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SUSTAINABLE LEAN IN SMEs: A QUANTITATIVE ANALYSIS INTO IMPROVEMENT ACTIONS

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Abstract
Lean has established itself as the primordial approach to obtain operational excellence. Its simple and intuitive techniques focus on reducing lead time through continuous improvement, involving all levels of employees in the organization. However, the rate of successful implementations has remained low. This paper contributes to the understanding of continuous improvement in a Lean context, by analyzing a database of almost 10.000 improvement actions, from 85 companies, covering the time frame 2010–2018. It discusses categories of actions, their impact and cost, as well as key characteristics of the companies. It proposes an objective criterion to identify "success" and "failure" in Lean implementation and tries to link these to operational results. It is probably the first time an analysis of this magnitude on the subject has been performed.

Keywords
lean manufacturing, efficiency enhancement, productivity, continuous improvement.

Introduction

Lean has without any doubt become the leading method to pursue operational excellence in Western companies. The "Factory of the Future" document [1] from the European Commission states literally: "*In the present scenario of global market competition, the R&D challenges to achieve a higher competitiveness of the manufacturing systems should be considered in terms of general evolution drivers, such as:*

a) cost efficiency, with extensive adoption of standards in production machinery, equipment and controls and massive use of the Lean approach".

This popularity has led to a wealth of useful information about Lean implementation methods and success stories on publicly available sources. At the same time, almost every Western country has one or more agencies devoted to supporting companies in their quest towards Lean Knowledge and adoption. Finally, uncountable numbers of commercial advisors and consultants, both in large corporations themselves or as self-employed persons, offer their knowledge and expertise to companies that start on the Lean Journey. As a result, the Body of Knowledge on Lean is well published and available, and critical success factors (CSFs) are established.

It then remains almost a mystery why so few companies succeed, with published success rates ranging from a merely 2% [2] to 24% [3] and 30% [4]. A 2016 study of 85 companies involved in Lean for at least 8 years [5] reports that only 12% obtained complete success, and overall the level reached was 1.3 on a scale from 0 to 3.

This paper wants to contribute to understanding the causes for this low success rate, by analyzing the improvement behavior on the Gemba. In true Lean spirit, objective data has been gathered to allow for an unbiased look. From the analysis a first attempt

is made at suggesting causes of success and failure, as well as at proposing elements of the management system that more effectively will support true continuous improvement.

Lean Implementation in literature

While the volume of publications devoted to Lean is growing at a rapid pace, the segment devoted to CSFs for implementing Lean remains only a small part of it [6].

Most of those publications confirm the limited success rate of Lean in companies, especially in SMEs [7, 8]. Hu et al. [8] even conclude that "*On balance, the disadvantages appear to outweigh the advantages for SMEs ... when implementing Lean*". This confirms the validity of focusing on SMEs in this study.

In [9] a list of Lean practices and Barriers to success for SMEs was presented, culled from 26 leading publications. We will use this list as reference in this paper (see Table 1). We also refer to [10] where 19 CSFs were proposed, but based on a limited set of 4 case studies from large companies. We will try to verify which propositions are supported by our study (see Tables 2 and 3). Other studies contributed to the tally of Lean techniques used, such as [11].

Most CSF studies use a questionnaire approach, with answers restricted to a 5-point Likert scale [7, 12–15]. While this approach occasionally generates useful insights, it mostly yields middle of the road answers in the 2-4 range and little detail. It moreover remains unclear who in the organization fills out the questionnaires, but supposedly management is involved. We know from own experience that in many companies, management have coarse (and distorted) views of the Gemba, the workplace where waste and problems reside. And how much of the self-reporting is biased and polished? [5] states that in a study of 85 production companies average implementation level was self-reported as 1.64 (on a scale of 0 to 3), while research revealed a more moderate level of 1.3, and that 34% of them had not introduced any Lean tools (while only 8% had self-reported this).

As stated in [7], in most studies the sample size is limited from a few to a dozen or so companies [10, 14, 16, 17], a noted exception being [18]. So, one can understand why conclusive evidence regarding CSFs for Lean has remained elusive to date.

As Liker stated in [3], the key to obtaining sustainability in Lean is to allow improvement actions to permeate the daily work in an almost routine manner. This behavior is not well measured through periodic questionnaires, interviews or even site visits, which are the main research methods in literature [8, 10, 16, 17, 27]. Yet almost no studies register in detail what companies are doing in their Lean implementation, as opposed to what they tell they are doing. Day to day registration of actions was reported as a key success factor in [19–20] and [21], confirming our approach in this study.

The current paper reports on a study that set out to do just that: observe and register – daily and in detail – what improvement actions companies are taking, over a suitable long time horizon, and then try to learn from this why they are successful or not. A first version of this study, on a more limited data set covering 2009–2011, and reported in [22], showed the validity of this approach. It confirmed the low success rate among SMEs for one thing. It also proposed an Improvement Management system to improve sustainability of Lean (an effective measure proposed by [19]).

Registering daily improvement actions

Data registration

The aim was to gather detailed data regarding improvement actions on the Gemba, over a suitable long period in each company, from an as large as possible group of companies that up to that moment had not engaged in Lean. To organize this massive data collection effort, a tool was built (www.pdca.be) in the cloud, to support companies in registering and tracking problems and their solution. This was inspired by [21], where a formal recording method was found key to employee buy-in as well as attain sustainability of the improvement process. The Plan-Do-Check-Act method is a basic Lean technique to guide people in structurally solving problems [23].

The target group were SMEs from Flanders, Belgium, as the tool was in Dutch. This was a prerequisite to allow direct participation of the operators and supervisors on the shop floor. There were two mechanisms by which companies were recruited to participate in the study:

a) companies that engaged the support from Veltion, a consulting spin-off from Ghent University, to coach them towards Lean (74% of the sample).
b) companies that unsolicitedly chose to use the PDCA.be tool to support their Lean endeavor.

Companies could enlist throughout the complete reference period. Registration started in 2010, and data up to medio 2018 was gathered. In that time span 143 companies registered at least one activity record. In total 10.337 activities were recorded. Almost all companies had less than 400 employees, so they can be considered Small to Medium Enterprises (SME) according to EU classification rules.

A record was created for each problem that was registered. This record was then expanded with the solution (if any), and metadata, such as effort for solving, impact, as well as circumstantial information such as time stamps, category of the problem... Registration was mainly through a web interface. However, some companies also used smartphones and tablets as capturing devices, and a suitable upload app was developed to load registrations in the PDCA database. Once created, a problem/solution record was tracked throughout its PDCA phases, with timestamps for each transition. Calendar functions to remind supervisors through email were added, and also management reports showing progress and statistics. These functions improved the usability and therefore reduced instances of incomplete or inaccurate registration.

Data cleaning

Following activity data records were removed from the database:

- all records from bogus companies, identified by odd names or random letter combinations,
- records that served as test activities to explore the PDCA tool without any trace of real improvement intent.

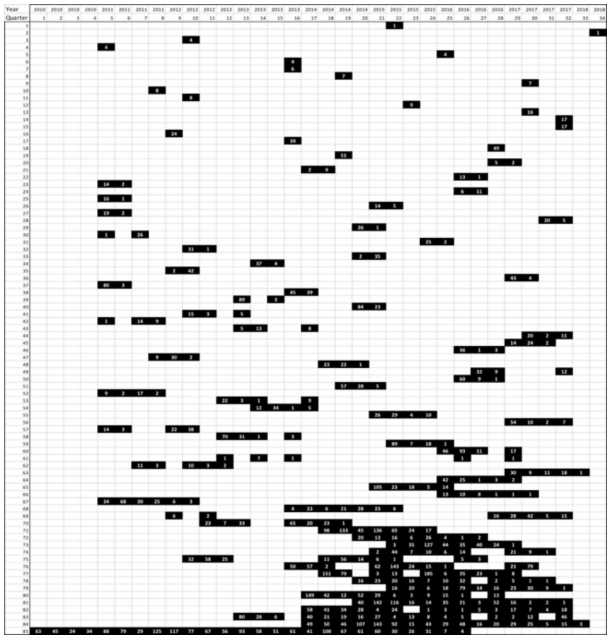

Fig. 1. Active quarters (2010–2018) by company.

This led to a data set deemed valid for analysis with the following characteristics (see also appendix):

- # companies: 85
- Average/median employee count: 153 / 60
- Avg/median sales revenue (mm€): 29,8/19,2
- Time span: 34 quarters (2010–2018)
- # activity records: 9356
- # activities "rejected" by company: 441 (5%)
- # completed activities: 5919 (63%)
- First activity start 1/01/10
- Last activity start 6/04/18
- First activity end 3/01/11
- Last activity end 25/04/18

The companies from the dataset counted between 10 and 300 employees, with a yearly revenue between 4 and 180 million euros.

Figure 1 shows the active quarters of each company, i.e. in which at least one action was started, ranked according to increasing number of active quarters. The patterns are contiguous, suggesting a true effort to engage in Lean (as opposed to merely testing the tool).

The nature of improvement actions

Action categories

The categories, indicating the theme or topic the action was addressing, were self-reported by the companies. We then homogenized the list (Table 1) Fig. 2 shows the number of actions per category, as well as the % completed (i.e. # completed / # started).

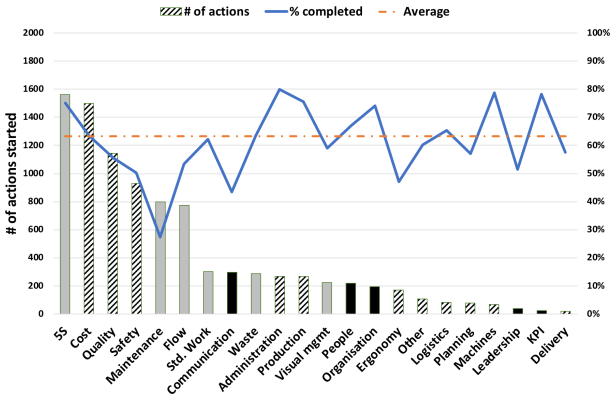

Fig. 2. # actions and completion rate per category (solid grey = Practices, solid black = Barriers, acc. [23]).

5S is clearly the most popular category (20%), since it is the one, most companies start with. That Cost is the second largest one (14%) may seem peculiar, since in itself cost reduction is not a primary goal of Lean. It indicates that the pressure for cost-down remains prevalent in SMEs, in line with [24]. Safety, Quality and Maintenance seem logical, as problems in those areas interfere with stable operations. Stable operations are a prerequisite for success in Lean according to the Toyota House of Lean [23]. Most

categories have a completion rate of 50 to 80%, with a notable dip for Maintenance (28%), Communication (42%) and Ergonomy (48%).

It is worrying to note the low share of actions which address **Barriers** to success (as defined by [9] and listed in Table 1). **Practices** to support Lean from the same reference are better represented, with Visual Management and Waste as exceptions. For definitions of the Lean tools mentioned we refer to [23] and [25].

Figure 3 shows the final status of all actions according to the PDCA model. The final solution rate of 63% is another indication of the backlog problem. We also remark that "Check" is an underused status, often skipped by the problem – solving teams. This phenomenon illustrates a certain lack of understanding about PDCA as problem – solving method (confirming [11]), and its Check phase as a key step to insure the solutions are effective, and therefore sustainable.

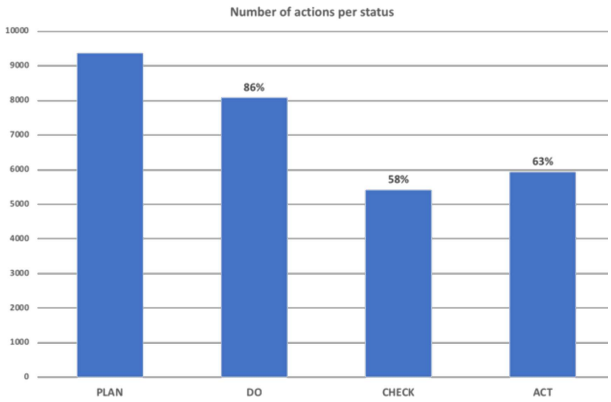

Fig. 3. Final status of all actions.

In [6] we proposed an implementation plan for SMEs, derived from a European research project, that starts from 3 phases that interlock:

- Phase 1: PDCA, in which employees are trained in problem solving and engage in continuous improvement. This starts the cultural switch.
- Phase 2: FLOW/PULL, that pursues lead time reduction by introducing Flow and afterwards Pull.
- Phase 3: MANAGEMENT System, to be introduced alongside phase 1 and 2, that visualizes the achieved improvement rate, and progress in lead time reduction. This Lean Management System (LEMAS) [6] should involve management early on in the Lean implementation process.

We indicate the phase of each category in Table 1.

We finally mapped the action categories unto the 4 elements of the Toyota Production System (also called the Toyota House [23]), as shown in Table 1, leading to Fig. 4.

Table 1

Action categories versus Toyota House.

	Practice / Barrier acc. to [9]	Phase acc. To [6]	HOUSE of TOYOTA			
			Operational stability	Jidoka	Culture	Just in Time
5S	P	1	X			
Administration		1	X			
Communication	B	3			X	
Cost		1	X			
Environment		1		X		
Ergonomy		1			X	
Flow	P	2				X
KPI	B	2		X		
Leadership	B	3			X	
Logistics		2				X
Machines		1	X			
Maintenance	P	1	X			
Organisation	B	3			X	
People	B	1			X	
Planning		2				X
Production		1	X			
Quality		1		X		
Safety		1		X		
Std. Work	P	1	X			
Visual mgmt	P	1	X			
Waste	P	1	X			

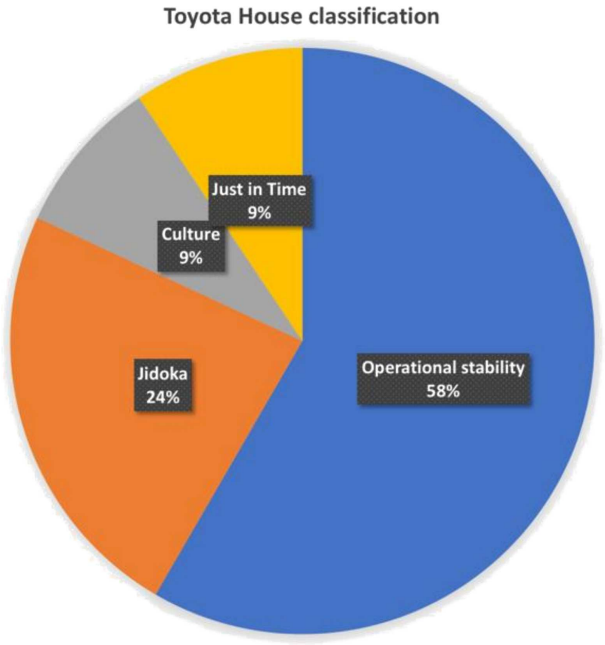

Fig. 4. Toyota House classification.

We see in Fig. 4 that Operational Stability represents the majority of improvement actions. Among the three pillars, Jidoka confirms the importance of quality (24%), while People and JIT remain limited to 9%. This suggests that the companies may fail to make the transition to these more complex challenges. Especially the People pillar is a CSF for sustainability in Lean implementation, while JIT has the largest impact on lead time and productivity.

Action lead time

The timestamps in each record allow us to investigate the time between first registration and final disposition of the problem/action record, which we denote the (solution) **lead time** of the action.

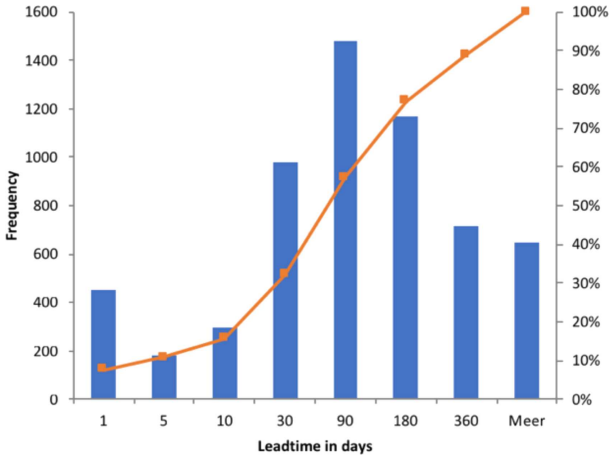

Fig. 5. Cumulative lead time of actions.

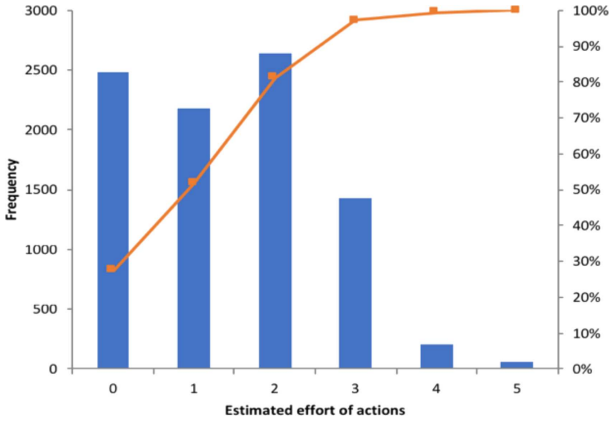

Fig. 6. Distribution of estimated effort to solve.

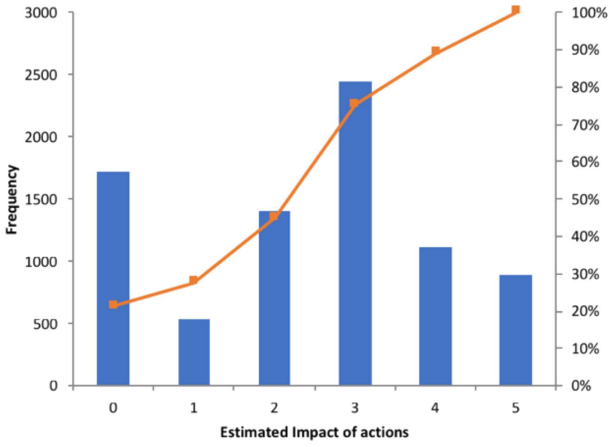

Fig. 7. Distribution of estimated impact of solutions.

We noted that a large part of the registrations followed calendar time buckets (week, end of month, end of year). However, given the large number of registrations we feel this bias does not invalidate the conclusions.

The first thing one notes from Fig. 5 is that lead times are relatively large. Only 20% of the problems is solved within 10 days and 40% takes more than 6 months. This is in stark contrast with the observation that up to 50% of the actions were deemed to require limited effort to solve, and that 50% were seen to have a moderate to large impact (Figs. 6 and 7).

The duration of the problem-solving cycle is a key performance indicator for Lean implementation. Simple problems should be solved fast (i.e. within one day to one week), while more complex ones within 3 months. When lead times are (too) long, there is a high probability that newly registered actions overwhelm the workforce, which degrades motivation. At the same time, management will see the growing backlog and could then decide the implementation approach is not working, leading to premature ending of the Lean implementation [24]. Further analysis showed no significant differences in lead time distribution between the categories, with the exception of 5S (25% of the actions solved in less than 10 days).

Sustainable continuous improvement

We then turned our attention to the 85 companies. We decided to develop an objective measure to identify success and failure with regard of sustainable continuous improvement. From literature and own observations, we propose to include the following conditions:

1. ActPer8: **Active Period at least 8 consecutive quarters.** Several publications suggest that this is required to obtain the needed culture shift towards "improving the job is part of the job" [12].
2. ActPer3: **At least 3 consecutive quarters**.
3. %Done: **Completion rate of at least 40%**. This measures whether the company continues to work on solving problems. The cutoff rate is chosen judiciously.
4. Avg/Qrt: **At least 5 completions on average per active quarter**, **provided the company has at least 3 or more active quarters**. This criterion was constrained to exclude short bursts of a large amount of registrations (i.e. to distinguish a short term KAIZEN action from sustained CI).

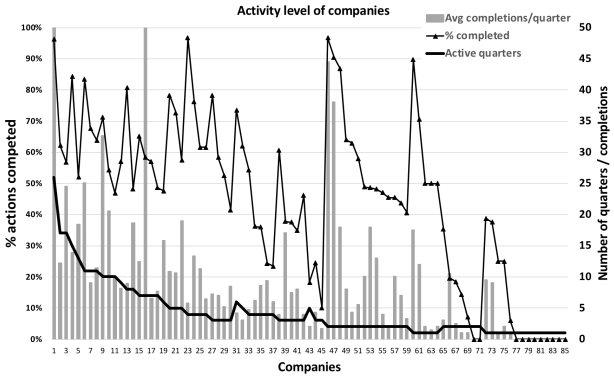

Fig. 8. Criteria for success for each company.

We then define the **success level** as the number of conditions that were met. This results in the following overall success rate in Fig. 9, with details reported in Table 2.

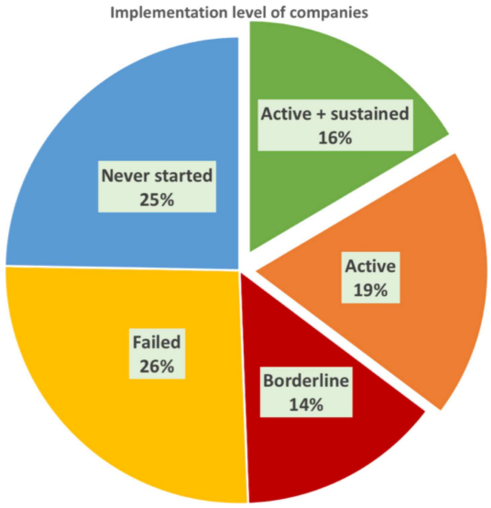

Fig. 9. Success rate of sustainable Lean implementation.

Table 2
Completion rates and lead times per success level.

Success level		# cies	Avg. completion rate	Lead Time (days)		Ext. Support
				Average	Median	
4	Active + sustained	14	66%	142	139	93%
3	Active	16	63%	99	96	63%
2	Borderline	12	44%	78	76	75%
1	Failed	22	54%	78	24	59%
0	Never started	21	11%	42	23	76%
Overall		**85**	**63%**	**90**	**76**	**74%**

We see that 35% of the companies can be considered successful, which is in line with literature. It is clear that only 14 companies (16%) have shown resilience beyond 2 years, which suggests that the required culture shift has occurred and that sustainability is achieved. The authors had access to each of these companies, allowing us to state here that they did have Lean installed as part of their management culture.

Unfortunately, we see also another statistic confirmed: 51% of the companies remained at level 0 or 1, indicating a failure to get Lean started or a quick abandonment (despite sometimes high completion rates). We refer to Fig. 1 for the detailed timings of active quarters.

From this we conclude that the Success Level metric as defined seems valid. We then tried to identify any significant differences in Lean practices between successful companies (level 4 or 3) and unsuccessful ones (levels 0, 1, 2).

The action completion rate has a clear correlation with the success level (Fig. 10). Success companies (levels 3 & 4) have a significant higher completion rate than the lower levels ($p < 0.05$), as determined by the Mann-Whitney U-test. Moreover, successful companies have a significant higher completion rate of High Impact actions (Mann-Whitney U, $p < 0.02$) (Fig. 11).

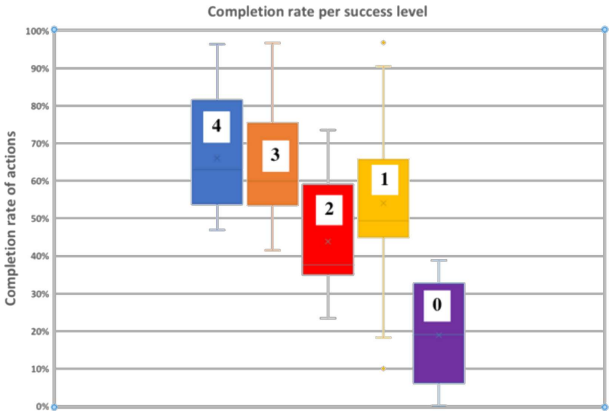

Fig. 10. Completion rate for each success level.

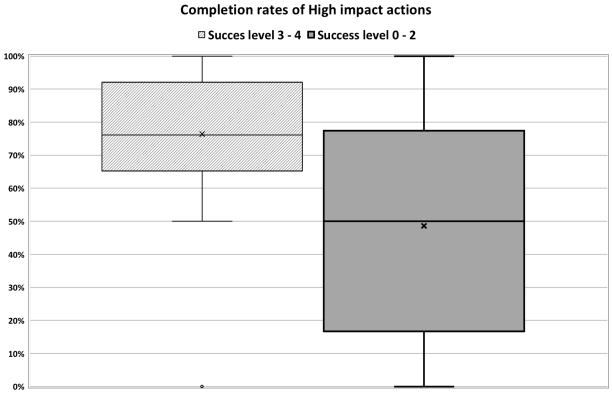

Fig. 11. Completion rate of High Impact actions.

Lead times however show a different pattern (Table 2): higher success levels have a higher average

lead time, as well as median. This can be explained partly by the fact that they tackle also the more difficult problems, and possibly also by the higher number of problems to deal with.

We also looked at the adoption rate (% companies using a given category) of key success factors, as reported by [10]. We found positive evidence on 6 of 19 propositions linking a high(er) adoption rate to successful companies (level 4), as compared to levels 1 to 3 (Table 3).

Table 3
Role of key success factors according to [10].

Proposition from [10]	% of companies using	
Successful companies use...	% Level 4	% Levels 1-3
Utilize consultants	93%	70%
Both mfg and non-mfg	29%	20%
Regular communications	71%	28%
Use standard work	57%	30%
Use visual mgmt and KPIs	50%	28%
Invest in leadership devt.	50%	20%

Longitudinal analysis

Next we show the timing of action starts for all companies, relatively from the kickoff quarter. If we focus on successful companies only (Level = 4 – Fig. 12) and mediocre ones (Level = 2 – Fig. 13) we see a marked difference. After a roaring start, successful companies have either sustained action starts in consecutive quarters, or they exhibit regular restarts after short periods of inactivity. Of course, the backlog of problems will keep the overall improvement effort going.

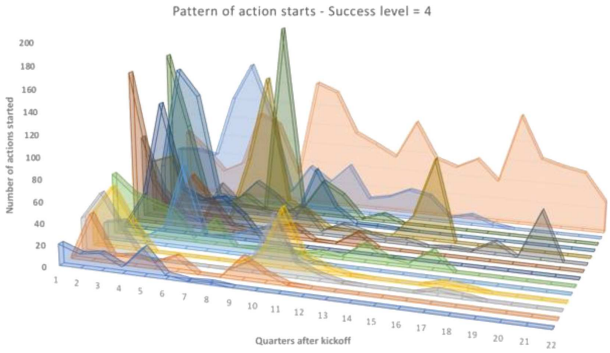

Fig. 12. Timeline of action starts for Level 4 companies.

For less successful companies, the pattern looks totally different. The start is equally promising (albeit with less activities than level 4), but then the implementation peters out after about 5 quarters, in most cases despite some indications of restarts. This confirms what was found earlier in [22] and [26] that two years are needed to achieve sustainability.

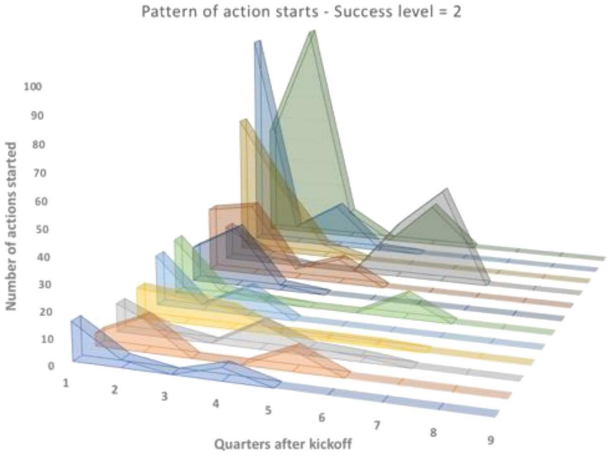

Fig. 13. Timeline of actions starts for Level 2 companies.

Best in Class Company

We deemed it useful to finalize this company review by focusing on the one company that was truly outstanding among all 85 companies. It was active during 26 consecutive quarters (7.5 years), totaling 1507 actions. Its accomplishments are impressive:

- completion rate: 96% (highest of them all),
- average actions/quarter: 58,
- lead time: average = 177 days, median=79 days.

This qualifies the company as Best in Class within this sample. If we compare the share of categories that BIC employs with the share all other companies (BIC excluded), we see some marked differences (Fig. 14). BIC identified 14% more actions in the 5S category, and 12% more in the People category. Visual Management was also more important, while Cost and Communications were less. This pattern was not really different when we compared BIC with its fellow Level 4 companies (success). This suggests the BIC does break away from the pack in some of the key categories from [9] (see Table 1).

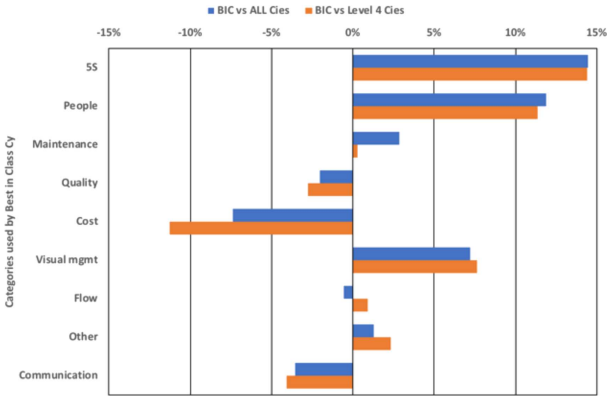

Fig. 14. Best in Class categories versus rest of sample.

Key Lessons Learned

In this final section we try to formulate some key Lessons Learned about reasons of success or failure of Lean implementation in SMEs, based on the findings of previous sections.

1. To ascertain success in implementing Lean a company needs to remain **active** in continuous improvement **for at least 8 consecutive quarters** (2 years). This rule of thumb [26] follows from the time needed to establish a change in corporate culture towards Lean. When we used this criterion to identify successful companies, we arrived at meaningful differences.
2. Most companies seem to **take too much time to solve problems** and implement the related corrective action (only 30% within 30 days and 40% 6+ months). A short problem-solving cycle is crucial to maintain motivation among employees, as well as to avoid being overwhelmed by the backlog of open actions. Fig. 15 clearly shows this backlog of open actions accruing for Level 4 companies. This backlog can give the wrong signal to employees that Lean is an uphill battle, and to management that Lean is not for their company. Causes can be insufficient resources devoted to continuous improvement, or defining too large problems that cannot be solved by one team or without considerable investment or outside support.
3. Many companies seem to remain **stuck in phase 1 topics** [6], which reduce waste, but mostly have little effect on the bottom line. Phase 2 actions towards Flow/Pull are key to achieving shorter production and delivery lead times, and hence to increasing productivity and customer satisfaction. It could be that SMEs lack knowledge to tackle the more complex Phase 2 problems. Also there seems a clear **lack in management involvement** (Phase 3).
4. On top of that, Level 4 companies seem to be able to **solve a larger share of problems**, including the high impact types.
5. Companies do **not use the PDCA method as it is intended.** The Check/Act steps are often skipped or signed off as a routine matter. This reduces the completion rate of actions, because solutions tend to be ineffective, and problems resurface, adding to the backlog.
6. Six propositions, put forward in [10], seem to be confirmed by this study. We cite:
   Successful companies ...
   1. *utilize consultants ... as sensei to guide their initial learning and Lean improvement*
   2. *implement Lean in both manufacturing and non-manufacturing areas*
   3. *provide regular communications on Lean throughout the organization*
   4. *see value in developing internal leaders*
   5. *utilize standard work as the basis for continuous improvement*
   6. *utilize appropriate metrics and visual management to drive Lean improvements*

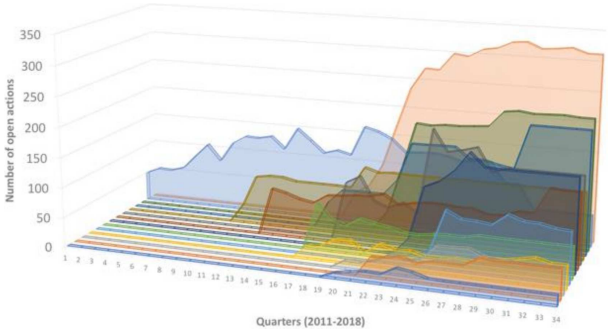

Fig. 15. Evolution of backlog of open actions (Level 4).

Conclusions

This study is presumably the first in its kind when one considers the unique combination of length of the reference period (2011–2018), large size of the company sample ($N = 85$), and the detail and size ($n = 9356$) of measurements, performed directly on the Gemba (work-floor). The size compensates for the fact that all registrations are self-reported, and that some time stamps are wrong because of lack of timely registrations, or input errors. However, the key findings on an aggregate level are well in line with previous published research. Given that the latter has been performed differently (interviews and case studies), this provides a kind of triangulation that, in our view, validates the dataset and the approach in this paper.

Future research will focus on the content of the actions and will try to quantify the impact of continuous improvement on operational excellence and finance. However, the key findings should already prove useful for SMEs wanting to either embark on a Lean journey, or to improve their rate of improvement.

The authors thank the company Veltion for making available the data repository of their PDCA tool.

Appendix: Key characteristics of the 85 companies in the sample

Company	# of employees	Yearly sales (million €)	Start year	End year	# actions started	# actions finished	Average lead time to solve	Success level	Average over all actions: Impact (0-5)	Average over all actions: Effort to solve (0-5)	# categories
1	55	26,42	2010	2017	1499	1446	178	4	1,1	1,0	10
2	178	34,9	2014	2018	730	417	195	4	2,6	1,1	8
3	61	181	2014	2016	504	359	168	4	3,8	2,3	12
4	25	12	2014	2018	458	239	128	4	2,9	1,7	9
5	43	5,6	2013	2017	453	247	188	4	1,9	1,5	9
6	93	26,65	2013	2018	332	207	179	4	3,3	1,7	13
7	26	22,02	2014	2017	329	276	74	4	2,6	1,7	7
8	324	102,4	2015	2017	305	149	55	4	2,8	1,2	9
9	28	8,13	2014	2018	248	209	94	4	2,8	1,6	8
10	85	52,3	2015	2018	232	148	149	4	2,3	1,5	10
11	165	62,8	2012	2016	211	99	315	4	2,5	1,1	10
12	40	7,94	2014	2017	133	90	118	4	2,3	1,5	9
13	218	54,3	2015	2017	114	65	70	4	2,1	1,3	8
14	36	7,47	2014	2016	88	71	71	4	3,2	1,4	9
15	n.a.	n.a.	2014	2015	516	302	88	3	2,5	1,7	11
16	93	33	2012	2014	172	112	73	3	2,3	1,3	12
17	n.a.	n.a.	2015	2016	165	95	105	3	2,2	1,3	12
18	42	7,39	2011	2012	165	79	74	3	3,0	2,1	9
19	109	5	2012	2018	114	65	125	3	2,8	2,0	8
20	58	8,8	2013	2015	110	54	121	3	2,4	1,4	4
21	153	25,3	2012	2014	105	80	95	3	3,2	1,5	7
22	17	n.a.	2016	2017	73	53	143	3	1,9	1,9	5
23	37	22,24	2017	2017	73	45	92	3	4,1	2,6	6
24	22	7,2	2017	2018	69	54	95	3	3,3	1,8	7
25	94	41,61	2013	2014	52	32	100	3	2,7	1,8	4
26	88	23,7	2014	2015	46	36	97	3	2,3	1,4	7
27	n.a.	n.a.	2011	2012	41	17	41	3	3,5	1,4	7
28	138	66,67	2016	2017	40	21	69	3	2,1	2,0	3
29	n.a.	n.a.	2011	2012	29	29	116	3	3,4	1,7	7
30	n.a.	n.a.	2011	2012	24	14	152	3	3,1	0,9	6
31	94	41,61	2016	2017	166	60	55	2	2,2	1,8	7
32	87	12,4	2015	2015	115	28	66	2	1,5	0,7	8
33	45	6	2014	2014	90	34	24	2	2,8	1,0	9
34	310	23,12	2011	2012	77	18	29	2	2,9	1,1	8
35	17	n.a.	2015	2015	69	25	77	2	1,3	0,9	6
36	37	7,27	2017	2017	40	15	92	2	2,5	1,9	8
37	9	n.a.	2012	2014	35	19	148	2	4,1	1,8	7
38	n.a.	n.a.	2016	2017	33	25	74	2	2,4	2,1	4
39	204	99,95	2017	2018	33	20	80	2	2,4	1,6	6
40	n.a.	n.a.	2011	2013	29	18	128	2	2,8	1,3	4
41	57	6	2013	2014	26	12	158	2	3,3	1,3	4
42	1654	65,2	2012	2012	23	8	11	2	2,3	0,6	6
43	14	4	2013	2013	92	89	133	1	2,9	2,4	6
44	103	20,34	2013	2014	84	76	56	1	3,3	1,9	6
45	n.a.	n.a.	2011	2012	83	72	501	1	3,5	1,7	5
46	780	18,08	2016	2017	70	7	106	1	1,6	0,9	7
47	757	20,5	2016	2017	52	13	11	1	2,0	1,5	8
48	n.a.	n.a.	2012	2012	44	20	12	1	3,1	1,7	7
49	250	35	2013	2013	41	20	22	1	3,7	1,5	6
50	58	34,46	2013	2014	39	35	26	1	3,5	1,5	3
51	n.a.	n.a.	2014	2015	36	18	23	1	3,0	1,1	5
52	24	6,6	2014	2014	27	13	12	1	2,2	1,4	4
53	23	7,2	2011	2013	27	17	203	1	4,1	1,3	6
54	32	4,95	2017	2017	25	16	14	1	3,4	1,7	4
55	592	21,5	2012	2013	25	13	165	1	2,3	1,8	6
56	n.a.	n.a.	2015	2015	18	11	12	1	1,9	1,8	2
57	n.a.	n.a.	2016	2016	17	8	98	1	4,1	2,1	6
58	204	99,95	2017	2017	17	12	7	1	3,1	2,1	1
59	53	8,1	2011	2011	16	7	104	1	2,9	2,1	5
60	n.a.	n.a.	2014	2014	11	5	75	1	3,0	1,0	3
61	n.a.	n.a.	2012	2013	9	2	106	1	2,9	1,8	3
62	780	18,08	2013	2014	6	3	18	1	3,2	1,3	1
63	604	158,6	2012	2012	4	2	16	1	3,8	1,8	3
64	42	7,39	2016	2016	4	2	1	1	0,0	0,3	1
65	65	10	2014	2015	107	21	21	0	2,9	0,7	9
66	86	13,56	2014	0	51	0		0		0,0	6
67	25	12	2016	2017	49	19	23	0	2,0	1,7	2
68	94	41,61	2017	0	46	0		0	0,0	0,0	1
69	40	7,94	2015	2016	26	5	48	0	2,3	1,3	2
70	n.a.	n.a.	2012	2012	24	9	29	0	3,9	1,5	7
71	n.a.	n.a.	2011	0	21	0		0	2,0	0,0	4
72	60	15,68	2017	2018	17	1	22	0	2,0	1,9	2
73	n.a.	n.a.	2011	2012	17	6	214	0	2,3	1,4	4
74	45	6,2	2017	0	16	0		0	3,2	1,2	4
75	53	6,9	2016	2016	14	1	48	0	1,5	0,5	3
76	65	29,77	2015	0	9	0		0	1,8	1,4	2
77	32	4	2011	0	8	0		0		0,0	2
78	n.a.	n.a.	2012	2012	8	2	19	0	2,8	1,6	5
79	n.a.	n.a.	2014	0	7	0		0	3,9	2,0	4
80	n.a.	n.a.	2017	0	7	0		0	4,0	2,2	3
81	64	n.a.	2016	2017	6	1	1	0	2,7	1,7	3
82	11	n.a.	2011	2011	4	1	1	0	2,3	0,8	3
83	n.a.	n.a.	2013	0	4	0		0	3,3	0,8	3
84	n.a.	n.a.	2015	0	1	0		0		0,0	1
85	n.a.	n.a.	2018	0	1	0		0	0,0	1,0	1

References

[1] Bueno R. [Ed.], *Factories of the Future PPP Strategic Multi-annual Roadmap*, Publication of the European Office, no. EUR 24282, p. 13, 2010.

[2] Pay R., *Everybody's jumping on the Lean Bandwagon, but many are being taken for a Ride*, Industry Week, May 1, 2008, p. 3, available from: http://www.industryweek.com/articles [accessed 22 November, 2018].

[3] Liker J., Rother M., *Why Lean Programs Fail*, Lean Enterprise Institute, 2011, pp. 1–5, available from: http://www.Lean.org [accessed 22 November, 2018].

[4] Hines P., *Creating Sustainable Lean Change*, [in:] Best Practices in Managing Continuous Improvement", Letens G. [Ed.], IIE Webinar Nov. 14, 2012, available from: http://www.iise.org [accessed 22 November, 2018].

[5] Glassa R., Seifermanna S., Metternicha J., *The Spread of Lean Production in the Assembly, Process and Machining Industry*, Procedia CIRP 55, pp. 278–283, 2016.

[6] Van Landeghem, H. *A management system for sustainable lean implementation*, [in:] Handbook of Research on Design and Management of Lean Production Systems, V. Modrak, P. Semanco [Eds.], Business Science Reference (an imprint of IGI Global), pp. 173–187, 2014, print.

[7] Koloszàr L., *Opportunities of Lean thinking in improving the competitiveness of the Hungarian SME sector*, Management and Production Engineering Review, 9, 2, 26–41, 2018.

[8] Hu Q., Mason R., Williams S., Found P., *Lean implementation within SMEs: a literature review*, Journal of Manufacturing Technology Management, 26, 7, 980–1012, 2015.

[9] Pereira L., Tortorella G., *Identification of the relationships between critical success factors, barriers and practices for Lean implementation in a small company*, Brazilian Journal of Operations & Production Management, 15, 2, 232–246, 2018.

[10] Sisson J., Elshennawy A., *Achieving success with Lean*, International Journal of Lean Six Sigma, 6, 3, 263–280, 2015.

[11] Jaca C., Viles E., Mateo R., Santos J., *Components of sustainable improvement systems: theory and practice*, The TQM Journal, 24, 2, 142–154, 2012.

[12] Butcher B., *Better Lean through better behavior*, Industry Market Trends, Sept. 14, 2010, available on: http://news.thomasnet.com/IMT [accessed 3 January, 2013].

[13] Jusko J., *Lean Confusion*, Industry Week, Aug. 13, 2010, available on: http://www.industryweek.com/articles/Lean_confusion_22538 [accessed 3 January, 2013].

[14] Nguyen N., Chinh N., *Exploring critical factors for successfully implementing Lean manufacturing at manufacturing companies in Vietnam*, International Journal for Quality Research, 11, 2, 437–456, 2017.

[15] Uhrin A., Bruque-Caĕmara S., Moyano-Fuentes J., *Lean production, workforce development and operational performance*, Management Decision, 55, 1, 103–118, 2017.

[16] Belhadi A., Ezzahra E.T., El Fezazi S., *A Framework for effective implementation of lean production in small and medium-sized enterprises*, Journal of Industrial Engineering and Management, 9, 3, 786–810, 2016.

[17] Worley J., Doolen T., *Organizational structure, employee problem solving, and Lean implementation*, International Journal of Lean Six Sigma, 6, 1, 39–58, 2015.

[18] Bevilacqua M., Ciarapica F., De Sancti I., *Lean practices implementation and their relationships with operational responsiveness and company performance: an Italian study*, International Journal of Production Research, 55, 3, 769–794, 2017.

[19] Zarbo R., Copeland J., Varney J., *Key management subsystem driver of knowledge – based continuous improvement in the Henry Ford production system*, American Journal of Clinical Pathology, 148, 354–367, 2017.

[20] Timmons T., Bondarenko S., Chura J., *Lean daily management supports perioperative team in achieving safe quality patient care*, Journal of Perianesthesia Nursing, 33, 4, E12–E12, 2018.

[21] Bateman N., *Sustainability: the elusive element of process improvement*, International Journal of Operations & Production Management, 25, 3, 261–276, 2005.

[22] Van Landeghem H., Bauters K., Limère V. *A management system for sustainable lean implementation*, Industrial and Systems Engineering Research Conference, Proceedings 2013, pp. 941–950.

[23] Bicheno, J., Holweg M., *The Lean Toolbox*, 5th edition, Picsie Books, Buckingham, pp. 342, 2016.

[24] Marodin G., Saurin T., *Managing barriers to Lean production implementation: context matters*, International Journal of Production Research, 53, 13, 3947–3962, 2015.

[25] Sundar R., Balaji A., SatheesKumar R., *A review on Lean Manufacturing Implementation Techniques*, Procedia Engineering, 97, 1875–1885, 2014.

[26] Stoll J., *New study downplays effects of Lean manufacturing*, Reuters, 2011, available on: http://www.reuters.com [accessed: 3/1/2013].

[27] Danese P., Manfè V., Romano P., *A systematic literature review on recent lean research: state-of-the-art and future directions*, International Journal of Management Reviews, 20, 579–605, 2018.