Heath, 2009) and, in our study, we are especially interested in the roles of variability and buffers because interventions in these areas are expected to have a considerable impact. Hopp and Spearman (2004) and Hopp (2008) identified a transition from an initial focus on direct waste to a focus on variability and buffers at Toyota. Given these arguments, we expect organizations to focus increasingly on reducing variability and buffers as they mature in their Lean approach, although it is understandable why organizations would initially focus on direct waste. Whilst medical professionals are hampered by variability, they do not seem to be inclined to reduce it, even though Lean is an appropriate way towards variability reduction. Although healthcare-oriented literature (e.g. Graban, 2009; Snyder and McDermott, 2009) emphasizes flow, it tends to ignore the roles of buffers and variability. In a study on hospital quality improvement initiatives, almost 80% of cases reported a focus on flow, whilst only 6% explicitly used Lean (Cohen *et al.*, 2008). These are surprising findings since improving flow requires a reduction in variability (Schmenner and Swink, 1998) and reducing variability is an integral part of Lean. Studies by Jimmerson *et al.* (2005), Proudlove *et al.* (2008), and Mazzocato *et al.* (2010) indicate that, in health care, Lean is viewed as a continuous improvement approach with a focus on direct waste. It is unclear whether Lean improvement initiatives in practice seek to reduce buffers and variability.

In this longitudinal research, we study Lean interventions in a hospital recognized for its pioneering use of the Lean philosophy. By classifying Lean interventions made over a five-year period, we establish the changing focus and the development of Lean interventions over time. Then, through a field experiment, we investigate whether the focus of interventions can be encouraged to shift towards more mature Lean issues. The central research questions for this field research are therefore: (1) how should one qualify the focus of existing Lean interventions; (2) does this focus change, or mature, over time; and (3) does knowledge on buffers and variability influence the intervention focus? Our studied case relates to one of the first hospitals in the Netherlands to adopt Lean, one that is considered to be leading in its Lean approach. We further focus on a medical laboratory in this large teaching hospital. The laboratory has been adopting Lean principles for more than seven years and keeps meticulous records of its interventions.

3.2 THEORETICAL BACKGROUND

Samuel *et al.* (2015) note that a general Lean theory is still lacking. However, one can identify key Lean aspects in the literature. Reducing ‘unnecessary’ waste in order to increase the value or ‘value-added’ for customers is often considered central to Lean (Holden, 2011). However, many scholars, such as Hasle *et al*. (2012), argue that Lean is about more than direct or ‘obvious’ waste reduction, and that reducing buffers and variability, should be part of a Lean approach.

Direct waste refers to waste that is obviously present in the workplace and that can be linked to one of the seven waste types distinguished in Lean literature (e.g. O’Neill *et al*., 2011). Direct waste in general covers “operations that are not needed, excessive setup times, unreliable machines that can be made more reliable, rework that can be eliminated, etc.” (Hopp and Spearman, 2004, p. 145). Contrarily, waste can also result from a more complex causal chain, starting with some source of variability, which finally results in buffering by inventory, overcapacity, or customer waiting time. The original source of waste in terms of variability is less obvious as it is hidden by the buffer. As such an inventory can be direct waste, for example in case of overstocking, while it might also be the buffer that hides variability as a root cause. Thus, we posit that direct waste can be typified by the fact that its cause is not hidden by a buffer, a distinction with that resulting from variability (Hopp and Spearman, 2008). Reflecting on the perspectives of Hopp and Spearman (2004), De Treville and Antonakis (2006), Narasimhan et al. (2006), Shah and Ward (2007), Hopp and Spearman (2008), and Browning and Heath (2009), we can conclude that Lean encompasses the reduction of direct waste, variability, and buffers.

Even though variability is considered an aspect of Lean, it only receives limited attention in Lean-related studies. A Lean approach should include a focus on reducing the variability that is hidden behind buffers, and this is something that seems to have been lost in translating Lean from manufacturing to service environments. Since buffers are used to cope with variability, reducing buffers implies a need to reduce variability. In our study, especially the works of Hopp and Spearman (2004) and Schmenner and Swink (1998) provide a theoretical perspective against which we evaluate our findings. Hopp and Spearman stress the importance of buffer reduction in Lean, whilst the 'Theory of Swift and Even Flow' (Schmenner and Swink, 1998) underlines the disruptive effect of variability on a process.

We distinguish between two types of variability: artificial variability and natural variability (Litvak *et al.*, 2005). An example of natural variability in health care concerns the different reactions to treatment amongst patients. Artificial variability results for instance from batching activities, which has been observed in health care for many years (e.g. Berwick, 1996; Vissers *et al.,* 2001). Another type example of artificial variability relates to the daily ward rounds of physicians, which require multiple resources to be available at the same moment, while decisions during the round may cause peaks in requirements elsewhere in the hospital. Natural variability cannot, or to a limited extent, be influenced or controlled. Conversely, artificial variability is created by one's own actions, such as introducing rules and legislation. Artificial variability is thus controllable, and can potentially be reduced. Consequently, this is the type of variability one should focus on in Lean interventions.

In our research, we are especially interested in artificial variability. Reports on Lean research tend not to distinguish between natural and artificial variability. Although Joosten *et al.* (2009) make this distinction in their study on the application of Lean in health care, it is not a central theme. It is important to recognize that variability will always lower process performance (Hopp and Spearman, 2008), and so the ideal is to minimize artificial variability. Further, Lean interventions that focus on variability reduction can be expected to have a large impact on process flow (Fredendall *et al.*, 2009; Schmenner and Swink, 1998).

Based on the review by Mazzocatto *et al.* (2010) it appears as if variability is hardly addressed in Lean approaches in healthcare. In turn, studies in healthcare environments that do address variability (e.g. Allder *et al.*, 2010; Hosseini and Taaffe, 2015) tend to focus on natural variability. Yet, it is artificial variability that could actively be reduced. In a case study by McManus *et al.* (2003), we can observe the effects of artificial variability in an emergency care unit. The authors report that "scheduled patient flow, although theoretically controllable is, counterintuitively, more variable than the random demand of emergencies" (McManus *et al.* 2003, p. 1493). These types of artificial variability will result in either patients waiting for treatment or medical personnel waiting to provide treatment. In other words, in order to cope with variability in practice, organizations inevitably use buffers.

It is common to distinguish between three different types of buffers: time, inventory, and capacity (Hopp and Spearman, 2008; Thürer *et al.*, 2014). Whilst different types of buffers are witnessed in healthcare organizations, inventory buffers are not appropriate to the core healthcare process of providing patient care because it is the patients that are being transformed in the healthcare process. Clearly, it is not feasible to produce these 'products' (i.e. cured patients) in advance of demand. Based on the definitions of Hopp (2008), a queue of waiting patients should be seen as the use of a time buffer (buffering by customer waiting time), and not as an inventory buffer. This leaves healthcare organizations with two viable options to cope with variability: time buffers and capacity buffers.

Coping with variability through increasing capacity buffers is costly and unattractive from a financial perspective. Similarly, coping with variability through increasing time buffers is similarly unattractive as it results in longer patient waiting times. Whilst having a reduced set of buffer options might suggest an easier choice when it comes to choosing which buffer to apply, health care is faced with two unattractive options. This implies that both the patient's and the healthcare provider's interests need to be balanced in any situation where buffering is a necessity. While flexibility in the capacity buffers may help reduce the required size of buffers, ultimately, the only viable option to avoid the need for buffers is to reduce artificial variability.

One would expect the reduction of variability to receive attention in Lean practices in healthcare environments. However, there seems to be a strong focus on direct waste reduction in studies published on Lean in the healthcare sector (e.g. Dickson *et al.*, 2009; Jimmerson *et al.*, 2005). In a healthcare environment, unnecessary diagnostic procedures, medication errors, and expired supplies (Graban, 2009) are good examples of direct waste. The fact that direct waste is not hidden by buffers could explain why most organizations focus on waste – it is simply the most obvious thing to do.

Reducing direct waste, thereby obtaining quick wins, is often the first step when healthcare organizations start their Lean journey (Radnor *et al.*, 2012). We would then expect to see organizations moving through distinct phases: first focus on direct waste, then try to reduce buffers and variability – a transition that Hopp and Spearman (2004) identified at Toyota. This conceptual idea related to Lean maturity is largely ignored in the literature, and has so far only been identified in the Toyota production environment. It is unclear whether service providers, such as healthcare organizations, show the same kind of transition through these Lean phases.

The studies reporting on Lean in health care seem only interested in waste issues (Mazzocato *et al.*, 2010). An initial focus on direct waste is perfectly sensible: any improvement that avoids the needless occupation of capacity may help to avoid congestion and waiting times. However, opportunities to reduce direct waste will eventually become hard to find and, at that point, organizations should move towards addressing the hidden causes of performance inefficiencies. As time passes, and an organization becomes more mature and experienced in its Lean approach, and once quick wins through waste reduction are achieved, interventions should move on to target reductions in buffers and variability.

3.3 METHODOLOGY

Our study applied a field research approach that can be typified by the collection of qualitative and quantitative data from real-life settings (Edmondson and McManus, 2007). Field research allows one to "explore the implementation of managerial norms and solutions as well as the practical validity of theoretical models" (DeHoratius and Rabinovich, 2011, p. 372) and is thus an ideal approach for exploring and validating the focus of Lean interventions. Since we were interested in the development of Lean interventions over time, we required in-depth data over multiple years. Furthermore, we required numerous interventions because we wanted to establish the main focus of Lean interventions. In reality, there are few organizations that meet these criteria and, therefore, we studied a single case. This approach is generally seen as effective when the case is treated as unique, when the study is longitudinal, and when in-depth insights are required (Yin, 2009). We triangulated our study through the combination of different data sources as advised by scholars such as Voss *et al.* (2002) and Barratt *et al.* (2011).

The current research is typified by two parts. In the first part of our research, we investigated how Lean interventions can be qualified. We combined archival data with interview data in order to increase the reliability of our findings. In this part of our research, we started by classifying the Lean interventions identified to establish their focus. Subsequently, we conducted semi-structured interviews to investigate how Lean was interpreted in our case, and to what extent practitioners were knowledgeable about the roles of buffers and variability. In the second part of our study, we conducted an exploratory field-quasi-experiment (Pelham and Blanton, 2003; Franklin, 2005). Exploratory field experiments are useful to investigate new relationships and have been conducted by Hui *et al.* (2007) and by Shantz and Latham (2009) amongst others. The exploratory field-quasi-experiment was setup as a 'knowledge session', which allowed us to investigate whether it had been a lack of knowledge that was inhibiting broader interventions, or if we should seek out other factors that were limiting Lean in health care.

Case setting

Our research setting was a medical laboratory in a clinical teaching hospital in the Netherlands. The hospital, and particularly its laboratory, was among the first to adopt a Lean philosophy. The hospital is considered to be among the leading organizations in the Netherlands in terms of working with Lean, and is considered a national example of a successful Lean organization. New employees receive in-house Lean training and, at the time of our study, almost all laboratory employees had received such training. The laboratory started to introduce Lean principles in late 2007, and there have been hundreds of both large and small interventions over recent years. The laboratory has kept meticulous records of all its Lean interventions since 2009, providing us with a unique dataset. Additionally, we have been able to make a distinction between large-scale interventions (LSIs) and small-scale interventions (SSIs). The laboratory itself refers to LSIs as A3's, and to SSIs as Kaizens. Both have their own format (template) within the laboratory. The formats require the user to provide information on the problem at hand, including the current state, the required actions, and the expected results. LSIs are used for projects that span periods of several weeks or longer, and that require the input of multiple people, disciplines, or departments. Together, the LSIs and the SSIs form the foundation or the laboratory's approach to continuous improvement.

Part 1: Lean intervention qualification

During the first part of this research, the main objective was to establish insight into the current focus of Lean initiatives. We investigated how Lean interventions could be qualified. In our classification, we distinguished between four groups, namely interventions related: to direct waste, to buffers, to variability, and those not related to any of these aspects. The process to classify the interventions based on their content involved three steps. First, when classifying an intervention, we searched for explicit mentions of reductions in direct waste, buffers, or variability. Second, if none of these were obviously present, we studied interventions further to see if the steps taken could logically be expected to lead to reductions in direct waste, buffers, or variability. Third, if neither explicit information nor logic could distinguish a focus, the intervention was placed in the group of interventions apparently unrelated to Lean. For example, one of the 'Lean' interventions that we attempted to classify concerned whether a specific type of bacteria could test positive under certain conditions. Whilst this is relevant to the functioning of the laboratory, the question in itself does not represent a Lean intervention, and so we classified this specific question as unrelated to Lean. Further, within the direct waste group, we recognized the seven types of waste identified by Womack *et al.* (1990) and were able to show which types of waste were most often addressed.

The inputs for our classification were the Lean interventions undertaken in the laboratory during the period from 2009 through to 2013. As suggested by Miles and Huberman (1994), the interventions were put into tables to create case displays. In the classification process, we used a two-step approach with two independent investigators to strengthen the reliability of the study. In the first step, investigator *A* classified all the interventions, and investigator *B* classified a randomly selected sample of 10% of the interventions. Then, in step two, the results were compared to determine inter-assessor agreement. We measured the level of agreement using Cohen's Kappa (Cohen, 1960; Hsu and Field, 2003) and were aiming for at least a moderate agreement score (k > 0.40). Cohen's Kappa is a more robust measure than the percentage overlap because it accounts for the possibility of agreement occurring by chance. Similar two-step approaches have been used with success by Done *et al.* (2011) amongst others.

To investigate the current interpretation of Lean in the laboratory, and increase the reliability of the first part of this research, we conducted eight semi-structured interviews of thirty minutes each with two participants from each department, two of whom were female. The interviewees consisted of four chief analysts (department heads) and four analysts. They were selected because they had completed the most Lean interventions in the past five years. Before the start of the interviews, all interviewees signed an informed consent form. The interviewees were aged from 40 to 58, with a median of 48.5, and had been with the laboratory for between 17 and 30 years, with a median tenure of 26 years. All the interviewees had between 5 and 9 years of Lean experience, with a median of 6.5 years. Further, all the interviewees had been trained in the Lean philosophy, completing an in-house basic Lean training course plus various seminars and presentations.

The interviews allowed us to explore the current conceptual knowledge of Lean, and to determine whether a knowledge deficiency was the likely cause of any identified underrepresentation of Lean aspects during the classification. During the interviews, we explicitly avoided references to 'buffers' and 'variability' in our questions. Rather, we asked general questions regarding the participants' personal ideas on Lean. The rationale behind the questions was that this would allow the interviewees to provide us with their understanding of the Lean concept. The interview questions are included in the appendix and were not related to specific Lean interventions. Interviews were transcribed and the information put into tables, as advised by Miles and Huberman (1994).

If our classification process had shown that interventions focused only on direct waste reduction, we would then have expected professionals to only mention direct waste when asked about their ideas on Lean. However, if despite such a focus on waste in practice, the professionals did mention the roles of buffers and/or variability during the interviews, we would then need to investigate why these aspects were not being targeted in the current interventions.

Part 2: An exploratory field quasi-experiment

Through the use of an exploratory field-quasi-experiment, we tried to investigate if the scope of interventions was dependent on having knowledge related to managing variability and buffering. This allowed us to explore the possibility of the presence of a knowledge deficiency, a limited understanding of the Lean concept, within our studied case. Those eight employees in the case organization who had earlier participated in the interviews and had completed the most Lean interventions, were invited to a session to implement learning about variability and buffers in Lean, which was conceived as a concise three-hour class exercise. Thus, rather than a random sample of participants, we purposefully selected participants to increase the likelihood of obtaining meaningful data, i.e. linked to completed interventions. Participants in the three-hour session can be considered the treatment group. The control group is made up of all the employees that did not attend the three-hour session. The session took place on October 3rd 2014, and was facilitated by both investigators (*A and B*). It is important to note that this was not an attempt to change existing continuous improvement procedures.

The class consisted of a 30-minute introduction on the roles of variability and buffers in our daily lives, and specifically in health care, followed by a 150-minute game-playing exercise related to variability. The work of Hopp (2008) served as a starting point in explaining steps that can be identified as an organization's Lean approach matures. The game was then aimed at increasing the understanding of the practical effects of variability. The exercise was an adaptation of the dice game that has been successfully used by Goldratt and Cox (1984), Umble and Umble (2005), and Knight (2014). Instead of product flows in a factory, the focus was changed to patient flows in a hospital. For example, rather than thinking in terms of build-up of inventory, we focused on patient waiting times. The game showed that larger buffers, increased patient waiting times, could be used to cope with variability in patient arrivals. Further, participants experienced how low variability reduced patient waiting times without downsides. Each round of the game was followed by a plenary discussion to stress the meanings of buffers and variability identified during play. The session ended with a short recap of the 'lessons' of the day. Three days after the class, participants received an e-mail containing slides used during the session. Approximately two months after the class took place, participants received another e-mail as a reminder of the issues discussed.

To determine whether the exploratory field-quasi-experiment had changed the focus of interventions, we investigated all the interventions, by participants and non-participants, that were carried out in the period between October 3rd 2014 and January 13th 2015. In other words, we compared the results of our treatment group with the results from the non-treatment group. As the basis for this comparison, we again applied the classification process used in the first part of our research to determine the focus of these new interventions. We retained the basics of the two-step approach, but made some alterations to boost reliability. Given the smaller number of interventions, it was practical for both original investigators to classify all the interventions, rather than selecting a random subset for investigator *B*. Investigator *A* anonymized all the interventions before handing them over to investigator *B* such that they no longer contained any information on date, department, or owner/initiator. As such, there was nothing that Investigator *B* could use to distinguish between interventions performed by the treatment group and those by the non-treatment group. A benefit of this adaptation to our classification approach is that it controls for false positives. Consequently, one should expect investigator *B* to make the most objective judgements. If the two investigators did classify an intervention differently, investigator *B*'s decision was adopted.

3.4 ANALYSIS AND RESULTS

The raw data in the form of archival records amounted to 324 interventions. After data cleaning, 284 (88%) documents where seen fit for further analysis. The removed data consisted of documents that did not report on an intervention, were double entries, were undated, or were appendixes to other interventions.

Results of Part 1: Establishing the focus

Our classification started by comparing the determinations of investigator *A* with the randomly assigned subset classified by investigator *B*. Here, we achieved a moderate Cohen's Kappa (k= 0.531), and an agreement level of 88%, and, on this basis, concluded that the classification was successful. Of the thirty interventions assessed by both investigators, four interventions were classified differently. Three of these were considered to be related to direct waste by investigator *A*, while investigator *B* did not consider these interventions to be Lean-related. This was primarily due to the practical nature of some of the interventions, it can be difficult to determine whether solving practical issues should be categorized as direct waste reductions. The fourth disagreement was a more interesting case in that it was labelled as variability reduction by investigator *A*, but was seen as direct waste reduction by investigator *B*. The intervention concerned the absence of a standard procedure for petri-dishes that could not be fully processed during weekends, and had to be seen again during the following week. Investigator *A* felt that changing to a standard procedure implied a reduction in variability. However, investigator *B* did not believe the intervention would reduce variability in such a way that it could be expected to reduce the size of buffers. After discussing the matter extensively, and noting that the specific intervention did not explicitly mention either variability or buffer reduction, waste reduction seemed the more appropriate category. Table 3.1 provides an overview of the number of interventions related to the different categories, and covers the entire set of Lean interventions based on the classifications by investigator *A*.

Table 3.1. Classification of interventions by year.

Year	2009		2010		2011		2012		2013	Total	
Group	SSI	LSI	SSI	LSI	SSI	LSI	SSI	LSI	SSI	SSI	LSI
Direct	53	9	16	8	41	16	65	1	41	216	34
Waste											
Buffers		1	1	2	1					2	3
Variability	1		2							3	
Other	7	2	3	7	3	3	1			14	12
Total	73		39		64		67		41	284	

Table 3.1 shows that interventions relating to buffers and variability reduction were rare. During the period studied, we in fact only identified eight interventions in total falling into either of these categories (compared with 250 related to direct waste). In the later years of our review period, there were no interventions tackling either buffering or variability. These results are in direct contrast to the anticipated development in the intervention focus. Based on the theory on Lean maturity, we had expected an initial focus on waste and then an increasing focus on buffers and variability. Rather, even in our mature Lean situation, we observed a reversed pattern – with buffer and variability interventions only in the early days.

Since nearly all interventions related to direct waste, we investigated whether there was a focus on specific types of waste. Interventions were attributed to one, or more, of the seven types of direct waste as indicated in Table 3.2. If interventions appeared to be related to more than one type of direct waste then multiple categories were credited. The results show that the most common reason for an intervention was to reduce the number of defects, over 40% in our sample. However, most of the defect-related interventions did not report a specific hitch or malfunction that had actually occurred, rather these were preventive actions that related to the *possibility* of a fault that could be avoided if the intervention's suggestions were applied. Thus, apart from corrective improvements, the laboratory also has a focus on preventative actions.

Table 3.2. Intervention focus: waste types addressed.

Year	2009		2010		2011		2012		2013	Total
Group	SSI	LSI	SSI	LSI	SSI	LSI	SSI	LSI	SSI	
Waiting	3	2			3	1	12		18	39
Inventory	11	2	2	1	6	4	14		3	43
Defects	37	7	12	8	31	11	33	1	24	164
Over-processing	3			1	3	1	30		20	58
Transport				1			9		5	15
Movement	6		1		9	3	22		15	56
Overproduction	2	1					4		4	11

Next, we investigated how Lean was perceived by the experienced practitioners and whether they were knowledgeable on the roles of buffering and variability. Professionals tended to refer to personal aspects, such as more enjoyable work, when they thought of Lean rather than patient value. Further, when talking about Lean, they generally refer to direct waste reduction and continuous process improvements. Only one of the interviewees mentioned reducing time to result (throughput time) as an objective of Lean, but even this interviewee did not think in terms of buffering or variability to obtain this objective: rather, the removal of direct waste was supposed to reduce throughput times. During the interviews, it became apparent that our healthcare professionals did not share a definition of Lean as reflected in the following quotes:

"To me, Lean stands for studying your processes, and removing the parts of your job that are undesirable. Thus, you remove waste from your processes and, as a result, the job becomes easier, better, and more enjoyable."

"For me personally, it especially means improving the process and removing all types of waste."

"Lean is, if I am allowed to use catchwords: process improvement, time-to-result reduction, increasing efficiency, and problem-solving skills. To me personally, Lean is fun, and Lean is the reduction of waste in your processes."

Given that reduced buffers or variability are widely seen as outcomes of Lean interventions, we were interested in the ideas of this group of professionals concerning Lean intervention success. If process performance was one of the main criteria, it would be logical to have interventions related to reducing buffers or variability. However, the healthcare professionals struggled to provide concise success criteria. They might provide practical examples from successful interventions, or they might consider an intervention successful if it resulted in positive sentiments in the people involved. In general, they were unable to give clear criteria used to determine intervention success.

"Eventually the result of the change you make is to have everyone working in accordance with your idea."

"It is of major importance that the improvement is accepted by those people it affects. They should feel good about it. They should feel that the process was actually improved, and they should profit from it. Not in financial terms, but profit in terms of the process."

"I consider every Lean intervention we have performed to be successful. Even though sometimes this is only as a learning experience, for I personally consider learning a goal of Lean."

The professionals thought about human aspects when asked for success criteria - the acceptance of the suggested improvements by peers seemed of major importance. It appeared that neither buffers nor variability were part of the Lean mindset. This would seem to support the reliability of our earlier classification, and it reinforced our belief that there could be a knowledge deficiency concerning the roles of buffers and variability.

Results of Part 2: Exploratory field-quasi-experiment

The inputs for assessing the effect of the exploratory field-quasi-experiment were all the interventions initiated by the participants in the period October 2014 – January 2015. We collected data on 35 interventions from this period. After data cleaning, 33 (94%) of the 35 interventions remained for the post-experiment assessment. We again applied our classification and compared the findings of investigator *A* with the findings of investigator *B*. We obtained a good Cohen's Kappa (k =0.704), and an agreement level of 81%. The overall results of the classification have been added in Table 3.3.

Table 3.3. Classification of interventions after the knowledge session

Group	Initiator did not attend session	Initiator attended session	Total
Waste	15	6	21
Variability & Buffers		3	3
Other	6	3	9
Total	21	12	33

Of the 33 interventions, 12 were undertaken by people who had attended the session. Of the 21 interventions initiated by non-participants, 15 related to direct waste, the remaining 6 were not related to Lean aspects. Further, we found no interventions related to buffers or variability. Of the 12 interventions undertaken by participants of the session, 6 related to direct waste, 3 were not related to Lean, and 3 were related to either buffers or variability. The 'new' buffer and variability-oriented interventions explicitly mentioned time reduction as an important outcome goal. We will now further describe each of the three buffer and variability related interventions.

In one of the new interventions, the incubation process of microorganisms (i.e. growing bacteria) in patients' urine samples was being considered. During this process, laboratory equipment is used to take photographs of petri-dishes that contain urine samples. These pictures are assessed by a laboratory analyst to determine the presence of microorganisms. Photographs were taken of several dishes at the same time – that is, they assembled batches of samples before starting the photographic step. However, this was considered as less than ideal because some microorganisms grow rapidly. Given this relatively rapid growth, the testing process of these samples could potentially be completed sooner. The proposed intervention suggested an additional assessment step, and this was expected to significantly reduce throughput times. In this intervention, the laboratory would reduce an artificial variability in the form of batching, and this reduction in variability should result in a smaller time buffer, leading to a reduction in patient waiting time.

The second of the three interventions related to variability or buffering aimed to reduce the number of incubation methods used. In a way, this intervention has features in common with the first of the new interventions discussed. The various incubation methods have their own protocols to be followed by the laboratory practitioners. The number of different incubation methods, and their corresponding protocols, makes it difficult for practitioners to remain up-to-date on all procedures. The intervention stated that practitioners have to spend considerable time reading, and re-

reading, protocols. The intervention aimed to reduce the number of methodologies and protocols in use, easing the burden on practitioners and reducing the variety in applied incubation methods. In essence, the current structure was putting a strain on the available capacity, and we should expect this to have increased patient waiting time. The steps in the intervention should reduce this strain, which should allow for shorter throughput times.

In the last of the three buffer or variability interventions, the focus was again on reducing throughput times. In the laboratory, various techniques help identify the type of microorganism present in patient samples. These techniques differ in the time they take to produce a conclusive result. Having such a large number of different techniques was identified as disruptive, and the suggestion was to adopt a standard technique. It was suggested that this new standard would reduce throughput times and costs, and result in higher quality. In considering this intervention, the number of different techniques was seen as hindering the flow of patient samples.

Table 3.4 summarizes the content of the three variability and buffer related interventions. All three interventions focus on the reduction of throughput times, which translates into reduction of time buffers.

Table 3.4. Summary of the variability and buffer focused interventions.

Intervention	Focus	Variability*	Actions	Results**
1	Incubation process of microorganisms.	Artificial variability caused by batching.	Add an additional assessment step that eliminates waiting for complete batches.	Reduced throughput times.
2	Set of incubation methods.	Artificial variability caused by differences in methodologies.	Avoid needless methods and protocols.	Reduced variety.
3	Techniques used to identify microorganisms.	Artificial variability in terms of identification techniques.	Avoid needless techniques.	Reduced throughput times.

**Identified by researchers, **Identified by initiators intervention*

Two of these three interventions had reduced throughput times as an explicit goal, while one intervention explicitly referred to variety. In addition, we should expect all of these interventions to eventually impact patient waiting times. Since this was to be achieved without adding capacity, the interventions needed to reduce variability. We observe that in the first intervention the laboratory decided to stop its batching activities in order to reduce artificial variability, and in the latter two interventions the laboratory aims to reduce the number of applied methods and techniques. Whilst these interventions are related to variability and buffering aspects, we have to remain cautious in our appraisal of these interventions and the effect of our knowledge-raising exercise. Most notably, the word ‘buffer’ was never used, even though the interventions did indicate that time reduction was important. Nevertheless, findings from the experiment did provide evidence that a knowledge deficiency could be a cause of the singular focus on direct waste we observed in the earlier Lean interventions.

3.5 DISCUSSION

In this research, the main questions were how the focus of existing Lean interventions should be qualified, how this focus developed or matured over time, and whether knowledge on buffers and variability influenced the focus of interventions. In terms of our first research question, the findings show that Lean interventions tend to be strongly focused on simple practical improvements that reduce waste. This is in line with the suggestions of many authors that identify waste as the first step in a Lean transition (e.g. Hopp and Spearman, 2004; Shah and Ward, 2007). Further, the tradition in health care of improving quality and safety (Stelfox *et al.*, 2006; Weiner *et al.*, 2006) is reflected in the focus of the Lean interventions. Most of the interventions in the medical laboratory focused on reducing direct waste, with half linked to eradicating defects or boosting quality.

The fact that the focus of the interventions hardly changed over time answers our second research question: we could not identify changes in focus over time, nor do our results show a move towards a more mature Lean approach. The continuing focus on direct waste reflected a lack of attention on reducing buffers and variability. In other words, we saw a narrow perspective of Lean, despite the length of its experience with Lean at our case site. Radnor *et al.* (2012) identify two reasons why a narrow view of Lean persists in health care. Firstly, they saw it as difficult to influence or control services beyond the individual organization because of structures related to funding of services and the regulation of services through government targets. Secondly, the authors argued that Lean is mainly seen as a managerial tool for waste reduction. Our findings strongly support this latter view – that Lean is especially seen as a means to reduce waste. However, we did not find evidence for the former issue regarding a lack of control beyond the specific organization related to funding or service regulation. Radnor and Osborne (2013) argued that public services have over-focused on the technical tools of Lean without understanding the underlying principles. However, in our study, we did not come across an overuse of tools, although we did encounter a lack of knowledge on underlying principles regarding variability and buffers.

In responding to our third research question, we can conclude that knowledge on variability and buffers does seems to influence the focus of Lean interventions. Having only a limited knowledge on the roles of variability and buffers in Lean hinders healthcare professionals in targeting these aspects. The quasi-experiment showed that a small investment in knowledge had clear impacts in terms of the interventions. The healthcare professionals we interviewed mainly thought of Lean as an approach for continuous improvement. Radnor and Osborne (2013) argued that service organizations need to establish a logic suited to the service domain, rather than adopt one based on production environments. This could especially be relevant where buffers are concerned. The absence of inventory buffers in service environments has the consequence that variability can only be buffered by additional capacity or by increasing patient waiting times. In other words, it creates an additional burden on capacity and patients, and puts more emphasis on reducing variability in Lean service organizations.

It is important to question the implementation of Lean at the specific investigation site. Are the findings simply the result of a weak application of Lean principles? Considering the basis for selecting the case organization, this seems highly unlikely. The specific site is generally seen as an exemplary applier of Lean ideas. The hospital has its own in-house Lean training scheme that is mandatory for new personnel. In addition, employees – including physicians – travel the globe to share their Lean views and study Lean in other healthcare providers. The site has a well-structured continuous improvement system with daily Kaizen meetings that have resulted in hundreds of interventions. More recently, the laboratory has adopted visualization tools to continuously monitor performance. There is no denying that the site has been successful in terms of reducing waste, and its application of Lean appears to result in a smoothly running organization. However, the lack of variability- and buffer-related knowledge provides an opportunity for further high-impact improvements.

Based on the phases identified at Toyota (Hopp and Spearman, 2004; Hopp, 2008), we would have expected to find interventions related to direct waste in the early phases of Lean adoption, and interventions related to buffers and variability as an organization matures in its Lean approach. However, our findings did not identify such a pattern. Interventions related to buffers and variability seemed to occur somewhat randomly, and the few interventions that did relate to buffers or variability had occurred quite early during the laboratory's Lean journey. We suspect that these early variability- and buffer-focused interventions had more to do with chance – due to the sheer number of interventions – then with a deliberate attempt to reduce variability and buffers. One could perhaps argue that, despite over seven years of Lean experience, the organization has still to reach the mature stage. Whilst there is no established period for reaching maturity, we would have expected any shift of focus to be apparent within this period. An alternative explanation for the limited attention to buffers and variability could be related to the specific environment. Health care lacks an equivalent of inventory buffers. In production environments, inventory buffers can 'hide' variability but, in health care, there is no natural form of equivalent buffer. This could make coping with variability more complex as it leads to a direct trade-off between patient waiting times and excess capacity.

It seems probable that the limited focus in the Lean interventions, and the lack of attention towards buffers and variability, is a manifestation of a lack of knowledge. By conducting an exploratory field-quasi-experiment we investigated the possible role of a knowledge deficiency while limiting the involvement of the researchers. Our findings show that, following the experiment, buffer and variability related interventions were generated. We saw that explicit attention was given to variability-related issues in the later interventions, and that this was linked to initiator's expectations related to throughput performance. Following the experiment, we were able to identify three interventions related to buffers and variability within a period of three months, compared to just eight over the previous five years. The specific interventions aimed at reducing artificial variability in terms of batching, incubation methodologies and identification techniques. We would expect these interventions to eventually result in reduced time buffers.

It seems that a lack of variability-related knowledge could explain the initially identified bias in focus on direct waste issues. The three variability related interventions could be seen as examples of interventions that require additional investigation and understanding. In turn, this could explain why the literature has struggled to demonstrate conclusive results on the effects of Lean in service industries. Our findings in the healthcare sector strengthen the suggestion by Radnor and Osborne (2013) that, in public services, there is a limited understanding of Lean's underlying principles. The empirical findings lead us to the following proposition, for which this current study has provided some initial evidence:

"Healthcare industries may suffer from a deficiency of knowledge related to buffers and variability that hinders organizations to reach Lean maturity".

In addition to our theoretical contributions, our study has implications for practice. The classification adopted shows a dominant focus on waste issues in this healthcare organization. However, our experiment indicates that this focus can be shifted towards variability-related issues if managers and organizational leaders invest in Lean knowledge that emphasizes the roles of variability and buffering. We were able to attain results through the application of a small-scale experiment, which shows that minimal investments could have a large impact.

3.6 CONCLUSIONS

In this research, we executed an in-depth case study including an exploratory field-quasi- experiment to determine how the focus of Lean interventions could be qualified, how this focus changed over time as Lean experience grew, and how knowledge on buffers and variability played a role in the intervention focus. Our research has made the following contributions:

- It offers support for the common view that there is a tendency to focus on waste issues in Lean healthcare;
- It shows that time (our case study took place in the Dutch hospital with the longest experience of embedding Lean) does not guarantee interventions that go beyond obvious waste reduction. This contrasts with the literature assuming that the switch to buffer and variability reduction in later stages to be the key to success at Toyota;

- It underlines the view that neither variability nor buffers appear to be a conscious part of the Lean mindset in the service sector;
- It suggests that providing knowledge on the role of variability does facilitate initiatives to start variability-related Lean interventions, and that only a small investment is required to instill this knowledge (a single three-hour session sufficed in our study).

This research is a step towards a better understanding of Lean interventions in practice, and their limited impact on buffer reduction. The use of real-life data covering a large number of interventions is a unique feature of our research. Whilst our study does provide new insights, it naturally has some limitations. By selecting an organization that can be seen as an excellent example of Lean in health care, we tried to mitigate the limitations concerning generalizability normally associated with case studies. Additionally, whilst our experiment was aimed at knowledge transfer, we have not focused on the sustainability of the provided knowledge and restricted ourselves to the question as to whether knowledge (or lack of) could be a factor. Clearly, it was impossible to conduct a controlled experiment in our case setting, and this hinders the ability to make statements concerning causal relationships. Nevertheless, our experiment does show the importance of buffer and variability related knowledge when formulating Lean interventions.

Future research could benefit from our approach to classification. It would be especially interesting to investigate the sustainability of Lean interventions and to observe differences between cases. A basic question still unanswered is whether buffers and variability reduction have a role in day-to-day improvement activities in other healthcare environments? Additionally, we would suggest future studies to consider the understanding of the roles that variability plays in health care. If, as our single case suggests, reducing direct waste is the main driver of Lean in health care, then there is work to do for both business and healthcare scholars to educate practice on additional Lean aspects that could prove beneficial.