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# The relative importance of improvement routines for implementing lean practices

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## Abstract

**Purpose** – This paper examines whether and when improvement routines are critical for implementing lean practices in small- and medium-sized manufacturing enterprises (SMEs). Improvement routines such as "employees initiate and carry through improvement activities" are generally seen as an important means to achieve the full benefit of structural lean interventions. Womack and Jones (2003) suggest that these improvement routines should be developed as the company becomes more experienced in lean. The purpose of this paper is to explore the relative importance of individual improvement routines at various degrees of lean practice implementation.
**Design/methodology/approach** – A Between-Case Comparison Analysis (Dul and Hak, 2012) and a Necessary Condition Analysis (Dul, 2016) were performed on self-assessment data from 241 respondents at 38 Dutch manufacturing SMEs.
**Findings** – The importance of improvement routines depended on the degree of lean practice implementation. Lean practices could be implemented to some extend without developing specific improvement routines, yet certain routines were necessary for more advanced implementations of lean. These routines relate to employees conducting shared improvement activities and in the most advanced cases to aligning different improvement activities.
**Originality/value** – These findings question existing lean implementation models that neglect improvement routines and indicate the need to integrate improvement routines into every lean transformation for it to be sustainable.

**Keywords** Operational performance, Organizational learning, Necessary Condition Analysis, SMEs manufacturing

**Paper type** Research paper

## 1. Introduction

As small- and medium-sized manufacturing enterprises (manufacturing SMEs) seek to increase their operational performance in terms of quality, delivery and costs (Slack *et al.*, 2010), they can turn to lean management, which is known to increase operational performance (Womack and Jones, 2003). Lean practices are a set of methods, procedures,



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techniques and tools aimed at continuously creating customer value and reducing product lead time (Shah and Ward, 2007). To implement lean practices, certain improvement routines have been found necessary. Improvement routines are referred to as learned patterns of behaviour that enable high levels of sustained involvement (Bessant and Caffyn, 1997). However, manufacturing SMEs find it difficult to develop these improvement routines (McGovern *et al.*, 2017; Shah and Ward, 2003; White *et al.*, 1999). To provide guidance for SMEs in this development, this study explores the relative importance of individual improvement routines at various degrees of lean practice implementation for increasing operational performance in manufacturing SMEs.

Lean management consists of a variety of aspects, covering shop floor tools, lean practices, improvement cycles, problem-solving routines, improvement Kata and coaching Kata, leader standard work, generic principles and strategic lean thinking (Bicheno and Holweg, 2016; Deming, 1993; Hines *et al.*, 2004; Liker, 2004; Rother, 2010; Shah and Ward, 2003; Womack, 2013). This study focusses on lean practices that are directly linked to operational performance. Examples of lean practices are "addressing equipment downtime through total productive maintenance", "facilitating pull production through a limit on work-in-progress" and "creating continuous flow of value-added activities" (Shah and Ward, 2007). Based on survey data from 1,757 large, medium and small US manufacturing firms, Shah and Ward (2003) found that the synergistic effect of all lean practices were associated with better operational performance. When products are produced in a single-piece flow and value-added activities follow each other continuously, operational performance increases (Shah and Ward, 2003; Womack and Jones, 2003).

To successfully implement lean practices, organisations need to continuously improve their processes (Bessant *et al.*, 2001; Spear and Bowen, 1999; Womack and Jones, 2003). Continuous improvement is a dynamic organisational capability that involves specific employees conducting improvement activities (Anand *et al.*, 2009; Boer *et al.*, 2000; Rother, 2010; Zollo and Winter, 2002). This dynamic capability consists of "a particular bundle of routines which can help an organisation improve what it currently does" (Bessant *et al.*, 2001, p. 68). Improvement routines, therefore, form the backbone of continuous improvement. Examples of improvement routines are "employees initiate and carry through improvements" and "employees use appropriate techniques to improve" (Bessant *et al.*, 2001).

The order of Womack and Jones' (2003) five widely acknowledged principles of lean management: identifying value, streamlining the value stream, establishing flow, pull and aiming for perfection suggests that in order to create a lean organisation, it is essential to implement lean practices to some extent (establishing flow and pull) before developing routines to improve them (aiming for perfection). According to Womack and Jones (2003, p. 269), "[…] there is a critical transition as you move your organisation through the lean transformation, a point when managers must become coaches rather than tyrants and employees become proactive. This transition is the key to a self-sustaining organisation". This transition suggests that improvement routines should be developed as a company becomes a more experienced lean practitioner.

Yet manufacturing SMEs struggle to develop improvement routines and implement lean practices (McGovern *et al.*, 2017; Shah and Ward, 2003; White *et al.*, 1999). SMEs are important as, on a worldwide average, they contribute 42 per cent to a country's gross domestic product and provide work for 54 per cent of a country's labour force. Large enterprises also depend on entire networks of suppliers, most of which are SMEs (Ayyagari *et al.*, 2007). Part of the difficulty SMEs have with improvement routines lies in their intrinsic characteristics and features. According to Gelinas and Bigras (2004), SME managers have a low propensity to delegate and consult, preventing employees from developing improvement routines. Furthermore, SMEs often only plan in the short term, resulting in a mismatch between daily operating routines and long-term improvement routines.

An inherent lack of resources like time, money and expertise makes it even more difficult for SMEs to hire consultants, take training courses and perform activities to develop improvement routines (Middel *et al.*, 2007; Welsh and White, 1981). These SME-specific characteristics often hinder the development of improvement routines, resulting in an unsustainable and, hence, unsuccessful lean practice implementation approach.

Previous research suggests that the importance of improvement routines differs at various degrees of lean practice implementation (Bessant *et al.*, 2001; Womack and Jones, 2003). Importance means that improvement routines become necessary to activate further improvements. The increasing importance of improvement routines during a lean journey implies that the importance of each particular improvement routine also evolves. Therefore, the aim of this study is to explore the relative importance of individual improvement routines at various degrees of lean practice implementation for increasing operational performance in manufacturing SMEs. The paper concludes with propositions about individual improvement routines in relation to lean practices and operational performance.

This knowledge will help manufacturing SME managers who are trying to create lean organisations to identify the most relevant improvement routines for their degree of lean practice implementation. This study questions lean implementation models that ignore improvement routines and strongly supports the notion that improvement routines are relevant for every lean transformation, yet different routines are crucial for different levels of maturity.

## 2. Improvement routines for implementing lean practices and increasing operational performance in manufacturing SMEs

This section explains the link between organisational learning and continuous improvement and summarises the literature on the relationships between aggregate improvement routines with lean practices and operational performance, before delving deeper into the importance of individual improvement routines. Given the scarcity of literature on this subject, research in large enterprises is described before elaborating on their specific role in SMEs. As previous research has shown a link between lean practices and operational performance (Shah and Ward, 2003; Womack and Jones, 2003), research on the link between routines and lean practices as well as operational performance is described. As the aim is to explore the relative importance of individual improvement routines, consistency was important and, therefore, only papers that studied improvement routines as identified by Bessant and Caffyn (1997) or Bessant *et al.* (2001) were considered.

### *2.1 Organisational learning as a core of continuous improvement*

Organisations strive to increase their operational performance by establishing suitable operating practices and by continuously learning how these practices can be improved. Of interest to this study are the lean practices developed by Shah and Ward (2007). To improve these lean practices, organisations must develop their dynamic capabilities (Zollo and Winter, 2002). Dynamic capability is defined as "a learned and stable pattern of collective activity through which the organisation systematically generates and modifies its operating routines in pursuit of improved effectiveness" (Zollo and Winter, 2002, p. 340). According to Fiol and Lyles (1985), dynamic capabilities are developed through organisational learning, which means "improving actions through better knowledge and understanding" (p. 803). In the context of this study, organisational learning occurs in learning cycles or improvement cycles, like "plan-do-study-act" or "define-measure-analyse-improve-control" (Bessant *et al.*, 1996; Deming, 1993). So, to improve lean practices and increase operational performance, organisations need to understand their operating routines and articulate the need to improve them.

*2.2 Aggregate improvement routines for lean practices and operational performance*

According to Womack and Jones (2003), improvement routines grow in importance during the implementation of lean practices. This transition has been substantiated by many other studies. Savolainen (1999) studied three Finnish manufacturers that started to implement lean, which in turn led to the development of continuous improvement routines. The four ways of improvement described by Berger (1997) (individual, expert task-force, organic and wide-focus improvement) indicate that as groups of people are involved and improvement is integrated with ordinary tasks, implementing lean practices mutually reinforces the development of sustained improvement routines. Similarly, the four typologies reported by Rijnders and Boer (2004) (novices, sprinters, exercisers and stayers) indicate that a clear focus on practical concepts as well as presence of an improvement structure mutually enacted wider comprehension of improvement as well as learning. De Jager *et al.* (2004) found that developing continuous improvement routines led to the implementation of lean practices which, in turn, reinforced the improvement routines and led to improved operational performance. These findings indicate that there is a strong interaction between improvement routines and lean practices.

In a decade-long research programme on continuous improvement in over 70 companies, Bessant *et al.* (2001) developed the notion of improvement routines further and suggested that different routines might be important at various levels of improvement. Kaltoft *et al.* (2004) suggest that next to management initiatives, developing improvement routines early in the improvement process may be the best way to implement lean practices. Kim *et al.* (2014) found that enterprises with mature improvement programmes equally combine management-initiated and employee-initiated improvement activities. Thus, organisations could start implementing lean practices without the presence of improvement routines, while different routines may be of varying importance as they continue to implement lean. This research will explore the relative importance of individual improvement routines given various degrees of lean practice implementation for increasing operational performance.

*2.3 Importance of individual improvement routines*

There are several different improvement routines (for an overview see Appendix 1 – improvement routines) yet the findings on which of these are most important for implementing lean practices are mixed. One case study and three survey studies were reviewed.

Based on interviews conducted at three large South African mines, de Jager *et al.* (2004) found that "strategy deployment behaviour" was considered the most important routine for beginning to improve operational performance; managers said that creating a common goal was the first necessity to show the urgency for the proposed change. Two other important routines were mentioned: "understanding improvement behaviour" (behaviour changes when people understand and believe in the reason for change) and "improvement leadership" (managers trust their employees and recognise their contribution to improvement).

Dabhilkar and Bengtsson (2004) conducted a survey on improvement routines in 127 Swedish manufacturing firms. Their regression analysis showed that "systematic and strategic improvement" had the strongest link with operational performance. This was a cluster of several routines: "employees understand and share the idea of improvement", "employees proactively participate in improvement" and "improvement activities are linked to the strategy". Three other important routines were: "customer and supplier involvement" (the organisation can extend their improvement activity across organisational borders), "idea management and reward systems" (idea management systems are used and employee contributions are rewarded) and "strategic knowledge deployment" (employees learn and then develop, capture and share that knowledge).

In a later study using survey data from 452 European and Australian manufacturing companies, Dabhilkar *et al.* (2007) remarkably found no significant differences in the relative importance of improvement routines for operational performance, neither within nor across countries. A possible explanation is that they analysed this relationship using a regular regression. This supposes that the increased presence of improvement routines is directly linked to higher operational performance. However, the general assumption is that improvement routines are a necessary condition but no guarantee for implementing lean practices.

Finally, using survey data from 543 manufacturers in ten countries in Asia, Australia and Europe, Jørgensen *et al.* (2006) found that the ability to "strategically manage the development of improvement" had the strongest correlation with operational performance. This means that employees assess and prioritise improvements against the organisational strategy and monitor whether improvements affect this strategy. Two other important routines were "the ability to learn" and "the ability to improve across organisational boundaries".

So far these findings are inconclusive. The fact that systematic strategy deployment was found repeatedly might be due to size: larger organisations generally require more alignment. The question remains which order of routines is critical for the context of SMEs.

### *2.4 Individual improvement routines in manufacturing SMEs*

Only a few studies were found that specifically describe improvement routines and lean practices in manufacturing SMEs. For instance, in an extensive literature review of 209 research papers on lean manufacturing, Bhamu and Singh Sangwan (2014) found that the success of lean in manufacturing SMEs largely depends on cultural practices. They only identified one study (Meiling *et al.*, 2012) that investigated the relationship between improvement routines and lean practices in SMEs. That study looked at two Swedish case studies and found that the SME-specific characteristics "leading the way" and "getting the improvement habit" were extremely important to creating organisational change in those SMEs and that an SME-specific challenge – "lack of focus" – prevented one company from obtaining sustainable improvements. Singh and Singh (2015) conducted an extensive literature review on continuous improvement but found no other papers on improvement routines and lean practices specifically targeting SMEs.

More recently, Matthews *et al.* (2017) found that the more effective employees at six UK manufacturing SMEs were "willing and able" to perceive new ways of working and participated in a "shared problem-solving" approach, helping them align with and build on the work of peers. This seems to be in line with SMEs specifically, as they transfer information informally and responsibility is less precisely divided (Gelinas and Bigras, 2004). Furthermore, they found that in these more effective cases "managers supported and led improvement activities" and that "organisational learning" was achieved by sharing personal knowledge using formal procedures. The former is specific to SMEs but the latter counters our understanding, as SMEs tend to be informal and unstructured (Gelinas and Bigras, 2004). These formal procedures might be a key to sustaining improvement efforts in manufacturing SMEs. However, these cases were "mature improvers", as they already had an accredited ISO 9000 quality management system and other formal and external audit procedures. The authors concluded that improvement activities can result in organisational learning, which eventually leads to increased operational performance.

To summarise, the research so far has shown that the importance of improvement routines changes depending on the degree of lean practice implementation, yet it does not identify which routines are important in which situation. Papers that do focus on individual importance show that in large enterprises and SMEs combined, systematic strategy deployment is the most important routine for increasing performance. In SMEs specifically, management support and leadership, as well as shared problem-solving, are the most important improvement routines for implementing lean practices and increasing operational performance. Furthermore, embedding improvements into formal procedures might sustain results in generally informal manufacturing SMEs.

Though the studies described above (Dabhilkar *et al.*, 2007; Dabhilkar and Bengtsson, 2004; de Jager *et al.*, 2004; Jørgensen *et al.*, 2006) note the importance of using different improvement routines, only a few focus on SMEs (Matthews *et al.*, 2017; Meiling *et al.*, 2012). None of them relate this importance to the degree of lean practice implementation or operational performance, or analyse their data using the assumed necessary perspective. This paper, therefore, explores the relative importance in which individual improvement routines are necessary to implement various degrees of lean practices in SMEs.

## 3. Methods

This section describes the sample and measures and how a Between-Case Comparison Analysis (BCCA) (Dul and Hak, 2012) and a Necessary Condition Analysis (Dul, 2016) were conducted.

### *3.1 Sample and data collection*

A total of 38 manufacturing SMEs were recruited through the network of (the HAN Lean-QRM Center) in the Netherlands (see Table I for details). Manufacturing was defined using the classification of economic activities in the European Community (commonly referred to as NACE) as "Level 1, Group C: Manufacturers" (European Commission, 2010). SMEs were defined as companies that employ 10–250 employees (European Commission, 2005).

To overcome single respondent bias (Bowman and Ambrosini, 1997), multiple respondents with relevant knowledge were asked to participate in each case. The production manager was always involved, complemented by the owner/director, general manager, managers of different cells, or managers from different departments like marketing, sales, R&D, engineering and/or logistics and/or team leaders.

Respondents filled in the questionnaires individually during a joint session with all the respondents. To ensure that they all had the same understanding of the concepts surveyed, the concepts were explained – both orally and in writing – before they filled in the questionnaires. This helped to overcome idiosyncratic variation and increased construct validity for multiple respondents. Respondents for each case varied from two to thirteen, depending on the number of employees (over 6 on average, 241 in total).

### *3.2 Measures*

Improvement routines were measured using Bessant *et al.'s* (2001) 35-item questionnaire, a further development of the earlier version (Bessant and Caffyn, 1997), that is commonly used in other studies (like de Jager *et al.*, 2004; Jørgensen *et al.*, 2006; Singh and Singh, 2015). It measures eight improvement routines: (i) understanding improvement, (ii) getting the improvement habit, (iii) focussing improvement, (iv) leading the way, (v) aligning improvement, (vi) shared problem-solving, (vii) improvement of improvement and (viii) the learning organisation. Since Bessant *et al.* (2001) do not propose a scale, a five-point Likert scale was used. With multiple questions per item, five points are sufficient to overcome measurement error (Finstad, 2010). The scale ranged from (1) "no presence" to (2) "some presence", (3) "moderate presence", (4) "extensive presence" and (5) "full presence".

Lean practice implementation was measured using a questionnaire developed by Shah and Ward (2007), which has become a standard for measuring this construct (like Hofer *et al.*, 2012; Marodin and Saurin, 2013; Vinodh and Balaji, 2011). The questionnaire consists of 41 questions, covering ten lean practices: (i) productive maintenance, (ii) controlled processes, (iii) pull, (iv) flow, (v) low setup, (vi) supplier feedback, (vii) JIT delivery, (viii) developing suppliers, (ix) involved customers and (x) involved employees. Since practice (x), involved employees, significantly overlaps with improvement routines, it was left out of the construct. As for Shah and Ward (2007), a five-point Likert

| Case | Employees | Respondents | Variety/volume | Industry | Products | Operational performance | Lean practices |
|---|---|---|---|---|---|---|---|
| 1 | 24 | 7 | Jobber | Metalworking | Sheet metalworking | 6.5 | 2.9 |
| 2 | 58 | 4 | High-variety low-volume | Electronics | Switchboxes | 6.0 | 2.2 |
| 3 | 38 | 2 | High-variety low-volume | Machinery | Machines | 7.6 | 3.3 |
| 4 | 51 | 8 | High-variety low-volume | Electronics | Panels | 7.2 | 3.0 |
| 5 | 16 | 4 | High-variety low-volume | Manufactured goods | Hinges | 6.5 | 2.8 |
| 6 | 94 | 7 | High-variety low-volume | Machinery | Conveyor belts | 6.9 | 2.7 |
| 7 | 60 | 4 | Low-variety high-volume | Construction industry | Paving stones | 6.3 | 3.0 |
| 8 | 103 | 9 | Low-variety high-volume | Manufactured goods | Flue gas discharges | 6.8 | 2.5 |
| 9 | 35 | 5 | High-variety low-volume | Machinery | Presses | 5.6 | 2.6 |
| 10 | 123 | 7 | Low-variety high-volume | Plastics | Packaging materials | 7.4 | 3.1 |
| 11 | 27 | 2 | High-variety low-volume | Metalworking | Steel constructions | 7.4 | 2.7 |
| 12 | 250 | 13 | High-variety low-volume | Automotive | Garbage trucks | 5.9 | 2.5 |
| 13 | 20 | 7 | Low-variety high-volume | Manufactured goods | Ropes | 6.4 | 2.4 |
| 14 | 90 | 6 | Jobber | Metalworking | Sheet metalworking | 6.4 | 2.6 |
| 15 | 47 | 4 | Low-variety high-volume | Plastics | Packaging materials | 6.6 | 3.3 |
| 16 | 87 | 7 | High-variety low-volume | Manufactured goods | Doors | 6.0 | 2.5 |
| 17 | 31 | 6 | Jobber | Metalworking | Sheet metalworking | 6.4 | 2.4 |
| 18 | 96 | 7 | High-variety low-volume | Electronics | Measuring equipment | 6.0 | 2.6 |
| 19 | 125 | 11 | Low-variety high-volume | Construction industry | Garden material | 6.0 | 3.0 |
| 20 | 40 | 7 | Low-variety high-volume | Construction industry | Paving stones | 7.1 | 3.2 |
| 21 | 40 | 4 | Jobber | Metalworking | Sheet metalworking | 7.1 | 2.3 |
| 22 | 136 | 11 | High-variety low-volume | Manufactured goods | Miscellaneous | 6.1 | 2.2 |
| 23 | 29 | 3 | Jobber | Construction industry | Glass | 6.7 | 2.7 |
| 24 | 164 | 7 | Jobber | Maintenance | Switchboxes | 7.7 | 3.3 |
| 25 | 34 | 8 | High-variety low-volume | Manufactured goods | Hydraulics | 6.9 | 2.1 |
| 26 | 18 | 6 | High-variety low-volume | Manufactured goods | Containers | 5.4 | 2.5 |
| 27 | 10 | 5 | Jobber | Metalworking | Steel constructions | 6.1 | 2.4 |

(*continued*)

**Table I.**
Overview of companies involved in the sample

| Case | Employees | Respondents | Variety/volume | Industry | Products | Operational performance | Lean practices |
|---|---|---|---|---|---|---|---|
| 28 | 94 | 9 | High-variety low-volume | Agricultural machinery | Slurry tanks | 6.1 | 2.6 |
| 29 | 160 | 8 | Low-variety high-volume | Construction industry | Stones | 6.6 | 2.7 |
| 30 | 101 | 8 | High-variety low-volume | Manufactured goods | Lighters | 7.3 | 3.0 |
| 31 | 26 | 7 | High-variety low-volume | Timber | Transformer insulation | 7.3 | 3.0 |
| 32 | 10 | 3 | Jobber | Metalworking | Sheet metalworking | 7.8 | 3.0 |
| 33 | 63 | 8 | High-variety low-volume | Plastics | Injection moulding | 6.1 | 2.9 |
| 34 | 40 | 4 | Jobber | Automotive | Company cars | 5.3 | 2.4 |
| 35 | 34 | 4 | Low-variety high-volume | Plastics | Injection moulding | 5.8 | 2.4 |
| 36 | 33 | 5 | High-variety low-volume | Manufactured goods | Fireplaces | 5.6 | 2.4 |
| 37 | 47 | 5 | High-variety low-volume | Manufactured goods | High pressure cleaners | 5.5 | 2.4 |
| 38 | 237 | 9 | High-variety low-volume | Agricultural machinery | Front loaders | 7.0 | 2.7 |
| | $\bar{x} = 82$ | $\Sigma = 241$ $\bar{x} = 6$ | | | | | |

**Table I.**

scale was used, ranging from (1) "no implementation" to (2) "some implementation", (3) "moderate implementation", (4) "extensive implementation" and (5) "full implementation".

Operational performance was measured using seven frequently used indicators: (i) cost, (ii) quality, (iii) delivery speed, (iv) delivery dependability, (v) delivery flexibility, (vi) product flexibility and (vii) volume flexibility (McKone *et al.*, 2001; Dal Pont *et al.*, 2008; Sakakibara *et al.*, 1997; Slack *et al.*, 2010; c.f. Vickery *et al.*, 1993). Single questions were used to measure each of these indicators, e.g. "How is this organisation's performance on cost, compared to that of its competitors?" Given the single questions per item, a nine-point Likert scale was used to overcome measurement error (Finstad, 2010). It ranged from (1) "very bad performance" to (9) "very good performance".

### *3.3 Data quality*

The outcomes of the instruments were treated as follows. First, the median of the multiple respondents was used to get one outcome per question per case. Second, the average of the multiple questions per construct provided the outcome for that construct. The median was used because it is less susceptible to skewed data and outliers than the mean. Due to the limits of a Likert scale, the data distribution cannot be normal towards the ends, an inherent cause of skewing. Outliers were present because respondents came from different backgrounds and departments and did not necessarily agree with the majority. Because of the diversity in respondents, they were not expected to be interchangeable, hence inter-rater reliability was not accounted for. The average of the multiple questions per construct provided the aggregated values of those constructs because the individual questions map the conceptual space surrounding these constructs.

To test whether the instruments were valid and reliable, a confirmatory factor analysis (CFA), internal correlation analysis and internal consistency analysis were performed. Construct validity was tested in SPSS 23 and Excel 2013 using the CFA (Joreskog, 1969);

convergent validity was estimated with factor loadings (the average gives an indication per construct) and average variance extracted (AVE) (Fornell and Larcker, 1981). Composite reliability was calculated with the Raju (1977) coefficient (Cho, 2016; Raju, 1977). Internal reliability was calculated as the coefficient $\alpha$ (Cho, 2016; Cronbach, 1951). These measures are given in Table II.

In general, all properties met the generally required threshold of 0.7 for factor loadings and coefficients and 0.5 for AVE. Only "operational performance" (factor loading of 0.6 and AVE 0.407), and "understanding improvement" (coefficient $\alpha$ of 0.496) deviated substantively. The deflecting item for operational performance was "costs" and for understanding behaviour was "employees" use of formal systems. Following judgemental criteria (Wieland *et al.*, 2017) and taking into account the content of the deflecting items (content validity), we decided to keep these items to maintain coverage of the identified constructs.

### *3.4 Data analysis*

Since the literature suggests a positive relationship between improvement routines, lean practices and operational performance, it was first validated whether this relationship also applied to this study's set of SMEs. Given our assumption that improvement routines are necessary though no guarantee for lean practice implementation, which in turn is directly linked to operational performance, this question was answered by conducting an asymmetrical Between-Case Comparison Analysis (aBCCA) and a symmetrical Between-Case Comparison Analysis (sBCCA), respectively (adapted from Dul and Hak, 2012).

The sBCCA was done as follows. For each pair of cases, the aggregated values of lean practices and operational performance were compared according to the following rule: if case A's lean practice implementation (LP-A) was higher than or equal to case B's lean practice implementation (LP-B) and case A's operational performance (OP-A) was higher than or equal to case B's operational performance (OP-B), the outcome was 1. Likewise, if LP-A was lower than LP-B and OP-A was lower than OP-B, the outcome was 1. In other words, the outcome was 1 if the pairwise comparison met the expected pattern that a higher value on lean practices was directly linked to a higher value on operational performance. If this was not true, the outcome was coded as 0.

The aBCCA was adapted to allow for cases that have a higher score on the necessary conditions combined with a lower score on the outcome: if case A's improvement routines (IR-A) were lower than case B's improvement routines (IR-B) and LP-A$\geqslant$LP-B then 0, else 1. This was done for improvement routines with lean practices as well as operational performance. To overcome sensitivity of cases very close to each other, a margin of plus or minus 5 per cent was applied. If cases fell within this range, the comparison was disregarded. In this way, only significant differences were considered. Applying this rule

**Table II.**
Data quality measures

| Construct | Average factor loading | Average variance extracted | Raju (1977) coefficient | Coefficient $\alpha$ |
|---|---|---|---|---|
| Understanding improvement | 0.701 | 0.507 | 0.749 | 0.496 |
| Getting the improvement habit | 0.711 | 0.509 | 0.804 | 0.677 |
| Focussing improvement | 0.802 | 0.649 | 0.88 | 0.814 |
| Leading the way | 0.781 | 0.618 | 0.865 | 0.786 |
| Aligning improvement | 0.825 | 0.681 | 0.895 | 0.83 |
| Shared problem-solving | 0.775 | 0.605 | 0.884 | 0.824 |
| Improvement of improvement | 0.812 | 0.667 | 0.888 | 0.83 |
| The learning organisation | 0.689 | 0.477 | 0.864 | 0.815 |
| Lean practices | 0.704 | 0.505 | 0.973 | 0.875 |
| Operational performance | 0.600 | 0.407 | 0.81 | 0.735 |

to each pairwise comparison ($n^2/2 - n/2 = 38^2/2 - 38/2 = 703$ pairwise comparisons in total) produces an overall score between 0 per cent (none of the pairwise comparisons meet this condition) and 100 per cent (all of the pairwise comparisons meet this condition). This indicates the strength of the relationship between improvement routines and lean practices in manufacturing SMEs. An outcome of 50 per cent would indicate that there was no relationship.

To tests for mediation, the traditional approach (Baron and Kenny, 1986; Preacher and Hayes, 2008) was followed while again using the BCCAs rather than regular multiple regression analyses. For mediation to show, the relationship between improvement routines and operational performance should be stronger when lean practices are high than when lean practices are low.

To identify the order in which improvement routines were important at various degrees of lean practice implementation, a Necessary Condition Analysis (NCA) (Dul, 2016) was performed. In contrast to regular regression analyses that study variables in a probabilistic relationship to each other, an NCA allows the study of variables that are necessary but no guarantee for a certain outcome (e.g. improvement routines are necessary but no guarantee for lean practice implementation).

An NCA starts by drawing a ceiling line through the upper-left observations of an $x$–$y$ plot. This line separates the "empty space" and the "full space" of the data set (Goertz *et al.*, 2012) and indicates the degree to which lean practices ($y$-axis) could be implemented without the presence of improvement routines ($x$-axis). See, for example, Figure 1; the broken line is a ceiling envelopment line and the solid line is a ceiling regression line, where the $x$ are two of eight improvement routines ("improvement of improvement" and "getting the improvement habit", respectively) and $y$ is the implementation of lean practices. These ceiling lines indicate the minimum presence of a given improvement routine to be able to implement a certain degree of lean practices. Listing the outcomes of the regression equations of all improvement routines in a bottleneck table identified a minimum extent of each improvement routine's presence for every degree of lean practice implementation.

This analysis method follows other examples of NCA application, such as Sousa and da Silveira (2017), who found necessary degrees of services in the process of servitisation, and Van Der Valk *et al.* (2016), who determined the criticality of contracts and trusts for supplier relations. All findings were discussed in two two-hour sessions with about 50 manufacturing SME managers and about 30 lean consultants, respectively (communicative validation). These discussions helped to refine the interpretation of the findings.

## 4. Findings

The findings confirm that lean practices mediated the relationship between improvement routines and operational performance in this study's set of manufacturing SMEs, and that individual improvement routines were not equally required for the implementation of lean practices.

### *4.1 Lean practices mediated between improvement routines and operational performance*

The literature notes a positive relationship between improvement routines, lean practices and operational performance. To see if this relationship also applied to this study's set of manufacturing SMEs, BCCAs (adapted from Dul and Hak, 2012) were performed. The resulting scores are presented in Figure 2 and suggest that lean practices mediated the relationship between improvement routines and operational performance. First, a strong relationship (92 per cent) was found between (i) improvement routines necessary for lean practices (50 per cent would indicate no relationship). Second, a moderate relationship (83 per cent) was found between (ii) improvement routines necessary for operational performance, as well as a moderate relationship (74 per cent) between (iii) lean practices and

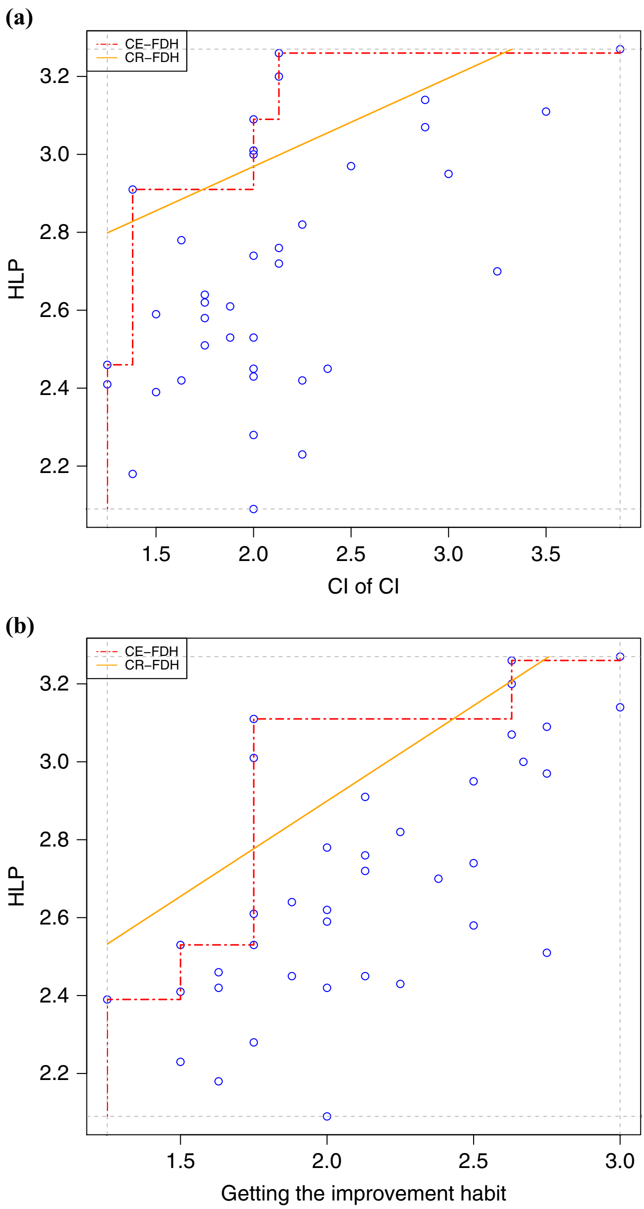


**Figure 1.**
NCA plots of (a) "improvement of improvement" (CI of CI); and (b) "getting the improvement habit", both for "lean practices" (HLP)

operational performance. Note that the latter was analysed as symmetrical rather than necessary, which generally results in a lower score. In 92 per cent of the 703 pairwise comparisons, a higher presence of improvement routines was associated with more implementation of lean practices.

Furthermore, for cases with high lean practices, a strong relationship (93 per cent) was found between improvement routines and operational performance. To explicitly discriminate between high and low lean practitioners, the threshold of high/low was set at two-thirds of the spread amongst lean practices, which was 2.8. In contrast, cases with low lean practices showed only a moderate link (79 per cent) between higher improvement routines and higher performance. These findings indicate that in this study's set of manufacturing SMEs, lean practices mediated the relationship between improvement routines and operational performance. In the following section, the relationship between improvement routines and lean practices is further analysed to determine the importance of individual improvement routines.

### *4.2 Improvement routines that directly implement lean practices*

BCCAs (Dul and Hak, 2012) were performed for all individual routines in relation to lean to assess whether the cases in this study's set of manufacturing SMEs obey the assumption mentioned in the introduction of this paper: that improvement routines are necessary for rather than directly leading to lean practice implementation. Results showed that only "getting the improvement habit" had a moderate symmetrical score; in 76 per cent of the between-case comparisons, more presence of getting the improvement habit was associated with more implementation of lean practices. Getting the improvement habit is defined as "the ability to generate sustained involvement in improvement" (Bessant *et al.*, 2001, p. 72). This means that employees use measurements, tools and techniques to initiate and carry through improvement activities (Bessant *et al.*, 2001). The moderate score shows that if employees initiated and carried through improvement activities, there was more lean practice implementation. This means that getting the improvement habit was not just necessary, but most likely leads to the implementation of lean practices. The between-case comparison scores of the other improvement routines showed a weak symmetrical link with lean practice implementation. This may be because of the necessary condition of their relationship with lean practices: the improvement routines are necessary but are no guarantee of lean practice implementation. Thus the improvement routines might be present without lean practices being implemented, resulting in a lower score. In the following section, it is analysed whether and to which extent the improvement routines are necessary for the implementation of lean practices.

### *4.3 Improvement routines that are necessary for lean practices*

To identify the extent to which individual improvement routines were necessary at various degrees of lean practice implementation, *x–y* plots were used for each improvement routine (as *x*) and lean practice (as *y*). Cases found in the upper-left corner of the *x–y* plot (Figure 1, plot a) indicate the implementation of lean practices without the presence of that specific improvement routine, showing that this routine is not necessary for the implementation of lean practices. If no cases are found in the upper-left corner (Figure 1, plot b), there is no

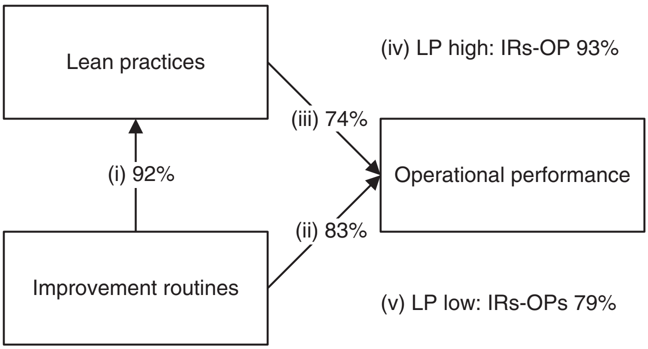


**Figure 2.** Between-case comparison scores of (i) improvement routines (IRs) for operational performance (OP), (ii) IRs for lean practices (LPs), (iii) LPs for OP, (iv) LP high: IRs for OP, and (v) LP low: IRs for OP

implementation of lean practices without the presence of improvement routines, suggesting that that routine is necessary for lean. Analysis of all the plots shows cases positioned in the upper-left corners for: "the learning organisation", "leading the way" and "improvement of improvement". This demonstrates that not all of the eight improvement routines are required for the degree of lean practices measured.

To determine the order in which individual improvement routines were necessary for various extents of lean practices, ceiling lines were drawn to indicate the degree to which lean practices ($y$-axis) were implemented without the presence of improvement routines ($x$-axis). The ceiling line could either envelop the upper-left observations with a piecewise-linear convex line (a ceiling envelopment line, CE-FDH hence known as CE line), or it could regress as a trend line through the upper-left observations of the data set (ceiling regression line, CR-FDH hence known as CR line) (Dul, 2016). Dul (2016) recommends using a CE line for a discrete data set and a CR line for a continuous data set.

The data in this study were gathered using a discrete scale. Then the median was found from multiple respondents and analysed using a continuous scale. Both CE lines and CR lines were drawn automatically using the R 3.3.1 software with the NCA 2.0 package. Both lines are shown in Figure 1; the CE lines are represented by the broken line; the CR lines are represented by the solid line. To determine the validity of the ceiling lines, the accuracy and effect sizes were calculated (Appendix 2 – Accuracy and effect size); both were found sufficient to use the CR lines in the NCA.

Using the regression equations ($y = f(x)$) of the CR lines, the presence of improvement routines was compared with the implementation of lean practices. The equation gave a level ($x$) that the improvement routine was required for every degree of implementation of lean practices ($y$). For example, the improvement routine with its CR line closest to the lower-right quadrant required the most presence for the implementation of lean practices. The improvement routines with CR lines closest to the upper-left quadrant required the least presence. The lines thus showed the specific improvement routine importance for the implementation of lean practices. Using the CR lines, a bottleneck table (Dul, 2016) was created for all eight improvement routines (Table III).

The bottleneck table can be interpreted as follows. The lean practices and improvement routines are shown as a percentage of the range of the lowest and the highest observed values. The first column gives the percentage of implementation of lean practices. As the lowest observed value was 2.1 on the Likert scale of 1–5, the first row "0" represents cases with some implementation of lean practices. For the highest observed value, 3.3 on a scale of 1–5, the last row "100" represents cases with moderate lean practice implementation. The other eight columns give the extent to which the eight improvement routines were present

**Table III.** Bottleneck table of the eight improvement routines for lean practice implementation

| Lean practices | (i) Understanding improvement | (ii) Getting the improvement habit | (iii) Focussing improvement | (iv) Leading the way | (v) Aligning improvement | (vi) Shared problem-solving | (vii) Improvement of improvement | (viii) The learning organisation |
|---|---|---|---|---|---|---|---|---|
| 0 | NN | NN | NN | NN | NN | NN | NN | NN |
| 10 | NN | NN | NN | NN | NN | NN | NN | NN |
| 20 | NN | NN | NN | NN | NN | NN | NN | NN |
| 30 | NN | NN | NN | NN | NN | 5.6 | NN | NN |
| 40 | NN | 3.5 | NN | NN | NN | 14.4 | NN | NN |
| 50 | NN | 17.3 | 11.6 | NN | 8.5 | 23.1 | NN | NN |
| 60 | 6.3 | 31 | 23.4 | NN | 20.7 | 31.8 | NN | 4.2 |
| 70 | 25.2 | 44.8 | 35.2 | NN | 32.9 | 40.6 | 19.7 | 19.9 |
| 80 | 44 | 58.6 | 47 | 29.1 | 45.1 | 49.3 | 39.4 | 35.6 |
| 90 | 62.9 | 72.4 | 58.8 | 58.9 | 57.3 | 58 | 59.2 | 51.4 |
| 100 | 81.7 | 86.1 | 70.6 | 88.7 | 69.5 | 66.8 | 78.9 | 67.1 |

(percentage of the range of the values). The lowest observed value was 1.0 on a Likert scale of 1–5 and the highest observed value was 4.5 on a Likert scale of 1–5, therefore "NN" stands for not necessary and "100" stands for the full presence of the improvement routine. Since the data do not cover the entire Likert scale of lean practices (1–5) or improvement routines (1–5), NN in the very first row means that there are no data to show what percentage is required to start with lean. NN and the numbers in the remainder of the table represent no, some, moderate, extensive and full presence of the improvement routines. This bottleneck table indicates the degree to which individual improvement routines are necessary for various degrees of lean practice implementation in this study's set of manufacturing SMEs.

Using the bottleneck table, the order in which improvement routines were necessary for the implementation of lean practices was identified. As NN stands for not necessary or 0 per cent, the table shows that in this set of manufacturing SMEs, some implementation of lean practices (up to 30 per cent = Level 2 of the five-point Likert scale) could be realised without developing existing improvement routines. As Figure 1 shows, there are many cases on the left side of both figures, meaning those cases had some degree of lean practice implementation without the additional presence of improvement routines. The presence of improvement routines only became important from row 30 per cent onwards, meaning that in this set of manufacturing SMEs, developing certain existing improvement routines only became important when some implementation of lean practices had occurred. The first group of improvement routines that were required for lean practice implementation were (vi) "shared problem-solving" (row 30 per cent) and (ii) "getting the improvement habit" (row 40 per cent). As lean implementation increased, (iii) "focussing improvement" and (v) "aligning improvement" (both row 50 per cent) were also required.

At the other end of the spectrum, the last three rows (80–100 per cent) indicate that for more advanced lean practitioners (level 3 of the five-point Likert scale), all improvement routines were present to some extent (at least 29.1 per cent or level 2 of the five-point Likert scale). The extent per routine is again given by the percentage; the higher the percentage, the more that routine was required for more advanced lean practitioners. The most attention was required for (iv) leading the way and (ii) getting the improvement habit, and (i) understanding improvement and (vii) improvement of improvement.

These results indicate that improvement routine criticality differs for various degrees of lean practice implementation. Furthermore, this bottleneck table suggests that in this study's set of manufacturing SMEs, "getting the improvement habit" was required for some as well as more advanced implementation of lean practices. It also shows that "leading the way", "understanding improvement" and "improvement of improvement" were not required for some implementation of lean practices, while they were most important for more advanced lean practitioners. This bottleneck table thus suggests the order in which improvement routines are required to implement lean practices and increase operational performance.

## 5. Propositions on different improvement routines for various degrees of lean practices

The aim of this study was to explore the relative importance of individual improvement routines at various degrees of lean practice implementation for increasing operational performance in manufacturing SMEs. A data set from manufacturing SMEs was analysed using BCCA and NCA.

### *5.1 Improvement routines more important for more advanced lean practice implementation*

This study confirmed that in this set of manufacturing SMEs, lean practices mediated the relationship between improvement routines and operational performance and found that in cases of more advanced lean implementation more improvement routines were required for higher operational performance than in cases with only some lean practice implementation. For some lean practice implementation, managers themselves were able to implement a basic structure of lean, without paying any special attention to improvement routines. For more advanced lean organisations, employees participated in improvement activities while managers could continue to create a lean organisation.

These findings confirm Womack and Jones' (2003) notion about the critical transition when managers should become coaches and employees should become proactive. They replicate Rahman and Bullock's (2005) finding of a mediating effect of lean practices between improvement routines and operational performance. However, in contrast to Rahman and Bullock's findings, the NCA confirms that this is a necessary relationship rather than a linear one.

For SME managers, this means that they can initiate lean practice implementation themselves, yet to further develop the implementation of lean practices, they must pass on the baton and enable and support their employees to identify, work on and learn from improvements while they themselves continue to work on overarching requirements. This study, therefore, proposes that in manufacturing SMEs:

*P1.* Lean practices can be partially implemented without developing improvement routines, yet more advanced implementation of lean practices requires at least some presence of improvement routines.

### *5.2 "Getting the improvement habit" most likely leads to lean practices*

Regarding individual improvement routines, the BCCAs suggest that only the "getting the improvement habit" routine had a linear relationship with and indicated a move towards the implementation of lean practices. Getting the improvement habit means that employees initiate and carry through improvement activities using measurement, tools and techniques. If employees made improvements in this way, lean practices were most likely to be implemented.

This contrasts with de Jager *et al.* (2004), who found that managers saw "focussing improvement" as most important. We believe that this difference is mainly related to the sample, since SMEs usually have no specialised department dedicated to neither lean implementation nor funds to hire consultants and it is, therefore, more important in SMEs that employees carry out and learn from improvements than in larger enterprises. This finding is in line with those of Dabhilkar and Bengtsson (2004), who showed that items corresponding to the improvement habit had the strongest link with actual improvements. This finding is also in line with those of Knol *et al.* (2018), who showed that facilitating actual shop floor improvement activities was most critical to implementing lean practices.

For SME managers, this means that their scarce resources are best spent on helping employees conduct improvement activities, especially if they aim to further develop their lean practice implementation, rather than on things like developing a shared improvement strategy. This study proposes that in manufacturing SMEs:

*P2.* If employees initiate and carry through improvement activities based on measurements, tools and techniques, it is more likely that lean practices will be implemented.

### *5.3 Improvement routines for further implementation of lean practices*

To start implementing lean practices, in this study's set of manufacturing SMEs no special attention for improvement routines appeared necessary. However, a number of improvement routines were required to move beyond some initial lean practice implementation. The first two were "getting the improvement habit" and "shared problem-solving". Getting the improvement habit was already discussed, there is a linear relationship between this routine and the implementation of lean, making it important for both some and more advanced lean practice implementation.

But moving beyond initial implementation of lean practices also requires shared problem-solving. This means that employees demonstrate a holistic and customer-centric view of improvement by cooperating with various hierarchical levels and across internal departments as well as with outside agencies (e.g. customers, suppliers). This finding is in line with Knol *et al.* (2018), who argue that manufacturing SMEs need first to facilitate internal integration. Only when progressing should they integrate suppliers and customers. This is also in line with de Jager *et al.* (2004), Dabhilkar and Bengtsson (2004) and Jørgensen *et al.* (2006), who found that cross-functional improvements were among the most important routines. SME managers that want to go beyond some implementation of lean practices first have to involve their own employees. Only then do they need to involve their suppliers and customers in improvement projects. This is because, in the long run, it is the employees that learn from each other to initiate and carry through improvements. If employees do not initiate measurement-based improvements and do not have a holistic customer-centric view to improve, it is difficult to develop a lean organisation.

The next set of improvement routines is required for further implementation of lean practices were "aligning improvement" and "focussing improvement". Aligning improvement refers to the improvement system being designed and continuously amended to fit within the current organisational structure and infrastructure. It seems to be difficult to continuously improve without the presence of a compatible improvement system. If the improvement system is not aligned with the organisational context, improvements will be frustrated and their effects, if any, will quickly fade. However, this improvement system is no guarantee for the implementation of lean practices, as some cases reported the presence of alignment, but were not lean. Alignment itself does not improve anything; improvement activities are still needed.

Dabhilkar and Bengtsson (2004) found no direct link between alignment and performance. Rather than increasing operational performance directly, alignment is an enabler to continuously improve towards a lean organisation. This finding is in line with de Jager *et al.* (2004), who noted that manufacturing managers considered alignment to be an important improvement routine. SME managers have to ensure that employees work with a suitable improvement system so that they are facilitated when conducting improvement projects to create a lean organisation.

The results also suggest that "focussing improvement" was required to move beyond some implementation of lean practices. This refers to employees' ability to use the organisation's strategic goals and objectives to assess and prioritise improvements, and their ability to monitor the impact of improvements on these goals and objectives. This is in line with findings by de Jager *et al.* (2004), Dabhilkar and Bengtsson (2004) and Jørgensen *et al.* (2006), who all deemed focussing improvement to be (among) the most important of the eight improvement routines. Though it might be difficult for SME managers who are often caught up in daily firefighting, aligning improvements with each other and with the overarching business strategy is needed when managing something as challenging as a transition towards lean. In summary, this study proposes that in manufacturing SMEs:

*P3.* Some initial implementation of lean practices can only exist if: (a) there are employee-initiated improvements, (b) the implementation is conducted across levels and across departments, (c) it uses a proper improvement system and (d) it is in line with the organisational strategy. The presence of the other routines is not yet required.

### *5.4 Improvement routines for more advanced lean practitioners*

Substantial development of four improvement routines was important for the most advanced lean cases in this set of manufacturing SMEs: "getting the improvement habit", "leading the way", "understanding improvement" and "improvement of improvement". "Getting the improvement habit" was already discussed.

"Leading the way" only seems important for more advanced lean practitioners. It refers to managers recognising employees' contributions to improvement and supporting employee experiments. This is in line with de Jager *et al.* (2004) and Dabhilkar and Bengtsson (2004), who found that "leading the way" was important to increasing performance. It is also in line with Knol *et al.* (2018), who note that the need for leadership increases as the number of improvement projects grows. When organisations are more advanced in their lean journey, they are often already running different improvement activities, probably continuously. If so, SME managers have to overcome their intrinsic need to stay in control. Instead, they need to empower more employees to create a company-wide structure of experimentation and learning, while they focus on the overall creation of a lean organisation.

"Understanding improvement" is one of the least important routines for some implementation of lean practices, but it becomes more important when employees initiate improvement activities. This means that employees from all levels demonstrate a shared belief in the value of incremental employee contribution and demonstrate that when something goes wrong, their natural reaction is to look for reasons why rather than to blame individuals. Understanding improvement enabled employees to initiate and continue their own improvement activities. This is in line with de Jager *et al.* (2004) and Jørgensen *et al.* (2006) who found that manufacturing managers believe understanding, articulating and demonstrating improvement are important. SME managers need to know that a lean organisation cannot be fully developed by only a few key actors in top and middle management, nor by lower-level employees who are not ingrained in the improvement philosophy.

The final routine necessary for more advanced lean cases is "improvement of improvement". This refers to the continuous monitoring and review of the improvement system in relation to the organisation as a whole, leading to its amendment or regeneration. Strategic development of the improvement system does not directly improve products or processes, especially in cases with limited lean practice implementation. However, in more advanced cases it seems important to facilitate the improvement culture.

This contrasts with Dabhilkar and Bengtsson (2004), who found no link between improvement of improvement and operational performance. Their findings were based on novel improvement practitioners; this study also reports that improvement of improvement is not yet necessary in these cases.

Our finding supports those of Jørgensen *et al.* (2006) who indicated that in 543 manufacturers from ten European, Asian and Australian countries, improvement of improvement was considered the third most important improvement routine. SME managers that want to improve the structure of lean also have to develop, learn about and improve their improvement system to do so. This study proposes that in manufacturing SMEs:

*P4.* Advanced implementation of lean practices can only exist if there is extensive presence of: (a) employee-initiated improvements, (b) employee understanding, (c) management involvement and support and (d) adjustment of the improvement system.

### *5.5 Non-necessary improvement routines for lean practices*

The results further suggest that in this study's set of manufacturing SMEs, one routine – "a learning organisation" – was less required than the others. In the definition used here, a learning organisation refers to using a formal knowledge management system through which employees at all levels articulate, consolidate and share their learning. This finding contrasts with those of de Jager *et al.* (2004) and Jørgensen *et al.* (2006), who report that managers view a learning organisation as important. For SMEs, however, this routine may appear more important than it actually is – Dabhilkar and Bengtsson (2004) also found that it only explained a very limited portion of variance in relation to improvement.

It seems that formal structures of a learning organisation may contribute to better improvement activities in the long term, helping organisations to become lean rather than increasing operational performance directly. In SMEs in particular, lines of communication are short and learning is often more informal. This paper, therefore, argues in line with Matthews *et al.* (2017) that a formalised system for managing knowledge is likely to be more important for larger organisations. This study's sample did not allow for comparison with large enterprises, leaving the question of the importance of a learning organisation for larger enterprises open for future research.

In conclusion, SME managers are advised that having a formal learning organisation on its own does not improve processes. Other routines are more important for conducting improvement activities, namely developing an improvement culture and transitioning into a lean organisation. This study, therefore, proposes that in manufacturing SMEs:

*P5*. Some implementation of lean practices as well as more advanced forms can exist without formal articulation, consolidation and sharing of learning.

In general, and in line with the five lean principles described by Womack and Jones (2003), this study found that manufacturing SME managers can, to some extent, initiate and implement lean practices themselves. However, to reap the full benefits of lean and to continuously increase operational performance, managers have to also focus on improvement routines, namely on stimulating their employees to initiate improvement, fostering their understanding and improving the system as such. Sustaining a stable pattern of improvement efforts helps develop organisational learning, enabling the continuous improvement of their lean practices and increasing their operational performance.



### *5.6 Theoretical contributions*

These insights into the importance of improvement routines and their relationship with lean contribute to the existing literature in four ways. First, using quantitative data, this study confirms the findings of earlier studies (Bessant *et al.*, 2001; Womack and Jones, 2003) that improvement routine importance depends on an organisation's position in their lean journey. Second, this study suggests the order in which improvement routines have to be developed and provides propositions for further research using longitudinal studies and/or larger samples. Third, this study shows that a stable pattern of improvement activities adds to the development of organisational learning and an organisation's dynamic capability. And fourth, using an NCA, this study also makes a methodological contribution, as it allows to analyse relationships in the field of operations management more specifically. The majority of methods use either statistical correlation or case studies. Using the ceiling lines and bottleneck table, NCA enables an investigation of the varying degrees of necessity for different conditions, linked to varying degrees of a particular outcome. This method thus gives a deeper understanding of how management practices affect organisational performance.

### *5.7 Practical implications*

These new insights into the relative value of improvement routines can help manufacturing SME managers in two ways. First, they help managers pursue those improvement routines that are most suitable for their position in the lean journey. If the organisation has only developed lean practices to a limited degree, managers should lead employees to take initiative by introducing improvement activities themselves. If the organisation is more advanced in lean, managers should focus their attention on creating consistency in the different projects and develop a more mature improvement structure.

Second, understanding the order in which improvement routines are important to develop a lean organisation helps managers deploy their resources more effectively. If certain routines are sufficiently present, resources can be spent on the remaining bottleneck routines. This sustains resource efficiency and increases the possibility that the value streams are developed, thereby increasing operational performance.

## 6. Recommendations for future research

This study was based on a Dutch sample and small set of cases, which does not allow for generalisation to other contexts and types of companies. Although Dabhilkar *et al.* (2007) found no national differences amongst the relationships between improvement routines and operational performance, this study took a novel approach. Future research should replicate this approach and study improvement routines as necessary conditions in different countries and industries, and/or use suitable samples to test the propositions developed in this study. This should preferably be done using longitudinal data to provide more insights into the interrelationships between individual improvement routines. In addition to replication studies, more in-depth studies should be conducted on the importance of improvement routines to better understand the underlying reasons for their relative importance and their dynamic relationship with lean.

Regarding the NCA method, other exciting opportunities for future research emerge. This study used linear ceiling lines to show the relationship between improvement routines and lean practices. This could be further refined using discontinuous or exponential functions. Furthermore, traditional analyses for mediation do not allow for relationships to be asymmetrical, so further development of this approach is required. The NCA approach could also be used to investigate other relationships to provide further improvement focus for increasing operational performance.

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## Appendix 1. Improvement routines

This appendix gives an overview of the different improvement routines listed in the literature. These routines were first conceptualised by Bessant and Caffyn (1997) and later developed by Bessant *et al.* (2001). After Bessant finished his research, de Jager *et al.* (2004), Dabhilkar and Bengtsson (2004) and Dabhilkar *et al.* (2007) altered the conceptualisation of the improvement routines based on, respectively, a case study and a statistical analysis. The routines of de Jager *et al.* (2004) show great overlap with the ones listed by Bessant *et al.* (2001). The ones Dabhilkar and Bengtsson (2004) found differ, but Dabhilkar *et al.* (2007) again found routines that were more in line with Bessant *et al.* (2001). An overview is given in Table AI.

## Appendix 2. Accuracy and effect size

To determine the validity of the ceiling lines, two parameters were calculated: accuracy and effect size. The accuracy of improvement routines depends on the number of observations on or above the ceiling lines. Dul (2016, p. 28) defines accuracy as "the number of observations that are on or below the ceiling line, divided by the total number of observations, multiplied by 100%". Because there can be observations above the ceiling line, the empty space is henceforth referred to as the "ceiling zone". If there were many observations above the ceiling line and in the ceiling zone, the improvement routines would not always be necessary for implementing lean practices. So, the more observations found above the ceiling line, the less accurate the indication of improvement routine criticality for implementing lean practices.

The NCA software further provides the improvement routine accuracies shown in Table AII. As the CE is a piecewise-linear line through the upper-left observations, the ceiling zone positioned left of the CE line was completely empty. This results in an accuracy of 100 per cent; the CE line was valid

**Table AI.**
Improvement routines by author and their definition

| | Bessant and Caffyn (1997) | Bessant *et al.* (2001) and Dabhilkar *et al.* (2007) | De Jager *et al.* (2004) | Dabhilkar and Bengtsson (2004) | Definition |
|---|---|---|---|---|---|
| (i) | Walking the talk | Understanding improvement | Understanding improvement behaviour | n/a | Employees from all levels demonstrate a shared belief in the value of incremental employee contribution and, when something goes wrong, their natural reaction is to look for reasons why rather than to blame individuals |
| (ii) | Getting the improvement habit | Getting the improvement habit | Consistency in improvement | n/a | Employees initiate and carry through improvement activities using measurement, tools and techniques |
| (iii) | Focussing improvement | Focussing improvement | Strategy deployment behaviour | n/a | Employees use the organisation's strategic goals and objectives to assess and prioritise improvements, and they can monitor the impact of improvements on these goals and objectives |
| (iv) | Leading the way | Leading the way | Improvement leadership | n/a | Managers recognise employees' contributions to improvement and support employee experiments |
| (v) | n/a | Aligning improvement | n/a | n/a | The improvement system is designed and continuously amended to fit within the current organisational structure and infrastructure |
| (vi) | Spreading the word | Shared problem-solving | Cross-functional improvement | n/a | Employees demonstrate a holistic and customer-centric view in improvement by cooperating with various hierarchical levels and across internal departments, as well as with outside agencies (e.g. customers, suppliers) |
| (vii) | n/a | Improvement of improvement | n/a | n/a | The improvement system is continuously monitored and reviewed in relation to the organisation as a whole, leading to its amendment or regeneration |
| (viii) | Building the learning organisation | The learning organisation | Idea management/participation in improvement | n/a | Employees at all levels articulate, consolidate and share their learning (e.g. using a formal knowledge management system) |
| (ix) | n/a | n/a | n/a | Systematic and strategic improvement | A formal improvement system has been introduced to involve all employees in ongoing improvement activities. Employees use measurement and appropriate tools and techniques to shape these improvement activities and they measure and monitor the results and their impact on organisational objectives |
| (x) | n/a | n/a | n/a | Customer and supplier involvement | Employees use supplier and customer feedback as a means to do improvement projects with them and improve performance |
| (xi) | n/a | n/a | n/a | Idea management and reward systems | Ideas and suggestions for improvement are responded to in a clearly defined and timely fashion and employees' contributions to improvement activities are recognised in formal but not necessarily financial ways |
| (xii) | n/a | n/a | n/a | Strategic knowledge deployment | Managers display leadership and active commitment to ongoing improvement activities and employees understand the organisational goals and objectives. Improvement activities are assessed against these objectives, employees learn from their improvements and appropriate mechanisms are used to deploy this learning across the organisation |

| Construct | Method | Accuracy (%) | Scope | Ceiling zone | Effect size |
|---|---|---|---|---|---|
| (1) Understanding improvement | CE | 100.00 | 2.167 | 0.286 | 0.132 |
| | CR | 89.50 | 2.164 | 0.383 | 0.177 |
| (ii) Getting the improvement habit | CE | 100.00 | 2.068 | 0.550 | 0.266 |
| | CR | 92.10 | 2.067 | 0.556 | 0.269 |
| (iii) Focussing improvement | CE | 100.00 | 2.358 | 0.540 | 0.229 |
| | CR | 84.20 | 2.360 | 0.498 | 0.211 |
| (iv) Leading the way | CE | 100.00 | 2.363 | 0.371 | 0.157 |
| | CR | 97.40 | 2.364 | 0.312 | 0.132 |
| (v) Aligning improvement | CE | 100.00 | 2.497 | 0.497 | 0.199 |
| | CR | 86.80 | 2.500 | 0.495 | 0.198 |
| (vi) Shared problem-solving | CE | 100.00 | 3.309 | 0.877 | 0.265 |
| | CR | 81.60 | 3.306 | 0.843 | 0.255 |
| (vii) Improvement of improvement | CE | 100.00 | 3.101 | 0.369 | 0.119 |
| | CR | 84.20 | 3.095 | 0.489 | 0.158 |
| (viii) The learning organisation | CE | 100.00 | 2.266 | 0.315 | 0.139 |
| | CR | 92.10 | 2.266 | 0.324 | 0.143 |

**Table AII.**
NCA parameters of eight improvement routines linked to lean practices

for all cases. The ceiling zone above the CR line, however, did contain cases, hence its accuracy was not 100 per cent. This lower accuracy may result from the limited number of cases and/or larger ceiling zones. Fewer cases increase the ratio of outliers compared to all cases, and with an equal distribution of cases, a larger ceiling zone leaves more room for outliers. Table AII shows a lower accuracy for larger ceiling zones. Given the limited number of cases in this study, the resulting CR line was considered valid for determining improvement routine necessity and thus could be used in the bottleneck table.

Because almost every scatterplot contains a ceiling zone in its upper-left corner, no matter how small, the size of the ceiling zone is also important. The smaller the size, the less effect the improvement routine has on the implementation of lean practices. It was, therefore, important to calculate the effect size of the improvement routines (i.e. how small their enabling effect was on the implementation of lean practices).

Dul (2016) defines the effect size ($d$) as the size of the ceiling zone ($C$) divided by the scope of all observations ($S$), or $d = C/S$. For example, the ceiling zone of (i) understanding improvement divided by its scope gives the effect size 0.383/2.164 = 0.177. As such, the effect size can range from 0 to 1. To establish the importance of the effect size, Dul (2016) proposes a general benchmark of $0 < d < 0.1$ as a small effect, $0.1 < d < 0.3$ as a moderate effect, $0.3 < d < 0.5$ as a large effect and $0.5 < d$ as a very large effect, possible for CE only. The smaller the effect size of the improvement routine, the less sensitive the implementation of lean practices was to the absence of the improvement routine.

The results are given in Table AII. A medium effect was found for all improvement routines. So, for some and for moderate implementation of lean practices, the implementation of lean practices is sensitive to all improvement routines.

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