On the Implementation of Lean Production in Manufacturing SMEs

PhD dissertation by Wilfred H. Knol
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On the Implementation of Lean Production in Manufacturing SMEs

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On the Implementation of Lean Production in Manufacturing SMEs

Dissertation

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according to the decision of the Doctorate Board
to defended in public on

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at 12.30 pm

by

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HAN University of Applied Sciences
Michigan State University, United States
Norwegian University of Science and Technology, Norway
To my wife and children
Indefessus Agendo
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<tr>
<td>5S</td>
<td>Abbreviation for Sort, Simplify, Scan, Standardize, Sustain. 5S is an approach to reduce waste, reduce variation and improve productivity on the shop-floor.</td>
<td>(Bicheno &amp; Holweg, 2016)</td>
<td>47</td>
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<td>A3</td>
<td>Problem solving and communication format, presenting an issue on an A3 paper template. A3 is considered a tool for CI and thus for Lean Production.</td>
<td>(Bicheno &amp; Holweg, 2016; Oversluizen &amp; Slomp, 2021)</td>
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<td>Artefacts</td>
<td>Structures external to actors, either physical (e.g., machines and products) or intangible (e.g., software and standards). They can range from single documents to systems of interdependent artefacts.</td>
<td>(Cacciatori, 2012; Hutchins, 1995)</td>
<td>51</td>
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<td>Continuous Improvement (CI)</td>
<td>Management concept covering “the planned, organised and systematic process of ongoing, incremental and companywide change of existing practices aimed at improving company performance.” CI includes: principles such as Perfection; meta-routines such as TQM; practices such as the initiation and performance of Kaizen activities.</td>
<td>(Boer, Berger, Chapman, &amp; Gertsen, 2018, p.1)</td>
<td>26</td>
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<tr>
<td>Continuous Improvement (CI)</td>
<td>The recognizable patterns of interdependent actions, involving multiple actors, that fall under CI.</td>
<td>NA</td>
<td>26</td>
</tr>
<tr>
<td>Critical Success Factors (CSFs)</td>
<td>Management areas that need to be in place to enable the implementation of Lean Production. CSFs are not sufficient, they do not produce, but rather are necessary for Lean Production implementation.</td>
<td>(Saraph, Benson, &amp; Schroeder, 1989)</td>
<td>30</td>
</tr>
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<td>DMAIC</td>
<td>Abbreviation for Define, Measure, Analyse, Improve, Control/Check. DMAIC is a sequence of steps to cyclically solve problems and improve processes using process data. Similar to PDCA, though it focuses more on the plan stage. DMAIC is commonly used in Six Sigma.</td>
<td>(Bicheno &amp; Holweg, 2016)</td>
<td>163</td>
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<tr>
<td>Enacting of routines</td>
<td>See ‘Performative aspect of routines’. Enacting of routines is an alternative term for the performative aspect of routines. They can be and are used interchangeably.</td>
<td>(Feldman, 2016)</td>
<td>32</td>
</tr>
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<td>Intervention-Based Research (IBR)</td>
<td>Research method to empirically test the usefulness and applicability of existing theory by intervening in the research setting. IBR differs from case studies as researchers intervene in the research setting. IBR also differs from action research as it are the researchers rather than employees themselves that conduct this intervention.</td>
<td>(Oliva, 2019)</td>
<td>33</td>
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<tr>
<td>Just-in-Time (JIT)</td>
<td>Approach and set of meta-routines to reduce times in the entire supply chain (between customers and suppliers and the organization as well as inside the organization) by delivering materials, components and information right before they are required. JIT is considered an approach within Lean Operations and thus Lean Production.</td>
<td>(Mackelprang &amp; Nair, 2010; Sakakibara, Flynn, Schroeder, &amp; Morris, 1997)</td>
<td>45</td>
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<tr>
<td>Kanban</td>
<td>Operating system that uses product related instruction cards to regulate the supply of materials, components and information to limit work in process. Kanban is considered a system for Pull and thus for JIT, Lean Operations and Lean Production.</td>
<td>(Bicheno &amp; Holweg, 2016)</td>
<td>31</td>
</tr>
<tr>
<td>Lean Operating Routines</td>
<td>The recognizable patterns of interdependent actions, involving multiple actors, that fall under Lean Operations.</td>
<td>NA</td>
<td>31</td>
</tr>
<tr>
<td>Lean Operating Structures</td>
<td>Rules and resources, recursively implicated in the reproduction of Lean Operations.</td>
<td>NA</td>
<td>26</td>
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</table>
| Lean Operations                           | Management concept that focuses on what an organization does, given its customer requirements, capabilities, stock, procedures, equipment etc., Lean Operations includes:  
  - principles such as Flow and Pull;  
  - meta-routines such as JIT and supplier integration;  
  - practices such as the use of Kanban, squares or containers for production control.  
  Lean Operations is considered a concept within Lean Production. | (extended on Nelson & Winter, 1982) | 26                       |
<p>| Lean Practices                            | The manifestation of Lean Production in actual activities and routines in and between organizations. Lean operating routines and CI routines are both considered Lean practices. | (Shah &amp; Ward, 2003, 2007) | 27                       |</p>
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<tr>
<td>Lean Production</td>
<td>Management concept that emphasises customer value, expressed in operational performance objectives such as quality, delivery, and cost, through a flow of activities in which all employees are focused on removing non-value adding elements in the process. Following Nelson and Winter’s (1982) distinction between operating and search or improvement routines, in this dissertation Lean Production consists of both Lean Operations and CI.</td>
<td>(Imai, 1986; Nelson &amp; Winter, 1982; Ōno, 1988; Sugimori, Kusunoki, Cho, &amp; Uchikawa, 1977; Womack, Jones, &amp; Roos, 1991)</td>
<td>10</td>
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<td>Necessary Condition Analysis (NCA)</td>
<td>Research method to identify necessary but not sufficient conditions in data sets. A necessary condition must be present to achieve an outcome: if the condition is not in place the outcome will not occur. But its presence is not sufficient to achieve the outcome: if the condition is in place, there is no guarantee that the outcome will occur.</td>
<td>(Dul, 2016, 2018)</td>
<td>31</td>
</tr>
<tr>
<td>Operational Performance</td>
<td>The primary process objectives of an organization measured in terms of flexibility, speed, dependability, quality, and cost.</td>
<td>(Slack, Chambers, &amp; Johnston, 2010)</td>
<td>26</td>
</tr>
<tr>
<td>Organizational Routine</td>
<td>“(Repetitive, recognizable pattern of interdependent actions, involving multiple actors.” Both Lean operating and CI routines are considered organizational routines.</td>
<td>(Feldman &amp; Pentland, 2003, p. 96)</td>
<td>29</td>
</tr>
<tr>
<td>Ostensive aspect of routines</td>
<td>Structures internal to actors: “the ideal or schematic form of a routine. It is the abstract, generalized idea of the routine or the idea in principle.” The ostensive aspect of routines relates to the patterning of routines. Though the ostensive aspect puts more emphasis on the internal side of routines, what goes on in the head.</td>
<td>(Feldman &amp; Pentland, 2003, p. 101)</td>
<td>32</td>
</tr>
<tr>
<td>Patterning of routines</td>
<td>The socially shared embodiment (more than something that goes on in the head) of organizational routines. Patterning relates to the ostensive aspect of routines. Though patterning incorporates, next to the internal side, more the embodiment of routines.</td>
<td>(Feldman, 2016)</td>
<td>29</td>
</tr>
<tr>
<td>PDCA/PDSA</td>
<td>Plan, Do, Check/Study, Act/Adjust. Sequence of steps to cyclically solve problems and improve. Also known as the Shewhart or Deming cycle. PDCA is similar to DMAIC, though it focuses more on experimenting. PDCA is commonly used in Lean Production. PDCA/PDSA is considered a tool for CI and thus for Lean Production.</td>
<td>(Bicheno &amp; Holweg, 2016)</td>
<td>163</td>
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<tr>
<td>Term</td>
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</tbody>
</table>
| Performative aspect of routines           | “The specific actions, by specific people, in specific places and times. It is the routine in practice.”  
The performative aspect of routines is an alternative term for the enacting of routines. They can be and are used interchangeably.                                                                                                                                             | (Feldman & Pentland, 2003, p. 101)                 | 32                       |
| Pull system                               | Operating system that "explicitly limits the amount of work in process that can be in the system." Job release is determined by the work in process at the next station; only when the next station is ready for it, this system sends a signal (e.g. a card) to the previous station to resume work. Pull is considered a system for JIT and thus for Lean Operations and Lean Production. | (Hopp & Spearman, 2004, p. 142)                    | 31                       |
| Push system                               | Operating system “that has no explicit limit on the amount of work in process that can be in the system.” Job release is the result of job arrival at the same station; this station can continue production, even if the next station has no capacity to process this work, e.g. due to machine downtime.                                                                                   | (Hopp & Spearman, 2004, p. 142)                    | 139                      |
| Routine Dynamics                          | “Research that orients to the internal dynamics of routines and takes as focal [point] the actions of human and non-human agents and the patterns created through those actions.”                                                                                                                                                    | (Feldman, 2016, p. 27)                             | 35                       |
| Small and Medium-Sized Enterprises [SMEs] | Companies that employ 10-250 employees.                                                                                                                                                                                                                                                                                                   | (EC 2005)                                          | 26                       |
| Structure                                 | “Rules and resources, recursively implicated in the reproduction of social systems. "Structure can be both external [artefacts] and internal [ostensive aspect] to actors.”                                                                                                                                                              | (Giddens, 1984, p. 377; Stones, 2005)              | 26                       |
| Total Productive Maintenance (TPM)        | Approach and set of meta-routines to maximize equipment effectiveness by promoting its maintenance and improvement by the teams and individual employees that impact on it, as well as management and engineers. TPM is an approach for CI and thus within Lean Production.                                                                                      | (McKone, Schroeder, & Gua, 1999, 2001)            | 42                       |
| Total Quality Management (TQM)            | Approach and set of meta-routines to continuously improve products and processes across all organizational disciplines (marketing, sales etc. as well as production) and by all hierarchical levels (top management, team leaders and employees). TQM is a more holistic continuation of Total Quality Control and its more specific predecessor Quality Control. TQM is an approach for CI and thus within Lean Production. | (Hackman & Wageman, 1995)                         | 42                       |
1. INTRODUCTION
1. RESEARCH IMPETUS

In this dissertation, I address the implementation of lean production for manufacturing small and medium-sized enterprises (SMEs). These manufacturing SMEs are essential to a nation’s economy: globally, they contribute to almost half a country’s gross domestic product and provide work for more than half its labour force (Ayyagari, Beck, & Demirguc-Kunt, 2007). In addition, large manufacturing enterprises (LEs) depend on entire networks of manufacturing SMEs for their supplies. Due to globalization, manufacturing SMEs are increasingly faced with global competition on operational performance capabilities such as quality, delivery and costs (Slack et al., 2010), and many struggle to survive (Armstrong, 2013). To increase their operational performance, they often turn to lean production (McGovern, Small, & Hicks, 2017), a management concept that emphasises customer value through a flow of activities in which all employees are focused on removing non-value adding elements in the process (Imai, 1986; Ōno, 1988; Sugimori et al., 1977; Womack et al., 1991). For manufacturing SMEs however, implementing lean production can be challenging (Shah & Ward, 2003).

1.2. KNOWLEDGE GAP AND MAIN RESEARCH QUESTION

To implement lean production, the literature identifies two approaches. In general, everyone agrees that both lean operations and continuous improvement (CI) are important (Cua, McKone, & Schroeder, 2001; Flynn, Sakakibara, & Schroeder, 1995; Shah & Ward, 2003). Lean operations relates to the primary structures and activities that deliver customer value, while CI relates to the structures and activities that improve those of the lean operation. The sequence of and interplay between lean operations and CI however is less unambiguous. The first approach focuses on implementing lean operating structures in order to develop local team leader and employee CI routines later on. The second approach focuses on developing local CI routines in order to implement lean operating structures. These two approaches are elaborated on below.

According to Womack and Jones (2003, p. 269), it is important to first implement lean operating structures to subsequently develop local CI routines. This emphasis on lean operating structures that trigger shop-floor improvements is also reflected in the pyramid model developed by Liker (2004). This model depicts operating principles as the foundation for the improvement principles at the pyramid’s peak. Though both Womack and Jones (2003) and Liker (2004)
stress the importance of improvement, they also consistently list the lean operations related principles before those of the people and improvement. This emphasis has been incorporated into the academic literature. Most notably, in Shah and Ward’s (2007) most frequently cited measuring instrument on lean practices, only one of the ten constructs explicitly covers the conceptual space surrounding employee related improvement activities. Lean practices are the manifestation of lean production in actual activities and routines. This emphasis has been further translated to intervention studies. For example, Done et al. (2011, p. 504) designed a best practice intervention to implement lean practices in which they train an expert facilitator rather than team leaders and employees to conduct an improvement project and implement lean operating structures.

This stream of literature argues that implementing lean production starts with top-down implementation of lean operating tools and techniques to develop local CI routines later on. This is also what often happens in practice. As a research group, we have supported over 50 manufacturing SME managers with implementing lean production. From this experience, we noticed that managers often have ideas about lean tools and techniques that could work in their operations. To showcase the benefits of these ideas, they tend to implement these themselves in a top-down fashion, with the intention of involving team leaders and employees to conduct their own improvement projects over time.

This is not to say that this is the only way. Other experts in the field put a different emphasis on the sequence of and interplay between lean operations and CI. For example, Spear and Bowen (1999, p. 98) describe the DNA of the Toyota Production System, listing three rules that show how Toyota sets up all its operations as experiments to learn from, and an additional rule that shows how Toyota teaches the scientific method to its managers and employees at every level of the organization. Similarly, from the Toyota study Rother (2010) explains how the improvement routine and the coaching routine enable Toyota to make CI core to their entire production system. This emphasis on team leader- and employee-led CI is also found in the academic literature. In his survey of the world automotive industry, MacDuffie (1995) showed that the best performing organizations integrated lean practices with innovative HR practices such as quality circles and root cause analyses. This emphasis has also been translated to intervention studies in which, for example, Bateman and Rich (2003, pp. 189-191) take an integrated approach in which experts and employees work together in a
team to implement lean practices.

This stream of literature argues that implementing lean production starts with developing local team leader and employee CI routines in order to implement lean operating tools and techniques. This approach aligns well with ‘The Toyota Way’, the managerial approach introduced in 2001 at Toyota that stresses the importance of respect for people and CI. This managerial approach aims to develop all employees in Toyota to continuously think of, initiate, and implement improvements in their work. Rather than taking ownership, managers are encouraged to help their team leaders and staff conduct their own improvements as it is considered disrespectful to deprive employees of their opportunity to learn for themselves (Sugimori et al., 1977).

Given the two different approaches, the literature is ambiguous in its recommendations about implementing lean production. Additionally, books and papers in the lean production literature mostly provide prescriptive approaches and guidelines, without a sound empirical foundation. Additionally, most research on lean production implementations focuses mainly on large manufacturing enterprises. As manufacturing SMEs are inherently different, more research on lean production implementations in manufacturing SMEs is needed. In sum, it is unclear which approach is most suitable for manufacturing SMEs to implement lean production. There is a need for a structural and empirical analysis of lean approaches, specifically for manufacturing SMEs. To better understand what to focus on in order to implement lean production in manufacturing SMEs, and its temporal order, the main research question in this dissertation is: Which organizational aspects are most important for lean production implementation in manufacturing SMEs, and how do these evolve over time? Answering this question will provide empirical insights into which approach is most suitable for implementing lean production and increasing operational performance, specifically for manufacturing SMEs.

1.3. RESEARCH DESIGN
The two different lean production approaches described above are considered part of the philosophical perspective on lean production (Shah & Ward, 2007). Both approaches have their own guiding principles and overarching goals. As these can be difficult to study, to find which approach is most suitable
for manufacturing SMEs, I studied lean production implementations from infrastructural, practical, and organizational routine perspectives. Taking these different perspectives also helps overcome any bias that might occur from taking a single perspective. These perspectives are taken in the first three studies of this dissertation.

The lean production literature frequently studies implementations from an infrastructural perspective (Ahmad, Schroeder, & Sinha, 2003; Anand, Ward, Tatikonda, & Schilling, 2009; Sakakibara, Flynn, Schroeder, & Morris, 1997). The infrastructural perspective focuses on aspects that enable lean practice implementation, such as critical success factors. In the first study I took the infrastructural perspective given its frequent use and focus on enabling aspects. Taking the infrastructural perspective provides a better understanding of the importance and stage dependencies of these infrastructural aspects.

In addition to the philosophical and infrastructural perspective, the lean production literature also describes a practical perspective (Li, Rao, Ragu-Nathan, & Ragu-Nathan, 2005; Shah & Ward, 2003). The practical perspective regards the set of lean operating and CI practices, tools, and techniques that can be readily observed (Shah & Ward, 2007). The practical perspective focuses on the main aspects that entail lean operations and CI. In the second study I used the practical perspective as it helps to identify lean operating and CI aspects. Taking a practical perspective provides a better understanding of the importance and stage dependencies of lean operating and CI aspects.

In the third study, to better understand the interplay between lean operating and CI activities, I took the organizational routines perspective (Adler, Goldoftas, & Levine, 1999; Peng, Schroeder, & Shah, 2008; Teece, Pisano, & Shuen, 1997). Organizational routines are comprised of shared enactment and shared understanding (patterning) (Feldman, 2016). Drawing on the concepts of enacting and patterning, I use the organizational routines perspective to zoom in on the interplay between lean operating and CI routines. Zooming in on operating and CI routines helps explain the interplay between them.

To understand how the findings from the first three studies could be translated to practice, I conducted a fourth study. In this I combine the findings from the first three studies to design a prototype intervention. As such, the study showcases an
approach to implement lean production in one manufacturing SME. Each of the perspectives provides a better understanding of which approach is most suitable to implement lean production in manufacturing SMEs. The constellation of the four studies is depicted in Figure 1. The studies are elaborated on below.

![Figure 1: Overview of this research](image)

**1.3.1. Study 1: Testing critical success factors for lean practice implementation**

The first study takes the infrastructural perspective which implies that for coordinating and supporting lean operations, certain infrastructural conditions or critical success factors have to be in place. Critical success factors are management areas that are not sufficient but need to be in place (Saraph et al., 1989) to enable lean production implementation. Examples are top management support, a shared improvement vision, leadership, and improvement training (Achanga, Shehab, Roy, & Nelder, 2006; Sila & Ebrahimpour, 2003). The term CSF gives the impression that their importance is universal; when in place, success is guaranteed. Furthermore, this perspective stresses that the presence of top management support, an improvement vision, and leadership is critical to achieve success, hinting at a more top-down approach. Netland (2016) argues
that the importance of critical success factors depends on the degree of lean practice implementation. However, their criticality has not yet been tested; this gap is covered in this first study.

Study 1 tests the criticality of success factors for lean practice implementation. Testing criticality helps us understand what to focus on when managing and maintaining specific critical success factors in different stages of lean implementation. Study 1 answers the question: 1. To which extent are success factors critical to enact different degrees of lean practices in manufacturing SMEs? To answer this question, I conducted a quantitative analysis at a firm level. Multiple respondent survey data were analysed using the novel Necessary Condition Analysis (NCA) method (Dul, 2016). Rather than a relationship in which more x is symmetrically linked to more y, NCA considers an asymmetrical relationship in which more x is necessary but is no guarantee for more y. Conducting the NCA generated several parameters and a so-called bottleneck table, all of which helped to test the degree of criticality of critical success factors for different degrees of lean practice implementation. This infrastructural perspective on the most important enabling aspects gives a first impression of the most suitable approach to implement lean production in manufacturing SMEs.

1.3.2. Study 2: The relative importance of continuous improvement routines for lean practice implementation

The second study takes the practical perspective. The practical perspective considers lean operating routines and CI routines. An example of a lean operating routine or lean practice is “We use Kanban … for production control” (Shah & Ward, 2007, p. 803). An example of a CI routine is “people (as individuals and/or groups) initiate and carry through CI activities” (Bessant, Caffyn, & Gallagher, 2001, p. 72). Research shows that the best performing organizations combined both lean practices and CI routines (Cua et al., 2001; Flynn, Sakakibara, et al., 1995; Shah & Ward, 2003). Womack and Jones (1996, p. 269) suggest that to develop this type of organization, it is important that managers first initiates structure interventions (establishing flow and pull) before they engage team leaders and employees to initiate CI (aiming for perfection). However, this stage-dependent importance of CI routines has not been explored in practice, therefore in Study 2 I examine this in relation to CI routines.
I explored the relative importance of CI routines for lean practice implementation to gain an understanding of what to focus on to develop specific routines at different stages of lean implementation. The second study sets out to answer the question: 2. What is the relative importance of continuous improvement routines to enact different degrees of lean practices in manufacturing SMEs? To answer this question, I again conducted a quantitative analysis on a firm level. Multiple respondent survey data were analysed. I first tested whether CI routines are symmetrically linked to lean practice implementation. As most CI routines are assumed to be necessary for different degrees of lean practice implementation, they were also analysed using NCA. Combining the symmetrical analysis with the NCA’s parameters and bottleneck table allowed me to explore the relative importance of CI routines for different degrees of lean practice implementation. This practical perspective on the importance of CI routines further indicates the most suitable approach to implementing lean practices in manufacturing SMEs.

1.3.3. Study 3: Establishing the interplay between lean operating and continuous improvement routines: a process view

To better understand the interplay between lean practices and CI routines, the third study takes an organizational routines perspective. This perspective considers lean production as a set of interrelated bundles of routines. Lean production consists of lean operating and CI routines (Cua et al., 2001; Flynn, Sakakibara, et al., 1995; Shah & Ward, 2003). Feldman and Pentland (2003) differentiate between enacting (linked to the performative aspect) and patterning (linked to the ostensive aspect) routines and explain that both aspects are mutually constitutive; enacting routines continuously drive patterning routines and vice versa. Integrating both streams of literature implies that the enacting of lean operating and CI routines helps to pattern these routines, respectively. However, it is unclear how this works exactly. Additionally, it is unclear how actors move from traditional routines to lean operating and CI routines. This lack of clarity is addressed in the third study.

Study 3 thus focuses on what actors do to move towards and between lean operating and CI routines. Explaining this interplay will help design more specific interventions to implement lean production. The study answers the question: 3. How do lean operating and continuous improvement routines develop during a lean production implementation? A processual understanding of organizations is required to address this question (Van De Ven & Poole, 2005). A process view aims to open the black box of a transformation process to explain how
relationships between the studied constructs arise (Sinha & Van De Ven, 2005). To this end, Three manufacturing SMEs were selected for a qualitative analysis on a routine level. Data analysis led to an empirical model explaining what actors did to move towards and between lean operating and CI routines. In addition to the first two studies, this organizational routines perspective sheds a third light on the most suitable approach to implementing lean production in manufacturing SMEs.

1.3.4. Study 4: Prototyping a routine-building intervention to implement lean production

Studies 1 and 2 indicate the extent to which different aspects are necessary for different levels of lean practice implementation. Study 3 unfolds lean production implementations to explain how successful interventions differed from unsuccessful events. In Study 4, I draw on these findings to prototype an intervention for implementing lean production. Additionally, I apply this intervention in a manufacturing SME to showcase how enacting CI routines helped to pattern and enact lean operating routines. The term prototype means that the intervention is not a foolproof approach to implementing lean production; it gives an indication of how the insights from the previous chapters can be used in one manufacturing SME. The findings lead to transferable insights on the most important aspects to implement lean production in manufacturing SMEs, and how these evolve over time.

Study 4 thus showcases a prototype intervention to implement lean production in a Dutch manufacturing SME. This will help manufacturing SME managers to reflect on their own approach. The fourth study answers the question: 4. Which elements of an intervention can build CI routines to pattern and enact lean operating routines? I conducted a qualitative analysis on a routine level, developing CI routine building exercises using intervention-based research (IBR). IBR takes action research principles and the process theory framework to leverage interventions as a mechanism for testing and developing theories (Oliva, 2019). The routine building exercises were followed up by coaching sessions to help employees build the CI routines and investigate their effects on the implementation of lean operating routines. Building routines like this improves our understanding of the interplay between lean operating and CI routines, leading to transferable insights on a suitable approach to implement lean production in manufacturing SMEs.
1.4. REFLECTION ON RESEARCH DESIGN

The four studies in this dissertation help provide a better understanding of which approach is most suitable to implement lean production in manufacturing SMEs. Each of these studies takes a specific perspective on lean production and is guided by its own research methodology. In this section, I reflect on the how and why of this research design.

Initially, the focus on critical success factors and CI routines led me to take a variance view and a quantitative approach as this is also the approach taken in most of the literature on lean production; practitioner research describes (bundles of) lean practices in relation to operational performance. In turn, scientific research conducts large cross-sectional surveys to validate and test these dependent and independent variables and their interrelations. Critical success factors and CI routines were described from case studies but not yet tested using necessity logic in quantitative studies. As these had not yet been tested, in Studies1 & 2, I used a deductive methodology. Hence, these concepts were studied in a static manner using an objective and etic approach, in line with a more positivist approach. Using the findings helped identify areas to focus on in order to implement lean production. However, these studies also showed that this variance approach did not suffice to explain in detail what organizations actually do to implement lean production and which activities are most important for lean production implementation in manufacturing SMEs.

Statistics merely scratch the surface, they draw attention to issues, but do not help you really see anything. Quantitative research gives an impression of the relative importance of concepts in relation to each other and/or to performance, but it does not give an impression of what actually happens, of who is involved in these practices, how these practices interfere with each other, or how they actually produce a certain performance. As explained to me by Professor Benders, their ‘use matters’; though these practices might receive the same score from different respondents, they might be used in an entirely different way. Similar critiques are provided by for example March and Sutton (1997) who explain that variance research does not provide and understanding of the complexity of the causal structure between variables and performance. In addition, Jarzabkowski et al. (2016) explain that next to the ‘what’ it is also important to incorporate the ‘who’ and the ‘how’ when studying practices. To a
certain extent, the NCA incorporates this as it allows observations with the same score on a certain condition but with entirely different scores on the outcome. NCA however still does not say much about how these conditions came about and enable the outcome over time.

Therefore, together with my supervisory team, I implemented qualitative literature and research methods to study lean production implementations using process approaches. Specifically, to better understand routines, I incorporated the routine dynamics literature and a process view. As this integration between the lean production and routine dynamics literature was non-existent, I explored how routine dynamics worked in a lean production context. This resulted in a shift to a more abductive methodology. This shows that rather than mere interdependencies between dependent and independent variables, implementing lean production depends on underlying processes regarding the mutually constitutive understanding and enactment, resulting in a shift towards a critical realist approach. Finally, designing a prototype intervention to implement lean production and showcasing this intervention in the fourth study again required a more abductive methodology. However, in contrast to Study 3, the application in a specific case required engagement with different people, each with their own beliefs and views on reality. This resulted in a more relativist view. In addition, it required a subjective and emic approach. Taken together, the Study 4 subscribes to a more constructivist approach.

Are these philosophical and research approaches incommensurable? In other words, is it possible to take different approaches for subsequent studies, especially in a single dissertation? I agree that for opposing paradigms it is often not useful for them to meaningfully exist next to each other (e.g., heliocentrism vs. geocentrism). I do not believe, however, that positivism, critical realism, and constructivism are opposing paradigms. Rather, I see them as different approaches to describe reality in different ways; ways that exist next to each other and even add to each other. In line with the positivist approach, I think that pre-set observations can produce valuable knowledge about relationships between variables (as in Studies 1 & 2). Additionally, and in line with the critical realist approach, I show that objects of observation have generative mechanisms (as in Study 3) that do not always manifest in pre-set observations (as in Studies 1 & 2). Finally, these generative mechanisms can be actualized to produce certain
outcomes (as in Study 4). By combining these different approaches (but not opposing paradigms) we can draw on their merits to ultimately reinforce the arguments made and describe what always will be parts of reality as it is.

In addition, in science in general and in the lean production literature specifically, we consistently draw on different approaches to advance our understanding. What frequently happens is that emic qualitative approaches describe lean practices, CI routines and critical success factors while etic quantitative approaches test these in large survey studies. Rather than being incommensurable, it seems appropriate to use different approaches as long as consistency within each approach is guaranteed. That is, as long as inappropriate inferences from using a specific approach are not derived. For example, from a quantitative cross-sectional dataset it is only possible to conclude that certain practices are present amongst high or low performers, but not that certain practices are important to start with or advance a lean production implementation. To make such an inference would require a longitudinal process view. In other words, it is important to stick to the norms and language of the specific research approach and to criticize one paradigm only with the norms and language of that same paradigm, not by using the norms and language of another.

For practitioners, be they managers or students, it seems paramount to not rely on one philosophical and methodological approach. For example, to learn what constitutes a generic bundle of lean practices as taught by more positivist research, and to try to apply that in a specific situation most likely will result in failure as the bundle of practices is not tailored to the specific circumstances at hand. Contingency theory helps specify bundles to certain circumstances, but never as far as the specific situation at hand. In contrast, I believe that both positivist and critical realist approaches serve each other: the findings from critical realist research can help to focus positivist research which in turn can help practitioners as they can take the bundles, experiment with their application, and continue with those best suited to their environment. In this way, learnings from specific contexts can be developed and theorized on at an abstract level, so that future practitioners can subsequently draw upon these to advance their own practices and accelerate their learning.
1.5. STRUCTURE OF THE DISSERTATION

In Chapter 2, I first position this dissertation centrally in the lean production literature (see the overview of the four studies in Table 1). To indicate which organizational aspects are most important for lean production implementation in manufacturing SMEs, in Chapter 3, I show that success factors differ in criticality between cases with little and those with more advanced presence of lean practices, indicating success factors critical for different degrees of lean practice implementation. In Chapter 4, I show that CI routines differ in importance between cases with little and those with more advanced presence of lean practices, indicating that CI routines need to be incorporated into every lean production implementation approach. To indicate how these aspects evolve over time, in Chapter 5 I describe the interplay between the enacting and patterning of lean operating and CI routines and it highlights the importance of active engagement at multiple organizational levels. Chapter 6 combines the findings from the first three studies into a prototype intervention to implement lean production, showcasing how the findings were used in a Dutch manufacturing SME. Finally, Chapter 7 concludes that implementing lean production requires an integrative approach; managing the infrastructure, and building CI routines to develop lean operating routines to increase operational performance, contingent upon the context of the specific manufacturing SME.
Table 1: Overview of the studies

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Research Question</th>
<th>Research type</th>
<th>Unit of analysis</th>
<th>Concepts of interest</th>
<th>Instruments</th>
<th>Method of analysis</th>
<th>Publication status</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>To which extent are success factors critical to enact different degrees of lean practices in manufacturing SMEs?</td>
<td>Testing</td>
<td>Firm</td>
<td>Critical Success Factors-Lean Practices-Operational Performance</td>
<td>Multiple respondent surveys</td>
<td>Necessary Condition Analysis</td>
<td>Published in: International Journal of Production Research</td>
</tr>
<tr>
<td>4</td>
<td>What is the relative importance of continuous improvement routines to enact lean practices in manufacturing SMEs?</td>
<td>Exploratory</td>
<td>Firm</td>
<td>Continuous Improvement Routines-Lean Practices-Operational Performance</td>
<td>Multiple respondent surveys</td>
<td>Necessary Condition Analysis, Between Case Comparison</td>
<td>Published in: International Journal of Operations &amp; Production Management</td>
</tr>
<tr>
<td>5</td>
<td>How do lean operating and continuous improvement routines develop during a lean production implementation?</td>
<td>Explanatory</td>
<td>Routines</td>
<td>Enacting and patterning lean operating and continuous improvement routines</td>
<td>Interviews, observations, documents</td>
<td>Comparative Case Study</td>
<td>Published in: International Journal of Operations &amp; Production Management Presented at: 79th Annual Meeting of the Academy of Management, Boston, USA</td>
</tr>
<tr>
<td>6</td>
<td>Which elements of an intervention can build continuous improvement routines to pattern and enact lean operating routines?</td>
<td>Designing</td>
<td>Routines</td>
<td>Enacting and patterning lean operating and continuous improvement routines</td>
<td>Interventions, interviews, observations, documents,</td>
<td>Intervention-Based Research</td>
<td>Presented at: 80th Annual Meeting of the Academy of Management, Vancouver, Canada (nominated for best student paper OSCM division), 27th Annual Meeting of the European Operations Management Association, Warwick, UK, and 12th International Process Symposium, Rhodes, Greece</td>
</tr>
</tbody>
</table>

Note: The self-assessment instrument of the first two studies was developed by J. Slomp. All data were gathered by the PhD candidate. All data are stored at the university's secured network disk (R-disk). The data will not be made available for third parties due to agreements with the respondents. All four chapters were written by the PhD candidate. The supervisory team contributed with feedback and comments on the text.
2. POSITIONING IN THE LEAN PRODUCTION LITERATURE
In this dissertation, I study the implementation of lean production in manufacturing small and medium sized enterprises (SMEs). However, the term ‘lean production’ is subject to a proliferation of definitions, principles, practices, tools and techniques, which makes it difficult to study (Hines, Holweg, & Rich, 2004). To better understand why this is the case, in this chapter I first discuss how this proliferation in terminology has arisen. To make clear how the lean production concept is used in this dissertation, I then describe the stream of lean production literature that I draw upon, and which area in this stream I focus on. Next, I discuss the main critiques on lean production and how these shape the way I use the concept in this dissertation. To set the conceptual stage for the remainder of this dissertation, I end this chapter with an overview and definitions of the most important concepts, and in which chapters they are discussed.

2.1. AMBIGUITY OF THE LEAN PRODUCTION CONCEPT

Lean production is conceptualized from the Toyota Production System (TPS). After the term lean production was first coined by Krafcik (1988), it has been mentioned in countless books, papers, studies and applications. Currently, the lean production concept includes a variety of definitions, principles, practices, tools and techniques that help a company improve value and reduce waste. Additionally, lean production is not the same as but is related to or even overlaps other concepts such as the Total Productive Maintenance (TPM), Just-in-Time Manufacturing (JIT), the Theory of Constraints, Total Quality Management (TQM), Six Sigma, and Quick Response Manufacturing. This shows that lean production has been and still is very useful in many areas. However, this multitude of elements related to the concept also makes it difficult to study. This can be explained by three related reasons: the interpretive viability of the concept in general, the rhetoric and reality of the concept in practice, and its application and research in different areas and by different disciplines.

2.1.1. Concept level

The different perspectives on the lean production concept can partially be explained by what Benders and Van Veen (2001) call interpretative viability. This implies that management concepts, such as lean production, benefit from a certain degree of ambiguity; rather than a clear definition and demarcation, ambiguity means that the concept consists of different and loosely defined
elements. This ambiguity increases the potential market for the concept as it enables more users to eclectically select those elements of the concept that best suit their specific needs. Benders and Van Veen (2001) explain that this can even take place within one organization, where different groups select those elements that best suit their needs, uniting parties as each is in favour of the concept for its own particular interest. But this ambiguity also prevents any judgements about the efficacy of the concept in a generic sense. The performance is influenced by too many factors to single out and assess the concept’s effect, leaving only attributions of the concept’s effect. To say anything about effects, elements or implementation, it is necessary to first define which aspects of lean production are of interest and to demarcate the study to those aspects only.

2.1.2. Usage level

In addition to ambiguity at the concept level, the different perspectives on the lean production concept can also be explained by ambiguity at the usage level; that is, how practitioners and academics talk about a concept and how a concept actually is manifested on the shop floor. Drawing on a comparison of five case studies, Zbaracki (1998) explains that there is a difference between the rhetoric and reality of TQM. Rhetoric is defined as “the managers’ stated claims and accounts of TQM use, especially in the context of ongoing organisational life”; reality as “[grounded in] a set of specific technical practices.” (Zbaracki, 1998, p. 605). Zbaracki explains that in TQM, as in any other concept, rhetoric differs from reality. Managers often take the successful rhetoric of TQM to develop their own TQM program and they subsequently tend to filter their experiences to present their own rhetoric of success (Zbaracki, 1998). This eventually results in an overly optimistic view of TQM. Zbaracki adds that this happens in many organizational concepts.

This difference between rhetoric and reality also applies to the lean production concept. This is, for example, described in Mehri’s (2006) ethnographic study of the TPS which shows that though the TPS provides significant benefits, it also has significant disadvantages. The latter are often overlooked or simply ignored as they are implicitly hidden by Japanese culture; Japanese expressions (tatemae) are often more positive than their actual feelings (honne). In general, this provides a more positive image about the TPS than is found in practice. Though culturally driven, this is similar to the rhetoric and reality explained by
Zbaracki (1998). From a comparative case study of seven cases, Langstrand and Drotz (2016) indicate that managers adopt the general positive rhetoric on lean production to repeat the positive reasons for and expected outcomes of applying lean production. These findings confirm that this overly optimistic filtering also adds to the different perspectives on lean production, making it hard to define and study lean production.

2.1.3. Variety of disciplines
Further to ambiguity at a concept and usage level, the different perspectives on the lean production concept can be explained by the plurality of practice areas and research disciplines working with the concept. In an in depth case study, Nicolai and Dautwiz (2010) explain that the conceptual ambiguity has a linguistic nature, relating to the way it is talked about, and a contextual nature, relating to the concept’s interpretation in a plurality of different contexts. Examples of practice areas other than production in which lean production concepts are applied and developed are product development, IT, accounting, services, healthcare, and education. Each of these takes existing lean production principles, practices, routines, tools, and techniques and applies these to their field to develop them and/or to identify entirely new ones. Furthermore, this contextual nature also extents to management research. Examples of the variety of research disciplines other than Operations Management in which lean production is studied are Strategy, HRM, IT and Accounting. Each of these areas again takes the theory and lenses used in their discipline to study (aspects of) lean production to develop their discipline specific-literature and/or the lean production literature. Given the linguistic and contextual nature of ambiguity explained above, the remainder of this chapter is dedicated to defining lean production as studied in this dissertation.

2.2. OVERVIEW OF THE LEAN PRODUCTION CONCEPT IN THIS DISSERTATION
In this section I first provide a brief overview of the stream of literature on lean production that I draw upon. Second, from a set of different perspectives I discuss which general definition of lean production I use. And third, from a set of different areas, I discuss on which major area in the lean production literature I focus.
2.2.1. Original stream of literature on lean production

My focus is on the original stream of literature on the lean production concept. In this stream of literature, it is documented that lean production is conceptualized from what is known as the Toyota Production System (TPS) (Holweg, 2007). Holweg explains the genealogy of lean production and the TPS: in an attempt to match and exceed the early 20th century dominant US automobile production, several key managers and consultants at Japan’s Toyota developed and implemented a series of important production techniques. These improvements build on Sakichi Toyoda’s advanced loom (1918), able to stop automatically when there was a defect. His son, Kiichiro Toyoda, additionally developed Just-in-Time (JIT) production, to have all required parts available only as required. Autonomation and JIT formed the pillars of the TPS house. Building on these, numerous production techniques (such as takt time for matching demand and production, Kanban for limiting work-in-progress, Kaizen for improvement, and Single Minute Exchange of Die for setting up machines) eventually led to the system now called the TPS. The TPS enabled Toyota to compete mass production with their own small lot-size production.

Shimokawa and Fujimoto (2009) explain that in addition to autonomation and JIT, the TPS has benefited crucially from Total Quality Control (TQC), precursor of TQM. Hackman and Wageman (1995) propose that TQM is based on four main assumptions: quality is less costly than poor workmanship, employees care about quality, problems invariably cross functional lines, and quality is the responsibility of top managers. They add that the TQM concept subsumes a number of focused initiatives such as quality circles and cross-functional project teams. Shimokawa and Fujimoto (2009) explain that rather than having a master plan that led to the development of the TPS, it was TQM or the process of endless cycles of trial, error and improvement that eventually developed the TPS. In 2001, continuous improvement (CI) and ‘Respect for People’ formed the pillars of ‘The Toyota Way’. Shimokawa and Fujimoto (2009) conclude that Toyota’s consistent competitiveness eventually stemmed from their ability not only to manage their processes, but to nurture their capability of organizational learning.

Holweg (2007) continues to explain that in 1979, an MIT led international network of universities initiated ‘The future of the automobile’ program, later called the ‘International Motor Vehicle Program’ (IMVP). This IMVP conducted a benchmark
to compare the efficiency of several automobile assembly plants. The results showed that NUMMI, a joint venture between Toyota and GM, assembled 50% more efficiently compared to the other GM plants. Additional results showed that ‘lean production systems’, be they home based or transplants, outperformed traditional mass production systems in accounts of quality, productivity and mix complexity (Krafcik, 1988). These results and the underlying production system were best described in Womack, Jones and Roos’ (1991) book ‘The Machine that Changed the World’ (Holweg, 2007). In an attempt to help managers implement lean production, Womack and Jones (1996) additionally wrote the book ‘Lean Thinking’. As many organizations have tried to implement lean production, both books sparked the usage of the term ‘lean’. It is this stream of literature from Toyota and the IMVP that I mostly draw from in this dissertation.

2.2.2. General definition of lean production

To provide a general definition of lean production, I first explain the discussion surrounding its broad definition. As shown by the brief historical overview, lean production is not the same as but is partially derived from the TPS. Spear and Bowen (1999) summarize the DNA of the TPS in four rules. 1. All work is specified regarding content, sequence, timing, and outcome. 2. Every customer-supplier connection is direct and unambiguous. 3. Every product and service has a simple and direct pathway. 4. Improvements are made according to the scientific method. Lean production itself in its first instance implies production with a high level of work standardization, a moderate span of control, small inventories and buffers, very small repair areas, and a high level of team work (Krafcik, 1988). Both the rules by Spear and Bowen and the aspects by Krafcik cover different but related aspects of production systems. Regarding a general definition however, there has been much debate about what that is or might be.

Lean production is frequently defined as ‘improving customer value by decreasing waste’. In a recent forum discussion in the Journal of Operations Management, Hopp and Spearman (2020, p. 3) explain that waste is defined as ‘anything that does not create value’ calling this definition unhelpful. In another perspective, lean production is defined as improving quality and delivery and reducing cost. Again, Hopp and Spearman (2020) argue that quality is primarily addressed under the headings of TQM and Six Sigma, whilst delivery reliability and speed are largely addressed by Time-Based Competition, Agile
Manufacturing, and Quick Response Manufacturing. They conclude that lean production focuses primarily on efficiency, addressing the price/cost dimension. In a reply in the same discussion series, others strongly dispute this efficiency view, focusing on either improving customer value whilst reducing waste and/or improving quality, delivery, and costs altogether (Cusumano et al., 2021). This shows that several of the most experienced and established researchers in the lean production field have yet to agree on a general definition of lean production. As most of these researchers define lean production as improving customer value and reducing waste, expressed in quality, delivery, and cost, I have taken this as a general definition for the purpose of this dissertation.

2.2.3. Position in the lean production literature

To explain which major areas in the lean production literature I focus on, I first discuss the major areas that it consists of. Contrary to its broad definition, researchers tend to agree that there are four major areas in the traditional lean production literature. These are summarized by Hopp and Spearman (2020) as the four ‘Lenses of Lean’. To a certain extent, these lenses align with the developmental stages of the lean production literature described by Hines et al. (2004).

First, the ‘process lens’ defines lean as the ‘pursuit of waste elimination’ and is rooted in Frederick W. Taylor’s Scientific Management (Hopp & Spearman, 2020, p. 4). Scientific Management established the concept of standardized work. Browning and de Treville (2021) call this lens the ‘activity lens’ as it focuses mainly on single nodes in a network rather than a process consisting of multiple nodes. This first lens shows great similarities with the first developmental stage described by Hines et al. (2004) called the ‘cell and line’ stage, lasting mainly from 1980-1990 and described as highly prescriptive and tool based. The seven wastes (transportation, inventory, motion, waiting, overprocessing, overprocessing, and defects) and 5S (sort, set in order, shine, standardize, and sustain) are probably the best-known tools in this approach. Frequently, managers aiming to implement lean production start with this approach, helping people reduce waste and often implementing 5S in many areas. Hopp and Spearman (2020) explain that this approach can help improve efficiency by focusing on specific steps. However, it does not go into the underlying causes of waste, leaving the user to focus only on waste that is directly visible.
Second, the ‘flow lens’ defines lean as ‘to minimize the cost of excess inventory, capacity or time’ as these three buffers help reduce variability (Hopp & Spearman, 2020, p. 5). In contrast to waste elimination as described above, this lens focuses on variability as a major cause of waste. Variability can be the cause of predictable (e.g., maintenance) and unpredictable events (e.g., outages) and can add (e.g., variety) or decrease customer value (e.g., machine failures). Additionally, rather than single workplaces, this lens focuses on a series of interlinked workplaces. This second lens shows similarities with the second developmental stage described by Hines et al. (2004) called the ‘shop floor’ stage with a peak between 1990-mid 1990. This stage is described as highly prescriptive and a best practice approach. Preventive maintenance, production smoothing, standardized work, and cross-training are well known techniques in this approach. Though this approach moves beyond a narrow focus, it still targets specific flows rather than the entire networks that systems consist of.

Third, in the ‘network lens’ Hopp and Spearman (2020, p. 9) define lean as ‘a systematic process of reducing the cost of waste’, focusing on the improvement process in general rather than unspecific types of waste. This improvement process moves to the network level rather than the workplace or shop floor level, as most systems consist of many interconnected flows. The idea is that first improving the network level helps prevent suboptimization. This third lens shows great similarities with the third developmental stage described by Hines et al. (2004) called the ‘value stream’ stage, lasting mainly from mid-1990-2000. It is described as prescriptive, following one best way; the Toyota Way or alternatively the five steps provided by Womack and Jones (1996). Browning and de Treville (2021) call this lens ‘the process lens’ as it focuses on the overall process of a production system. Note that this is the same term as is used for the first lens, underlining the conceptual ambiguity. The bottleneck, that is the network node with the highest utilization, is a well-known concept in this approach. As the effect of utilization is exponential and that of variability is linear, this approach tries to first reduce utilization, improving the bottleneck, then reduce variability, and finally reduce specific wastes on specific workplaces.

Fourth, the ‘organizational lens’ defines lean as “an organizational culture that encourages continual reduction of the cost of waste” (Hopp & Spearman, 2020, p. 10). This approach moves beyond the physics of flows, recognizing that people
working in organizations create and manage the waste and variability reduction called for in lean production. This fourth lens shows similarities with the fourth developmental stage described by Hines et al. (2004) called the ‘value system’ stage, lasting from 2000 and beyond. It is described as taking a contingency approach and as moving towards a learning organization. Bottom-up problem-solving tools and techniques such as Kaizen and system 1 (fast) and system 2 (slow) thinking are used in this approach. It is noted that this lens is not used much yet, hence there seems to be a large opportunity to leverage behavioural theory in lean production research and practice (Browning & de Treville, 2021; Cusumano et al., 2021; Hopp & Spearman, 2020). An overview of the four lenses is given in Figure 2. The arrows indicate repeated cycling through the various perspectives, resulting in a continually changing and improving system. Below I discuss which area I focus on in this dissertation.

Figure 2: The staged use of the four lean lenses (Source: Hopp and Spearman, 2020, p.14)

Similar to the general definition of lean production, there is discussion on the extent to which all four lenses can be used to demarcate lean production. In a reflection on the four lenses, Cusumano mentions that his idea of lean production is mostly linked to the process lens (personal view in Cusumano et al., 2021). Shah and Holweg (in Cusumano et al., 2021) add that though organizational culture might have gained attention only recently, it was very much part of the original TPS. Netland (in Cusumano et al., 2021) adds that the four lenses take a positivistic view, whilst early lean production research especially is phenomenon rather than theory driven. He calls for a more phenomenon-based
perspective, incorporating the changing nature that comes with the socio-technical system that lean production is (in Cusumano et al., 2021). Furthermore, Browning and de Treville (2021) conclude that the lenses are too broad as they and their underlying concepts do not meet the requirements of formal conceptual definitions. Instead, they propose a ‘lean view on lean’ consisting of for example JIT, pull, quick setups, etc. but also calling for future research to compile the formal concepts that underlie lean production.

My stance is that lean production addresses value creation and waste reduction in organizational processes and that this requires variability reduction and network rationalization. However, I also believe that this can only be achieved by integrating lean structures with organizational culture. This is not to say that cultural notions are specific to lean production. Much of the generic literature on organizational culture is also applicable to lean production. But in a similar vein, the TPS and lean production literature also provide many insights for the organizational culture literature to draw on; specifically, on how this structure and culture can operate in tandem. For example Sugimori et al. (1977) showed that respect-for-people helps to embed and sustain JIT practices. Additionally, I believe it would only make sense to consider the changing nature of lean production. Given its focus on value creation, waste reduction, etc. new structures emerge that can help to further develop the lean production concept. For example, Suri (1998) developed several tools and techniques to increase value and reduce waste in a high-variety/low-volume environment. A provision is that we use and maintain formal conceptual definitions.

As many manufacturing SMEs struggle to implement lean production and as the literature is ambiguous on the most suitable approach for manufacturing SMEs, I will investigate which organizational aspects are most important for lean production implementation in manufacturing SMEs and how these evolve over time. This research question thus does not focus on the design of lean production, but on how lean production can be implemented and developed. The process, flow and network lens focus more on the tools and techniques that constitute lean production. The organizational lens focuses more on the people, their behaviour and the implementation of lean production. Therefore, in this dissertation I draw mostly on the organizational lens. The authors mentioned above all call for more research in this field. And this lens is related to the
current ‘value system’ developmental-stage of the lean production literature. Especially in the second half of my dissertation (Chapters 5 and 6), I follow the recommendations to incorporate more behavioural theory into this lens.

2.4. SPECIFIC LEAN PRODUCTION AREAS IN THIS DISSERTATION

2.4.1. Overview on lean production in this dissertation
In the introduction, I started with the question: Which organizational aspects are most important for lean production implementation in manufacturing SMEs, and how do these evolve over time? In this dissertation, I apply the lean production concept to its original field: production and manufacturing. Additionally, I study the lean production concept from its original discipline: Operations Management. I explained that I draw on the original lean production stream of literature and that I use the most common general definition; that lean production focuses on improving customer value while decreasing waste in terms of quality, delivery and costs. Specifically, I take the organizational lens to study activities that people working in manufacturing SMEs undertake to implement lean production. To prevent any remaining ambiguity, in the remainder of this section I specify the most important concepts and in which chapters these are discussed further.

2.4.2. Lean operations
To study lean production activities, a distinction is made between lean operations, CI and critical success factors. Lean operations is considered to encompass the principles, routines and artefacts related to the primary activities of an organization. Central to these operations are the pillars described by Sugimori et al. (1977): autonomation and JIT. Autonomation or Jidoka implies that abnormal or defective conditions are signalled, the operation is stopped, and employees are helped by team leaders to fix the issues to prevent defective products. JIT implies that all processes have available: the minimum stock required to produce the minimum parts required by the (internal) customer. Lean operations relate to, for example, nine of the ten lean practices conceptualized by Shah and Ward (2007) (their bundle ‘employee involvement’ relates more to CI). Tools and techniques such as pull systems, supermarkets, FIFO lanes etc. help to keep lot sizes and lead times small and quality and flexibility high (Hall,
1983; Monden, 1983; Ōno, 1988; Schonberger, 1982). Most of these tools and techniques are comprehensively described by Bicheno and Holweg (2016) in their book ‘The Lean Toolbox’. In this entire dissertation, I repeatedly draw on this concept of lean operations as the set of primary activities that directly influence operational performance.

2.4.3. Continuous improvement

CI encompasses the principles, routines and artefacts related to improving the primary activities of an organization. CI relates much to Kaizen, the Japanese approach to improvement. The essence of both CI and Kaizen is the Plan-Do-Study-Act (PDSA) approach introduced by Edwards Deming (1993). PDSA is a structured approach to analyse problems, experiment with solutions, implement improvements, and sustain these improvements in improved working standards (Deming, 1993). It is a scientific approach to problem-solving which, because of its structure and applicability, is especially useful on the shop-floor. Related tools and techniques are, for example, quality circles in which groups of employees get together to conduct PDSA cycles, A3 reports which help to further structure and communicate the entire improvement project, and Hoshin Kanri which helps align different improvement projects with each other and with the general aims of the organization. Again, most of these tools and techniques are comprehensively described by Bicheno and Holweg (2016). In this entire dissertation, I repeatedly make this distinction between lean operations and CI. In Chapters 4 and 5, I specifically address their interplay.

2.4.4. Critical success factors

The literature also describes many critical success factors to implement lean production. In line with Saraph et al. (1989), critical success factors are considered management areas that are not sufficient but need to be in place to enable the implementation of lean production. This means that critical success factors do not produce but rather enable the implementation of lean production. They can be considered the conditions necessary to implementing lean production. Alternative terms for critical success factors are, for example, crucial or essential factors (Kaye & Anderson, 1999). Critical success factors are often the opposite of critical failure factors, failure determinants, failure routines (Alibliwi, Antony, Lim, & van der Wiele, 2014; Secchi & Camuffo, 2019) or just barriers or obstacles (Bhasin, 2012; Marodin & Saurin, 2015b). Key factors identified are top
management support, a shared improvement vision, and good communication (Achanga et al., 2006; Marodin & Saurin, 2015a). Others regard the improvement culture, e.g., leadership, a focus on people, and a focus on learning (Yusof & Aspinwall, 1999, 2000), the improvement structure, e.g., sufficient resources, improvement training and performance management system (Salaheldin, 2009; Sohal & Terziovski, 2000), and an integrated focus, e.g., a supplier link, a customer link and support congruence (Sohal & Terziovski, 2000). Netland (2016) argues that the criticality of these success factors depends on the degree of lean production implementation, indicating opportunities to focus attention. I use this perspective to study the criticality of success factors for manufacturing SMEs (Chapter 3).

2.4.5. Practices and routines

In the second part of this dissertation (Chapters 5 and 6), I adopt practices and routines as the level of analysis to study lean production. Feldman and Pentland (2003, p. 96) define a routine as a “repetitive, recognizable pattern of interdependent actions, involving multiple actors”.

Previously, practices and routines were mostly seen as static, following Nelson and Winter’s (1982) conceptualization. Adler et al. (1999) distinguish between routine tasks (recurring day-to-day activities) and nonroutine tasks (newly developed activities). They add that meta routines such as problem-solving activities help to transfer nonroutine tasks to routine tasks. The operations management literature largely draws on this conceptualization. For example, Peng et al. (2008) follow Nelson and Winter’s (1982) distinction between operating and search routines in which the latter helps to develop the former.

More recent developments in the organizational literature on routines that are currently less well known in operations management have emphasized that practices and routines are dynamic ever-changing, ongoing accomplishments by themselves (Feldman, 2016). Practice theory is an important source when interpreting routines as being dynamic. This concept of practices relates to Bourdieu’s (1990) notion of habitus, or our internalized and embodied understanding of the structure of society, and our place in the social world. This also relates to Giddens’ (1984) notion of agency, with the understanding that what people do is also shaped by social structures. The dynamic view allows a more thorough understanding of what, how and possibly why things are done in organizations.
As explained in the introduction, I started this dissertation (Chapters 3 and 4) using the quantitative approach and the instruments by Shah and Ward (2007) and Bessant et al. (2001). I use this to better understand the interaction between lean practices and improvement routines and other constructs at a firm level. However, this does not provide a thorough understanding of what is actually done. To provide more details, I decided to take a routine dynamics lens in the second part (Chapters 5 and 6). Routine dynamics makes a distinction between the enacting and the patterning of routines. Enacting is defined as the “specific actions, [done] by specific people, in specific places and times … it is the routine in practice” (Feldman & Pentland, 2003, p. 101). Patterning is considered to be “the ideal or schematic form of the routine … it is the abstract, generalised idea of the routine or the idea in principle” (Feldman & Pentland, 2003, p. 101). This ideal form is embodied in employees’ shared understanding of the routine. Taking a routine dynamics lens helps provide a better understanding of what routines are performed, by whom, and in which way to show which organizational aspects are most important for lean production implementation in manufacturing SMEs.
Chapter 2. Positioning in the lean production literature
3. TESTING ‘CRITICAL SUCCES FACTORS’ FOR LEAN PRACTICE IMPLEMENTATION
ABSTRACT

Lean practices are known to increase operational performance. Previous research has identified critical success factors for implementing lean practices. This study aims to examine the extent to which success factors are critical for various degrees of lean practice implementation. Using multiple-respondent self-assessments from 33 Dutch manufacturing small and medium-sized enterprises (SMEs), we conducted a Necessary Condition Analysis (Dul, 2016). Our findings indicated that the criticality of success factors is progression dependent. In the initial stages of the lean journey, SMEs could improve their lean practices in a bottom-up manner through local factors such as a learning focus, improvement training and support congruence. Only when lean practices are more advanced, some company-wide factors must also be present: top management support, a shared improvement vision and a supplier link. Our findings question the universality of success factors such as strategic involvement and indicate the need for a more dynamic model of lean production implementation.

3.1. INTRODUCTION

Manufacturing SMEs are important for a nation’s economy. To survive in an increasingly competitive business environment, they can turn to lean production to increase their operational performance (Krafcik, 1988; Ōno, 1988; Womack et al., 1991). Lean production is a set of management practices that improve customer value and reduce waste (Cusumano et al., 2021). However, manufacturing SMEs find it difficult to implement lean practices (McGovern et al., 2017; Shah & Ward, 2003; White, Pearson, & Wilson, 1999).

One proposed reason is the absence of critical success factors (Hu, Mason, Williams, & Found, 2015). Saraph, Benson and Schroeder (1989, p. 811) define success factors as “areas of managerial planning and action that must be practised to achieve effective quality management in a business unit”. These are key organizational issues that managers need to address to be able to implement lean practices. Alternative terms for success factors are for example crucial or essential factors (Kaye & Anderson, 1999). Success factors are oftentimes the
opposite of for example critical failure factors, failure determinants, failure routines (Albliwi et al., 2014; Secchi & Camuffo, 2019) or just barriers or obstacles (Bhasin, 2012; Marodin & Saurin, 2015b). Examples of success factors are ‘top management support’ and ‘a shared improvement vision’ (Sila & Ebrahimpour, 2003).

However, the term ‘success factor’ may be misleading, as the mere presence of a factor does not automatically lead to more success (Woodside, 2013). Success factors are similar to Herzberg’s (1968) hygiene factors, which do not guarantee job satisfaction, but do need to be in place to prevent dissatisfaction. The same goes for success factors: they are necessary, but not a sufficient condition for success. The mere presence of top management support, for example, does not ensure the implementation of lean practices. Lean practices are implemented via improvement activities (Kim, Sting, & Loch, 2014). But it is considered to be a necessary condition for success: if there is no top management support, it is very difficult to sustain the implementation of lean practices. So the general assumption for manufacturing SMEs is that success factors need to be present before lean practices can be implemented.

Previous research found that the importance of success factors depends on the stage of implementation of lean practices. Based on a cross-national survey amongst 432 respondents from two LEs, Netland (2016) found that the importance of success factors changed according to the stage of implementation of lean practices; some success factors are important in the initial stages, while others become important as organizations continue to implement lean practices. This is an important research topic because success factor criticality helps SMEs to focus their improvement efforts, enabling the implementation of lean practices and increasing operational performance. Netland (2016) linked success factors to the implementation of lean practices, but he did not deduce the criticality of these success factors (i.e. he did not identify which factors must be present for different stages of implementation of lean practices). After reviewing the literature on success factors, we found no studies that identify this criticality at different stages of implementation of lean practices. Therefore, the aim of this research is to identify the extent to which success factors are critical for different stages of implementation of lean practices in manufacturing SMEs.
The next section briefly highlights the key studies on success factors for the implementation of lean practices. The methodology section then justifies how this study investigated the criticality of success factors to implement lean practices; we specify the variables in our study and justify the multiple-respondent self-assessment as the method of gathering data and Necessary Condition Analysis (NCA) as the method of linking success factors to the implementation of lean practices. The results section indicates that success factors differ in criticality between cases with little implementation of lean and cases with more advanced lean practices. We then discuss these results and provide implications for manufacturing SME managers. The final section provides directions for future research.

3.2. SUCCESS FACTORS FOR LEAN PRACTICE IMPLEMENTATION
We reviewed the literature on success factors for the implementation of lean practices, as well as for related concepts: Total Quality Management (TQM) and Just-in-Time production (JIT). TQM aims to meet customer requirements through continuous improvement, emphasising measurement and control (Ross, 1999). JIT aims to reduce work in progress, variation and lead time (Monden, 1981). Saraph, Benson and Schroeder (1989) were amongst the first to identify success factors for TQM and their study has been replicated several times (Badri, Davis, & Davis, 1995; Motwani, Mahmoud, & Rice, 1994; Quazi, Jemangin, Kit, & Kian, 1998). Numerous other validation and replication studies have been conducted (for example Ahire, Golhar, & Waller, 1996; Antony, Leung, Knowles, & Gosh, 2002; Black & Porter, 1996; Karuppusami & Gandhinathan, 2006; Sohal & Terziovski, 2000; Tari, 2005). In a meta-analysis of 76 articles from different countries, Sila and Ebrahimpour (2003) identify 18 universally applicable success factors for the implementation of TQM. Only a few studies have extended their scope beyond TQM, towards other bundles of lean practices such as JIT and ‘supplier and customer integration’ (Chong, White, & Prybutok, 2001; García & Maldonado, 2014; García & Rivera, 2013; Kaye & Anderson, 1999; Marodin & Saurin, 2015a). All of these studies were used to identify success factors for this study.

Stemming from success factors for manufacturing companies in general (Ahire et al., 1996; Black & Porter, 1996; Saraph et al., 1989), Yusof and Aspinwall (1999)
were amongst the first to suggest success factors specifically for SMEs. They found that most success factors for SMEs are similar to those for LEs; they only added ‘sufficient resources’ and ‘an informal culture’. Other SME-specific studies use data from specific countries (Achanga et al., 2006; Dorota Rymaszewska, 2014; Salaheldin, 2009) or industries (Azyan, Pulakanam, & Pons, 2017; Dora, Kumar, & Gellynck, 2016; Dora, Kumar, Van Goubergen, Molnar, & Gellynck, 2013). They found that SMEs generally have more management involvement, but they lack resources and plan short-term. In a literature review of 16 articles from different countries and industries, Hu et al. (2015) identified 11 success factors specific to manufacturing SMEs. That literature review and other SME-specific studies have found a large overlap in the success factors for SMEs and LEs, so we used studies about LEs and SMEs to list success factors for this study. In our discussion, we emphasize success factors that are more relevant to SMEs.

To come to a comprehensive list of managerial aspects that need to be in place to be able to implement all lean practices, we compared all the success factors identified in the literature, merged some (e.g., process management and data and reporting (Saraph et al., 1989) became a performance management system) and compiled them into a list of six groups and 12 success factors (see Table 2). These 12 success factors are very much in line with the 11 factors identified by Hu et al. (2015), though at the time of compilation (2013) we had added ‘leadership’ (Yusof and Aspinwall 1999; Yusof and Aspinwall 2000; Salaheldin 2009; Dora et al. 2013; Dora, Kumar, and Gellynck 2016). We also split up ‘supply chain integration’ because we were interested in the importance of ‘a supplier link’ and ‘a customer link’ separately, and we left out ‘technical factors’ because they are only mentioned in relation to manufacturing resource planning (Chin & Rafuse, 1993). To our knowledge, these 12 success factors cover the most important managerial areas from which we aim to identify factors that are critical for the implementation of lean practices.
## Table 2: Success factors for lean practice implementation

<table>
<thead>
<tr>
<th>Group</th>
<th>i. Top management support</th>
<th>ii. Shared improvement vision</th>
<th>iii. Good communication</th>
<th>iv. Leadership</th>
<th>v. People focus</th>
<th>vi. Learning focus</th>
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</thead>
<tbody>
<tr>
<td>Description</td>
<td>Top management assume responsibility for and are positively involved in improvements to increase performance</td>
<td>A company-wide long-term direction, objectives and goals for improvement, aligned with the company’s vision and strategy, are developed, shared and followed</td>
<td>Ideas, information and knowledge are exchanged honestly, clearly and transparently, both orally and in writing, in all organizational directions</td>
<td>Team leaders facilitate, coordinate and balance improvements from shop-floor employees</td>
<td>Organizational systems help employees to do their work versus employees being bound to organizational systems</td>
<td>Both positive and negative experiences are shared and mistakes are considered opportunities for improvement rather than punished</td>
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On the implementation of Lean Production in manufacturing SMEs
### Critical Success Factors

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<tr>
<th>Group</th>
<th>Improvement structure</th>
<th>Integrated focus</th>
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<td>Sufficient resources</td>
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<td>x. Supplier link</td>
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<td>Improvement training</td>
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<td>xi. Customer link</td>
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<td>Performance management system</td>
<td>ix.</td>
<td>xii. Support congruence</td>
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### Description

- **Sufficient time and money are available for training and improvement activities**
- **Managers and shop-floor employees get training in improvement concepts, tools, techniques and team building**
- **Process data from all levels is measured and displayed to control production, prevent defects and indicate opportunities for improvement**
- **Suppliers provide and get feedback and are rated to select a limited number of suppliers and to improve long-term cooperation for improvement**
- **Customers provide and get feedback and cooperate for improvement, e.g., to reduce bulk requests**
- **Employee targets, assessments and rewards of all departments are in line with the improvement vision**

### Article

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Only a few studies have gone beyond identifying success factors for implementing lean practices. Motwani (2001) developed a TQM success factor implementation model, but his proposed sequence of success factors has not been empirically substantiated. Other studies identify sequences for success factors, based on their importance (Achanga et al., 2006; Badri et al., 1995; Sohal & Terziiovski, 2000) or their interrelationships (García & Maldonado, 2014; García & Rivera, 2013; Kaye & Anderson, 1999; Marodin & Saurin, 2015b; Motwani, 2001). In those studies, ‘top management support’ and ‘shared improvement vision’ were consistently ranked as more important than ‘sufficient resources’ and ‘improvement culture’, indicating that a top-down approach might be more successful when implementing lean practices.
### Critical Success Factor

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<td>X</td>
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</tbody>
</table>

Netland (2016) found that the stage of lean implementation influences the importance of success factors, and that ‘leadership’ was ranked most important for both some implementation and for advanced implementation of lean practices. The same study also found that the importance of top management support increases with the extent of implementation of lean practices, and that the importance of improvement training, sufficient resources and support congruence decreases with advanced implementation of lean practices. This stage-dependent importance is in line with the process view on lean practice implementation as suggested by Shah and Ward (2007) and studied by Danese, Romano, and Boscari (2017). This chapter will test the stage-dependent importance of the 12 success factors identified in the literature in a sample of manufacturing SMEs.
3.3. RESEARCH METHODOLOGY
To test the extent to which success factors identified in the literature are critical for the implementation of lean practices, we conducted a Necessary Condition Analysis using self-assessment data.

3.3.1. Sample and data collection
The sample consisted of multiple-respondent self-assessments from 33 manufacturing SMEs recruited through the network of the Research Group Lean/World Class Performance at HAN University of Applied Sciences. Manufacturing was defined using the classification of economic activities in the European Community (commonly referred to as NACE) as ‘Level 1, Group C: Manufacturers’ (EC 2010). SMEs were defined as companies that employ 10–250 employees (EC 2005). We gathered data between 2013 and 2016 using multiple-respondent self-assessments.

To overcome respondent bias (Bowman & Ambrosini, 1997), we asked multiple respondents per case to participate. To ensure that participants were suitable to fill in the self-assessment, they were selected based on their own understanding of the questions and their familiarity with the concepts surveyed. The production manager was always involved, but was complemented by the owner/director, general manager, managers of marketing, sales, R&D, engineering and/or logistics, production leaders and/or team leaders, resulting in a cross-level and cross-functional self-assessment. The number of respondents per case was linked to the number of employees at the company and varied from two to 13, with an average of six respondents per case.

3.3.2. Measures
The 12 success factors identified in the literature are: (i) top management support, (ii) shared improvement vision, (iii) good communication, (iv) leadership, (v) people focus, (vi) learning focus, (vii) sufficient resources, (viii) improvement training, (ix) performance measurement system, (x) supplier link, (xi) customer link and (xii) support congruence (see Table 2). Each factor was measured with a single item: e.g., ‘To what extent is top management support present for the implementation of lean practices in this organization?’. To overcome idiosyncratic variation and increase construct validity for multiple respondents, we explained all the items beforehand, both orally and in writing. We also gave the results back
to the respondents and discussed them with them afterwards. This enabled us to check whether the results were representing the constructs we intended to measure for that case. When using single questions to measure an item, nine-point Likert scales leave sufficient room for discrimination and are suitable for preventing measurement error (Finstad, 2010). The Likert scale ranged from (1) ‘no presence’ to (9) ‘full presence’ of the success factor.

To measure the implementation of lean practices, we used the widely accepted questionnaire developed by Shah and Ward (2007) (Hofer, Eroglu, & Rossiter Hofer, 2012; Marodin & Saurin, 2013; e.g., Vinodh & Balaji, 2011). The questionnaire consists of 41 questions covering ten lean practices: (i) involved employees, (ii) productive maintenance, (iii) controlled processes, (iv) pull, (v) flow, (vi) low setup, (vii) supplier feedback, (viii) JIT delivery, (ix) developing suppliers and (x) involved customers. Compared to well accepted lean rules or principles (Liker, 2004; Spear & Bowen, 1999; Womack & Jones, 2003), these 41 questions are more practical, making it easier to assess their presence by the respondents. Additionally, compared to the rules and principles the questions are more extensive, providing a more reliable assessment by the respondents. Compared to other well accepted questionnaires (e.g., Furlan, Vinelli, & Dal Pont, 2011; Peng et al., 2008; Sakakibara, Flynn, & Schroeder, 1993), the questionnaire by Shah and Ward is more comprehensive and/or better in line with the state of art. Using Shah and Ward’s questionnaire, we used multiple questions to measure all lean practices. And, like Shah and Ward, we used a five-point Likert scale where: (1) ‘no implementation’, (2) ‘some implementation’, (3) ‘moderate implementation’, (4) ‘extensive implementation’ and (5) ‘full implementation’. With multiple questions per item, five points are sufficient to overcome measurement error (Finstad, 2010). Given the diversity within lean practices, we decided not to use descriptive scores.

It might be noted that the terms training, suppliers and customers are used in both the measurement instrument on success factors and that on lean practices. Though that is correct, these terms have different meanings in both instruments. In general, the items on success factors relate to areas that support the primary process of an organization, the items on lean practices relate to the actual primary process of the organization. Regarding training, the item as success factor covers improvement training such as the use of A3s or conducting Toyota
Kata routines, the one question on training for lean practices covers cross functional training of daily work. The same goes for the items on suppliers. The supplier item as success factor measures a condition that facilitates improvements with suppliers. The supplier bundles of lean practices measure the actual cooperation with suppliers in the primary process and supply chain of the organization. And the same goes for the items on customers. The customer item as success factor measures a condition that facilitates improvements with customers. The customer bundle of lean practices measures the actual cooperation with customers in the primary process and supply chain of the organization.

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 (Dal Pont, Furlan, & Vinelli, 2008; McKone et al., 2001; Sakakibara et al., 1997; Slack et al., 2010; Vickery, Droge, & Markland, 1993). These seven formative indicators of operational performance were each measured with single questions: e.g., ‘How is this organization’s performance on cost, compared to that of its competitors?’.

Given our elaborate approach to gather the data, we think there is no difference in reliability for relative performance data (that is compared to competitors) versus actual performance data. Additionally, for the analyses in this chapter, we think relative performance data is equally relevant to actual performance data. The questions were explained and checked in the same way as the success factors, and again a nine-point Likert scale was used, ranging from (1) ‘very bad performance’ to (9) ‘very good performance’.

3.3.3. Data analysis
Since we found a positive relationship between lean practices and operational performance in the introduction, we first validated whether this relationship also applied to our set of SMEs. Given the relatively small sample size, we answered this question by conducting a between-case comparison (Dul & Hak, 2012). For each pair of cases, the average values of lean practices and operational performance were compared according to the following rule: if case A’s operational performance (OP-A) was higher than or equal to case B’s operational performance (OP-B) and case A’s lean practice implementation (LP-A) was higher than or equal to case B’s lean practice implementation (LP-B), the outcome was
1. Likewise, if case A’s operational performance (OP-A) was lower than case B’s operational performance (OP-B) and case A’s lean practice implementation (LP-A) was lower than case B’s lean practice implementation (LP-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 linked to a higher value on operational performance. If this was not true, then the outcome was coded as 0. Applying this rule to each pairwise comparison (\( \frac{n(n-1)}{2} - \frac{32}{2} = 328 \) pairwise comparisons in total) produces an overall score between 0% (none of the pairwise comparisons met this condition) and 100% (all the pairwise comparisons met this condition) indicating the strength of the relationship between the implementation of lean practices and operational performance in manufacturing SMEs. An outcome of 50% would indicate there was no relationship.

To identify the extent to which success factors were critical at different stages of implementation of lean practices in manufacturing SMEs, we conducted a Necessary Condition Analysis (Dul, 2016). In contrast to the more regular regression analyses that study variables in a probabilistic relationship to each other, NCA allows us to study variables that are necessary but no guarantee for a certain outcome (e.g., success factors are necessary but no guarantee for the implementation of lean practices).

Using a regression analysis of the upper-left observations of an x-y plot, the NCA identifies a ceiling line. This line serves as a border between the ‘empty space’ and the ‘full space’ of the dataset (Goertz, Hak, & Dul, 2012), and indicates the degree to which lean practices (y-axis) could be implemented without the presence of success factors (x-axis). See, for example, Figure 3: the solid line is the ceiling line for the regression equation \( y = f(x) \), where \( x \) is ‘top management support’ and \( y \) is ‘the implementation of lean practices’. This ceiling line indicates the minimum presence of a given success factor to be able to implement a certain degree of lean practices. Using the regression equations of the ceiling lines of all success factors, we identified a minimum extent of each success factor’s presence for every stage of implementation of lean practices. This method of analysis follows other examples of NCA application such as Van Der Valk et al. (2016), who determined the criticality of contracts and trusts for supplier relations, and Sousa and Da Silveira (2017), who found necessary degrees of services in the process of servitisation.
3.4. RESULTS
This section first shows that more implementation of lean practices was indeed also linked to a higher operational performance in SMEs. We then report the extent to which the success factors were found to be critical for the implementation of lean practices in SMEs.

3.4.1. The effect of lean practices on operational performance in manufacturing SMEs
To analyse whether implementation of lean practices was also linked to higher operational performance in our set of manufacturing SMEs, we conducted a between-case comparison (Dul & Hak, 2012). Our findings confirm the improvement effect found in earlier studies of LEs: in most pairwise comparisons, SMEs with higher scores for implementation of lean practices also had higher operational performance. The between-case comparison score for this study - i.e., the percentage of 528 pairwise comparisons that met the expected pattern.
that a higher value on lean practices was linked to a higher value on operational performance – was 70.08%.

This relationship is not stronger because the observations, especially those of the lean practices, were close to each other. Between-case comparison is very sensitive to the absolute distance between observations (Dul & Hak, 2012). A margin of plus or minus 5% for the ‘bigger than or equal to’ or the ‘smaller than’ was applied. This means that the comparison was disregarded when the observations were within a 5% range of each other. Using this margin resulted in 413 pairwise comparisons and a positive finding of 75.30%.

Another reason for the relationship being weaker is that organizations often choose to excel at specific operational measures. For example, if price or quality are most important for certain customers, companies that serve such customers might agree to perform less on other performance measures, resulting in a lower average operational performance compared to other cases. Both arguments strengthen our finding that there is a relationship between the implementation of lean practices and increased operational performance in our set of manufacturing SMEs.

3.4.2. Critical success factors for the implementation of lean practices

To identify the extent to which success factors were critical at different stages of implementation of lean practices, we first used x-y plots for each success factor (x-axis) in relationship to each lean practice (y-axis). If visual inspection indicated an ‘empty space’ in the upper-left corner of the x-y plot (e.g., Figure 3), there was no implementation of lean practices without the presence of that specific success factor, which suggests that that success factor would have been necessary for the implementation of lean practices. The x-y plots of the 12 success factors and lean practices are presented in Figure 3 through 8. Visual inspection of all figures indeed showed an empty space in the upper-left corner of each figure. These empty spaces indicated that all 12 success factors were necessary for implementing lean practices.
Figure 4: NCA plot of shared improvement vision for lean practices

Figure 5: NCA plot of good communication for lean practices
Figure 6: NCA plots of improvement culture: (a) leadership, (b) learning focus and (c) people focus for lean practices
Figure 7: NCA plots of improvement structure: (a) sufficient resources, (b) improvement training and (c) performance management system for lean practices
Figure 8: NCA plots of integrated focus: (a) supplier link, (b) customer link and (c) support congruence for lean practices.

Visual inspection of the x-y plots suggest that all the success factors are necessary, but their criticality was not quantitatively specified. To further analyse the findings for criticality, we first drew a ceiling line to indicate the degree to which lean practices (y-axis) were implemented without the presence of success factors (x-axis). The ceiling line could either envelop the upper-left observations with a piecewise-linear convex line (a ceiling envelopment line, CE-FDH hereafter referred to as CE line), or it could be a regression trend line through the upper-left observations of the dataset (ceiling regression line, CR-FDH hereafter).
referred to as CR line) (Dul, 2016). Dul (2016) recommends using a CE line for a discrete dataset and a CR line for a continuous dataset. The data in this study were gathered using a discrete scale, then averaged from multiple respondents, and analysed using a continuous scale. Therefore, both CE and CR lines were drawn. Using the software ‘R 3.3.1’ with the package ‘NCA 2.0’, ceiling lines were automatically drawn for the CE and CR. Both lines are shown in Figures 3 through 8; the CE lines are represented by broken lines and the CR lines are represented by solid lines.

To determine the validity of the ceiling lines, two parameters are calculated: the accuracy and the effect size. The accuracy of success factor criticality depends on the number of observations on or above these 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 are many observations above the ceiling line and in the ceiling zone, the success factors will not always be critical for implementing lean practices. So, the more observations found above the ceiling line, the less accurate the indication of success factor criticality for implementing lean practices.

The success factor accuracies are further provided by the NCA software, shown in Table 3. As the CE is a piecewise-linear line through the upper-left observations, the ceiling zone left of the CE line was completely empty. This results in an accuracy of 100% (i.e., the CE line was valid for all cases). The ceiling zone above the CR line, however, did contain cases, hence its accuracy was not 100%. This lower accuracy might have resulted 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 3 generally shows a lower accuracy for higher ceiling zones. Given the limited number of cases in this study, the resulting CR line was considered valid for finding success factor criticality and thus could be used in the bottleneck table later in this section.
Table 3: NCA parameters of 12 success factors for lean practices

<table>
<thead>
<tr>
<th>Construct</th>
<th>Method</th>
<th>Accuracy</th>
<th>Scope</th>
<th>Ceiling zone</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Top management support</td>
<td>CE</td>
<td>100%</td>
<td>4.220</td>
<td>1.049</td>
<td>0.249</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>90.9%</td>
<td>4.220</td>
<td>0.875</td>
<td>0.207</td>
</tr>
<tr>
<td>ii. Shared improvement vision</td>
<td>CE</td>
<td>100%</td>
<td>5.226</td>
<td>1.494</td>
<td>0.286</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>87.9%</td>
<td>5.226</td>
<td>1.558</td>
<td>0.298</td>
</tr>
<tr>
<td>iii. Good communication</td>
<td>CE</td>
<td>100%</td>
<td>4.119</td>
<td>1.833</td>
<td>0.287</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>90.9%</td>
<td>4.119</td>
<td>1.148</td>
<td>0.277</td>
</tr>
<tr>
<td>iv. Leadership</td>
<td>CE</td>
<td>100%</td>
<td>4.334</td>
<td>0.893</td>
<td>0.216</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>97.0%</td>
<td>4.334</td>
<td>0.831</td>
<td>0.201</td>
</tr>
<tr>
<td>v. People focus</td>
<td>CE</td>
<td>100%</td>
<td>3.761</td>
<td>0.739</td>
<td>0.196</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>93.9%</td>
<td>3.761</td>
<td>0.604</td>
<td>0.161</td>
</tr>
<tr>
<td>vi. Learning focus</td>
<td>CE</td>
<td>100%</td>
<td>4.769</td>
<td>1.420</td>
<td>0.298</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>90.9%</td>
<td>4.769</td>
<td>1.274</td>
<td>0.267</td>
</tr>
<tr>
<td>vii. Sufficient resources</td>
<td>CE</td>
<td>100%</td>
<td>4.520</td>
<td>1.275</td>
<td>0.262</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>87.9%</td>
<td>4.520</td>
<td>1.075</td>
<td>0.260</td>
</tr>
<tr>
<td>viii. Improvement training</td>
<td>CE</td>
<td>100%</td>
<td>5.620</td>
<td>2.192</td>
<td>0.390</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>81.8%</td>
<td>5.620</td>
<td>1.916</td>
<td>0.341</td>
</tr>
<tr>
<td>ix. Performance management system</td>
<td>CE</td>
<td>100%</td>
<td>6.436</td>
<td>1.846</td>
<td>0.287</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>90.9%</td>
<td>6.436</td>
<td>1.449</td>
<td>0.225</td>
</tr>
<tr>
<td>x. Supplier link</td>
<td>CE</td>
<td>100%</td>
<td>4.364</td>
<td>1.540</td>
<td>0.303</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>87.9%</td>
<td>4.364</td>
<td>1.232</td>
<td>0.296</td>
</tr>
<tr>
<td>xi. Customer link</td>
<td>CE</td>
<td>100%</td>
<td>4.523</td>
<td>0.706</td>
<td>0.156</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>97.0%</td>
<td>4.523</td>
<td>0.443</td>
<td>0.098</td>
</tr>
<tr>
<td>xii. Support congruence</td>
<td>CE</td>
<td>100%</td>
<td>5.821</td>
<td>2.071</td>
<td>0.356</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>84.8%</td>
<td>5.821</td>
<td>1.765</td>
<td>0.303</td>
</tr>
</tbody>
</table>

The size of the ceiling zone is also important, because almost every scatterplot contains a ceiling zone, no matter how small, in its upper-left corner. The larger the size of the ceiling zone, the more effect the success factor has on the implementation of lean practices. It was therefore important to calculate the effect size of the success factors (i.e., how large 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) top management support divided by its scope gives the effect size \( \frac{1.049}{4.220} = 0.249 \). 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 larger the effect size of the success factor, the more sensitive the implementation of lean practices is to the absence of the success factor. The results are given again in Table 3. A large effect was found for a shared improvement vision, good communication, sufficient resources, improvement training and a supplier link; a small effect was found for a customer link; and a moderate effect was found for all the other success factors.

To test the extent to which success factors were critical, we created a bottleneck table (Dul, 2016). The presence of the success factors was compared with the implementation of lean practices, using the regression equation (y=f(x)) from the CR line. For every level of y (implementation of lean practices), this equation gave a level of x that the success factor appeared critical. The success factor(s) that require(s) the highest presence for a certain degree of implementation of lean practices can be seen as the most critical. If the required aspect is not yet in place, this success factor might have been the bottleneck for the implementation of lean practices. If this success factor was met, the next most critical success factor might have been the next bottleneck for the implementation, and so on, until all success factors were met.

Table 4 presents the bottleneck table for all 12 success factors. The lean practices and success factors are shown as a percentage of the range of the lowest and highest observed values. The first column gives the percentage of implementation of lean practices. Because the bottleneck table only covers the data spectrum we observed, the NCA software translates the lowest observed outcome, 2.24 on the 5-point Likert scale, to ‘0’ for the first row, and it translates the highest observed outcome, 3.28 on the 5-point Likert scale, to ‘100’ for the last row. The former are cases with initial implementation of lean practices, and the latter are cases with more advanced implementation of lean practices. The other 12 columns give the extent to which the 12 success factors were present.
Again, the percentage of the range of the conditions is given. The lowest observed condition was 1.4 and represents no presence on the 9-point Likert scale and the highest condition was 8.5 and represents full presence on the 9-point Likert scale. Therefore ‘NN’ stands for not necessary and ‘100’ stands for full presence of the success factor. Since our data do not cover the entire Likert scale of lean practices (1-5) or success factors (1-9), NN in the very first row means that we do not have data to show what percentage is required to start with lean. NN and the numbers in the remainder of this bottleneck table indicate the success factor criticality for various stages of implementation of lean practices.

Table 4: Bottleneck table of the 12 critical success factors for lean practice implementation

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
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<td>NN</td>
</tr>
<tr>
<td>10</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>3.8</td>
<td>NN</td>
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<td>NN</td>
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<td>NN</td>
<td>NN</td>
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<td>NN</td>
<td>9.5</td>
<td>6.2</td>
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<td>10.5</td>
<td></td>
</tr>
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<td>NN</td>
<td>10.2</td>
<td>NN</td>
<td>15.2</td>
<td>12.7</td>
<td>16.5</td>
<td>10.9</td>
<td>1.4</td>
<td>NN</td>
<td>17.1</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>NN</td>
<td>11.7</td>
<td>18.4</td>
<td>NN</td>
<td>20.9</td>
<td>19.2</td>
<td>26.2</td>
<td>16.6</td>
<td>13</td>
<td>NN</td>
<td>23.7</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>9.9</td>
<td>24.1</td>
<td>26.5</td>
<td>NN</td>
<td>4</td>
<td>26.7</td>
<td>25.6</td>
<td>33.9</td>
<td>22.2</td>
<td>24.7</td>
<td>30.3</td>
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<tr>
<td>60</td>
<td>22.2</td>
<td>36.4</td>
<td>34.6</td>
<td>11.6</td>
<td>15.2</td>
<td>32.4</td>
<td>32.1</td>
<td>41.6</td>
<td>27.9</td>
<td>36.4</td>
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<td>36.8</td>
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<td>70</td>
<td>34.5</td>
<td>49.8</td>
<td>42.7</td>
<td>30.4</td>
<td>26.4</td>
<td>38.1</td>
<td>38.6</td>
<td>49.4</td>
<td>33.5</td>
<td>48.1</td>
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<td>80</td>
<td>46.9</td>
<td>61.2</td>
<td>58.8</td>
<td>49.2</td>
<td>37.6</td>
<td>43.9</td>
<td>45.1</td>
<td>57.1</td>
<td>39.2</td>
<td>59.8</td>
<td>21.3</td>
<td>50</td>
</tr>
<tr>
<td>90</td>
<td>59.2</td>
<td>73.6</td>
<td>68.1</td>
<td>48.8</td>
<td>49.6</td>
<td>51.5</td>
<td>64.8</td>
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<td>71.5</td>
<td>85.9</td>
<td>67.1</td>
<td>86.9</td>
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<td>55.3</td>
<td>58</td>
<td>72.5</td>
<td>50.5</td>
<td>83.2</td>
<td>66.9</td>
<td>63.1</td>
</tr>
</tbody>
</table>

Using the bottleneck table, we identified the required sequence of critical success factors for the implementation of lean practices. The first row of
percentages in Table 4 (outcome 10%) suggests that in our set of manufacturing SMEs, only some presence of a learning focus (3.8%), improvement training (3.1%) and support congruence (4%) (corresponding to 1-2 on the 9-point Likert scale) are critical to starting to implement lean practices. The next set of success factors for implementing lean practices (outcome 20%) are good communication (2.1%), sufficient resources (6.2%) and a performance management system (5.2%). These results show that manufacturing SMEs that started to implement lean practices also had some sort of measurements to guide the process, they had a few people who were open to improvements and discussed them, and they had a basic improvement structure (some training, time and money to make improvements).

Looking at the other end of the spectrum, the last three rows (outcome 80–100%) showed percentages for all success factors, meaning that all success factors were at least partially present (21.2%-61.3% corresponding to 3-6 on the 9-point Likert scale) at manufacturing SMEs with more advanced implementation of lean practices (3 on the 5-point Likert scale). The extent per success factor is again given by a percentage. The factors that require the greatest presence are a shared improvement vision (85.9%), leadership (86.9%) and a supplier link (83.2%) (corresponding to 8 on the 9-point Likert scale); these percentages indicate that these success factors are very present in more advanced implementations of lean practices. This means that in our set of manufacturing SMEs, more advanced lean practitioners gradually focused more on developing a shared and overall improvement vision and they needed managers to coordinate the different improvement projects.

The factors that require the least presence for more advanced implementation are a performance management system (50.5%), a learning focus (55.3%) and sufficient resources (58%) (corresponding to 5-6 on the 9-point Likert scale). These results indicate that the success factor criticality changes with various extents of implementation of lean practices. This bottleneck table suggests that the only success factors critical for some implementation of lean practices are good communication, a learning focus, an improvement structure (sufficient resources, improvement training and a performance measurement system) and support congruence, and that the most critical factors for more advanced lean practitioners are a shared improvement vision, leadership and a supplier link.
3.4.3. High-variety/low-volume cases are most efficient with success factors

Special cases can provide new insights into success factors for lean practices. Cases of particular interest were found on the CE line, because these cases were the most efficient performers: their implementation of lean practices was the highest, while their success factor presence was the lowest. By listing these cases for all success factors, we found that cases 4, 10, 21, 29 and 32 were on the CE line for eight or more of the 12 success factors. We consider these five cases to be the most efficient performers. Case 10, however, was in the bottom 25% of lean practice implementers (bottom left), while the other four cases were amongst the top 25% of lean practice implementers (upper right). The latter four cases were thus highly efficient as top performers in implementing lean. These four top cases had varying numbers of employees (38–250) and were from different industries (electronics and manufactured goods), but all of them were high-variety/low-volume producers.

Looking at the implementation of lean practices, the top cases had higher implementation of the pull driven flow of value-added activities (3.3–3.9) than the other 29 cases (average of 2.7). Controlled processes and productive maintenance, and supplier and customer integration were only slightly better (2.5–2.9 / 2.3 and 2.9-3.3 / 2.8, respectively). Employee involvement was not better than in the other cases. This extent of implementation of lean practices enabled the top-performing medium-sized cases to excel at product flexibility (7.1-8.0 / 6.8) and the top-performing small-sized cases to excel at volume flexibility (7.8-8.5 / 6.5). In sum, these results indicate that high-variety/low volume manufacturers more easily reach the full potential of lean practice implementation, compared to low-variety/high volume manufacturers and jobbers, enabling them to perform in a highly flexible way while meeting their customer requirements.

3.5. DISCUSSION

The aim of this study was to identify which success factors are critical at different stages of lean practices implementation. We analysed a dataset from manufacturing SMEs using a novel method: NCA.
3.5.1. Shop-floor activities for all levels of lean practice implementation

Our results indicate that the following factors are critical for companies with little implementation of lean practices and above: good communication, a learning focus, an improvement structure (sufficient resources, improvement training and a performance management system) and support congruence. It is logical that good communication is important for initiating lean practices, because improvements always require communication with colleagues, team leaders, upstream and downstream processes and so forth. This finding is in line with Achanga et al. (2006) and Dora, Kumar and Gellynck (2016), who found that some degree of communication is desirable when implementing any kind of improvement. A learning focus also seemed crucial from the start, which seems plausible: improvements require experimenting, so employees need to be allowed to make mistakes and learn from them. This is in line with Yusoff and Aspinwall (1999, 2000) and Dora, Kumar and Gellynck (2016), who found that a ‘blame game’ in companies was linked to low levels of trust and hence counters employee initiative.

An improvement structure also needs to be present from the start. Sufficient resources and improvement training are needed to think of, experiment with and implement improvements, and a performance management system is needed to monitor whether these implementations actually lead to improvements. According to Yusoff and Aspinwall (1999, 2000) and Dora, Kumar and Gellynck (2016), a lack of resources can act as an excuse not to improve, and the measurement of results, progress and performance is critical for implementing lean practices. Zhou (2016) found that the lack of time and budgets was high for companies with initial implementation of lean practices and Hu et al. (2015) found that training was important to diffusing lean implementation. The criticality of support congruence in the initial stages of implementing lean is also plausible because employees act, or refrain from acting, based on the rewards they receive, both intrinsically and extrinsically. If these rewards are not in line with required improvements, there is no drive to improve (Achanga et al., 2006; Dora et al., 2016).

All these success factors are linked to shop-floor activities, so they seem mostly linked to local improvements. This is in line with Bessant, Caffyn and Gallagher (2001) and Dora, Kumar and Gellynck (2016), who found that all
the manufacturing SMEs they studied adopted a gradual approach to the implementation of lean practices. This gradual approach may be suitable to SMEs in particular because they lack the resources to launch a company-wide implementation programme (Dora et al., 2016). In sum, we can conclude that good communication, a learning focus, an improvement structure and support congruence are critical for the initial stages of lean practice implementation on a local level.

3.5.2. Strategic involvement only critical for advanced lean practitioners

We also conclude that different success factors are critical for manufacturing SMEs that are more advanced lean practitioners. Only those organizations that achieved more advanced implementation of the lean practices showed an extensive presence of top management support, a shared improvement vision, leadership and a supplier link. This contrasts with the received wisdom that strategic involvement is most important from the start (Achanga et al., 2006; Badri et al., 1995; García & Maldonado, 2014; García & Rivera, 2013; Hu et al., 2015; Kaye & Anderson, 1999; Motwani, 2001; Netland, 2016; Sohal & Terzirovski, 2000). In hindsight, further development of these factors seems more relevant for continued company-wide improvements. Such a company-wide approach is only possible if top management supports these initiatives (Motwani et al., 1994; Saraph et al., 1989). This is especially true for SMEs where managers are already more actively involved in day-to-day operations and operators rather than consultants or staff are needed to make improvements, shifting efforts from the board room to the shop floor (Dora et al., 2016). Furthermore, a shared improvement vision may only become critical when a company-wide approach is being attempted; it ensures that improvement projects in different departments are in line with each other, not causing any sub-optimisation. According to Salaheldin (2009), Achanga et al. (2006), and Dora, Kumar and Gellynck (2016), a shared improvement vision is needed to guarantee the long-term effectiveness of the improvements. Finally, leadership was only found to be a critical success factor when coordinating different improvement projects, even within the same departments. This is in line with Saraph, Benson and Schroeder (1989), Yusof and Aspinwall (1999, 2000), and Achanga et al. (2006), who found that leadership enables the integration of different improvements, which helps to succinctly implement lean practices. Therefore, we conclude that, in contrast to previous literature, a more extensive presence of top management support, a shared
improvement vision and leadership are only critical for continued company-wide implementation of lean practices in manufacturing SMEs.

3.5.3. Upstream improvements precede downstream improvements
The bottleneck table shows that dependencies on external processes were only stronger for those manufacturers that had improved internal processes, starting with the success factor ‘a supplier link’. Sakakibara Flynn and Schroeder (1993) and Danes, Romano and Bortolotti (2012) found no direct link between external JIT and performance, and argue that external JIT might be necessary for internal JIT rather than directly linked to performance. Saraph, Benson and Schroeder (1989), Motwani, Mahmoud, and Rice (1994), Yusof and Aspinwall (1999, 2000), Hu et al. (2015) and Zhou (2016) found that suppliers came in at a later stage, after many of the internal improvements had been accomplished. This order of improving the supply chain was replicated in our findings. First, there was alignment within the organization (support congruence). Next, improvements were achieved together with suppliers (a supplier link). Finally, when processes were reliable and in line with suppliers, improvements also extended to customers (a customer link). Such a customer link means that organizations not only take customer value as the starting point – which, according to Womack and Jones (1996), is the first principle of lean – but also cooperate with customers in their improvement activities. Cooperation with customers will probably only be achieved if both internal and upstream processes are in good order. Therefore, we conclude that in manufacturing SMEs, organizations might only continue to improve upstream processes when the internal processes are in good order; only thereafter cooperation with customers becomes a critical success factor for improving the entire supply chain.

3.5.4. Lean in high-variety/low-volume organizations
The analyses further show that the most efficient top-performing cases were all high-variety/low-volume producers. Compared to the other cases, these companies had the highest implementation of JIT practices (a pull driven flow of value-added activities) and the highest performance of product flexibility and volume flexibility. JIT practices are seen as the core of lean (Shah & Ward, 2003). This might indicate that lean practices come fully into play in organizations that produce small bulk or custom-made products. An explanation for this finding is that JIT practices are counterproductive in conditions of extremely low demand
variability (King, 2009; Powell, Alfnes, & Semini, 2010) and extremely high demand variability (Bortolotti, Danese, & Romano, 2011, 2013).

3.5.5. Theoretical contributions
Previous research identified many success factors presumed necessary for implementing lean practices. This study suggests that, in manufacturing SMEs, there might be a sequence in which success factors become critical for success: not all success factors are critical for organizations that are in the initial stages of implementing lean practices, and some success factors appear to only be critical for organizations that have already become advanced lean practitioners.

This insight into the temporal nature of success factors contributes to the existing literature in two ways. First, our findings provide a more nuanced understanding of the criticality of success factors, suggesting that rather than being static in nature, success factor criticality changes during an organization’s lean journey. Further confirmation in longitudinal studies and in a larger sample notwithstanding, these findings can help to advance the body of knowledge on how to stage and tailor improvement activities to an organization’s maturity in terms of lean practices. Second, the study also makes a methodological contribution in showing that some relationships are better analysed using a necessary perspective rather than a probabilistic perspective and that the NCA method can be applied to open up novel perspectives on improving management practices. While the majority of statistical methods work based on correlations, NCA allows us to investigate criticality, which helps to deepen our understanding of management practices and performance outcomes.

3.5.6. Practical implications
These new insights into success factor criticality can help manufacturing SME managers in two ways. First, it can help them focus on those specific managerial areas that enable either starting or advancing the implementation of lean practices. If an organization only wants to implement lean practices to a limited degree, they can focus on shop-floor-related success factors, such as communication, a learning focus, an improvement structure and support congruence. If an organization wants to be more advanced in lean terms, managers can focus on company-wide success factors, such as top management support, a shared improvement vision and a supplier link. Second, understanding
which success factors are critical for various stages of implementation of lean practices helps managers to re-allocate their resources to sustain resource efficiency. If certain bottleneck factors have been implemented, the remaining resources can be dedicated to other success factors for which the threshold has not yet been met. This combination of focus on critical success factors and sustaining resource efficiency helps SME managers to more effectively deploy their efforts and increase the possibility that lean practices are implemented in their organization.

3.6. RECOMMENDATIONS FOR FUTURE RESEARCH

Although the underlying question of this study on the criticality of success factors for the implementation of lean practices is generic in nature, the nature and size of our sample also limit its generalisability. Our data were self-reported from a small set of Dutch manufacturing SMEs and the findings may or may not extend to other sectors or locations. Future research could replicate the approach presented here and study success factors in different countries and/or use samples suitable for generalising success factor criticality. Additionally, future research could use performance data which is even more reliable. Furthermore, sectors other than manufacturing might require different success factors or different levels of criticality in relation to implementing lean practices. To enable further abstraction, future research could therefore focus on success factors and datasets in other branches such as maintenance or services. Such replication studies would validate the findings presented here.

In addition to replication studies, the NCA method offers other exciting opportunities for future research. For example, it is known that lean practices are implemented via improvement routines, such as a shared belief in improvement and employee initiative to improve (Bessant et al., 2001; Bortolotti, Boscari, & Danese, 2015; Koufteros, Vonderembse, & Doll, 1998). Future research could use the NCA view of necessity thinking to discover which improvement routines are critical for different stages of the implementation of lean practices. Furthermore, future research could use the NCA approach to determine whether different success factors are necessary for different combinations of lean practices, and whether different lean practices in turn increase operational performance. Further insights into sequencing of improvement routines and different
combinations of lean practices could help manufacturing SMEs to further increase their operational performance and competitive advantage. Finally, we used cross-sectional data to propose a sequential model of maturity, which could be confirmed in a longitudinal study to exclude other confounding factors such as the nature of their business (low volume – high variability).

Finally, although the quantitative analysis provides insights in the criticality of success factors for lean practice implementation, it does not say much about who is involved in managing and maintaining these factors, how these factors interfere with each other or how they enable lean practice implementation. This is why observations can have the same levels of certain success factors combined with entirely different levels of the lean practices. To a certain extent, the NCA does allow for this as it allows observation in the bottom left corner. But the NCA still does not show how these factors and practices come about and evolve over time. Therefore, future research could take a process view and qualitative approach to study the underlying processes that influence and shape how these factors and practices are used to enable or produce each other.
4. THE RELATIVE IMPORTANCE OF IMPROVEMENT ROUTINES FOR LEAN PRACTICE IMPLEMENTATION
Chapter 4. The relative importance of improvement routines for lean practice implementation
THIS CHAPTER IS BASED ON:

ABSTRACT
This article examines whether and when improvement routines are critical for lean practice implementation 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 (1996) suggest that these improvement routines could be developed as the company becomes more experienced in lean. This study explores the relative importance of individual improvement routines at various degrees of lean practice implementation. A Between-Case Comparison Analysis (Dul & Hak, 2012) and a Necessary Condition Analysis (Dul, 2016) were performed on self-assessment data from 241 respondents at 38 Dutch manufacturing SMEs. The importance of improvement routines depended on the degree of lean practice implementation. Lean practices could be implemented to some extent 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. 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.

4.1. INTRODUCTION
As manufacturing SMEs seek to increase their operational performance in terms of quality, delivery and costs (Slack et al., 2010), they can turn to lean production, which is known to increase operational performance (Womack & Jones, 1996). 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 & Caffyn, 1997). However, manufacturing SMEs find it difficult to develop these improvement routines (McGovern et al., 2017; Shah & 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 production 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 & Holweg, 2016; Deming, 1993; Hines et al., 2004; Liker, 2004; Rother, 2010; Shah & Ward, 2003; Womack, 2013). This study focuses 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 & 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 & Ward, 2003; Womack & Jones, 1996).

To successfully implement lean practices, organizations need to continuously improve their processes (Bessant et al., 2001; Spear & Bowen, 1999; Womack & Jones, 1996). Continuous improvement is a dynamic organizational capability that involves specific employees conducting improvement activities (Anand, Ward, Tatikonda, & Schilling, 2009; Boer et al., 2018; Rother, 2010). This dynamic capability consists of “a particular bundle of routines which can help an organization 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’s (1996) five widely acknowledged principles of lean management (1) identifying value, (2) streamlining the value stream, (3) establishing flow and (4) pull and (5) aiming for perfection suggests that to implement lean production, 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 (1996, p. 269), “…there is a critical transition as you move your organization 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 could 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 & Ward, 2003; White et al., 1999). SMEs are important as, on a worldwide average, they contribute 42% to a country’s gross domestic product and provide work for 54% 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, op de Weeg, & Gieskes, 2007; Welsh & 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 & Jones, 1996). 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 chapter 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 implement lean production to identify the most relevant improvement routines for their degree of lean practice implementation. This study questions lean
4.2. IMPROVEMENT ROUTINES FOR LEAN PRACTICE IMPLEMENTATION AND OPERATIONAL PERFORMANCE IN MANUFACTURING SMES

This section explains the link between organizational learning and continuous improvement and summarizes 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 & Ward, 2003; Womack & Jones, 1996), 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.

4.2.1. Organizational learning core to continuous improvement

Organizations 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, organizations must develop their dynamic capabilities (Peng et al., 2008). Dynamic capability is defined as “a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness” (Zollo & Winter, 2002, p. 340). From the work of Fiol and Lyles (1985), we can reason that dynamic capabilities are developed through organizational learning, which means “improving actions through better knowledge and understanding” (p. 803). In the context of this study, organizational learning occurs in learning cycles or improvement cycles, like Plan-Do-Study-Act or Define-Measure-Analyse-Improve-Control (Bessant, Caffyn, & Gilbert, 1996; Deming, 1993). So, to improve lean practices and increase
operational performance, organizations need to understand their operating routines and articulate the need to improve them.

4.2.2. Aggregate improvement routines for lean practices and operational performance

According to Womack and Jones (1996), 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 helped 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 and presence of an improvement structure mutually enacted wider comprehension of improvement and learning. De Jager et al. (2004) found that developing continuous improvement routines helped to implement certain lean practices which, in turn, reinforced the improvement routines and 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. (2007) suggest that next to top-down management initiatives, developing improvement routines bottom-up early in the improvement process may be the best way to approach improvement. Kim et al. (2014) found that enterprises with mature improvement programmes equally combine management-initiated and employee-initiated improvement activities. Thus, organizations could start implementing lean practices without 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.
4.2.3. 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 recognize 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 organization can extend their improvement activity across organizational 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 prioritize improvements against the organizational strategy and monitor whether improvements affect this strategy. Two other important routines were ‘the ability to learn’ and ‘the ability to improve across organizational boundaries’.

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

4.2.4. 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, Backlund, & Johnsson, 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 organizational 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 & Bigras, 2004). Furthermore, they found that in these more effective cases ‘managers supported and led improvement activities’ and
that ‘organizational 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 & 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 organizational learning, which eventually helps to increase operational performance.

To summarize, 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, leadership and 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 (Dabhihkar & Bengtsson, 2004; Dabhilkar et al., 2007; 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 chapter therefore explores the relative importance in which individual improvement routines are necessary to implement various degrees of lean practices in SMEs.

4.3. METHODS
This section describes the sample and measures and how a Between-Case Comparison Analysis (Dul & Hak, 2012) and a Necessary Condition Analysis (Dul, 2016) were conducted.
4.3.1. Sample and data collection
A total of 38 manufacturing SMEs were recruited through the network of the HAN Lean-QRM Centre in the Netherlands. See Table 5 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).

Table 5: Overview of companies involved in the sample

<table>
<thead>
<tr>
<th>Case</th>
<th>Employees</th>
<th>Respondents</th>
<th>Variety/volume</th>
<th>Industry</th>
<th>Products</th>
<th>Operational performance</th>
<th>Lean practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24</td>
<td>7</td>
<td>Jobber</td>
<td>Metalworking</td>
<td>Sheet metal working</td>
<td>6.5</td>
<td>2.9</td>
</tr>
<tr>
<td>2</td>
<td>58</td>
<td>4</td>
<td>High-variety low-volume</td>
<td>Electronics</td>
<td>Switchboxes</td>
<td>6.0</td>
<td>2.2</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>2</td>
<td>High-variety low-volume</td>
<td>Machinery</td>
<td>Machines</td>
<td>7.6</td>
<td>3.3</td>
</tr>
<tr>
<td>4</td>
<td>51</td>
<td>8</td>
<td>High-variety low-volume</td>
<td>Electronics</td>
<td>Panels</td>
<td>7.2</td>
<td>3.0</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>4</td>
<td>High-variety low-volume</td>
<td>Manufactured goods</td>
<td>Hinges</td>
<td>6.5</td>
<td>2.8</td>
</tr>
<tr>
<td>6</td>
<td>94</td>
<td>7</td>
<td>High-variety low-volume</td>
<td>Machinery</td>
<td>Conveyor belts</td>
<td>6.9</td>
<td>2.7</td>
</tr>
<tr>
<td>7</td>
<td>60</td>
<td>4</td>
<td>Low-variety high-volume</td>
<td>Construction industry</td>
<td>Paving stones</td>
<td>6.3</td>
<td>3.0</td>
</tr>
<tr>
<td>8</td>
<td>103</td>
<td>9</td>
<td>Low-variety high-volume</td>
<td>Manufactured goods</td>
<td>Flue gas discharges</td>
<td>6.8</td>
<td>2.5</td>
</tr>
<tr>
<td>9</td>
<td>35</td>
<td>5</td>
<td>High-variety low-volume</td>
<td>Machinery</td>
<td>Presses</td>
<td>5.6</td>
<td>2.6</td>
</tr>
<tr>
<td>10</td>
<td>123</td>
<td>7</td>
<td>Low-variety high-volume</td>
<td>Plastics</td>
<td>Packaging materials</td>
<td>7.4</td>
<td>3.1</td>
</tr>
<tr>
<td>11</td>
<td>27</td>
<td>2</td>
<td>High-variety low-volume</td>
<td>Metalworking</td>
<td>Steel constructions</td>
<td>7.4</td>
<td>2.7</td>
</tr>
<tr>
<td>12</td>
<td>250</td>
<td>13</td>
<td>High-variety low-volume</td>
<td>Automotive</td>
<td>Garbage trucks</td>
<td>5.9</td>
<td>2.5</td>
</tr>
<tr>
<td>13</td>
<td>20</td>
<td>7</td>
<td>Low-variety high-volume</td>
<td>Manufactured goods</td>
<td>Ropes</td>
<td>6.4</td>
<td>2.4</td>
</tr>
<tr>
<td>14</td>
<td>90</td>
<td>6</td>
<td>Jobber</td>
<td>Metalworking</td>
<td>Sheet metal working</td>
<td>6.4</td>
<td>2.6</td>
</tr>
<tr>
<td>15</td>
<td>47</td>
<td>4</td>
<td>Low-variety high-volume</td>
<td>Plastics</td>
<td>Packaging materials</td>
<td>6.6</td>
<td>3.3</td>
</tr>
<tr>
<td>16</td>
<td>87</td>
<td>7</td>
<td>High-variety low-volume</td>
<td>Manufactured goods</td>
<td>Doors</td>
<td>6.0</td>
<td>2.5</td>
</tr>
<tr>
<td>17</td>
<td>31</td>
<td>6</td>
<td>Jobber</td>
<td>Metalworking</td>
<td>Sheet metal working</td>
<td>6.4</td>
<td>2.4</td>
</tr>
<tr>
<td>18</td>
<td>96</td>
<td>7</td>
<td>High-variety low-volume</td>
<td>Electronics</td>
<td>Measuring equipment</td>
<td>6.0</td>
<td>2.6</td>
</tr>
<tr>
<td>19</td>
<td>125</td>
<td>11</td>
<td>Low-variety high-volume</td>
<td>Construction industry</td>
<td>Garden material</td>
<td>6.0</td>
<td>3.0</td>
</tr>
<tr>
<td>20</td>
<td>40</td>
<td>7</td>
<td>Low-variety high-volume</td>
<td>Construction industry</td>
<td>Paving stones</td>
<td>7.1</td>
<td>3.2</td>
</tr>
<tr>
<td>21</td>
<td>40</td>
<td>4</td>
<td>Jobber</td>
<td>Metalworking</td>
<td>Sheet metal working</td>
<td>7.1</td>
<td>2.3</td>
</tr>
<tr>
<td>22</td>
<td>136</td>
<td>11</td>
<td>High-variety low-volume</td>
<td>Manufactured goods</td>
<td>Miscellaneous</td>
<td>6.1</td>
<td>2.2</td>
</tr>
<tr>
<td>23</td>
<td>29</td>
<td>3</td>
<td>Jobber</td>
<td>Construction industry</td>
<td>Glass</td>
<td>6.7</td>
<td>2.7</td>
</tr>
</tbody>
</table>
To overcome single respondent bias (Bowman & 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 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 six on average, 241 in total).
4.3.2. Measures

Improvement routines were measured using Bessant et al.’s (2001) 35-item questionnaire, a further development of the earlier version (Bessant & Caffyn, 1997), both of which are commonly used or built on in other studies (e.g., de Jager et al., 2004; Jørgensen et al., 2006; Singh & Singh, 2015). It measures eight improvement routines: (i) understanding improvement, (ii) getting the improvement habit, (iii) focusing improvement, (iv) leading the way, (v) aligning improvement, (vi) shared problem solving, (vii) improvement of improvement and (viii) the learning organization. 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, Eroglu, & Rossiter Hofer, 2012; Marodin & Saurin, 2013; Vinodh & Balaji, 2011). As for the previous chapter, we chose this questionnaire over well accepted lean rules or principles (Liker, 2004; Spear & Bowen, 1999; Womack & Jones, 2003) because these 41 questions are more practical, making it easier to assess their presence by the respondents. Additionally, compared to the rules and principles the questions are more extensive, providing a more reliable assessment by the respondents. Compared to other well accepted questionnaires (e.g., Furlan et al., 2011; Peng et al., 2008; Sakakibara et al., 1993), the questionnaire by Shah and Ward is more comprehensive and/or better in line with the state of art. 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 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 (Dal Pont et al., 2008; McKone et al., 2001; 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 organization’s performance on cost, compared to that of its competitors?’ Given our elaborate approach to gather the data, we think there is no difference in reliability for relative performance data (that is compared to competitors) versus actual performance data. Additionally, for the analyses in this chapter, we think relative performance data is equally relevant to actual performance data. 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’.

4.3.3. 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 (Jöreskog, 1969); convergent validity was estimated with factor loadings (the average gives an indication per construct) and average variance extracted (AVE) (Fornell & 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 6.
Table 6: Data quality measures

<table>
<thead>
<tr>
<th>Construct</th>
<th>Average factor loading</th>
<th>Average variance extracted</th>
<th>Raju (1977) coefficient</th>
<th>Coefficient alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding improvement</td>
<td>0.701</td>
<td>0.587</td>
<td>0.749</td>
<td>0.496</td>
</tr>
<tr>
<td>Getting the improvement habit</td>
<td>0.711</td>
<td>0.599</td>
<td>0.804</td>
<td>0.677</td>
</tr>
<tr>
<td>Focusing improvement</td>
<td>0.802</td>
<td>0.649</td>
<td>0.88</td>
<td>0.814</td>
</tr>
<tr>
<td>Leading the way</td>
<td>0.781</td>
<td>0.618</td>
<td>0.865</td>
<td>0.786</td>
</tr>
<tr>
<td>Aligning improvement</td>
<td>0.825</td>
<td>0.681</td>
<td>0.895</td>
<td>0.83</td>
</tr>
<tr>
<td>Shared problem solving</td>
<td>0.775</td>
<td>0.605</td>
<td>0.884</td>
<td>0.824</td>
</tr>
<tr>
<td>Improvement of improvement</td>
<td>0.812</td>
<td>0.667</td>
<td>0.888</td>
<td>0.83</td>
</tr>
<tr>
<td>The learning organization</td>
<td>0.689</td>
<td>0.477</td>
<td>0.864</td>
<td>0.815</td>
</tr>
<tr>
<td>Lean practices</td>
<td>0.704</td>
<td>0.585</td>
<td>0.973</td>
<td>0.875</td>
</tr>
<tr>
<td>Operational performance</td>
<td>0.600</td>
<td>0.467</td>
<td>0.81</td>
<td>0.735</td>
</tr>
</tbody>
</table>

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, Durach, Kembro, & Treiblmaier, 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.

### 4.3.4. 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 & 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 ≥ LP-B then 0, else 1. This was done for improvement routines with lean practices and operational performance. To overcome sensitivity of cases very close to each other, a margin of plus or minus 5% was applied. If cases fell within this range, the comparison was disregarded. In this way, only significant differences were considered. Applying this rule to each pairwise comparison (2703 pairwise comparisons in total) produces an overall score between 0% (none of the pairwise comparisons meet this condition) and 100% (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% would indicate that there was no relationship.

To tests for mediation, the traditional approach (Baron & Kenny, 1986; Preacher & 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 dataset (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 9; the broken line is a ceiling envelopment line and the solid line is a ceiling regression line, where the x’s 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.

Figure 9: NCA plots of (a) ‘Improvement of improvement’ (CI of CI) and (b) ‘Getting the improvement habit’, both for ‘Lean practices’ (HLP)
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.

4.4. 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.

4.4.1. 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 & Hak, 2012) were performed. The resulting scores are presented in Figure 10 and suggest that lean practices mediated the relationship between improvement routines and operational performance. First, a strong relationship (92%) was found between (i.) improvement routines necessary for lean practices (50% would indicate no relationship). Second, a moderate relationship (83%) was found between (ii.) improvement routines necessary for operational performance, and a moderate relationship (74%) between (iii.) lean practices and operational performance. Note that the latter was analysed as symmetrical rather than necessary, which generally results in a lower score. In 92% 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%) 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 2/3 of the spread amongst lean practices, which was 2.8. In contrast,
cases with low lean practices showed only a moderate link (79%) 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.

Figure 10: 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

4.4.2. Improvement routines that directly implement lean practices

BCCAs (Dul & 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 chapter: 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% 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 also seemed sufficient for 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.

4.4.3. 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 9, 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 9, plot b), there is no implementation of lean practices without the presence of improvement routines, indicating that that routine might be necessary for lean. Analysis of all the plots shows cases positioned in the upper-left corners for: ‘the learning organization’, ‘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 dataset (ceiling regression line, CR-FDH hence known as CR line) (Dul, 2016). Dul (2016) recommends using a CE line for a discrete dataset and a CR line for a continuous dataset.

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 9; 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 7).

Table 7: Bottleneck table of the eight improvement routines for lean practice implementation

<table>
<thead>
<tr>
<th>Lean practices</th>
<th>i. understanding improvement</th>
<th>ii. ii. Getting the improvement habit</th>
<th>iii. Focusing improvement</th>
<th>iv. Leading the way</th>
<th>v. Aligning improvement</th>
<th>vi. Shared problem solving</th>
<th>vii. improvement of improvement</th>
<th>viii. The learning organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
</tr>
<tr>
<td>10</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
</tr>
<tr>
<td>20</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
</tr>
<tr>
<td>30</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
</tr>
<tr>
<td>40</td>
<td>NN</td>
<td>3.5</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
<td>NN</td>
</tr>
<tr>
<td>50</td>
<td>NN</td>
<td>17.3</td>
<td>11.6</td>
<td>NN</td>
<td>8.5</td>
<td>23.1</td>
<td>NN</td>
<td>NN</td>
</tr>
<tr>
<td>60</td>
<td>6.3</td>
<td>31</td>
<td>23.4</td>
<td>NN</td>
<td>20.7</td>
<td>31.8</td>
<td>NN</td>
<td>4.2</td>
</tr>
<tr>
<td>70</td>
<td>25.2</td>
<td>44.8</td>
<td>35.2</td>
<td>NN</td>
<td>32.9</td>
<td>40.6</td>
<td>19.7</td>
<td>19.9</td>
</tr>
<tr>
<td>80</td>
<td>44</td>
<td>58.6</td>
<td>47</td>
<td>29.1</td>
<td>45.1</td>
<td>49.3</td>
<td>39.4</td>
<td>35.6</td>
</tr>
<tr>
<td>90</td>
<td>62.9</td>
<td>72.4</td>
<td>58.8</td>
<td>58.9</td>
<td>57.3</td>
<td>58</td>
<td>59.2</td>
<td>51.4</td>
</tr>
<tr>
<td>100</td>
<td>81.7</td>
<td>86.1</td>
<td>70.6</td>
<td>88.7</td>
<td>69.5</td>
<td>66.8</td>
<td>78.9</td>
<td>67.1</td>
</tr>
</tbody>
</table>
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 (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 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%, the table shows that in this set of manufacturing SMEs, some implementation of lean practices (up to 30% = level two of the five-point Likert scale) could be realized without developing existing improvement routines. As Figure 9 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% 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%) and ii. ‘getting the improvement habit’ (row 40%). As lean implementation increased, iii. ‘focusing improvement’ and v. ‘aligning improvement’ (both row 50%) were also required.
At the other end of the spectrum, the last three rows (80-100%) indicate that for more advanced lean practitioners (level three of the five-point Likert scale), all improvement routines were present to some extent (at least 29.1% or level two 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 and 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.

4.5. 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 dataset from manufacturing SMEs was analysed using BCCA and NCA.

4.5.1. Improvement routines more important for 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. Only for some lean practice implementation, managers themselves were able to implement a basic structure of lean, without paying any special attention to improvement routines.
Beyond the first stages of lean practice implementation, employees participated in improvement activities while managers could continue to implement lean production.

These findings challenge Womack and Jones’s (1996) notion about the critical transition when managers must become coaches and employees become proactive. Rather, the NCA indicates that team leader and employee improvement routines are important for lower levels of lean practice implementation as well. They replicate Rahman and Bullock’s finding (2005) 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 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:

1. **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.**

4.5.2. ‘Getting the improvement habit’ symmetrically linked to lean practices

Regarding individual improvement routines, the BCCAs suggest that only the ‘getting the improvement habit’ routine had a symmetrical 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 likely to be implemented.

This contrasts with de Jager et al. (2004), who found that managers saw ‘focusing improvement’ as most important. We believe that this difference is mainly related to the sample, since SMEs usually have no specialized department dedicated to 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:

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

4.5.3. 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, across internal departments and 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 could 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 implement lean production.

The next set of improvement routines required to further implementation of lean practices were ‘aligning improvement’ and ‘focusing improvement’. Aligning improvement refers to the improvement system being designed and continuously amended to fit within the current organizational 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 organizational 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. Dabhiklar and Bengtsson (2004) found no direct link between alignment and performance. Rather than increasing operational performance directly, alignment is an enabler to continuously improve a lean production system. 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 implement lean production.

The results also suggest that ‘focusing improvement’ was required to move beyond some implementation of lean practices. This refers to employees’ ability to use the organization’s strategic goals and objectives to assess and prioritize 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), Dabhiklar and Bengtsson (2004) and Jørgensen et al. (2006), who all deemed focusing 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:

3. 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 organizational strategy. The presence of the other routines is not yet required.

4.5.4. 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 recognizing employees’ contributions to improvement and supporting employee experiments. This is in line with de Jager et al. (2004) and Dabhillkar 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 organizations 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 implementation of lean production.

‘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 lean production cannot be fully implemented 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 organization 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 Dabhihkar 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:

4. 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.

4.5.5. Non-necessary improvement routines for lean practices

The results further suggest that in this study’s set of manufacturing SMEs, one routine – ‘a learning organization’ – was less required than the others. In the definition used here, a learning organization 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 organization 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 organization may contribute to better improvement activities in the long term, helping organizations 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 chapter therefore argues in line with Matthews et al. (2017) that a formalized system for managing knowledge is likely to be more important for larger organizations. This study’s sample did not allow for comparison with large enterprises, leaving the question of the importance of a learning organization for larger enterprises open for future research.

In conclusion, SME managers are advised that having a formal learning organization 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 organization. This study therefore proposes that in manufacturing SMEs:

5. Some implementation of lean practices and 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 (1996), 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 organizational learning, enabling the continuous improvement of their lean practices and increasing their operational performance.

4.5.6. Theoretical contributions
These insights into the importance of improvement routines and their relationship with lean practices 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 & Jones, 1996) that improvement routine importance depends on an organization’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 organizational learning and an organization’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 organizational performance.

4.5.7. 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 organization only wants to implement lean practices to a limited degree, managers can lead employees to take initiative by introducing improvement activities themselves. If the organization wants to be a more advanced lean practitioner, managers can 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 implement lean production 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.
4.6. 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 can 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 is preferably done using longitudinal data to provide more insights into the interrelationships between individual improvement routines. In addition to replication studies, more in-depth studies could 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.
Chapter 4. The relative importance of improvement routines for lean practice implementation
5. ESTABLISHING THE INTERPLAY BETWEEN LEAN OPERATING AND CONTINUOUS IMPROVEMENT ROUTINES: A PROCESS VIEW
On the implementation of Lean Production in manufacturing SMEs

This chapter is based on:


An earlier version was presented as:


**ABSTRACT**

Building on the routine dynamics literature, this chapter expands our philosophical, practical and infrastructural understanding of implementing lean production. The authors provide a process view on the interplay between lean operating routines and continuous improvement (CI) routines and the roles of different actors in initiating and establishing these routines. Using data from interviews, observations and document analysis, retrospective comparative analyses of three embedded case studies on lean implementations provide a process understanding of enacting and patterning lean operating and CI routines in manufacturing SMEs. Incorporating the ‘who’ and ‘how’ next to the ‘what’ of practices and routines helps explaining that rather than being implemented in isolation or even in conjunction with each other, sustainable lean practices and routines come about through team leader and employee enactment of the CI practices and routines. Neglecting these patterns aligned with unsustainable implementations. Nuancing the existing lean implementation literature, the proposed process model shows that CI routines do not stem from implementing lean operating routines. Rather, the model highlights the importance of active engagement of actors at multiple organizational levels, and strong connections between and across levels to change routines and work practices for implementing lean production. The proposed process model provides a valuable way to integrate variance and process streams of literature to better understand lean production implementations. The process model helps manufacturing managers, policy makers, consultants and educators to reconsider their approach to implement lean production or teach how to do so.

**5.1. INTRODUCTION**

This chapter expands our understanding of how lean production can be implemented by changing existing and establishing new organizational routines.
Research has comprehensively shown that lean production requires an interplay between lean operations and continuous improvement (CI) (Cua et al., 2001; Flynn, Sakakibara, et al., 1995; Imai, 1986; Karlsson & Åhlström, 1996; Liker, 2004; Ōno, 1988; Shah & Ward, 2003, 2007; Sugimori et al., 1977; Womack et al., 1991). It is less clear how this interplay unfolds over time. Some suggest that lean production can be implemented starting with management or expert-led improvements, involving team leaders and employees later on (Liker, 2004; Womack & Jones, 2003). This approach is reflected in maturity models on lean production and continuous improvement depicting the learning organization as the final ideal stage (Bessant & Francis, 1999; Hines et al., 2004). More recently, Galeazzo et al. (2021) draw on cross sectional data to suggest that a top-down approach is preferable when CI is low, whereas a bottom-up approach is helpful for more advanced CI practitioners. This study takes a process view to revisit how lean operations and CI unfold over time and examine how different actors contribute to this process.

To understand how lean production implementations unfold, this chapter draws on the routine dynamics literature (Feldman & Pentland, 2003). Routine dynamics literature distinguishes between the enacting and the patterning of routines (Feldman, 2016). Enacting relates to how a routine is performed, while patterning relates to the shared understanding or ‘ostensive’ aspect of that routine (Feldman & Pentland, 2003). This chapter draws on enacting and patterning and their interplay within organizational routines to show how actors move towards and between lean operating and CI routines. Understanding how lean operating and CI routines co-evolve is essential for understanding when and why lean production implementations succeed or fail, and how the implementation process can be managed. This chapter addresses the question: How do lean operating and continuous improvement routines develop during a lean production implementation? To answer this question, this chapter reports on an abductive analysis of three series of interventions in three manufacturing SMEs. This analysis helped to develop a process model to better understand how actors move towards and between enacting and patterning lean operating and CI routines.

To take a dynamic view on lean production implementations, a processual understanding of organizations is required (Van De Ven & Poole, 2005).
majority of studies on lean production implementations have (implicitly) adopted a variance view, meaning they address the effect of predictors on outcomes, rather than the transformation process between them. A process view aims to open this black box to explain how the relationships between the studied constructs come about and to understand the organizational transition (Sinha & Van De Ven, 2005). The difference can be compared to a noun (variance) and a verb (process), or a picture (cross sectional) and a film (longitudinal): a picture can capture a static object, only a film can capture how it is moving. In organization theory, a process view differs from how the term ‘process’ is commonly used in operations management (e.g., Holweg, Davies, De Meyer, Lawson, & Schmenner, 2018) and in lean production regarding process mapping tools (e.g., Rother & Shook, 1999). In organization theory, a process view considers any organizational activity as an ongoing accomplishment (Feldman, 2000). As such, a process view helps to explain how practices and routines come about and can be shaped to create a collective understanding of lean production.

The findings have important implications for research and practice. First, this chapter proposes a process model that explains, on a fundamental level, how the interplay between patterning and enacting lean operating and CI routines unfolds over time. Second, this chapter shows how different actors contribute to establishing new routines, providing a more accurate picture of how infrastructural or critical success factors such as top management support and leadership actually play out in implementation processes. Third, the process model sheds new light on our understanding of how to implement lean production, specifically regarding maturity models and the implicit sequencing of lean principles.

The remainder of this chapter first introduces the concepts of enacting and patterning of lean operating and CI routines in implementing lean production. The empirical part consists of a comparative analysis of a series of lean production interventions in three manufacturing SMEs. The findings illustrate how enacting and patterning routines interplay over time and the role that different actors play in this process. The chapter ends by explaining how researchers and practitioners might use this approach to better understand and guide lean production implementations.
5.2. IMPLEMENTING LEAN PRODUCTION: ORGANIZATIONAL ROUTINES

This section conceptualizes how the enacting and patterning of lean operating and CI routines might interact.

5.2.1. Lean operating routines and continuous improvement routines

Organizations act and change based on certain routines (Nelson & Winter, 1982). An organizational routine is defined as “a repetitive, recognizable pattern of interdependent actions, involving multiple actors” (Feldman & Pentland, 2003, p. 96). Nelson and Winter (1982) differentiate between routines in day-to-day operations and routines for improving those operations. Routines in day-to-day operations are called operating routines. They relate to what an organization does, given its customer requirements, capabilities, stock, procedures, equipment etc. Operating routines follow a sequence of steps, with each step triggering another, based on tacit knowledge and more or less automatic choices. These operating routines are key to ensure the short-term survival of the organization. Routines for improvement are called search or improvement routines and focus specifically on developing operations (Nelson & Winter, 1982). Improvement routines are part of an organization’s dynamic capabilities to do different or new things (Anand et al., 2009; Peng et al., 2008). These routines can be developed through a recursive pattern of production, learning, or better understanding, and reproduction of either actual operations or actual improvements (Zollo & Winter, 2002).

In the context of lean production, lean operating routines relate to principles such as flow and pull (Womack & Jones, 2003), meta-routines such as JIT (Sugimori et al., 1977) and supplier integration (Lamming, 1996) and practices such as the use of Kanban, squares or containers for production control. CI routines relate to principles such as perfection (Womack & Jones, 2003), meta-routines such as TQM (Hackman & Wageman, 1995) and CI (Bessant & Caffyn, 1997), and practices such as the initiation and performance of Kaizen activities. Some principles such as value (Womack & Jones, 2003), meta-routines such as TPM (Nakajima, 1988) or concepts such as employee involvement seem to relate both to lean operations and CI. In line with the above definition, this study considers lean operating and CI routines to be recognizable patterns of interdependent actions, involving multiple actors.
5.2.2. The shared enacting and patterning of routines

Feldman and Pentland (2003) distinguish between the performative and the ostensive aspect of routines. The performative aspect refers to enacting routines, the “specific actions, [done] by specific people, in specific places and times ... it is the routine in practice” (Feldman & Pentland, 2003, p. 101). The ostensive aspect is considered to be “the ideal or schematic form of the routine ... it is the abstract, generalised idea of the routine or the idea in principle” (Feldman & Pentland, 2003, p. 101). This ideal form always exists inside and across actors; it is their shared understanding of the routine. The ostensive aspect has more recently been conceptualized as patterning to indicate that it is not merely a mental construct but also embodied (Feldman, 2016). Feldman and Pentland (2003) view the enacting and patterning of a routine not as two opposing phenomena but as a duality, influencing each other continuously. Patterning is both the input and the outcome of enacting (Feldman & Pentland, 2003).

To better understand the difference between enacting and patterning, think of for example a professional soccer team. For their entire life, the players are individually and collectively training to play soccer; to pass, dribble, shoot etc. Playing soccer has become their second nature. It is ingrained in their mind and also in their body, their muscles, nervous systems, responsiveness etc. Collectively, they are the soccer team even when they are not playing at all. This shared embodiment of the routine is referred to as patterning, while the actual performance during a game is called enacting. This concept of routines builds on Giddens’ (1984) idea of duality of structure and agency: the schematic understanding of the routine guides the enacting, while the enacting simultaneously constitutes the patterning.

In lean operations, an example of enacting is employees using a pull system, i.e., initiating an order only if triggered by a request downstream. An example for CI would be employees mapping their current situation, looking for ways to improve their operations. Patterning in lean operations can be seen in employees’ shared understanding of concepts such as ‘pull limit’. An example in CI is employees’ shared understanding of how a current state could be mapped. The routine dynamics literature emphasizes that enacting and patterning always need to be considered in tandem.
5.2.3. Artefacts and organizational routines
Organizational routines both influence and are influenced by artefacts (D’Adderio, 2008; Pentland & Feldman, 2008). Artefacts are defined as structures external to actors, either physical (e.g., machines and products) or intangible (e.g., software and standards), and can range from single documents to systems of interdependent artefacts (Cacciatori, 2012; Hutchins, 1995). Artefacts can be classified in a three-level hierarchy: 1) primary artefacts used to do work (e.g., machinery and tools), 2) secondary artefacts that facilitate work (e.g., production orders and standard operating procedures), and 3) tertiary artefacts that form the infrastructure (e.g., buildings, rooms, furniture, ICT, documents) (Nicolini, Mengis, & Swan, 2012). Cacciatori (2012) explains that routines are developed using systems of artefacts (e.g., occupation-specific artefacts such as tools and techniques linked to more generic artefacts such as planning systems), stressing the importance of an integrated approach.

In lean operations, examples of physical artefacts are the Kanban cards used to limit work-in-progress. Examples of intangible artefacts are formulas and techniques such as takt time and Little’s Law that help to determine the number of Kanban cards in the system. In CI, examples of physical artefacts are performance boards and A3 problem-solving reports to identify and address improvements. Examples of intangible artefacts are tools such as plan-do-study-act and 5-whys (Bicheno & Holweg, 2016) that help to analyse and improve identified issues. The routine dynamics literature emphasizes that artefacts must be implemented not only in line with each other, but also in line with the enacting and patterning of organizational routines.

5.2.4. Moving from prior routines to lean operating routines
Neither organizational routines nor artefacts are static: they can be modified through ongoing enactment (Feldman & Pentland, 2003; Giddens, 1984) and deliberate problem solving (Adler et al., 1999; Hackman & Wageman, 1995). Ongoing enactment may lead to continuous incremental change of routines (Feldman & Pentland, 2003; Giddens, 1984). This change occurs when employees adjust routines to the circumstances at hand and to their own understanding (Rerup & Feldman, 2011). Deliberate problem solving can also lead to change in routines. CI activities are an example of such deliberate change: employees experiment and alter the underlying lean operating routines. Through trial-and-
error learning and reflecting on what works and why, they develop a new shared understanding of what could be done (Feldman & Pentland, 2003; Giddens, 1984; Rerup & Feldman, 2011). Thus, the interaction between enacting and understanding lean operating routines and CI routines provides a continuous opportunity for learning and improvement. This shared learning is further stimulated by artefacts (Aoki, 2020). It is this employee reflexivity that, over time, contributes to organizational learning and actual improvements (Argote & Miron-Spektor, 2011).

This chapter conceptualizes implementing lean production as developing the interplay between enacting and patterning lean operating and CI routines: (i) Enacting lean operating routines and enacting CI routines mutually influence each other, and they jointly shape how both types of routines are patterned. (ii) Patterning lean operating routines and patterning CI routines also mutually influence each other and both patterns shape how these routines are enacted. (iii) Artefacts related to lean operations and CI influence each other and jointly influence and are influenced by the enacting and patterning of lean operating and CI routines, respectively. As employees develop lean operating and CI routines again and again, operational performance increases, and at the same time the patterning of what lean operating and CI routines could achieve improves, thus leading to employee learning. Over time, this continual interplay helps to implement lean production in a sustainable way.

5.2.5. Understanding the process of changing routines and work design
Patterning routines could be seen in the context of work design. Work design contains the structural rules, norms, and understandings of how to do the work and an understanding of the responsibilities of actors at different organizational levels. Sinha and Van De Ven (2005) propose to examine work design from a complexity perspective that traces the sequence of events that unfold over time in a changing work system configuration. The more static concepts of contingency and configuration theory have proposed ingredients for performance that are either present or absent, such as critical success factors. Instead, a processual approach sees work design as emerging and pays more attention to the transition from one work design to another. In the case of lean production, the literature has identified top management support and leadership as critical success factors for implementing lean production (Achanga et al.,
2006; Saraph et al., 1989; Sila & Ebrahimpour, 2003), yet this literature provides limited insight into when and how managers affect the transition of work design. More practice-oriented research gives a detailed account of CI routines (improvement kata) and how these are developed (coaching kata) at Toyota (Rother, 2010), yet it is less clear how different actors contribute to this transition to new CI routines. In this study, the implementation of lean operating and CI routines is analysed as a process of transiting to new work design arrangements and specifically the role of different actors is investigated.

5.3. METHODS

5.3.1. Retrospective comparative analysis
Retrospective case studies were chosen because they allow for investigating the long-term effect of what actors did and thus provide insight into how organizations develop over time (Pettigrew, 1990). Compared to longitudinal case studies, they allow for examining this effect in cases for which the outcome is known. Given the complexity of the research question, multiple cases were needed (Eisenhardt & Graebner, 2007; Meredith, 1998). For each case, several interventions were investigated.

5.3.2. Case selection
In line with Yin (2013), a quantitative inquiry of candidate case characteristics was conducted to select contrasting cases that (un)succesfully implement lean production.

To select cases, hard lean practices and critical success factors were used as indicators. Hard lean practices were chosen as they are similar to lean operating routines (Bortolotti, Boscari, et al., 2015) and a reliable indicator for lean production organizations. They were measured using Shah and Ward’s (2007) questionnaire on lean practices. Critical success factors were chosen as these are not directly linked to hard lean practices - they are considered necessary but not sufficient for implementing lean production (Knol et al., 2018). Presence of critical success factors indicated the extent to which cases invested in implementing lean production. For critical success factors, the questionnaire by Knol et al. (2018) was used. To select successful cases, we chose one (Case A) with the highest presence of hard lean practices, and one with much presence of lean
practices and low presence of critical success factors (Case B, see dotted red line in Figure 11). To contrast the successful lean production cases, an unsuccessful lean production case was also selected. To this end, a case was selected with much presence of critical success factors but low levels of hard lean practices (Case C).

Dimensions of interest that were not used are operational performance, soft lean practices and CI routines. Operational performance matters to all organizations, yet in itself is only a partial indicator for lean production, as operational performance can also be achieved by non-lean producers. Soft lean practices indicate practices that are related to critical success factors, such as ‘top management support’ and ‘training employees’, and to CI routines, such as ‘solving problems in small groups’ and ‘striving to continuously improve products and processes’ (Beraldin, Danese, & Romano, 2019; Bortolotti, Boscari, et al., 2015). CI routines are different from hard lean practices, but their enactment ultimately results in lean production organizations, making hard lean practices and critical success factors the most useful indicators to select successful and unsuccessful lean production cases.

To select cases that covered both dimensions, multiple respondents (6 on average, 251 in total) from 42 manufacturing SMEs were asked to fill in a self-assessment on their plant. Case A featured advanced lean practices (dashed circle), representing a successful case. Case B featured some lean practices combined with some critical success factors (dotted circle), showing how lean practices can be relatively high without much presence of critical success factors. These cases were supplemented with one extreme or polar case, Case C, which featured the presence of critical success factors but little lean practice implementation (dashed-dotted circle). A summary of the three case characteristics is given in Table 8. Given this diverse set, these three cases were considered sufficient to explore the interplay between lean operating and CI routines to implement lean production (Eisenhardt, 1989; Stuart, McCutcheon, Handfield, McLachlin, & Samson, 2002).
Figure 11: Case selection: diverse cases (A. dashed and B. dotted circle) and polar type (C. solid-dotted circle)

Table 8: Summary of the three case characteristics

<table>
<thead>
<tr>
<th>Selection strategy</th>
<th>Case</th>
<th>Presence of lean practices</th>
<th>Presence of CSFs</th>
<th>Industry/products</th>
<th>Strategy</th>
<th>Layout</th>
<th>Number of employees</th>
<th>Interviewees</th>
<th>Introduced lean operating structures</th>
<th>Introduced CI structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diverse cases</td>
<td>A</td>
<td>Advanced</td>
<td>Extensive</td>
<td>High-tech electronics</td>
<td>Product leader</td>
<td>Cells</td>
<td>250</td>
<td>11</td>
<td>Lines, cells, teams, 5S, standards vs. specials, Kanban boards</td>
<td>Quality control, PDSA, 8D problem-solving reports, stand-ups, PDSA, single-minute exchange of die, A3 reports, stand-ups, X-matrix</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Some</td>
<td>Some</td>
<td>Concrete paving materials</td>
<td>Product leader</td>
<td>Mass-production line</td>
<td>40</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Polar type</td>
<td>C</td>
<td>Few</td>
<td>Some</td>
<td>High-quality metal building materials</td>
<td>Customer intimacy</td>
<td>Functional</td>
<td>100</td>
<td>11</td>
<td>Pull, i.e., a train and Kanban, small lot sizes, standard operating procedures</td>
<td>-</td>
</tr>
</tbody>
</table>
5.3.3. Data collection

An embedded case study design was used to study improvements to both lean operating and CI routines (Yin, 2013). Data gathered were retrospective, lasting from the first lean initiatives to the current state of CI interventions. To limit recall bias and enhance accuracy (Eisenhardt & Graebner, 2007; Golden, 1992), the researchers focused on important recent and present activities. To limit informant bias, employees, team leaders, managers and CEOs from production and supporting departments were involved and data was collected using interviews, observations and archives (internal documents and websites) (Eisenhardt & Graebner, 2007; Jick, 1979).

Per case 10-11 interviews were conducted. Interviewees worked for their company between one and 36 year(s) with an average of 17 years. They were working with Lean production between three and 17 years with an average of nine years. Their understanding of lean production ranged from limited to good. And all of them had tenure (not temporal) allowing them to speak freely. They were selected due to their involvement in lean production interventions and from different hierarchical levels (CEO, manager, team leader and employees). We included employees as they also contributed to the lean production implementations. As insights evolved, interview questions developed from open (e.g., ‘What did you do to implement lean production?’) to semi-structured (e.g., ‘How did you improve enactment of lean operating routines?’) (see Appendix 1 - Interview guide). As data collection developed, a code book was also developed to maintain more focus (Fereday & Muir-Cochrane, 2006; Van Maanen, 1979). Interviews took between 28 and 85 minutes with an average of 53 minutes. They were recorded and transcribed, with transcripts ranging from five to 17 pages with an average of 10 pages. The transcripts were discussed with colleagues and fellow researchers afterwards to enhance data analysis and increase reliability of the study results.

To limit common method bias, interviews were complemented with numerous observations and documents (Eisenhardt & Graebner, 2007). Observations took place whilst the first author was working at the case site for three to four days over the course of three to four weeks. Observations took place during semi guided tours, work sessions such as stand-ups or project meetings, walk arounds on the shop floor and informal talks in for example the canteen. Observations
were especially conducted to verify interviewee experiences with the interplay between the enacting and patterning of lean operating and CI routines. For example, to identify interactions between the concepts, work was studied in the different cells, at stand-ups and during 8D improvement sessions in Case A, at the production machinery, at stand-ups and during A3 improvement sessions in Case B and at the workstations in Case C. Documents were used to establish the chronology of improvement interventions, build the timelines, guide the interviews and counteract any biases originating from the interviews. Documents were either policy documents, performance sheets, standard operating procedures, presentations or training materials. All findings were presented to and discussed with the case participants afterwards to increase understanding of the case and the quality of the data gathered (Call-Cummings, 2017; Jick, 1979).

5.3.4. Data analysis
Induction and deduction were combined into an abductive analysis of each case (Ketokivi & Choi, 2014). The process of lean production implementation was traced as follows.

We used the thematic coding technique to conduct within-case and cross-case analyses in an iterative fashion (Flick, 2009, pp. 318–323). As a first orientation and to map the chronology of each case, written narratives (see Findings from the within-case analyses) and timelines (see Appendix 2 - Case timelines) were created for each case from the interviews (Miles, Huberman, & Saldaña, 2013). These descriptions were continuously rechecked and modified during further interpretations of the cases. To increase validity, these were validated against the document analyses and reviewed by the respective Production Manager (Miles et al., 2013). To reduce the effects of telescoping or recall bias (Beckett, Da Vanzo, Sastry, Panis, & Peterson, 2001), these timelines in turn helped to cross check the sequence and details of events derived from different interviews per case. In general, the interviewees agreed largely in their account of events. If their accounts differed, the document analysis was used to arbitrate.

Next, a deepening analysis was conducted per case. This led to a focus on the themes enacting and patterning lean operating and CI routines. Open coding was done by the first author to identify first-order constructs. These constructs were organized in statement cards to better understand the themes in the data.
What struck us was the importance of structure and agency during all lean production implementations. These concepts first led us to Giddens’ structuration theory (Giddens, 1984) and subsequently to the routine dynamics literature (Feldman & Pentland, 2003). We started to analyse our data in terms of enacting and patterning lean operating and CI routines. The findings were frequently contrasted with the literature to build and periodically refine the code book (McCutcheon & Meredith, 1993), see Table 9. This led to ideas for the interplay, which acted as a framework for another round of comparing the empirical results of the case studies, helping to develop the interplay further (Yin, 2013).

Finally, the two diverse cases were juxtaposed with each other and with the polar case to cross-check how the interplay between enacting and pattering lean operating and CI routines evolved over time. This eventually led to an empirical process model. This process model underlay the comparative analysis of each of the three cases. Analysing what was similar or contrary to this broad empirical framework enabled theory building from the cases. The empirical process model was presented to and discussed with the interviewees in a final round (communicative validation (Call-Cummings, 2017; Jick, 1979)) to increase the quality of our interpretation.

Table 9: Code book on interventions to implement lean production

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Action</th>
<th>Definition</th>
<th>Quotation</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing ostensive aspects</td>
<td>Engaging employees to develop understanding of the principles and ideas of operating and improvement routines</td>
<td>The importance of operating and improvement structures is sold to employees through lean games, internal or external excursions, training, performance management and/or involvement in improvement activities, and discussions.</td>
<td>“When I asked [him] if he wanted to do the course and explained that he would also do two or three projects every year, he was very hesitant, he was very busy already. He saw it as extra work. ... While I was talking, I tried to make it clear to him: ‘You are doing those projects already. Only now you get a tool to do it in a structured way, with a head and a tail, to efficiently manage your projects.’ Then he understood that he did not have to do anything extra but that his current work would be done in a more structured manner. Now he is almost done with his first project which is going very, very well!”</td>
<td>Improvement Manager, Case B</td>
</tr>
</tbody>
</table>
### 5.4. FINDINGS FROM THE WITHIN-CASE ANALYSES

#### 5.4.1. Case A – Advanced presence of lean practices

Case A started implementing lean production in 2004, when a new lean-minded Managing Director was appointed (see Appendix 4. Case timelines, Figure 21 for an overview). In 2009, CI activities were started in two departments to improve their operations. First, lean games were played to improve employees’ understanding of lean operating routines. Next, an external consultant guided two team leaders to involve employees in mapping current states, conducting root cause analyses, mapping future states etc. with the aim to create a production line (system of artefacts). The approach focussed on involving employees: “So do not say: ‘You must do this differently’, but just ask: ‘How could that mistake happen, how was that possible?’ Then slowly try to get things better, without throwing anyone under a bus.” (Engineering Manager, Case A). These interventions improved employees’ operating routines and as a result improved...
the quality, flow and lead time. Additionally, employees mentioned that the approach helped them to understand the importance of CI routines and related artefacts such as 8D problem-solving reports. When major successes were achieved, the team leader moved to other departments to repeat the CI efforts. The first two departments continued with their efforts.

In 2011, a CI Manager was appointed. She aimed to integrate CI routines into the work routines of employees to help them understand the reasons for and functioning of lean operating routines. During our presence, we saw that she often engaged employees, explained CI and lean operating artefacts, and coached them to conduct their own CI activities. “You can guide people without having to prescribe the route they take. They have to make mistakes to learn why a 5-why is carried out in one way and not the other. The moment they run into something, you can send them in the right direction. The progress is much better and the effect too; people are more positive about it.” (CI Manager, Case A).

In 2015, a new lean-minded Operational Director joined the company and started to implement 5S company-wide. 5S is a workplace organization method aimed at increasing productivity. All employees were trained to improve their understanding of 5S artefacts and then told to conduct weekly 5S actions. However, there was little follow-up on the initial training and no coaching to assist the employees to better understand or enact these weekly 5S routines. As a result, employees experienced the 5S method as forced and only for show. The approach resulted in bad reception and eventual abandonment.

The new Operational Director also changed the work design and introduced cells, making employees responsible for their own processes. “Remove the functional in production and start thinking in cells. ... So, I asked the teams which production cells they see. We have given them a guideline and told them, ‘You can build a cell in it’ ... and they slowly grew into it.” (Operational Director, Case A). From informal conversations with employees during our visits we understood that continuously conducting cycles of improvements helped them to internalize their cell routines and implement related artefacts such as Kanban boards. The Quality Manager added: “Every time you think you have solved something, you notice six other problems that also need to be addressed”. From multiple conversations, we also understood that continuous support in terms of coaching,
time and resources strengthened the shared understanding and shared enacting of the new work design and the associated CI routines.

5.4.2. Case B - Some presence of lean practices
Case B is one of four sites or plants of a manufacturing SME. In Case B, the initial improvements started with the arrival of a new Plant Manager in 2001 (see Appendix 4. Case timelines, Figure 22 for an overview). After years of local improvements, other managers became interested and attempted to implement 5S company-wide, including at Case B. However, like in Case A, there was little coaching about implementing 5S artefacts or developing 5S routines. From the interviews we learned that this first implementation was experienced as forced and led to employee resistance, and only few changes were sustained.

A new lean-minded Operational Director and CI Manager joined the company in 2013 and continuously engaged employees in CI activities, such as mapping current states, conducting root cause analysis, mapping future states, etc. They also introduced a focus on flow and introduced amongst others A3 reports to realize more structure in CI activities. Some employees were encouraged to take up lean Green Belt training but they told us that because of their high workload they were not very enthusiastic at first. To overcome this resistance, the CI Manager repeatedly tried to engage them in conducting CI projects and explained the need (see second quote in Table 9).

In 2017, management decided to implement 5S again, however not company-wide as previously, but team by team, in weekly cycles and with a focus on engaging in CI activities. The need for 5S was clearly explained upfront and during CI activities. However, employees still felt it was forced upon them. The CI Manager tried to mitigate this by engaging in dialogue (see last quote in Table 9). He explained the need and encouraged them to conduct for example quicker product changeovers by using for example shadow boards. Weekly audits were introduced to sustain the achieved results. These audits were still being done during our visits. When the roll-out moved to the second team, they were already interested in 5S because of the first team’s results. At the end of the study, both teams continued to enact and develop 5S routines as part of their standard practices.
By now, management considered the cycle of involving employees in CI routines to internalize lean operating routines and to implement related artefacts for subsequent improvement as crucial for implementing lean production. “In the past, you often saw projects where people were not engaged. Then as soon as you were gone, they fell back again. If you engage them, it is more likely to succeed.” (Quality Manager, Case B).

5.4.3. Case C - Little presence of lean practices

Improvements at Case C started with the arrival of an Engineering Manager and an Aluminium Team Leader in 2007 (see Appendix 4. Case timelines, Figure 23 for an overview). They first used a lean game to involve the Production Manager and then played the game with the entire company. This helped to increase employees’ understanding of lean operating routines. However, there was little follow-up; there were no attempts to stimulate employees to enact CI activities and there was no guidance regarding lean operating routines or artefacts. During several interviews, employees mentioned that the efforts of the two lean change agents were experienced as ineffective, expensive and pushy. The training raised awareness but did not succeed in getting everyone started.

In the Aluminium department, the team leader tried to implement 5S using training. From his explanation we noticed that there was little engagement and coaching to stimulate employees to conduct CI activities, to implement 5S artefacts or to improve their 5S routines. Employees themselves indicated that 5S was not internalized. And a lack of evidence on the shop floor showed that this 5S implementation was not sustained. In 2013 a temporary lean team changed the order system to pull principles in an expert-driven manner. When they faced resistance, they staged a “coup”:

Then we figured out that the way we produce here must be done completely differently, it must be done with a ‘train system’. We changed this through a coup. … We presented the idea to the MT and the team leaders and explained that this is how it will be done. … But what happened? I went to the Production Manager on Friday and asked if everything was prepared. “No”, he said, “not yet”. I said, “This is not what we agreed upon.” He asked, “Can we talk about this with the rest of the team leaders?” We then gave everyone instructions. I
went to the planner to ask if he was ready, but he was very busy and not prepared. I said, “There is no choice, we agreed upon this, we are going to do it!” Within four hours, we changed everything to the new system with a different planner. (Engineering Manager, Case C, authors’ emphasis).

The team leader and planner had not enacted CI routines and they had not created a shared understanding of lean operating routines; they were left unprepared. The change in work design was still present during our visits, but it was not further developed, hence resulted in a one-off exercise. A second attempt to introduce improvements also showed little engagement and no attempts to stimulate team leaders and employees to conduct CI activities. Team leaders were instructed in writing to reduce their lead time by half. However, employees on the shop floor did not see the need and the initiative fell flat.

The interviewees explained that in a third attempt, external consultants were hired to conduct daily performance sessions for a year. These meetings required strict business cases and yielded some results. However, the frequency of these meetings declined over time until they ended completely. There were no CI routines or related artefacts to engage employees and, during our presence, there was no sign of coaching or templates such as 8D or A3 as in Case A and B, let alone cycles to further develop this entire process.

At the end of the study, improvements occurred only from time to time and involved only a small number of improvement experts. Their initiatives failed often due to a lack of time: “I am engaged in engineering. I do not have time to do that anymore. … So, it is an extra job and we are busy, it falls back again” (Engineering Manager, Case C).

5.5. FINDINGS FROM THE CROSS-CASE COMPARISON

5.5.1. Moving from prior to improvement routines

In all cases, the findings show that introducing lean operating routines clashed with the prior way of working. New managers, experienced with lean production from previous roles, challenged the shared understanding of existing operating routines such as functional layouts and push systems. In the two successful
cases, A and B, several leaders (Directors, Managers and Team Leaders) played a key role in the implementation process. Rather than starting with management or expert driven improvements for employees to learn from, in Cases A and B managers engaged and coached team leaders and employees in conducting improvement projects; triggering them to make current state maps, root cause analyses, future state maps etc. This helped them to create a shared understanding of lean operating routines such as lines, cells and pull systems. To engage employees who did not want to participate in improvement activities, the CI Manager in Case B provides two excellent examples (importance of Green Belt and second attempt at 5S) of what to do: initiate a conversation, ask what bothers them, convince them otherwise and stimulate and facilitate them to try. Noticeably, operational performance only played a minor role in managers’ motivation. This is illustrated in Figure 12a; (top) managers break with prior non-lean operating routines and challenge team leaders and employees to conduct improvement projects.

Figure 12a: Process model on the move from prior to improvement routines (‘R’ implies a reinforcing loop, ‘+’ implies positive influence and ‘<>’ implies little influence)

5.5.2. Moving from improvement routines to lean operating routines
Enacting improvement routines to pattern lean operating routines and implement related artefacts.

The cross-case analysis further explains the move from CI routines to lean
operating routines. First, conducting improvement projects (mapping current states, conducting root cause analyses, mapping future states, etc.) helped to create a shared understanding of lean operating routines (lines, cells, pull systems etc.). In the unsuccessful Case C, two leaders (Engineering Manager and Aluminium Team Leader) tried to trigger the interplay between lean operating and CI routines by engaging managers and employees in lean games. When they faced resistance, they tried to have team leaders and employees enact lean operating routines straight away by showcasing potential benefits using 5S and a pull system. Only when further improvements were unforthcoming, they tried to conduct improvement projects but they used consultants. Though some results were achieved, over time both approaches (enacting lean operating routines without enacting CI routines and enacting CI routines using consultants) resulted in neglect and regression to previous routines. In contrast, Case A and B took a different approach; it was their upfront involvement of team leaders and employees in conducting improvement projects that helped to develop a shared understanding of lean operating routines. This is illustrated in Figure 12b; conducting improvement activities helped team leaders and employees to create a shared understanding of their lean operating routines. The remainder of Figure 12b will be elaborated upon below.

Figure 12b: Process model on the move from CI routines to lean operating routines
Second, involving team leaders and employees in conducting improvement activities also helped to implement line, cell, pull etc. artefacts. Using cycles of improvement activities, Case A successfully introduced lines, cells and cross-functional teams, and Case B successfully introduced 5S, total predictive maintenance and just-in-time deliveries. Lean operations related artefacts subsequently helped enacting of lean operating routines to increase operational performance. When CI routines were not enacted by employees, implementations of lean operating artefacts were unsuccessful. All three cases tried to implement 5S structures in a predominantly top-down fashion. This was problematic and eventually failed in all cases. Only when Case B challenged employees to enact CI routines did employees discover the importance of 5S for operations, helping them to successfully implement 5S artefacts. This is illustrated in Figure 12b; enacting CI routines also helped team leaders and employees to implement lean operating artefacts. **Enacting lean operating routines to pattern improvement routines and implement related artefacts**

Third, the case data indicate that team leader and employee enacted lean operating routines in turn helped to pattern their CI routines. In the successful Case A, conducting improvement activities led to changes in work design from two functional departments into lines, gradually increasing performance. Seeing the work become easier and their performance increase, triggered employees to continue improvements. These positive results encouraged managers to repeat these improvement cycles in other departments. In the successful Case B, the recurring improvement activities and discussions to implement 5S in the first department were sufficient to continue and achieve success also in a second department. Seeing the success of their colleagues, enacting and patterning their own CI routines, eased efforts to implement 5S for their peers. This is illustrated in Figure 12b; enacting lean operating routines in turn helped team leaders and employees to develop a shared understanding of/pattern their CI routines.

Fourth, enacting lean operating routines also helped to implement CI artefacts. In the successful cases, A and B, CI artefacts were introduced to further extend their improvements: Plan-Do-Study-Act cycles for regular improvements combined with more advanced A3 or 8D formats for more complex issues. In the unsuccessful Case C, no CI artefacts were used. For some time, there were daily performance meetings to think of and implement improvements. However, there
was no guidance around developing these or other CI routines before or during visits to the company. This is illustrated in Figure 12b; enacting lean operating routines also helped team leaders and employees to implement CI artefacts.

5.5.3. Continuous improvement of lean operating and improvement routines

Finally, as team leaders and employees implemented lean operating routines by enacting CI routines, their continued enactment also continued to improve both lean operating and CI routines. As is inherent in improvement activities and routine dynamics, lean operating and CI routines also continued to evolve. For example, once production lines were up and running in the first two departments of Case A, employees continued to adjust and develop them. And after 5S was implemented in the first department of Case B, employees continued to develop it further. This shows that lean operating and CI routines in themselves can also be a source of change: employees not only adjust how they enact a routine to the given circumstances, as the routine dynamics literature has pointed out, but also consciously modify the patterning and related artefacts as part of improvement activities. This interplay is illustrated in Figure 12c; team leaders and employees enacting CI and lean operating routines shaped their patterning and helped them to continuously improve related artefacts, and vice versa.

Figure 12c: Process model on the balanced enacting and patterning of lean operating and CI routines
5.6. INVOLVEMENT OF DIFFERENT ACTORS IN CHANGING Routines AND WORK DESIGN OVER TIME

Based on the process models on enacting and patterning lean operating and CI routines, the following section maps the involvement of different actors in the change process with illustrations of their respective contribution over time. These process maps characterize the underlying processes that allowed these firms to transition towards enacting and patterning CI and lean operating routines. In Case A the CEO asked middle managers to conduct improvement projects and hired consultants to help them do so (see Figure 13). These middle managers then asked two team leaders to map current states, conduct root cause analyses, map future states, develop implementation plans etc. They involved employees and together identified ways to improve their functional production into lines. This integrated approach resulted in changing the work design towards lean operating routines and in patterning and continued enacting of CI routines. The CEO and middle managers continued to support this process, for example by hiring a CI manager and later also a Lean minded Operational Officer. As such, top management asked middle managers and team leaders to enact CI routines and supported them in doing so. They were thus able to actively engage all organizational levels to implement lean operating routines resulting in an integrative approach.

Case B encountered unsuccessful and successful events surrounding 5S implementations (see Figure 14). The first attempt was initiated by top managers
in a top-down manner and was unsuccessful. Middle managers were simply told to implement 5S and in turn ordered team leaders to do so without enacting any CI related routines such as mapping current states, conducting root cause analysis, mapping future states etc. Few employees understood the need and the implementation failed. In a second attempt, a new CI manager took a different approach in one of the plants, starting out with enacting cycles of 5S related CI routines. They took time to analyse their current way of working, to identify what was adding value and what was not, to think of better ways of working, including 5S techniques etc. He also encountered resistance but engaged in discussions and provided coaching. This approach enabled them to actively engage team leaders and employees in the implementation process and over time also spread to other departments.

Case C encountered unsuccessful events surrounding the ‘coup’ and subsequent CI activities (see Figure 15). One middle manager tried to implement a pull system using a limited set of carts, yet without involving team leaders and employees in mapping current states, conducting root cause analyses, mapping future states, etc. This prevented the development of a shared understanding of the pull system. Although eventually employees did use the carts, no further improvement projects were conducted, resulting in a one-off implementation. When the CEO ordered all managers to reduce their lead times by half, experiences were mixed. People did not understand the need, and no improvement projects were enacted. Contrary to Case A and Case B, the managers at Case C did not actively engage all levels of the organization to implement lean operating routines. The absence of CI routines prevented

Figure 14: Process map of 5S implementations at Case B
managers and team leaders from patterning their lean operating routines, which means they lacked the understanding behind the work design changes.

Figure 15: Process map of coup and subsequent events at Case C

5.7. DISCUSSION

5.7.1. Generic process model

This chapter provides new insights on the interplay between lean operating and CI routines and how different actors can contribute to initiating and establishing these routines. A central idea is the interplay between the enacting and patterning of lean operating and CI routines. The specific process models (Figure 12a-12c) show how this interplay evolved in the different cases. From these specific process models, this chapter proposes an abstract process model that indicates how this tandem relation could evolve in general (See Figure 16a-16c). This proposed process model can be read as follows. Dissatisfied with prior routines, managers stimulate team leaders and employees to enact CI routines, such as kaizen events or A3 projects (Figure 16a). Enacting CI routines helps team leaders and employees to first pattern and then enact lean operating routines and implement related artefacts, such as working with a Kanban system of cards or a two-bin system. This in turn helps team leaders and employees to pattern their CI routines and implement related artefacts, while both help to enact improved CI routines (Figure 16b). When lean operating and CI routines are implemented, they do not become static, but continue to develop due to their dynamic character (Figure 16c).
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Figure 15: Process map of coup and subsequent events at Case C

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Figure 16a: Process model (1/3): the interplay between prior and lean routines

Figure 16b: Process model (2/3): the interplay between CI and lean operating routines

Figure 16c: Process model (3/3): the continued enacting and patterning of lean operating and CI routines
The proposed process model is in line with earlier literature that proposed that lean operating and CI routines are best performed in tandem (Cua et al., 2001; Flynn, Sakakibara, et al., 1995; Shah & Ward, 2003). This stream of literature however does not open up the black box to explain how these routines evolve. Wenzel et al. (2021) explained that rather than a static black box, organizational routines are dynamic and evolving. This chapter unfolds how routines evolve in the context of lean production implementations. Shook (2010) and Liker (2020) explained that to change employee thinking it is important to change their behaviour. Our empirical evidence and the proposed process model support this notion. More specifically, this chapter shows that CI routines do not stem from implementing lean operating routines. Rather, for managers to change team leaders and employees’ lean operations-thinking it is important to start with triggering their CI behaviour. This will help to change their shared lean operations thinking.

Keating et al. (1999) suggest that the main determinant of failure is the inability to manage an improvement project as a dynamic process. They conclude that activating cycles of employee pull helps to sustainably improve processes without ‘command-and-control management’. From a Six Sigma implementation study, De Mast et al. (2021) add that implementations of management systems such as Six Sigma and Lean Production are dynamic learning processes. This chapter continues with this dynamic perspective as it focuses on the interplay between lean operating and CI routines, and the role of different actors in establishing these routines. This chapter refines earlier findings by Secchi and Camuffo (2016) that developing local improvement capabilities rather than centralized improvement expertise was linked to the best performers. And this chapter expands earlier insights that organizations may start implementing lean practices without CI routines, but that for advanced lean practitioners CI routines are always necessary (Knol, Slomp, Schouteten, & Lauche, 2019). This chapter shows that the most advanced lean practitioners developed CI routines from the start.

5.7.2. What actors do to change routines and work design
The process maps (Figure 13-Figure 15) show the importance of active engagement of team leaders and employees by managers, and strong connections between and across both levels. Top management support and
leadership are crucial for implementing lean production as previous literature on infrastructural or critical success factors has found (e.g., Achanga et al., 2006; Sila & Ebrahimpour, 2003). Yet this initiative at the top level is most useful if it is directed at encouraging leaders to actively participate, and it can be counterproductive if it attempts to prescribe the actual implementation in a top-down manner. Middle managers can then advance the implementation, again not by implementing lean operating routines themselves but by stimulating team leaders and employees to enact CI routines and then adapt work design for lean operating routines. This approach transformed initial employee resistance into ownership and effective solutions, as employees themselves addressed the lean operating patterns. Scherrer-Rathje et al. (2009) explain that integrating top-down and bottom-up activities helps to implement lean production. The process model illustrates how top-down and bottom-up activities unfold over time as it specifies the interaction between different hierarchical levels. While earlier findings had shown that the timing of critical success factors matters (Knol et al., 2018; Netland, 2016), the current research adds insights on how and by whom CI and lean operating routines could be enacted to create the most lasting impact in the change process.

Wenzel et al. (2021) explained that organizational routines can be developed through emergent and deliberate manners. This chapter further unfolds the role of managers and team leaders and employees in lean production implementations; the most successful organizations in this study did not rely solely on management or expert led interventions, nor did they leave improvements to team leaders and employees. Rather, they engaged team leaders and employees in enacting CI routines. While interventions in the work design create the structural conditions for enacting lean operations, they do not automatically create understanding for the need for these changes, in particular if conducted top-down and without coaching. Starting with enacting CI enables employees to take ownership and become actively involved in the subsequent enacting and patterning of lean operating and CI routines.

The proposed process model helps to understand when and why lean production implementations succeed but is not intended as a fail-safe ‘how to’ guide to successful lean production implementations. There are always conditions of uncertainty and there can always be unforeseen events (Fiol &
Even after careful experimentation, new issues might still emerge, causing change to lead to routine corruption and regression towards or worsening of the previous state. The data show that for example in Case A, employees were allowed to make mistakes to learn from. In these unsuccessful implementations, routines regressed or worsened at first, but over time improved. In addition, work design in general (Sinha & Van De Ven, 2005) and lean production implementations in specific (Shah & Ward, 2003; Young, 1992) are always contingent on their environment. As such, the process model can serve as a framework for lean production implementations while remaining attentive to how the implementation process evolves, tailoring the approach to the people and circumstances at hand.

5.7.3. Alternative sequence of activities
Some authors argue that lean operating routines can also be patterned through management driven improvements (e.g., Liker, 2004; Womack & Jones, 2003). Equifinality indicates there are different paths to the same outcome. The proposed process model indicates that the enacting and patterning of lean operating routines mutually reinforce each other. This means that the lean operating routine could improve over time. For example, implementing Kanban systems of cards helps to lower the level of work-in-progress (WIP). Employees experiencing this benefit might continue to strive for a better level of WIP. However, patterning lean operating routines in this way is not linked to enacting CI routines making it hard for employees to develop alternate lean operating routines, especially when top-down efforts by managers reinforce the prior way of leadership. This is in line with generic (e.g., Secchi & Camuffo, 2016) and specific findings on expert driven interventions to implement lean production (e.g., Done et al., 2011; Secchi & Camuffo, 2019) showing regression afterwards. And this is in line with findings on interventions to develop employees’ CI routines (e.g., Anand, Chandrasekaran, & Sharma, 2021; Bateman, 2005) showing more sustainable results. For equifinality it is important to consider the entire system as the outcome, including the patterns that developed the system. In that sense, the same lean operating routines can be the observable top of two entirely different systems.

5.7.4. Theoretical contributions
This chapter provides new insights on how different actors can contribute
to initiating and establishing lean operating and CI routines. This refines our practical, infrastructural and philosophical understanding of how to implement lean production. A practical perspective studies lean production from what is observable, its set of practices, routines, tools and techniques. There is a vast amount of research on lean production (e.g., Flynn, Schroeder, & Sakakibara, 1995; Krafick, 1988; Shah & Ward, 2007) and how its bundles of routines are related to each other (e.g., Cua et al., 2001; Dal Pont et al., 2008; Flynn, Sakakibara, et al., 1995). This stream of research has typically taken a variance approach to study these practices and routines. This provides insights into the constellation of these bundles yet does not say much about how they develop over time. Taking a process view, incorporating the ‘who’ and ‘how’ next to the ‘what’ of practices and routines (Jarzabkowski et al., 2016; March & Sutton, 1997; Sinha & Van De Ven, 2005), this chapter explains that rather than being implemented in isolation or even in conjunction with each other, sustainable lean practices and routines come about through team leader and employee enactment of the CI practices and routines. As such it provides a great way to integrate variance and process streams of literature to better understand lean production implementations.

Furthermore, this chapter refines our infrastructural understanding of how to implement lean production. The literature provides many insights in which infrastructural (e.g., Ahmad, Schroeder, & Sinha, 2003; Anand et al., 2009; Sakakibara et al., 1997) or success factors (e.g., Achanga et al., 2006; Saraph et al., 1989; Sila & Ebrahimpour, 2003) are critical for lean production implementation. These studies have adopted almost exclusively a variance perspective, even those with a longitudinal design (e.g., Bateman & Rich, 2003; Done et al., 2011; Secchi & Camuffo, 2019). Building on process research, this chapter maps the implementation process and moves from a contingency approach to a complexity approach (Jarzabkowski et al., 2016; March & Sutton, 1997; Sinha & Van De Ven, 2005). Secchi and Camuffo (2019) already showed that the absence of obstacles and barriers is not sufficient for success; rather how the approach is organized matters for sustainable implementation. This study expands that insight by accounting for the role that different actors play at different times, which illustrates that management support and leadership are by no means sufficient conditions for success in themselves: they can be enacted in a top-down fashion that neglects the need for enacting and patterning CI routines and can jeopardize the entire implementation process.
Finally, the chapter refines our philosophical understanding of how to implement lean production. Seminal works (Liker, 2004; Womack & Jones, 1996) comprehensively describe principles that are fundamental to a lean production system and have been applied many times. While each of these works stress the mutual reinforcement between lean operations and CI, they consistently and persistently present the lean operations principles before the CI related principles (Liker, 2020; Womack & Jones, 2003). Additionally, the learning organization is typically portrayed as the final stage of lean maturity (Bessant & Francis, 1999; Hines et al., 2004). This implicitly and sometimes explicitly suggests a temporal order. This chapter challenges this constellation of principles and depiction of stages, as the findings clearly indicate that enacting CI is also essential at the start. While the initial version of ‘The Toyota Way’ depicted problem solving as the top of the pyramid (Liker, 2004), the more recent edition acknowledges that rather the principles are equal and interconnected like a jigsaw puzzle (Liker, 2020). This study provides evidence that CI principles are best not regarded as a final addition but as primary mechanism for change both in terms of the temporal order and their importance for the implementation process.

5.7.5. Practical contributions
The proposed process model helps manufacturing managers, policy makers, consultants and educators to reconsider their approach to implement lean production or teach how to do so. First, lean operating structures and artefacts can easily be misused. For example, implementing 5S shadow boards in any top-down fashion to develop CI and learning later on neglects the interplay between enacting and patterning lean operating and CI routines to develop these routines. In such an approach, standardization can be locked-in by implementing shadow boards directly, but it is unlikely that this will lead to employee-initiated improvement projects. From an employee’s point of view, this is quite understandable. An employee might wonder why to start an improvement project if a manager ordered him to perform 5S in the first place. The employee would tend to expect the manager to continue this style of managing and tell them what to do next. When instead artefacts are implemented as the result of enacting CI routines, the artefacts will help to pattern lean operating routines and this will more likely result in continued improvement.

Second, the proposed process model indicates that also for infrastructural or
critical success factors some consideration is in order. Contrary to their definition, critical success factors are no guarantee to success or to prevent failure. For example, in the unsuccessful case, management support was interpreted as supporting lean production implementation in a top-down fashion. Such an approach prevents team leaders and employees from starting A3 projects to identify and implement suitable lean operating routines, resulting in an insufficient implementation and possibly decay. Next to the ‘what’ of such factors, it is therefore also important to incorporate the ‘who’ and the ‘how’ of critical success factors. To ensure that over time, lean production implementations run along intended rather than unintended lines, it is not the critical success factors but the enacting and patterning of lean operating and CI routines that is most important.

Third, this study also offers new insights compared to contingency theory. Previous research has shown that the suitability of lean practices depends on an organization’s context or contingencies (e.g., McKone et al., 1999; Shah & Ward, 2003; Sila, 2007). The process view illustrates that context and contingencies are not static but can evolve as part of the implementation process. By starting with CI activities, practitioners can mould the evolving routines to their specific situation and develop work designs that emerge as suitable for their requirements. Normative guidelines can act as inspiration for developing artefacts and patterning routines that are tested and refined as they are enacted. The resulting CI and lean operating routines may again show similarities that could be described as contingencies by future research.

As a final comment, there is discussion whether a ‘sense of urgency’ is a suitable trigger or a hindrance for change (Stouten, Rousseau, & De Cremer, 2018). This chapter also indicates that this can be a hindrance. If an organization is in urgent need for change, this is often addressed through top-down or expert interventions. However, such top-down interventions can hinder the enactment of CI routines by team leaders and employees, thereby obstructing the patterning and learning required for a sustainable implementation. Creating social patterns is not as straightforward as installing a new software package – developing routines takes time. The findings of this chapter indicate that the only way to speed up this process is to support team leaders and employees in enacting and patterning CI and lean operating routines and to provide sufficient coaching.
5.8. LIMITATIONS AND FUTURE RESEARCH

This chapter focused on the interplay between generic routines. Though the comparative case analysis draws on specific events, the proposed process model is generic in nature. Future research can use the proposed process model to focus on the enacting and patterning of specific (clusters of) lean operating and CI routines. For example, which CI routines help to pattern and enact JIT, supplier or customer-related routines and ultimately improve performance? Or which lean operating routines help to pattern and enact Kaizens and A3 projects? This can provide more details to practitioners that want to implement lean production.

Furthermore, this chapter focused on the role of management support and leadership. Future research can use the proposed process model to study the role of other critical success factors. For example, which role does organizational culture play in building lean operating and CI routines? Or how does training help to enact and pattern lean operating and CI routines? Additionally, this chapter focused on central concepts; the enacting and patterning of organizational routines. Future research could elaborate on adjacent concepts such as learning and un-learning, enforcing routines, truce and power. This will help to better understand the complex and dynamic nature of routine development.

This chapter presents the results of a comparative analysis of retrospective case data. Although this allowed to study cases that were proven successful, it did not allow to keep a close track of the routine development. Certain events were not observed directly and interviewees might suffer from recall bias (Beckett et al., 2001). Additionally, the data was coded by one author. This might have led to observation bias. Future research could take a more ethnographic approach to data collection and a more collective approach to data analysis to more thoroughly understand the implementation of lean production.

Another limitation of this study is its focus on manufacturing SMEs. As these organizations have their own inherent features and characteristics, findings cannot be generalized blindly. Future research can use the proposed process model to study lean production implementations in other contexts, such as more high-tech, larger organizations, more hierarchical enterprises, organizations that employ more different levels of education, and less informal organizations.
Finally, this chapter was limited to understanding the interplay between enacting and patterning lean operating and CI routines. Future research can take a longitudinal approach (e.g., interventionist research and design science (Oliva, 2019; van Aken, Chandrasekaran, & Halman, 2016)) to develop interventions that pattern lean operating and CI routines in a variety of contexts, carefully considering the balance between managers and experts, and team leaders and employees. This will provide more detail to understand and help enact and pattern these routines in other organizations.
6.
A PROTOTYPE ROUTINE BUILDING-INTERVENTION TO IMPLEMENT LEAN PRODUCTION
ABSTRACT

In this chapter, I develop and showcase a prototype intervention to support the implementation of lean production. This intervention shows how the insights from the previous chapters can be translated to practice. The intervention aims to build team leader and employee continuous improvement (CI) routines that subsequently develop lean operating routines. Managers and experts are required to foster this process. The intervention consists of five CI workshops and several coaching sessions for team leaders, employees, top managers and middle managers. To showcase the intervention, I applied it in a small Dutch manufacturing organization. This application shows that such a series of activities can be used to build CI routines. These CI routines subsequently help team leaders and employees to understand and enact lean operating routines and implement related artefacts. These findings suggest a way to translate the insights from the previous chapters to practice. Combined with the earlier findings in this dissertation and the literature, this leads to a set of three intervention principles on implementing lean production in manufacturing small and medium-sized enterprises (SMEs). Manufacturing SME managers can use the findings to reflect on their own implementation approach. Consultants and educators can use them to reflect on their activities, educational programs and belts, to incorporate organizational routine-building into their approach.
Chapter 6. A prototype routine-building intervention to implement lean production

6.1. INTRODUCTION
To show how the insights from the previous chapters can be translated to practice, I draw on the process model in the previous chapter to develop a prototype routine-building intervention. I apply this intervention in a Dutch manufacturing SME aiming to build continuous improvement (CI) routines that subsequently develop lean operating routines. Implementing lean production is challenging for manufacturing SMEs (McGovern et al., 2017; Shah & Ward, 2003; White et al., 1999). To provide more focus, Chapters 3 and 4 indicate conditions that are necessary for different levels of lean practice implementation. Chapter 5 compares successful interventions to unsuccessful events to explain that enacting CI routines helps to pattern and enact lean operating routines. In this chapter, I draw on these findings to prototype an intervention to implement lean production. The term prototype means that the intervention is not a fool proof approach to implement lean production. It indicates that the insights from the previous chapters were used to showcase an application in one manufacturing SME. The findings lead to insights on activities to implement lean production in manufacturing SMEs. The aim of this chapter is: to prototype an organizational routine-building-intervention to help implement lean production.

The literature indicates that lean operations and CI are mutually constitutive (Hines et al., 2004; Holweg, 2007; Liker, 2020; Schonberger, 2007). To understand the interplay between lean operations and CI, in the previous chapter I developed a process model. This process model draws on Feldman and Pentland’s (2003) distinction between enacting and patterning organizational routines. Enacting relates to how a routine is performed, patterning relates to the shared and embodied understanding of that routine (Feldman, 2016). The process model shows that team leader and employee enacted CI routines help them to understand lean operating routines and implement related artefacts. Subsequently, these patterned lean operating routines and artefacts help them to also enact lean operating routines. This process model is derived from practice, but it not used explicitly to design and apply a lean intervention. Therefore, this chapter tries to answer: Which elements of an intervention can build CI routines to pattern and enact lean operating routines?

Many studies have analysed interventions to implement lean production. For example, in a study on expert driven approaches Done et al. (2011) studied eight interventions in seven manufacturing SMEs and found that they did not
develop adequate capability for sustainable improvement. Secchi and Camuffo (2019) studied expert driven interventions in 17 offices of a large European bank to find that these did not translate into operational change and performance improvement. Taking an employee centred approach, Bateman and Rich (2003) and Bateman (2005) studied 40 interventions in 21 UK manufacturers to find that this approach was linked to more sustainable implementations. During a lean implementation in a USA hospital, Anand et al. (2021) found that more team leader and employee involvement was required in the CI process to overcome resistance and achieve sustainable results. Comparing lean implementations in seven multinationals, Secchi and Camuffo (2016) conclude that developing local improvement capabilities (contextual ambidexterity) rather than centralized improvement expertise (structural ambidexterity) was linked to the best performers. Combined with the process model on enacting and patterning lean operating and CI routines, these findings are input for the prototype intervention developed in this chapter.

This chapter describes in detail a so far effective intervention to implement lean production. The prototype intervention described in this chapter draws on the process model to build CI routines to understand and start practicing lean operating routines. Specifically, the prototype intervention indicates a set of activities that worked in this case. Combining the findings with the insights from the previous chapters and the literature, I suggest three principles to design interventions to implement lean production. This is not to say that following these principles will guarantee lean production implementations. Each case has its own characteristics and requirements. I do think that these principles help to understand the process model and that they help to identify sets of activities that are suitable in other cases. Researchers can use the findings in this chapter to reflect on their research on lean production implementations, specifically the extent to which both the interplay between lean operations and CI, and organizational routine-building are taken into account. Practitioners can use the findings to reflect on their lean production implementations, specifically the extent to which team leaders and employees are stimulated to enact CI routines to pattern and enact lean operating routines. Consultants and educators can use them to reflect on their activities, educational programs and belts and incorporate the interplay between lean operations and CI, and organizational routine-building into their approach.
The next section elaborates on the link between lean production and organizational routines. I then explain the case, the set-up of the intervention and how I gathered the data. The fourth section elaborates on my findings that enacting CI routines helped to improve lean operating routines. And the fifth section links these findings back to the literature on lean production implementations, leading to a set of principles for lean interventions.

### 6.2. BUILDING ORGANIZATIONAL ROUTINES FOR LEAN PRODUCTION

#### 6.2.1. Common lean production interventions

Lean production implementations are often supported by Yellow, Green and Black Belt training programs. These belts are taken over from the Six Sigma training approach and tend to focus on improving results rather than learning or routines. A common Green Belt training includes explanations of the Lean/Toyota principles, flow concept, mapping tools, plan-do-study-act/define-measure-analyse-improve-control, 5 why’s, fishbone/Ishikawa diagram, 8 wastes, 5S and pull. And in some cases, participants can obtain an additional certificate if they complete next to the theoretical part also a practical project, sustainably reducing operating costs with for example €10,000.- annually.

Black belts are more extensive and include for example Hoshin Kanri, culture and change, leadership, coaching and mentoring, performance management, as well as some more complex lean concepts and tools such as level loading and spaghetti diagrams. Additionally, they usually require a practical project sustainably reducing operating costs with for example €100,000.- annually. In general, such Yellow, Green and Black Belt trainings focus on both operating and improvements tools and techniques and often involve an actual improvement project. But they do not focus much on building routines.

#### 6.2.2. An organizational routine building-approach to implement lean production

To develop a prototype intervention that does incorporate routine building, I draw on the process model developed in the previous chapter, on the interplay between lean operations and CI (see Figure 16). In this process model I use the distinction between operating routines and improvement routines and that between the enacting and the patterning of routines. This process model should be read as follows. (a/b) (top) managers break with prior non-lean routines and
challenge (c/d) team leaders and employees to enact CI routines. This helps team leaders and employees to (e1) understand lean operating routines and (e2) implement related artefacts. Subsequently, these help them to (f) enact lean operating routines. In turn, enacting lean operating routines (d1) patterns their CI routines and (d2) helps them to implement related artefacts, while subsequently these improve (c/d’) their enactment of CI routines. First have team leaders and employees enact CI routines to pattern and enact their lean operating routines makes developments more sustainable. Enacting lean operating routines eventually increases operational performance. The link between enacting lean practices and operational performance is not studied in this chapter as it is shown to increase as a result of enacting lean operating routines (Shah & Ward, 2003). In this chapter, I focus on interventions that build CI routines to pattern and enact lean operating routines.

6.2.3. Generic intervention principles

To design a routine-building intervention, certain principles can help. The routine dynamics literature however focuses much on understanding existing and emerging routines but not much on designing and building organizational routines. An exception to this is the paper by Pentland and Feldman (2008)
in which they provide a guideline to build live routines. Using the example of software implementations, they argue that artefact-centred approaches to changing routines oftentimes neglect the idea that routines are live patterns of interdependent human actions. To build live routines, they suggest to pattern routines through training, practice, feedback and more practice, similar to athletes, military, musicians, etc. For it is this continued practice that eventually patterns routines. Additionally, they stress to consider the point of view of each actor, their interests, their current routines and the related routines. For it is best that not managers or experts but these actors design the actual patterns of action, as these actors are the ones that will enact the routines. Additionally, they indicate the importance of incentives to create and maintain the patterns that are designed. To this end, physical artefacts can help. Finally, they indicate that even when all of this is taken into account, change will always be part of the journey. And these deviations need to be managed by engaging and enabling relevant actors to take appropriate steps.

6.2.4. Guidelines for lean production interventions
To indicate which interventions can build local team leader and employee CI routines for patterning and enacting lean operating routines, I propose the following generic guidelines. Following the process model, it is important to focus on CI routines and artefacts rather than lean operating routines and artefacts as it is enacting CI routines that help to pattern and enact lean operating routines. Following the routine building guidelines, it is important that the suggested intervention helps employees to practice with appropriate tools. It seems to be better to learn a single tool and apply that to one’s situation than it is to teach a multitude of tools and techniques without practice, feedback and more practice. In essence, the intervention aims to have team leaders and employees conduct an improvement project using a structured format such as the improvement Kata, A3 or 8D. Toyota Kata is the problem solving routine practiced by Toyota employees (Rother, 2010). A3 and 8D are structured ways to help solve problems (Sobek II & Smalley, 2008). The intervention can use experimentation cycles such as PDCA/PDSA, DMAIC or the four Kata steps. And problem diagrams such as Fishbone or Ishikawa diagrams, combined with 5 why’s. To guide employees, it is important that key team members such as managers and team leaders are equipped with coaching skills, for example using the coaching Kata. Tools related to countermeasures, such as visual management,
pull systems, or level loading, can be useful to guide problem solving efforts, but their implementation is no requirement in themselves. In the next section, these guidelines will be used to develop an intervention for a specific case. In the Discussion, I will reflect on these guidelines.

6.3. METHODS
6.3.1. Intervention-based research
An intervention-based approach was selected as research strategy. Intervention-based research aims to “empirically test the usefulness and applicability of existing theory” by intervening in the research setting (Oliva, 2019, p. 713). Intervention-based research differs from case studies as researchers intervene in the research setting and it differs from action research as it are the researchers rather than employees themselves that conduct this intervention (Chandrasekaran, 2019). In interventionist research, pragmatic validity (the evidence that the findings will produce the desired result) and practical relevance (the contribution to a significant problem) are important (Oliva, 2019). Following the intervention guidelines provided in the previous section, prototyping an organizational routine-building intervention to implement lean production requires a CI routine building-approach. Deep engagement with practice to help actors improve their operating routines by building CI routines and observing the effects of this intervention helps to better understand the reality of how the organizational routine building-approach to implement lean production works.

6.3.2. Case
As this dissertation focuses on manufacturing SMEs, I used manufacturing and SME as the first two criteria to select a case for this study. The third criterium was that both managers and employees indicated a need for lean production related structures but team leaders and employees would not be enacting CI routines yet. The fourth criterium was that they would be enthusiastic which was important as it would reduce their tendency to tweak data to create a more favourable impression (Schein, 1995). External validity, specifically sample size and representativeness, is considered not an issue as the aim is not to produce or test generic theory but to apply the findings from the previous chapters to derive transferable insights (Oliva, 2019).
The selected case was a small engineering and manufacturing enterprise. It has around 30 permanent and 5 flexible employees, mostly working on sales and engineering. Following a ‘customer intimacy’ strategy (Treacy & Wiersema, 1996), they develop and produce unique machinery for the B2B market. They are a high-variety/low-volume producer, meaning that they produce mostly unique products, mostly project based and always customer initiated. All products follow a more-or-less similar pathway through the organization: design is done at the case, most of production is done in eastern Europe, and the remainder and assembly is again done on location. After a buy-out from a large multinational in 2006, the organization was management owned at the time of the study. It has about $2 million in turnover and $2 million in assets. The location and the buildings are quite old.

The company provides high quality products to their customers, but it oftentimes lacked high internal quality, exceeding delivery times and expected costs. To improve, they previously introduced modules and standards in their product architecture, 5S at the shop floor, a new ERP base module and several additional modules, and bin systems, scanners and bar codes in warehousing. Furthermore, they assumed that the functional design of their organization was in part causing many quality issues; the office and assembly buildings are separated and different functions too are grouped together into a functional design, as opposed to cell or line design. But they had no idea how to work in a more integrated way.

They were aware of the issues caused by the distances between the different functions, or “silos” as they referred to it. They already initiated a work group called “Closer” aimed to bring all functions closer to each other, both literally and figuratively. But rather than focusing on working together, they made a shared terrace for sales and production and they intend to build a shared canteen for both groups too, focusing on implementing non-work-related artefacts rather than developing integrated operating routines. They had no idea how to organize a process in which people actually work together. Nor did they feel sufficiently capable to manage the change required for such a project. As a consequence, they managed to get the right products at the customers in time, but internal quality was low, costs often exceeded the planned budget and employees were frustrated because of this way-of-working.
6.3.3. Measures

To measure the four central concepts (enacting CI routines, patterning lean operating routines, related artefacts and enacting lean operating routines), I draw on the code book (Fereday and Muir-Cochrane, 2006; Van Maanen, 1979) from the previous chapter. An overview is given in Table 10. The lean operating aspects were deduced from Spear and Bowen (1999). Contrary to the principles of for example Womack and Jones (1996) or Liker (2004), Spear and Bowen derive four rules related to the DNA and behaviour of Toyota employees. The CI aspects were deduced from Bessant et al. (2001). Contrary to for example the indicators of Peng et al. (2008) and Anand et al. (2009), the routines of Bessant et al. more specifically relate to employee and manager behaviour. As Feldman and Pentland (2003) linked the distinction between enacting, patterning and related artefacts to the organizational routines, this distinction was taken from them.

Table 10: Concepts

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
<th>Instruments</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enacting CI routines</td>
<td>Specific actions, done by specific people, in specific places and times to continuously improve your daily work</td>
<td>Interviews (t1, t2 and t3)</td>
<td>Observations (personal, pictures, video), reflections and journal</td>
</tr>
<tr>
<td>Patterning lean operating routines</td>
<td>The ideal or schematic form of primary activities that realize customer value with flow and pull</td>
<td>Survey (t1, t2, t3) answered on 2-step 9-point Likert scale</td>
<td>- Structure of improvement activities &lt;br&gt;- Involvement of others in improvement activities &lt;br&gt;- Alignment of improvement activities with the goals of the company</td>
</tr>
<tr>
<td>Lean operating artefacts</td>
<td>Structures external to actors, physical or intangible and single or entire systems, that realize customer value with flow and pull</td>
<td>How do you understand your daily work?</td>
<td>- Understanding of standards and modules &lt;br&gt;- Understanding of a direct relationship with prior and subsequent departments &lt;br&gt;- Understanding of a simple and direct path that their products travel via them</td>
</tr>
<tr>
<td>Enacting lean operating routines</td>
<td>Specific actions, done by specific people, in specific places and times to realize customer value with flow and pull</td>
<td>How do you perform your daily work?</td>
<td>- Presence of standards and modules &lt;br&gt;- Presence of a direct relationship with prior and subsequent departments &lt;br&gt;- Presence of a simple and direct path that their products travel via them</td>
</tr>
</tbody>
</table>

| Instruments | Observations (personal, pictures, video), reflections and journal | - Structure of improvement activities <br>- Involvement of others in improvement activities <br>- Alignment of improvement activities with the goals of the company |
|            | - Understanding of standards and modules <br>- Understanding of a direct relationship with prior and subsequent departments <br>- Understanding of a simple and direct path that their products travel via them |
|            | - Presence of standards and modules <br>- Presence of a direct relationship with prior and subsequent departments <br>- Presence of a simple and direct path that their products travel via them |
|            | - Use of standards and modules <br>- Use of a direct relationship with prior and subsequent departments <br>- Use of a simple and direct path that their products travel via them |
6.3.4. Prototype intervention

The prototype routine-building intervention consisted of a series of problem-solving activities, because I wanted the case team leaders and employees to build CI routines to pattern and enact lean operating routines and the case managers to support them in this process. I developed, proposed and conducted a series of five workshops on Toyota Kata and A3 management followed by a series of five coaching sessions, all listed in Table 11.

To identify suitable lean operating and CI structures to incorporate in the intervention, an expert diagnosis was conducted by three lean production and product development experts and the trainers. We found that their high-end products indicate a good delivery of customer value and proper use of product architecture (modules and standards). But their value streams in general were functionally designed; there were large distances, both physically and socially, between especially sales and production. These physical and social distances were also experienced between managers and employees and between other functions. Previously, their production had changed partially from a dock design to a line design, but there was no pull system whatsoever leaving production in chaos, disrupted at every priority whim of sales.

As a potential solution, the experts suggested the following. Given their high-variety/low-volume production and initial functional operating structure, they would benefit from a cell design (that is cross functional teams, rather than functional silos, each focusing on a specific market segment) and related periodic cross-functional meetings to increase flow (Suri, 1998). A cell design would share responsibility of sales and production to improve the product designs to better reflect both customer requirements and operational capabilities and the cross-functional meetings would ease communication to reduce overall errors in the process. And given their high-variety/low-volume production and initial lack of a limit on work-in-process, they would benefit from a pull system, for example a Kanban board in office and POLCA in production (Hopp & Spearman, 2004). The limit on work-in-process would prevent anyone to change priorities and thus disrupt the process, preventing even more errors to occur. Following the organizational routine-building approach to implement lean production, implementation of these structures would follow not top-down but bottom-up, from their own enactment of CI routines.
**Table 11: Main intervention**

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Aim</th>
<th>Exercises</th>
<th>Content</th>
</tr>
</thead>
</table>
| 1       | Introduction A3 + Problem definition | To jointly determine a definition of the customer problem when multiple related incidents occur | - Orientation: what would you like to be capable of?  
- Identify and sell: 5 lean principles  
- Game: write down and then draw the problem  
- Game: cause and effect (build a tower)  
- Problem definition sheet: determine the customer problem  
- Homework: fill A3 customer problem + identify MCT and Swim lane + sell next time | - Paradigm shift costs vs. flow  
- 5 lean principles  
- Sand cone model  
- Incidents, (customer) problems  
- A3 format  
- A3 customer problem  
- PDCA/PDSA |
| 2       | Introduction Toyota Kata + Current state | To jointly map/ determine the current state and aim when a customer problem is determined | - Recap: what did we do last time?  
- Identify and sell: 8 lean wastes  
- Brown paper: map the current state MCT (generic)  
- Brown paper: map the current state Swim lane (specific)  
- Game: experimentation with seven Toyota Kata questions  
- Brown paper: make Toyota Kata performance board  
- Homework: fill A3 current state and aim + identify basic lean operating structures (e.g., line or cell design) + sell next time | - 8 wastes  
- Dock and functional design  
- Stage gate model  
- A3 current state and aim  
- MCT map and Swim lane  
- Toyota Kata steps, questions and performance board |
| 3       | Basic lean operating structures + Target condition | To jointly map a target condition when the aim is determined | - Recap: what did we do last time?  
- Coaching Kata: practice questions on other group  
- A3: explain A3 following coaching Kata questions  
- Game: mission impossible, the ideal state  
- Brown paper: map target condition  
- Brown paper: update Toyota Kata performance board  
- Homework: fill A3 target condition + identify Q3 structures (e.g., Ishikawa diagram or priority matrix) + sell next time | - Line and cell design  
- Concurrent engineering  
- 10-point plan  
- A3 target condition |
| 5       | Q3 structures + Implementation and Sustainment | To jointly compose an implementation plan and sustainment plan when countermeasures are determined | - Recap: what did we do last time?  
- Coaching Kata: practice questions on other group  
- A3: explain A3 following coaching Kata questions  
- Brown paper: map the implementation  
- Brown paper: map the KPIs  
- Brown paper: update Toyota Kata performance board  
- Homework: fill A3 implementation and sustainment | - Alternatives  
- Feasible steps  
- Sustainment  
- Visual management  
- One-point lessons  
- Skills matrix  
- Implementation plan  
- KPIs |
Table 11. continued

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Aim</th>
<th>Exercises</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>CI structures + Implementation and Sustainment</td>
<td>To jointly compose an implementation plan and sustainment plan when countermeasures are determined</td>
<td>• Recap: what did we do last time? • Coaching Kata: practice questions on other group • A3: explain A3 following coaching Kata questions • Brown paper: map the implementation • Brown paper: map the KPIs • Brown paper: update Toyota Kata performance board • Homework: fill A3 implementation and sustainment</td>
<td>• Alternatives • Feasible steps • Sustainment • Visual management • One-point lessons • Skills matrix • Implementation plan • KPIs</td>
</tr>
<tr>
<td>Coaching</td>
<td>NA</td>
<td>All of the above</td>
<td>• Coaching Kata: practice questions on other group • A3: explain A3 following coaching Kata questions • Brown paper: update Toyota Kata performance board • Homework: improve current or start new A3</td>
<td>All of the above</td>
</tr>
</tbody>
</table>

All four-hour workshops had the same overarching goal: following the process model and Lean intervention guidelines, I wanted to entice trainees to build Toyota Kata and A3 problem-solving routines to pattern lean operating routines and implement related artefacts, to subsequently enact lean operating routines. Toyota Kata and A3 are great as they cover suitable CI routines and artefacts for improvement projects. Each workshop also had a specific aim, depending on the stage of the A3 project. For example, the first workshop aimed to jointly determine the customer problem based on multiple related incidents. Such aims helped participants to better understand the problem, preventing them to jump to conclusions. To develop routines, each workshop consisted of many hands-on exercises, games and brown paper sessions (Gray, Brown, & Macanufo, 2010) to let them practice the Toyota Kata and A3 problem-solving routine. Next to these exercises, each workshop also challenged and helped them to understand certain CI and lean operating artefacts; the trainees were frequently asked to identify themselves artefacts we envisioned relevant to their context and sell the importance of these artefacts to their colleagues. We could then deduce their ostensive aspect and help them where necessary which would make it easier for them to continue to follow the organizational routine building-approach when we were to leave.
Next to these workshops, we conducted a series of five two-hour coaching sessions. These coaching sessions did not have any particular content, nor were they as extensive as the workshops. Their aim was to help them continue to build CI routines and make sure they were provided what was necessary to do so. During the coaching sessions we continued to focus on Toyota Kata and A3. Toyota Kata is not a standard part of A3 management, but we do consider its approach and seven coaching questions to help in building CI routines using the A3. To increase commitment, management, employees and we ourselves selected participants, listing a member of the board/the marketing director, the manager operations, a salesman, two sales engineers, three engineers, a manager purchasing and logistics, a team leader assembly, and a servicer, eleven in total. And we decided on the dates to do the workshops and coaching sessions. The workshops were given by an experienced trainer and one of the authors. This entire process of us guiding the workshops as experts, their building CI routines to pattern and enact lean operating routines, and management providing what was necessary to do so developed and implemented our initially envisioned lean operating structures, not directly but indirectly and over time.

6.3.5. Data collection
To limit informant bias, the CEO, COO and managers, team leaders and employees from production and the office were involved and to limit common method bias, data was collected using interviews, observations and archives (internal documents and websites) (Eisenhardt & Graebner, 2007; Jick, 1979). The first five interviews were done with employees, team leaders and managers from the organization, all participants to the intervention. They were done prior to our intervention (t1) to better understand the situation at the case, then five subsequent to our intervention (t2) to better understand its short-term effect, and finally five interviews six months after our intervention (t3) to better understand its long-term effect and validate the findings. Comparing t1, t2 and t3 also enabled reflecting on the intervention approach to implement lean production.

Observations and reflections were documented during the main intervention. During the workshops and sessions, many questions were asked, for example on what the participants thought of the activities or the content, and how they were using the patterned routines in their daily work. The answers and accompanying
observations were input for observation forms. Many pictures were taken, and all workshops and sessions were video recorded. Right after each session, both the researcher and the trainer filled in a reflection on the session, on what went well or difficult, and what the learnings were. Covering all instruments, workshops and sessions, one of the authors kept a private journal, using the plan-do-study-act cycle to reflect and act on everything that passed around the entire study. The combination of these instruments delivered data on their perception of their routines, their experience with the intervention and the results of this intervention.

6.4. FINDINGS
The findings are based on the first, second and third measurement and they follow the structure of the organizational routine building-approach to implement lean production. First, I elaborate on the state prior to the intervention. Next, I elaborate on what happened during the intervention regarding the organizational routine building-approach to implement lean production in Figure 17: (c) enacting CI routines to (e1) pattern lean operating routines and implement related artefacts. Then I elaborate on the effect this had on (f) enacting lean operating routines. I end with an elaboration on other noteworthy events.

6.4.1. Prior state
Prior to the intervention, management was trying to engage employees in CI activities to implement their envisioned operating structures (not related to the silo problem). There had been improvement projects for which management initiated cross-hierarchical and cross-functional teams. And management did organize the work group called ‘Closer’ who, next to the terrace, also arranged a workshop on giving feedback. However, management and employees had little (d1) understanding of CI routines nor used required (d2) CI artefacts. For example, they found it difficult to distinguish causes from effects and aims from means, both during workshop one’s game exercise ‘Cause and effect’, workshop three’s brown paper exercise ‘Map the target condition’ and workshop four’s brown paper exercise ‘Map the analysis’.

Additionally, prior to our arrival there were only a few performance boards that were also empty (d2. CI artefacts) (see Figure 18), only four ill structured
management made A3s (d2. CI artefacts) (see Figure 19), no employee initiated A3s (or the like) (d2. CI artefacts), hence there was little (d1) understanding or (c) enactment of CI. We found only one project initiated by a sales engineer (to extent their modular architecture from products to information as well). As a result, (c) enactment of CI routines initially was limited to minor product improvements. Curiously, there was a daily stand-up in the sales department during which incidents were discussed and solved.

Furthermore, there was little presence of lean operating routines or artefacts. They did use product architecture (modules and standards) to design their customer value, however their value streams in general were functionally designed. Only at production some functions had changed from a dock design to a partial line design resulting in little flow. In the past, their efforts were focused on a new ERP base module and several additional modules that were now operational. Additionally, they implemented bin systems, scanners and bar codes in warehousing. However, there was no pull system whatsoever. There were some signs of 5S at the shop floor, however this implementation was not successful.

**6.4.2. During the intervention**

(c) Enacting CI routines to (e1) pattern lean operating routines
To help them enact CI routines, the intervention was conducted. The guided problem-solving intervention combined with the guided application of the seven Kata questions and A3 format (d2. CI artefacts) built their problem-
solving routines (c. enacting CI). A sales engineer said: “The [A3] structure (d2. CI artefact) helps a lot in this project. [...] the Ishikawa, then the priority matrix, then the feasibility matrix helps to come to relevant and feasible improvement steps.” This was also observed during the training. For example, one manager wanted to start their project with an Ishikawa diagram. Using the A3 structure, with Ishikawa’s root cause analysis after the current state, the manager could be explained and he understood that it is better to first focus the scope of the project and then do the root cause analysis to prevent a complex knit of problems and causes.

In general, the data show that (c) enacting these CI routines (e1) patterned lean operating routines. Especially the exercises helped to achieve this. For example, the brown paper exercises ‘Map the current state MCT’ and ‘Map the Swim lane’ (c. enacting CI) in the second workshop “created a lot of awareness” (engineer), helped them to “better understand and appreciate each other’s operations!” (manager purchasing and logistics) and “clearly indicated areas for improvement” (marketing director) (e1. understanding lean operations). The same went for the brown paper exercise ‘Map target condition’ in the third workshop. It was observed that they added to the patterning of team leader and employee’s lean operating routines as they helped them to understand the current situation and the envisioned future situation of their work.

We also conducted the game exercise ‘Mission impossible’ in which participants do a brainstorm on all sorts of rational and irrational solutions to their specified problem. Conducting this exercise (c. enacting CI) patterned lean operating routines (e1) as well. This game challenges players to think of how to deliver their product in just one day (Gray et al., 2010). During this game, the participants thought of lean operating structures introduced by us, like concurrent engineering, but also thought of structures by themselves, like customer requirement assessments or design using virtual reality (e1. patterning lean operating routines). Afterwards, the trainer commented: “This exercise for them really makes it come alive, it sows the seeds for realization.” (see also Figure 20). Conducting these exercises made participants better understand their own and others daily work.

The Toyota Kata approach and specifically its seven coaching questions (c.
enacting CI) also (b1) patterned lean operating routines. This approach and these questions help to structure team leader and employee experimentation and learning for improvement. Practice was very much required though. The Kata approach and coaching questions were introduced during the second workshop but little to not used in between workshops. We repeatedly practiced them during all of the following workshops and coaching sessions, handed the questions out on cards and challenged them to use them in their daily work. They started doing so (c. enacting CI) as they experienced that they helped them to “think first” and “identify new perspectives” (e1. Patterning lean operating routines) and “identify feasible steps” and “experiment together” (c. enact lean operations) (pop-up reactions from all participants). Even the somewhat directive managers said they found the questions “really useful for our work”.

Figure 20: Impression of the brown papers during the fifth workshop

(c) Enacting CI routines to implement (d2) lean operating artefacts
In general, the data show that letting the participants search for and identify suitable lean operating structures themselves (a. enacting CI routines) using mainly books, lean events and the internet, and letting them present the definitions, importance and examples of these structures to the others during the workshops (e1) patterned their lean operating routines and (e2) implemented lean operating artefacts. For example, one couple of attendees had to explain ConWIP. They identified its definition and importance from the internet and used a clear and funny simulation to explain these to the other participants (a. enacting CI). This showed that they understood the concepts. Additionally, they indicated that this increased their understanding of the concept (b1. patterning
lean operating routines) and helped them to identify a Kanban board as an appropriate lean operating structure (b2. Implementing lean operating artefacts) to use for themselves.

In addition to them explaining ConWIP, we also explained the overarching pull concept, that of a limit on work-in-process. Throughout the entire intervention, we noticed that some participants were struggling with the amount of daily work. Explaining the pull concept created awareness about what to do to manage this workload. Without using any tangible system or board, several individuals indicated that the (intangible) pull structure helps them to limit their workload. Furthermore, following our explanation of ‘5 times why’, the sales employee understood the true meaning of this intangible artefact, understood that it was also applicable outside CI, during his daily work, and as a result of that, by now has this (intangible) diagnosis structure at his disposal during his sales activities. Additionally, the subsequent brown paper, finding and game exercises, periodically supported with the Toyota Kata performance board (c. enacting CI), helped to identify less and more complex artefacts like a standard operating procedure, poka yoke, a checklist, the decision-making unit, a skills matrix, a cross functional kick-off, concurrent engineering, documenting decisions, priorities of activities, and an archival structure.

6.4.3. After the intervention
(e1) Patterning lean operating routines and (e2) implementing related artefacts to (f) enact lean operating routines
Initially, there was little presence of understanding, enacting lean operating routines nor related artefacts. This changed after the problem-solving intervention. The data show that (e1) patterning lean operating routines and (e2) implementing lean operating artefacts improved (f) enactment of these lean operation routines. For example, after two participants explained ConWIP and we explained the pull concept, managers and sales employees now limit their work-in-process using a Kanban board. Additionally, several individuals now limit their daily workloads by following the pull principle. And sales employees now discover and answer underlying questions using the 5-why method. Next to these, people standardize their way-of-working using standard-operating-procedures (SOPs), they design their products in a fool-proof manner using poka yoke, they try to prevent mistakes using checklists, sales employees now first
identify the decision-making unit, sales and engineering start doing concurrent engineering, managers use skills matrices, projects are kicked-off in a cross functional manner, some documenting and following-up decisions is done during these projects, activities are better prioritized, and an operating employees now use an archival structure. In general, many lean operating routines, either suggested by us or thought up by the attendees themselves, are currently used in their daily work.

There were also positive side effects. For example, we explained the definition and importance of ‘5 times why?’ using a funny movie and an example. We intended that this structure would be understood and used by the participants to better analyse the root causes to their problems, which they did. Added to this, the sales employee understood that this structure is also very helpful to better identify customer needs. This confirmed our understanding that rather than implementing structures in a top-down fashion, an integrated approach improves both employee engagement and the quality of the application.

In general, their own (guided) selection of two projects, mapping of their current state, analysis of the issues, identification of suitable lean operating structures, and development of an approach to implement these structures (c. enacting CI) increased (e1) their understanding of the necessity of these projects, problems and solutions, increased their agreement that something had to be done and increased their commitment to do this themselves. Participants indicated that the workshops were very useful to reveal the good and bad in how they enact their operations making them very much aware of their work and where to improve. And several CI and lean operating artefacts are now implemented (e2. lean operating artefacts) and being used (f. enacting lean operations).

6.4.4. Reflection on other events
Time and resources and top management support
At the second workshop, the operational stress of the employees became clearly visible. One employee was absent because of the amount of his operational work. Another one was absent during the third workshop and another one during the third and fourth workshop and one of the coaching sessions. The fifth workshop was postponed by two weeks, almost twice, again because of operational stress. When it took place, four of them were absent. Sometimes,
homework was not done properly because of “a lack of time”. This issue was discussed frequently. During one of these discussions, the marketing director said, “Yes, we ask them to focus on operations, but they also do not indicate that they have CI tasks to finish. It has to be a two-way street.” However, given management’s attitude and some employees mentioning a “culture of fear”, employees’ reaction not to say “No.” still might be because of top management. In general, time and resources and top management support clearly link to enacting CI and lean operating routines.

Management and employee attitude
During the first workshop, we quickly became aware that the managers that were present would repeatedly tell employees what was best and thereby obstruct employee engagement in the CI activity. We had to take managers apart to highlight this and ask them to give employees time to think and provide input. As the manager operations said: “I am a driver of many things and I find it difficult to get people engaged. Sometimes, I get trapped and do it myself. I say: ‘If you don’t want to do it, then I’ll do it myself’ just to get it done.” This attitude took away most initiatives from the employees and hampered the performative aspect of CI. On the other hand, some employees were also holding back on which the trainer commented: “[She] might need more engagement, with [him] it appears to be the nature of the beast.” This does not mean that the participants were elusive towards their attitude. The manager operations said: “These workshops are very counterintuitive to me, I can feel it burning deep inside of me, it touches the very heart of our organization.” In general, attitude seems to play a massive role in the organizational routine building-approach to implement lean production; if management tells employees what to do, employees do not get the opportunity to learn.

Overall, the participants appreciated the workshops a lot. After the final workshop, 34 countermeasures were identified for the specific problem area. Additionally, everyone understood that numerous countermeasures could be identified when they were to extent this endeavour to the entire value stream. The marketing director said: “I am excited about the outcome; I want to give this workshop to the other employees as well.” One member of the work group ‘Closer’ said: “Thank you on behalf of the work group. The workshops went beyond our expectations. I was afraid that they would focus on the hard side
of lean. Your tender already convinced me otherwise. And it turns out to be even better than expected. This was a really good opportunity to gain insight in our cooperation and to respond to it. And with the introduction of our countermeasures, cooperation will extent to take place in our operations as well!”, indicating that indeed they move closer towards implementing lean production.

6.5. DISCUSSION
Drawing on the insights of the previous chapters, the aim of this chapter was to prototype an organizational routine-building intervention to implement lean production. The results show that the prototype intervention succeeded in building CI routines to pattern and enact lean operating routines in this manufacturing SME. This finding develops our understanding of implementing lean production and building organizational routines. It shows that rather than teaching attendees lean operating tools and techniques directly, combined with some CI ones, it is the attendees’ enacting of CI routines using related artefacts combined with some lean operating tools and techniques that helps them to pattern their lean operating routines. The Toyota Kata and A3 format are examples of CI that were used in this case but that are not required per se. Other CI routines and artefacts can work just as well, also depending on the context. Combining these findings with the lean intervention guidelines developed in the second section of this chapter, I develop a set of three lean intervention principles. At the end of this section, I discuss limitations, future research and practical implications.

6.5.1. Intervention principle 1: Continuous improvement before lean operations
Throughout this dissertation, I make a distinction between CI and lean operations. This is reflected in the process model developed in the previous chapter. And this is reflected in the prototype intervention developed in this chapter. In the prototype intervention, both CI and lean operations were incorporated and tailored to the organization at hand. In the case of this study the CI regarded amongst others the Toyota Kata and A3 format, lean operations the cells and pull systems. However, both are taught using very different emphases. The CI content is provided in the sense that the attendees have to enact the suggested CI routines. This helps them to get started and to pattern their own lean operating routines. The lean operating content is provided in the
sense that we suggest lean operating structures that we envision suitable for the organization. But the attendees have to conduct the CI routines and draw on the suggested lean operating structures and their own creativity to identify solutions for them to implement. Us guiding lean operating structures like this prevents them from selecting inappropriate solutions, increases their involvement and helps them to internalize the countermeasures. This approach is very different from most Yellow, Green and Black Belts which often put more emphasis on lean operating structures such as 5S, sometimes even teaching these as the best way to organize work. The prototype intervention stresses that team leaders and employees have to enact CI activities to identify lean operating structures themselves. As a result, I propose the following intervention principle:

1. **Incorporate continuous improvement routines (suitable for the organization) that attendees have to enact and incorporate lean operating structures (envisioned for the organization) that the attendees can draw on.**

6.5.2. Intervention principle 2: Collectively and repeatedly enacting for shared patterning

Second, the findings stress the importance of collectively and repeatedly enacting CI routines to pattern and enact lean operating routines; routines are defined as a “*repetitive, recognizable pattern of interdependent actions, involving multiple actors*” (Feldman & Pentland, 2003, p. 96). They are shared patterns of action. Additionally, Pentland and Feldman (2008) stress that the most important thing when designing live routines is practice, feedback, reflection and more practice. This is explicitly incorporated in the design of the prototype intervention. The findings show that collectively and repeatedly enacting CI routines helped attendees to better understand each other’s processes and to think of better countermeasures that were suitable to the entire team. This approach is quite deviant from many studies in the lean production literature. Oftentimes, such studies analyse best practice interventions in which the intervention focuses mostly on management or experts (e.g., Done et al., 2011; Secchi & Camuffo, 2019). Only some interventions focus on team leaders or employees (e.g., Anand et al., 2021; Bateman, 2005). Additionally, though there are notable exceptions, many Yellow, Green and Black Belts also oftentimes focus either on individual attendees or on the entire organization, rather than providing training for a selected group of employees that share their way-of-working.
The prototype intervention is based on the idea that routines are collective and repeated achievements and stresses that interventions best incorporate this. As a result, I propose the following intervention principle:

2. Collectively and repeatedly enact continuous improvement routines to create a shared pattern of lean operating routines, and in turn vice versa.

6.5.3. Intervention principle 3: Managing contextual factors while building routines

Finally, this chapter highlights the role of contextual factors while building CI and lean operating routines. The findings specifically highlight the importance of top management support, leadership and time and resources. These factors show great resemblance with some critical success factors mentioned throughout this dissertation. These factors also relate to so called failure routines or defensive routines (Albliwi et al., 2014; Argyris, 1986, 1999). The findings show that factors such as time and resources are necessary but not sufficient for building CI and lean operating routines. And that defensive routines such as by directive management can limit or block building CI and lean operating routines. For example, the marketing director and some employees were in discussion on each other’s responsibility to say “No.” to operating activities and “Yes.” to CI activities. Or the operations manager tried to help employees by enacting CI routines and implementing lean operating artefacts himself to show how it is done, hindering the patterning of lean operating routines and employee learning. This shows that a lack of top management support or certain types of leadership can hinder enacting CI routines and thus patterning and enacting lean operating routines.

Previous research indicated the importance of certain barriers for implementing lean production (e.g., Achanga et al., 2006; Saraph et al., 1989; Sila & Ebrahimpour, 2003). The organizational routines literature focuses on defensive routines that hinder building new routines. This chapter sheds more light on the interplay between such factors and routines, and routine building activities. As a result, I propose the following intervention principle:

3. Ensure that top management support, leadership and time and resources are present to enable building continuous improvement and lean operating routines.
6.5.4. Practical contributions
Managers can use the three intervention principles to reflect on their own lean production implementation approach, specifically by helping their team leaders and employees to collectively enact CI routines to pattern and enact lean operating routines. Similarly, consultants can use this knowledge to reflect on their training curriculum and better help their clients, by carefully selecting groups of attendees and the CI and lean operating structures for the organization, the mandatory or optional balance, and the level of practice involved. Policy makers can use the intervention principles to stimulate, next to developing knowledge of how ideal organizations look like, also knowledge how organizations can develop towards such an ideal state, specifically by better understanding the role of organizational routines in this process. And educators can use this knowledge to reflect on their educational programs to incorporate, next to lean operating tools and techniques, also CI tools and techniques, and exercises to let participants practice routines in using these CI tools and techniques.

6.6. LIMITATIONS AND FUTURE RESEARCH
This study draws on the findings of a single case. Though this allows for great insights in what happened during the intervention, it also brings some limitations. Most notably, the findings cannot be generalized based on the number of observations. Generalization from a case study requires theoretical analysis (Yin, 2013). Analytical generalization aims to expand and generalize theories. This is how the principles developed above have to be interpreted. They are not directly applicable to all other organizations. They are however developed based on the literature described in this chapter and the findings from the single case. This means that for example, it is not possible to say that all lean interventions best use CI structures as mandatory and lean operating structures as optional. It does mean that based on both theory and this application, this does seem like a suitable approach, which both future research and practitioners could build on by finding the sequence and extent to which lean operations and CI could be incorporated in their approach. The same goes for collectively enacting routines, practicing routines and incorporating contextual factors. It is not clear to which extent this will also add to lean production implementations in other organizations. It does seem that these principles are suitable to both future
research and practitioners to reflect on the extent to which routines are practiced and enacted in their current approach and the degree that contextual factors are accounted for. As such, the findings lead to insights that require future research in different organizations but they can also be useful for reflection by others.

To move from transferable insights to external validity, future research is required in the following areas. **First**, the balance between mandating CI structures and suggesting lean operating structures is not unambiguous. For example, when attendees are for cultural or educational reasons not inclined to provide the engagement required or when the urgency is high, organizations might have to settle for less CI routine development. For suitable applications, it is necessary to better understand this balance in different contexts such as different cultures, higher or lower levels of education and higher or lower levels of urgency.

**Second**, in this study certain CI structures were pre-selected for all participants to enact. However, these CI structures could also be taught in a different manner; rather than providing attendees with a problem-solving method up front, they could also be challenged to solve a problem by themselves and be coached on that using the CI structures only as a frame of reference for the coach. This can even more clearly expose the discrepancies between their enacting and patterning, improve their learning, and hence improve the patterning of CI routines as well.

**Third**, though we did not focus on contextual factors such as top management support, leadership and time and resources, they did play an important role in this research. Management was influencing the input of attendees and operational stress was oftentimes preventing some to participate. Therefore, it seems interesting to continue to study these factors in the context of organizational routines. For example, as much research on lean leadership has been done, it is interesting to better understand, for example, how to deal with more directive or coercive managers to develop these towards more supportive and coaching leaders.

And **fourth**, to increase external validity it is necessary to develop this approach in different contexts, such as low-variety/high-volume, process industries, project management or product development, different sectors and different countries.
Future research can continue to take the organizational routine building approach to gain deeper insights in lean production implementations rather than ideal state of lean operations.
7. DISCUSSION
In this dissertation, I address the implementation of lean production in manufacturing SMEs. From a philosophical perspective, two different approaches can be identified to implement lean production; the first approach suggests implementing lean operating structures in a top-down fashion in order to develop local team leader and employee CI routines over time. The second approach proposes first developing local CI routines in order to subsequently implement lean operating structures. The dissertation addresses the issue of which approach is most suitable to implement lean production in manufacturing SMEs.

To close this knowledge gap, I set out to identify: which organizational aspects are most important for lean production implementation in manufacturing SMEs, and how do these aspects evolve over time? To answer this research question, in addition to the philosophical perspective on lean production, I analysed three perspectives in three separate studies. In the first, I looked at the infrastructural perspective, in the second I took the practical perspective, and in the third I used the organizational routines perspective. In the fourth study, I used the findings from these three studies to prototype an intervention in order to implement lean production in one manufacturing SME.

To answer the main research question, in this final chapter I first discuss the key findings and contributions of each of the four studies in light of the two different approaches to implement lean production. I then provide an answer to the main research question and I explain the overall theoretical contribution. The combined research studies add to the underlying philosophical perspective by identifying the most suitable approach to implementing lean production in manufacturing SMEs. After the theoretical contribution, I explain the practical contribution for different societal groups. I conclude with remaining challenges and directions for further research.

7.1. KEY FINDINGS AND CONTRIBUTIONS OF THE FOUR STUDIES

Chapter 3 took an infrastructural perspective to answer the question: ‘1. To which extent are success factors critical to enact different degrees of lean practices in manufacturing SMEs?’ Both emphases on implementing lean production require different sets of critical success factors. A top-down approach requires factors
such as top management support, a shared improvement vision, and leadership. A team leader- and employee-centric approach requires factors such as time and resources, a learning focus, and improvement training. In Chapter 3, I specify that for all levels of lean practice implementation in manufacturing SMEs, local factors such as time and resources, a learning focus, and improvement training are critical. Only in cases where lean practices implementations were more advanced were additional company-wide factors required: top management support, a shared improvement vision, and leadership. These findings add to the infrastructural perspective on lean production as they question the universality of success factors such as top management support and indicate the need for a more dynamic model of lean practice implementation. Additionally, the importance of the local factors for all levels of lean production implementation is the first indication that a focus on developing local CI routines is crucial to implementing lean production in manufacturing SMEs.

Chapter 4 took a practical perspective to answer the question: ‘2. What is the relative importance of continuous improvement routines to enact different degrees of lean practices in manufacturing SMEs?’ Similar to the critical success factors, CI routines also play a different role in both emphases; a top-down approach requires CI routines when lean practices are more mature; a team leader- and employee-centric approach requires CI routines early on. Chapter 4 specifies that lean practices can be implemented to a limited extent without the presence of certain CI routines. However, this presence becomes critical beyond the first level of lean practice implementation. These routines relate to employees conducting shared improvement activities, and in the most advanced cases, to aligning different improvement activities. These findings add to the practical perspective on lean production; they question existing lean implementation approaches and models that neglect CI routines or postpone CI routine development to the end of a lean journey. Moreover, they show the need to integrate CI routines into every lean transformation for it to be sustainable. This is the second indication that the emphasis on developing CI routines may be appropriate when implementing lean production in manufacturing SMEs.

Chapter 5 took an organizational routines perspective to answer the question: ‘3. How do lean operating and continuous improvement routines develop during a lean production implementation?’ Published research indicates that lean
operating and CI routines are best performed in tandem (Cua et al., 2001; Shah & Ward, 2003). This dissertation indicates a more specific sequence; in the best performing organizations, managers and experts support team leaders and employees to conduct CI activities, as enacting CI routines helps to pattern and subsequently enact lean operating routines. In turn, enacting the improved lean operating routines helps to pattern and subsequently enact CI routines. Neglecting this pattern aligned with unsustainable implementations. These findings add to the organizational routines perspective on lean production. Rather than static constructs, I show that routines are dynamic and how they evolve during a lean production implementation. I then describe the approach taken by the best performing manufacturing SMEs when implementing lean production: develop local CI routines to subsequently implement lean operating routines.

In Chapter 6, I set out to answer the question: ‘4. Which elements of an intervention can build CI routines to pattern and enact lean operating routines?’ Studies 1 and 2 indicate the conditions necessary for different degrees of lean practice implementation. Additionally, Study 3 unfolds lean production implementations to explain how successful interventions differed from unsuccessful events. In this fourth study, I draw on these findings to prototype an intervention to implement lean production and apply this intervention in a manufacturing SME. Specifically, it showcases CI routine-building interventions that help to pattern and enact a variety of lean operating routines. Rather than describing a significant theoretical contribution, the findings lead to intervention principles and activities to draw upon when implementing lean production in manufacturing SMEs. Specifically, and in line with the findings from the first three studies, it shows that an emphasis on developing local CI routines helped to pattern and enact lean operating routines when implementing lean production in this manufacturing SME. Practitioners can draw on these principles and examples to develop their own approach to implementing lean production.

7.2. ANSWERS TO THE MAIN RESEARCH QUESTION
To answer the main research question, different perspectives on implementing lean production were taken. Across all studies, the findings indicate that rather than implementing lean operating structures in a top-down fashion
and developing local CI routines later on, the most suitable approach to implementing lean production, at least in the context of Dutch manufacturing SMEs, is by first building local CI routines in order to implement lean operating routines. Building local CI routines helps team leaders and employees to create the shared understanding of lean operating routines required to enact these routines. Activities such as developing current state maps, conducting root cause analyses, or mapping future state designs, help identify the best solution for a specific situation and to incorporate this solution in the way-of-working. Both help to sustainably implement lean operating routines. Starting with establishing local CI routines also sets the stage for improving lean operating routines later on, because implementing lean operating routines through local CI routines is compatible with the end goal of continuous improvement.

However, these results do not play down the role of managers; in contrast, all studies show the importance of top management support and leadership. Managers have to start and foster this process by stimulating team leaders and employees to enact CI routines. They also have to provide the critical success factors (e.g., time and resources, a learning focus and improvement training) necessary to achieve these. Additionally, in Chapter 6 I show that an authoritarian management attitude prevents team leaders and employees from enacting CI routines. To help team leaders and employees enact CI routines to implement lean operating routines, a three-step integrative approach is required.

Firstly, (top) management and/or lean experts can break with prior non-lean routines and can envision suitable lean operating routines. They are the most qualified to do so because they understand these lean operating routines and their own organization. But they cannot implement these lean operating routines without engaging team leaders and employees in CI activities. Secondly, engaging team leaders and employees in CI activities is important to help them develop a shared understanding of these lean operating routines, and to tailor them to their specific environment. Implementing lean operating routines in a top-down fashion might result in quicker gains, but it would be at the expense of both employee learning and adjusting the routines to the specific context, risking extension of the implementation. Implementing lean operating routines solely through employee-initiated CI activities, without envisioning suitable lean operating routines, can help ingrain the routines, but at the expense of the
time required. Combining the two approaches, as explained in Chapter 5 and showcased in Chapter 6, holds the potential to reap the benefits of both without risking reducing the effect of the implementation over time. Finally, it is important that those factors critical to this approach, including time and resources, a learning focus, and improvement training, are managed and maintained. Over time, this will help manufacturing SME managers to implement lean production and increase operational performance.

7.3. REFLECTIONS ON THE ANSWERS TO THE MAIN RESEARCH QUESTION
While some authors argue that a top-down approach is most successful (e.g., Liker, 2004; Womack & Jones, 2003), this dissertation provides evidence that, at least in Dutch manufacturing SMEs, a team leader- and employee-centric approach is more appropriate. If a top-down approach was appropriate, even in a few cases, it would have been identified in the NCA in the first and second study. The nature of NCA is such that if there is even one case with presence of the outcome but no presence of the conditions (in this case with presence of lean practices but no presence of local success factors or CI routines), it immediately dismisses this condition as not necessary. The analysis showed this to be the case for the more company-wide factors at lower levels of lean practice implementation, but not for the local factors or the CI routines, at least not at a significant level for any of the 33+ assessed cases.

The three in-depth case studies also question the notion that a top-down approach would have been suitable. It could be argued that if other cases had been selected, I might have identified a different approach. Note that the selection was not random: the three cases were purposefully selected from a set of 42 cases. Of these 42 cases, the two best performers and the worst performer clearly show that the team leader- and employee-centric approach outperformed the top-down approach. Equifinality implies that different paths can lead to the same outcome, yet the outcome has to cover the entire system, including the patterns and routines that underlie the system. This means that as the patterns and routines are different, equifinality does not hold as the systems are not the same. Considering the entire system, it is unlikely that a top-down approach would have resulted in the same level of lean production implementation in any of the 42 cases. This means that from the findings from this dissertation, it
is unlikely that a top-down approach would be appropriate when implementing lean production in Dutch manufacturing SMEs.

It can be argued that this would be different in non-Dutch cultures or larger enterprises. Organizational culture differs on aspects such as contract versus consensus, individualism versus collectivism, and a high or low power distance (Hofstede, 2011). According to Hofstede (1999, 2022), Dutch organizational culture typically is managed by consensus and convincing others of what should be done. Additionally, it has a high level of individualism and a low level of power distance. It makes sense that in the contexts of fact-based discussions, individual importance, and equality between managers and employees, both team leaders and employees require upfront involvement via CI activities. Where organizational culture is more contract driven (e.g., Japan and United States) or has a greater distance between management and employees (e.g., Japan and France), it is plausible that building and establishing lean operating and CI routines might require a different approach.

Additionally, this dissertation focused on SMEs. SMEs differ from larger enterprises on aspects such as delegating and consulting, their planning horizon, and their available resources. According to Gelinis and Bigras (2004), SME managers have a low propensity to delegate and consult, they often only plan in the short term, and they have an inherent lack of resources such as time, money and expertise. These SME-specific characteristics can hinder the implementation of lean production because it requires employee involvement, a long-term vision, and sufficient resources. Therefore, it might be more important for SMEs to build CI routines in order to develop lean operating routines as this would help overcome their inherent challenges; it develops important routines by employees rather than managers, it forces them to stick to a long-term routine building programme rather than a quick top-down implementation, and it forces them to draw on the expertise of their own employees rather than expensive experts. In larger enterprises, CI routines may follow on more naturally from top-down lean implementations.

I am not stating that in different cultures and larger enterprises, the interplay between lean operating and CI routines is not important. Practice theory in general and the routine dynamics literature in particular, both stress the
importance of agency and the role of patterning when building organizational routines. It is expected that this will remain important when building lean operating and CI routines in different organizational cultures or larger enterprises. However, in these contexts, this patterning and enacting of lean operating and CI routines may require a different approach. More research is needed to determine the extent to which the approach suggested in this dissertation is useful in those contexts.

7.4. THEORETICAL CONTRIBUTIONS

This dissertation refines our understanding of how to implement lean production in manufacturing SMEs. The individual studies contributed to the infrastructural, practical and organizational routines perspective on lean production implementation. Collectively, they show that implementing lean production requires a dynamic approach of building and establishing local CI routines in order to implement lean operating structures.

In line with the literature on organizational routines (Feldman & Pentland, 2003), this dissertation shows that lean operating and CI routines are dynamic by nature. This dissertation contributes by providing insights into how these operating and improvement routines interplay and evolve over time. This builds on and refines the static way practices and routines are approached in the lean production literature (e.g., Bortolotti, Danese, Flynn, & Romano, 2015; Cua et al., 2001; Shah & Ward, 2007). Additionally, this dissertation shows the need for greater focus regarding the importance of specific CI routines for implementing lean production. Several papers describe different CI routines (e.g., Anand et al., 2009; Bessant et al., 2001; Peng et al., 2008). This dissertation shows that only conducting shared improvement projects is symmetrically linked to lean practice implementation whilst the other CI routines were necessary but not sufficient to this end. Moreover, this dissertation contributes to our understanding of critical success factors for lean production, such as top management support, an improvement vision, and good leadership (e.g., Achanga et al., 2006; Netland, 2016; Sila & Ebrahimpour, 2003). Success factors are important, however I show that they do not to ensure a lean production implementation, they only enable the dynamic routine building process.
Combining the additions to the infrastructural, practical and organizational routines perspectives, the answer to the main research question also challenges the philosophical perspective on how to implement lean production in manufacturing SMEs. Seminal works (Liker, 2004; Womack & Jones, 1996) describe comprehensive principles that have become fundamental to a lean production system and have been applied many times. While each of these works stress the mutual reinforcement between lean operations and CI, they consistently and persistently present the lean operations principles prior to CI related principles (Liker, 2020; Womack & Jones, 2003). Additionally, in Shah and Ward’s (2007) most frequently cited measurement instrument on lean practices, only one of ten constructs explicitly covers the conceptual space surrounding employee-related improvement activities. Best practice interventions to implement lean practices, such as by Done et al. (2011, p. 504), often rely on training an expert facilitator, rather than team leaders and employees, to conduct an improvement project and implement lean operating structures. This implicitly and sometimes explicitly suggests a temporal order.

In this dissertation, I challenge this constellation of principles and depiction of stages, as the findings clearly indicate that enacting CI is also essential at the start. This is in line with other experts in the field who put a different emphasis on the sequence of and interplay between lean operations and CI. For example, Spear and Bowen (1999, p. 98) describe the DNA of the Toyota Production System, listing three rules that show how Toyota sets up all its operations as experiments to learn from, and an additional rule that shows how Toyota teaches the scientific method to managers and employees at every level of the organization. Similarly, from his study at Toyota, Rother (2010) explains the improvement and coaching routines that make CI core to Toyota’s entire production system. In his survey of the world automotive industry, MacDuffie (1995) showed that the best performing organizations integrated lean practices with innovative HR practices such as quality circles and root cause analyses. And in Bateman and Rich (2003, pp. 189–191), another best practice intervention for implementing lean production, they describe an integrated approach in which experts and employees work together in a team to implement lean practices.

While the initial version of ‘The Toyota Way’ depicted problem solving as the top of the pyramid (Liker, 2004), the more recent edition acknowledges that
the principles are equal and interconnected like in a jigsaw puzzle (Liker, 2020). In this dissertation, I provide evidence that CI principles are best not regarded as a final addition, but as primary mechanism for change both in terms of the temporal order and their importance for the implementation process. As such, it refines our philosophical understanding of how to implement lean production in manufacturing SMEs.

7.5. PRACTICAL CONTRIBUTIONS
Because of the distinct characteristics of manufacturing SMEs, implementing lean production through building local CI routines remains a challenging task. In general, SME managers have a low propensity to delegate and consult, they often only plan in the short term, and SMEs have an inherent lack of resources such as time, money and expertise and (Gelinas & Bigras, 2004). Engaging team leaders and employees to enact improvement activities requires manufacturing SME managers to delegate and consult improvements. Embarking on such an endeavour requires developing and adhering to a long-term plan. Moreover, enabling team leaders and employees to engage in improvement activities would also require managers to invest resources such as time and money and, additionally, it may require more expertise to guide them through the process. These requirements turn this approach into an especially challenging endeavour for manufacturing SMEs.

Therefore, the findings in this dissertation are important for several societal groups. First, for those team leaders and employees who see opportunities for improvement and are willing to utilize their talents, they can leverage the findings in this dissertation to initiate improvement activities and challenge management to facilitate the necessary critical success factors. Managers tend to initiate process improvements themselves or, at least, set the guidelines in which improvements have to take place. The findings in this dissertation show that team leader and employee-enacted CI routines help create an understanding of and subsequently enact lean practices. Top management support is not critical to initiate these improvement activities, even though it may be of value. Some implementations of lean practices are likely to trigger management to get involved and stimulate employee improvements.
Second, manufacturing SME managers who want to start or continue implementing lean production are advised to focus their efforts on facilitating and building local CI routines. Rather than wasting precious resources on managing success factors that are not (yet) critical, resources are best spent on those factors critical to conducting improvement projects. In general, it seems best for managers to initiate improvement projects themselves and stimulate employees to join, so they can develop the abilities needed to eventually conduct their own. Once several improvement projects have been successfully completed, more and more employees can be involved in more and more improvement projects. Caution is needed with regard to the pace of implementation; overestimating employee learning can result in resistance and fall backs and eventually hinder future initiatives. Over time, continually conducting improvement projects will develop CI routines amongst all employees and help to gradually implement lean production throughout the organization.

Third, consultants and educators are advised to carefully reflect on their training curriculum. When teaching lean production, a focus is generally given to lean operating structures; that is ‘an ideal’ lean operation. Much less attention is given to CI routines and the agency required for lean practices. Employees and students are best served by explaining both improvement structures and their interplay with lean operating structures, and how actors can be engaged to develop their understanding of lean operating and CI routines. This requires different approaches to theses as well. Rather than focusing on those that report ideal structures for organizations, students might better engage employees to conduct improvement projects themselves, as the students report on their findings. This will most certainly lead to more impact.

7.6. REMAINING CHALLENGES AND DIRECTIONS FOR FURTHER RESEARCH
This dissertation reports my research on lean production implementations in manufacturing SMEs. I focused on the importance of critical success factors and CI routines and the dynamics within these routines. To achieve this, I used a variety of research methods, namely multiple respondent surveys, case studies, and intervention-based research. Further research is required to fully understand the complex process of implementing lean production both in Dutch
manufacturing SMEs and in other, non-Dutch, non-manufacturing and non-SME organizations.

First, this dissertation prototyped an intervention to implement lean production in a Dutch manufacturing SME. To better understand how to use this prototype, it is important to further test, understand, and document this prototype. Previous research indicated that lean practices are contingent on their context (Shah & Ward, 2003). This study’s prototype did not deal with specific contexts nor does it provide elaborate stepwise guidelines for applying the approach to these contexts. Future research can tackle this by drawing on the intervention principles proposed in Chapter 6, using design science (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2008; van Aken et al., 2016) to replicate and develop the prototype routine-building intervention to specific contexts, for example, in healthcare, education, and service organizations. The employees in these organizations tend to have a higher level of education compared to manufacturing, possibly requiring a different balance between the role of managers, experts, team leaders and employees. Future research on the prototype intervention can also be extended to include larger enterprises. These organizations tend to delegate more, fund more, and plan on a longer term compared to SMEs, possibly requiring a different set of critical success factors such as leadership, time and resources, and a shared improvement vision. Future research should also extend to non-Dutch organizations as other cultures tend to have a more rigorous hierarchy, similar to non-manufacturing contexts, possibly requiring a different balance between the role of managers, experts, team leaders, and employees. Studying the prototype intervention in such contexts will help to further develop, test, understand, and document the intervention to implement lean practices in and beyond Dutch manufacturing SMEs.

Second, the methods used in the first part of this dissertation (Chapters 3-4) did not permit a more extensive study of the who and how of critical success factors and CI routines over time. Longitudinal research could investigate whether success factors that were not critical for some lean practice implementation, might still enable success in the long run if organizations focus on these critical success factors from the start. To better comprehend the functioning of the critical success factors, CI routines, and routine dynamics for implementing lean practices in manufacturing SMEs, these concepts and their relationships need to
be studied over time. Additionally, to better understand the functioning of these critical success factors and CI routines, it is important to zoom in on the who and how of those concepts and study their specifics in relation to implementing lean practices. For example, by using case studies to study the specific function of ‘good communication’ or ‘improving the improvement system’ for implementing lean practices. All of these different approaches, relationships and methods can lead to different and/or additional insights into how best to implement lean production in manufacturing SMEs. Conducting this research in organizations beyond Dutch manufacturing SMEs will provide an understanding of how this works in, for example, contract/consensus based or collective/individual organizational cultures, and in larger enterprises.

Third, this dissertation focused on critical success factors and CI routines in relation to lean practices and operational performance. These concepts can be related to each other in different ways. For example, some researchers link critical success factors to CI routines rather than lean practices (e.g., Kaye & Anderson, 1999). Future research can test the criticality of success factors for CI routines. Additionally, future research can also identify the relative importance of lean practices for CI routines rather than CI routines for lean practices. Ward et al. (1996) describe that lean practice bundles such as just-in-time and total-predictive maintenance are linked to different manufacturing strategies. Ward et al. (2007) linked these strategy-related configurations to substantive operational performance. Future research can test configurations of bundles of lean practices linked to substantive operational performance. Regarding operational performance, Ferdows and de Meyer (1990) argue that these capabilities are cumulative, building on each other; first quality, then delivery, then flexibility, and then costs. Others call for a contingency approach to this model (e.g., Schroeder, Shah, & Xiaosong Peng, 2011). Future research can test this cumulative model using the a-symmetrical NCA. All these studies will ultimately provide a better understanding of the importance of different aspects when implementing lean production.
REFERENCES


ANNEX. NECESSARY CONDITION ANALYSIS
A.1. INTRODUCTION
Necessary Condition Analysis (NCA) is a method to analyse necessary but not sufficient conditions. Necessary but not sufficient statements are commonplace in the literature. Traditional regression methods focus on additive rather than necessity logic and are thus unsuitable for analysing such conditions. NCA is an upcoming research approach to formulate and test necessary condition theories and was recently published in Organizational Research Methods (Dul, 2016; Dul, van der Laan, & Kuik, 2020). NCA can be performed alone or in combination with other methods. When conducted alone, the findings of an NCA help to focus on the necessary conditions rather than conditions that are not (yet) required, preventing failure and wasted resources. When conducted in combination with other methods, often the analysis moves beyond a focus on necessity to one on sufficiency, identifying (configurations of) conditions sufficient for a certain outcome to occur. In general, NCA can provide strong results that are complementary to traditional additive logic and regression approaches, and to Boolean logic and configurational approaches. In this annex, I briefly elaborate on this method of analysis.

A.2. EXAMPLE OF NECESSARY CONDITIONS
Let us first consider the following example. Recently, all of us have been overwhelmed by virtual meetings, be it via Teams, Zoom, Skype or any other platform facilitating these calls. If you want to attend a meeting, you have to fulfil several necessary conditions. You need a computer device to work on, you need power to run your device, you need the right software, and you need an internet connection to access the software. If one of these conditions is not satisfied, you simply are unable to attend a virtual meeting. However, none of these conditions in themselves are sufficient to attend a virtual meeting; it will not work with either a computer device or an internet connection. Additionally, these conditions cannot compensate for each other; a better device does not compensate for inappropriate software or too little power. And there is no alternate way to watch this video; you cannot watch it other than via a computer device etc. These conditions are therefore really necessary.
A.3. NECESSITY LOGIC

NCA enables the analysis of such necessary but not sufficient conditions. NCA is a research approach and method of data analysis based on the logic that factors can be necessary but not sufficient for an outcome to occur. For example, when A and B are required for a certain outcome, A and B are both necessary but not sufficient conditions. Neither of them alone is sufficient for the outcome to occur, they are both needed. The idea of necessary but not sufficient conditions is depicted visually in a contingency table (Table 12). Necessity logic differs from other causal logic like additive logic, in which multiple factors add to alter the outcome and can compensate for each other. For example, in \( x_1 + x_2 + 3x = y \), the \( x \)'s in the set can compensate for each other; less of \( x_1 \) can be compensated by more of \( x_2 \) etc. Necessity logic also differs from Boolean logic, in which different factors are combined by AND (+), NOT (-) and OR (*) operators to produce an outcome. For example, in \( A + B - C \cdot C - A + B = Y \), the set A and B not C or the set C not A and B can substitute each other to lead to the same outcome. This annex focuses on necessary conditions.

Table 12: Contingency table of necessary conditions

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Observations not allowed</th>
<th>Observations required</th>
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</table>

There are many alternate formulations of the theoretical mechanisms between X and Y. Consider for example, “X is needed for Y, crucial or essential”. Or “X is a requirement for Y, a prerequisite or a pre-condition”. Or “X allows or enables Y”. Or “there must be X to have Y”. All of these are alternate terms for necessary conditions. In addition, formulations that refer to “critical success factors” may refer to necessary conditions. There may be exceptions, as the term ‘success factor’ can also link to a condition sufficient for success, but it can also be used to indicate conditions necessary for success. Similar formulations are for example “critical failure factors” or “critical failure determinants”. If the necessary condition is not satisfied, we can say that the condition blocks, or limits the outcome or that the condition is a bottleneck for the outcome. In consulting, factors are often differentiated between “must have”, and “nice to have”. The “must have” factors are the necessary conditions. The “nice to haves” may be relevant to contribute to the outcome, but they are not necessary.
A.4. NECESSARY CONDITION ANALYSIS
To study necessary conditions using NCA, it is important to follow a structured approach consisting of hypothesis development and data analysis. First, hypotheses need to be developed. To hypothesize necessary conditions, three recommendations are important: first to argue why the absence of a factor causes the absence of an outcome, second to demonstrate that in other data where the outcome is present, the factor is also present, and third to discuss why there can be no substitutes to the factor for enabling the outcome. When the hypotheses are built, the conditions can be analysed using the data. To this end, five steps need to be followed:

1. to visually determine whether there is an empty space (no observations) in the upper left corner of the data plots;
2. to calculate the ceiling line (the ceiling envelopment or regression line through the upper left observations of the dataset);
3. to calculate the effect size (the size of the empty space compared to the entire scope of observations);
4. to calculate the p-value (the parameter that indicates whether the observed effect size could be due to random change),;
5. to develop the bottleneck table, (the table that helps to interpret for each level of outcome whether and the extent to which conditions are necessary).

All five steps equally contribute to analyse whether and the extent to which conditions are necessary for an outcome to occur.

A.5. REFLECTIONS
When developing necessary hypotheses or conducting an NCA, the following has to be considered.

A.5.1. Theoretical level of abstraction
As explained above, when setting up and conducting an NCA study, it is important to start with suitable hypotheses. In developing these hypotheses, a decision has to be made regarding a theoretically relevant level of abstraction. Consider the example of online meetings above; a computer device, power, appropriate software, and an internet connection are necessary to join such meetings. If the level of abstraction would be lowered, the analysis would
become meaningless. For example, if instead of a computer device, taking a laptop, tablet, and desktop as conditions, none of them would be necessary as they are substitutable: the others can substitute them. The same goes for a battery or cable power, Wi-Fi or cable internet, and version x, y or z of the appropriate software. This relates to the hierarchical structure of the concepts. The theoretically interesting overarching concept of laptop, tablet, or desktop is computer device. In hypothesizing about computer device, power, internet and software, it is this level of analysis that is meaningful. Future research could continue to study different levels of abstraction using different methods.

A.5.2. Use matters
The literature indicates that in addition to the ‘what’, it is also important to incorporate the ‘who’ and the ‘how’ of practices and routines. This is also true when using NCA. NCA is a great way to provide insights in whether conditions are necessary for an outcome, but it does not say much about how these conditions came about and enable the outcome over time. Consider the role of top management support (TMS) and leadership studied in this dissertation. Several cases report both high presence of these conditions and high performance, while there are no cases that report high performance without high presence of these conditions. The conditions in themselves are not sufficient, how they interact with other aspects, in the case of this dissertation with enacting and patterning lean operating and CI routines, is important as well. In other words, in addition to the ‘what’ of such conditions, it is also important to consider how they are used and by whom. As NCA does not dismiss a-symmetrical relationships as insignificant, it allows for this ‘use matters’. That is, given the same presence of certain conditions but very different outcomes, NCA allows such results, indicating that some organizations apparently made much better use of these conditions, resulting in a better condition/outcome ratio.

A.5.3. NCA provides focus for future research
This ‘use matters’ implies that it is important to extend NCA results with additional research. As explained above, NCA does not explain why certain conditions are necessary. In this dissertation, it took a process view to understand the interplay between TMS and leadership with enacting and patterning lean operating and CI routines to implement lean production. This is also true for other necessary but not sufficient conditions. Take for example training and time
and resources; we know that these conditions are necessary for implementing lean production, but this does not explain how this exactly works. To understand this, more detailed knowledge is required to identify additional factors that mediate between the condition and the outcome. In the case of this dissertation, this is the interplay between enacting and patterning lean operating and CI routines. It seems that when certain mediators are added to the link between conditions and outcome, a shift takes place from necessity logic to sufficiency logic, that is the necessary conditions are linked to the mediator which subsequently is sufficient for the outcome to occur. In this sense, NCA can be a great way to identify a focus area of certain conditions for future research to elaborate upon, either qualitatively using, for example, a process view to explore and identify additional factors, or quantitatively using, for example, mediators to test the refined model.

A.5.4. NCA combined with alternative methods
NCA is no substitute for traditional approaches. When necessary conditions are studied, traditional approaches are an ill fit as they do not account for the necessary nature of the research model. In such instances, NCA seems to be the most suitable approach. When additional research or theory suggests other conditions that are important, a combination of logics can be used to set up the research model, for example necessary and additive or Boolean logic. This model then can be analysed using NCA and complemented with other approaches such as traditional regression analysis or Qualitative Comparative Analysis (QCA). This was the case in Chapter 4 when different improvement routines for lean practice implementation were analysed; some improvement routines were necessary to a certain extent, but not sufficient for the outcome to occur; other improvement routines were necessary to a certain extent and sufficient for the outcome to occur. In such an instance, NCA is a suitable additional method for providing better insights into the interaction effects of conditions and outcomes.

A.5.5. Practical implications
As a final reflection and as in any other method, it is also important for NCA to interpret those necessary conditions not above and beyond what the data allows for. An NCA of cross-sectional data on necessary conditions can suggest whether and the extent to which conditions are necessary for a certain level of the outcome. This does not imply that the necessary conditions for the lowest level of
the outcome are also most important to start with. This entirely depends on the level of outcome an organization has as its final objective. If the initial level of the outcome is the end goal, then those necessary conditions would be a good area to focus on. If, however, a higher level of the outcome is the end goal, this implies that a trajectory is required, from no, to the initial level, to the higher level. Understanding which conditions are necessary for such a trajectory requires a longitudinal dataset. In this dissertation for example, the NCA in Chapter 3 suggested that for lower levels of lean practice implementation, TMS and leadership were not necessary, while for higher levels they were. If organizations want to move to and stay at the lower level, not focusing on those conditions might be fine. Chapter 5 however showed that for the best performing cases, TMS and leadership were also important. If organizations want to move beyond lower levels to higher outcome levels, TMS and leadership might be required from the start. In sum, to suggest something about necessity in a developmental journey, longitudinal research is always required.

A.6. FURTHER STUDYING

APPENDIX 1.
IMPROVEMENT ROUTINES
This appendix provides an overview of the different improvement routines listed in the literature. These routines were first conceptualized 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 conceptualization 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 13.

Table 13: Improvement routines by author and their definition

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<tbody>
<tr>
<td>i.</td>
<td>Walking the talk</td>
<td>Understanding improvement</td>
<td>Understanding</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>improvement behaviour</td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>ii.</td>
<td>Getting the improvement habit</td>
<td>Getting the improvement habit</td>
<td>Consistency in improvement</td>
<td>N/A</td>
<td>Employees initiate and carry through improvement activities using measurement, tools and techniques.</td>
</tr>
<tr>
<td>iii.</td>
<td>Focusing improvement</td>
<td>Focusing improvement</td>
<td>Strategy deployment behaviour</td>
<td>N/A</td>
<td>Employees use the organization's strategic goals and objectives to assess and prioritize improvements, and they can monitor the impact of improvements on these goals and objectives.</td>
</tr>
<tr>
<td>iv.</td>
<td>Leading the way</td>
<td>Leading the way</td>
<td>Improvement leadership</td>
<td>N/A</td>
<td>Managers recognize employees' contributions to improvement and support employee experiments.</td>
</tr>
<tr>
<td>v.</td>
<td>N/A</td>
<td>Aligning improvement</td>
<td>N/A</td>
<td>N/A</td>
<td>The improvement system is designed and continuously amended to fit within the current organizational structure and infrastructure.</td>
</tr>
<tr>
<td>vi.</td>
<td>Spreading the word</td>
<td>Shared problem solving</td>
<td>Cross-functional improvement</td>
<td>N/A</td>
<td>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).</td>
</tr>
<tr>
<td>vii.</td>
<td>N/A</td>
<td>Improvement of improvement</td>
<td>N/A</td>
<td>N/A</td>
<td>The improvement system is continuously monitored and reviewed in relation to the organization as a whole, leading to its amendment or regeneration.</td>
</tr>
<tr>
<td>viii.</td>
<td>Building the learning organization</td>
<td>The learning organization</td>
<td>Idea management/participation in improvement</td>
<td>N/A</td>
<td>Employees at all levels articulate, consolidate and share their learning (e.g., using a formal knowledge management system).</td>
</tr>
</tbody>
</table>

(continued on next page)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ix.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Systematic and strategic improvement</td>
<td>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 organizational objectives.</td>
</tr>
<tr>
<td>x.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Customer and supplier involvement</td>
<td>Employees use supplier and customer feedback as a means to do improvement projects with them and improve performance.</td>
</tr>
<tr>
<td>xi.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Idea management and reward systems</td>
<td>Ideas and suggestions for improvement are responded to in a clearly defined and timely fashion and employees’ contributions to improvement activities are recognized in formal but not necessarily financial ways.</td>
</tr>
<tr>
<td>xi.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Strategic knowledge deployment</td>
<td>Managers display leadership and active commitment to ongoing improvement activities and employees understand the organizational 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 organization.</td>
</tr>
</tbody>
</table>
APPENDIX 2.
ACCURACY AND
EFFECT SIZE
This appendix provides details on the accuracy and effect size reported in Chapter 4. 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 14: NCA parameters of eight improvement routines linked to lean practices. 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%; the CE line was valid for all cases. The ceiling zone above the CR line, however, did contain cases, hence its accuracy was not 100%. 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 14: NCA parameters of eight improvement routines linked to lean practices 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.
Table 14: NCA parameters of eight improvement routines linked to lean practices

<table>
<thead>
<tr>
<th>Construct</th>
<th>Method</th>
<th>Accuracy</th>
<th>Scope</th>
<th>Ceiling zone</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Understanding improvement</td>
<td>CE</td>
<td>100.00%</td>
<td>2.167</td>
<td>0.286</td>
<td>0.132</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>89.50%</td>
<td>2.164</td>
<td>0.383</td>
<td>0.177</td>
</tr>
<tr>
<td>ii. Getting the improvement habit</td>
<td>CE</td>
<td>100.00%</td>
<td>2.068</td>
<td>0.550</td>
<td>0.266</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>92.30%</td>
<td>2.067</td>
<td>0.556</td>
<td>0.269</td>
</tr>
<tr>
<td>iii. Focusing improvement</td>
<td>CE</td>
<td>100.00%</td>
<td>2.358</td>
<td>0.540</td>
<td>0.229</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>84.20%</td>
<td>2.360</td>
<td>0.498</td>
<td>0.211</td>
</tr>
<tr>
<td>iv. Leading the way</td>
<td>CE</td>
<td>100.00%</td>
<td>2.363</td>
<td>0.371</td>
<td>0.157</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>97.40%</td>
<td>2.364</td>
<td>0.372</td>
<td>0.132</td>
</tr>
<tr>
<td>v. Aligning improvement</td>
<td>CE</td>
<td>100.00%</td>
<td>2.497</td>
<td>0.497</td>
<td>0.199</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>86.80%</td>
<td>2.500</td>
<td>0.495</td>
<td>0.198</td>
</tr>
<tr>
<td>vi. Shared problem solving</td>
<td>CE</td>
<td>100.00%</td>
<td>3.309</td>
<td>0.877</td>
<td>0.265</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>81.60%</td>
<td>3.306</td>
<td>0.843</td>
<td>0.255</td>
</tr>
<tr>
<td>vii. Improvement of improvement</td>
<td>CE</td>
<td>100.00%</td>
<td>3.101</td>
<td>0.369</td>
<td>0.119</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>84.20%</td>
<td>3.095</td>
<td>0.489</td>
<td>0.158</td>
</tr>
<tr>
<td>viii. The learning organization</td>
<td>CE</td>
<td>100.00%</td>
<td>2.266</td>
<td>0.315</td>
<td>0.139</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>92.10%</td>
<td>2.266</td>
<td>0.324</td>
<td>0.143</td>
</tr>
</tbody>
</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, 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 14: NCA parameters of eight improvement routines linked to lean practices. 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.
APPENDIX 3.
INTERVIEW GUIDE
This appendix shows the interview guide that was used during the final case study interviews in Chapter 5 (see Table 15: Final interview guide for final case interviews). This guide was developed and grew over the course of the study. In general, the first interviews were more open, allowing for new subjects and relations to be found, while the last interviews were more structured to help check for missing information. This approach, from more open to more structured, was also taken in each individual interview. For example, in the final more structured interviews, the first questions were more open while subsequent questions could be more structured. These interviews started with questions such as: “What do you do to improve your work?”. Depending on the answer, questions were specified based on the interview guide. For example, “What do you do to create understanding of the basic values of CI?”. In this sense, instead of a strict list of questions that were asked in this exact order, the guide acted as a checklist to ensure that all topics were covered. Concepts such enacting and patterning routines and related artefacts were not addressed directly but were linked to the interview data during data analysis. This guide was translated from Dutch, which is the native language of the interviewees.

Table 15: Final interview guide for final case interviews

<table>
<thead>
<tr>
<th>Topics</th>
<th>Subjects</th>
<th>Example questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Introduction Reason for the interview Questions Audio recording Functionalities</td>
<td>If necessary: personal introduction Explanation of the subject, purpose, approach and time required. Explanation that they can ask questions any time. Is it okay to audio record this interview? * Explanation of reason why and use of the data and destruction of the data. What is your job description? What is it that you do on a regular day?</td>
</tr>
<tr>
<td>Open</td>
<td>Lean operations CI Organizational routines (enacting and patterning) Critical success factors</td>
<td>If necessary: explanation of lean operations and CI. What do you do in operations? What do you do in improvement? What do you do to develop routines? What do you do to develop conditions necessary to enact lean operating and/or CI routines?</td>
</tr>
<tr>
<td>Ostensive aspect</td>
<td>Patterning lean operating routines Patterning CI routines</td>
<td>How do you develop employees’ shared understanding of lean operating routines? How do you develop employees’ shared understanding of CI routines?</td>
</tr>
<tr>
<td>Performative aspect</td>
<td>Enacting lean operating routines Enacting CI routines</td>
<td>How do you develop employees’ enactment of lean operating routines? How do you develop employees’ enactment of CI routines?</td>
</tr>
<tr>
<td>Related artefacts</td>
<td>Artefacts related to lean operations Artefacts related to CI</td>
<td>How do you implement artefacts related to lean operating routines? How do you implement artefacts related to CI routines?</td>
</tr>
</tbody>
</table>

(continued on next page)
### Topics

**Operations (Shah & Ward, 2007, p. 799)**

- **Subjects**
  - Supplier feedback
  - JIT delivery
  - Developing suppliers
  - Involved customers
  - Pull
  - Flow
  - Low setup
  - Controlled processed
  - Productive maintenance
  - Involved employees

**Example questions**

- What do you do to ‘provide regular feedback to suppliers about their performance’?
- What do you do to ensure ‘that suppliers deliver the right quantity at the right time in the right place’?
- What do you do to ‘develop suppliers so they can be more involved in the production process of the focal firm’?
- What do you do to ‘focus on [the] firm’s customers and their needs’?
- What do you do to ‘facilitate JIT production including Kanban cards’?
- What do you do to ‘establish mechanisms that enable and ease the continuous flow of products’?
- What do you do to ‘reduce process downtime between product changeovers’?
- What do you do to ‘address equipment downtime through total productive maintenance and thus achieve a high level of equipment availability’?
- What do you do to ‘ensure each process will supply defect free units to subsequent process’?
- What do you do to involve cross-functional employees in problem solving?

### Improvement routines (Bessant et al., 2001)

- **Understanding CI**
- **Getting the CI habit**
- **Focusing CI**
- **Leading the way**
- **Aligning CI**
- **Shared problem solving**
- **CI of CI**
- **The learning organization**

**Example questions**

- What do you do to create understanding of ‘the basic values of CI’?
- What do you do to ‘generate sustained involvement in CI’?
- What do you do to ‘link CI activities to the strategic goals of the company’?
- What do you do to ‘lead, direct and support the creation and sustaining of CI behaviours’?
- What do you do to ‘create consistency between CI values and behaviour and the organizational context’?
- What do you do to ‘move CI activity across organizational boundaries’?
- What do you do to ‘strategically manage the development of CI’?
- What do you do to ‘enable learning to take place and be captured at all levels’?

### Critical success factors (Knol et al., 2018)

- **Top management support**
- **Shared improvement vision**
- **Good communication**
- **Leadership**
- **People focus**
- **Learning focus**
- **Sufficient resources**
- **Improvement training**
- **Performance management system**
- **Supplier link**
- **Customer link**
- **Support congruence**
- **Remainders**
- **Focus**
- **Follow-up**

**Example questions**

- What do you do to assume responsibility and involvement from top management?
- What do you do to develop, share and follow company-wide, long-term direction, objectives and goals?
- What do you do to exchange ideas, information and knowledge honestly, clearly and transparently in all organizational directions?
- What do you do to get team leaders to facilitate, coordinate and balance improvements from shop floor employees?
- What do you do to get organizational systems to help employees to do their work versus employees being bound to organizational systems?
- What do you do to share both positive and negative experiences and consider mistakes opportunities for improvement?
- What do you do to make sufficient time and money available for training and improvement activities?
- What do you do to provide training for managers and shop floor employees in improvement concepts, tools, techniques and team building?
- What do you do to measure and display process data from all levels to control production, prevent defects and indicate opportunities?
- What do you do to get suppliers to provide and get feedback and rate them to select a limited number of suppliers?
- What do you do to get customers to provide and get feedback and cooperate for improvement?
- What do you do to align employee targets, assessments and rewards of all departments with the improvement vision?
- Is there anything else related to lean operations and/or CI that you would like to share?

Of all we have discussed, what has been the most important?

Explanation (repetition) of the use of the data and the remainder of this research
This appendix shows the process models that were made per case in Chapter 5 (see Figure 21-Figure 23). The arrows indicate the order in which activities and events took place.

Figure 21: Timeline of Case A

Figure 22: Timeline of Case B

Figure 23: Timeline of Case C
In this dissertation, I report on my research into the implementation of lean production in manufacturing small and medium-sized enterprises (SMEs). To implement lean production, the literature identifies two approaches; 1. implement lean operating structures in order to develop team leader and employee continuous improvement (CI) routines later on, or 2. develop local team leader and employee CI routines to implement lean operating structures. The main research question is: Which organizational aspects are most important for lean production implementation in manufacturing SMEs, and how do these evolve over time? To answer this question, I first (Chapter 2) discuss my position related to the lean production literature and provide an overview of the most important concepts as used in this dissertation. I introduce four different perspectives: an infrastructural, practical, organizational routines and philosophical perspective.

In the first study (Chapter 3), I take an infrastructural perspective to test the criticality of success factors for lean practices (related to lean operating routines). This study indicates that shop-floor factors are critical for all levels of lean practice implementation. Only in more advanced cases of lean practices, were some company-wide factors required. In the second study (Chapter 4), I take a practical perspective to explore the relative importance of CI routines for lean practice implementation. I show that, to some extent, lean practices could be implemented without developing specific CI routines, yet certain CI routines were necessary beyond the first level of lean practice implementation.

In the third study (Chapter 5), I take an organizational routines perspective to zoom in on the interplay between lean operating and CI routines. The findings suggest a pattern: enacting CI routines helped team leaders and employees understand and subsequently enact lean operating routines, and vice versa. Neglecting this pattern aligned with unsustainable implementations. In the fourth study (Chapter 6), I prototyped an intervention in a manufacturing SME to implement lean production consisting of a series of hands-on improvement exercises for team leaders’ and employees’ daily work. I show that an emphasis on developing local CI routines helped to pattern and enact lean operating routines, implementing lean production in this manufacturing SME.
The final chapter (Chapter 7) aggregates the findings of the four studies. For manufacturing SMEs that want to implement lean production, it seems desirable to first develop local CI routines in order to implement lean operating structures. This helps team leaders and employees create a shared understanding of the reasons for and specifics of the lean operating routines. At the same time, this approach embeds the platform required to continue to improve on these operations. This approach adds to the philosophical perspective on implementing lean production.

Managers and consultants are advised to focus their efforts on facilitating improvement projects rather than implementing lean operating structures themselves. Lean educators are encouraged to incorporate interventions that build CI routines into their curriculum. Future research can continue to study lean production implementations in manufacturing SMEs by looking at different levels of and interplays between success factors, CI routines, lean operating routines, and operational performance. Moreover, it can use the four perspectives taken in this dissertation to study the implementation of lean production in different branches, large enterprises, and non-Dutch cultures.
SAMENVATTING

In dit proefschrift rapporteer ik mijn onderzoek naar de implementatie van lean productie in de midden- en kleinbedrijf (mkb) maakindustrie. Om lean productie te implementeren kunnen in de literatuur twee benaderingen worden geïdentificeerd; 1. Implementeer operationele lean structuren om later lokale continu verbeter (CV) routines van teamleiders en medewerkers te ontwikkelen, of 2. Ontwikkel lokale CV routines om daardoor operationele lean structuren te implementeren. De hoofdvraag is: Welke organisationele aspecten zijn het belangrijkst voor lean productie implementatie in de mkb-maakindustrie, en hoe ontwikkelen deze zich in de loop van de tijd? Om deze vraag te beantwoorden leg ik eerst mijn positie in de lean productie literatuur uit (Hoofdstuk 2). En geef ik een overzicht van de belangrijkste concepten zoals ik ze in dit proefschrift gebruik. Vervolgens maak ik gebruik van vier verschillende perspectieven: een infrastructureel, praktisch, organisatieroutine en filosofisch perspectief.

In de eerste studie (Hoofdstuk 3) neem ik een infrastructureel perspectief om de kriticaliteit van succesfactoren voor lean practices te testen. Deze studie geeft aan dat voor alle niveaus van lean practice implementatie lokale factoren van cruciaal belang zijn. Alleen wanneer lean practices geavanceerder waren moesten enkele bedrijfsbrede factoren ook aanwezig zijn. In de tweede studie (Hoofdstuk 4) neem ik een praktisch perspectief om het relatieve belang van CV routines voor lean practice implementaties te exploreren. Uit deze studie blijkt dat lean practices tot op zekere hoogte geïmplementeerd konden worden zonder specifieke CV routines te ontwikkelen, maar bepaalde CV routines waren nodig voor het eerste niveau van lean practice implementatie.

In de derde studie (Hoofdstuk 5) neem ik een organisatieroutine-perspectief om in te zoomen op het samenspel tussen operationele lean routines en CV routines. De bevindingen suggereren een patroon: het uitvoeren van CV routines hielp teamleiders en werknemers om operationele lean routines te begrijpen en vervolgens uit te voeren, en vice versa. Het negeren van dit patroon leidde tot onhoudbare implementaties. En in de vierde studie (Hoofdstuk 6) ontwerp ik een prototype interventie om lean productie te implementeren. Deze interventie bestaat uit een serie verbeteroefeningen op het dagelijkse werk van team leiders en medewerkers. En pas ik deze interventie toe in een maakindustrie mkb-
bedrijf. Deze studie laat zien dat een nadruk op het ontwikkelen van CV routines van teamleiders en medewerkers helpt bij het internaliseren en uitvoeren van operationele lean routines, en dus het implementeren van lean productie in dit bedrijf.

Het laatste hoofdstuk (Hoofdstuk 7) aggregeert de bevindingen van de vier studies. Voor maakindustrie mkb-managers die lean productie willen implementeren lijkt het het meest geschikt om eerst CV routines van teamleiders en werknemers te ontwikkelen om daarmee operationele lean structuren te implementeren. Dit helpt hen om een gedeeld begrip te creëren van de redenen voor- en details van operationele lean routines. Tegelijkertijd bedt deze aanpak het podium in om die operationele routines te blijven verbeteren. Deze aanpak draagt bij aan het filosofische perspectief op het implementeren van lean productie.

Managers en consultants wordt geadviseerd om hun inspanningen te richten op het faciliteren en laten uitvoeren van verbeterprojecten in plaats van zelf operationele lean structuren te implementeren. Lean onderwijzers worden aangemoedigd om in hun onderwijscurriculum interventies op te nemen die CV routines ontwikkelen. Toekomstig onderzoek kan de implementatie van lean productie in de mkb maakindustrie blijven onderzoeken door verschillende niveaus van- en wisselwerkingen tussen succesfactoren, CV routines, lean practices en operationele prestaties te onderzoeken. Of het kan de vier perspectieven die in dit proefschrift zijn genomen gebruiken om de implementatie van lean productie in verschillende branches, grote ondernemingen en niet-Nederlandse culturen te bestuderen.
This dissertation would not have been feasible without the hard work, input and support from many colleagues, friends, and loved ones.

First and foremost, thank you dear supervisors for your intensive guidance from the start. Dear Kristina, I’m deeply impressed by your devotion to research in general, to your field, your PhD students, and to me in particular. You didn’t ‘just’ set out the course of my research, you helped me to align the different studies in my research. As no other, you also helped me to write and rewrite my papers and dissertation as a whole for others to accept. Or in culinary terms, you didn’t just tell me that my purée could in fact be a paella, you also added the seasoning so, like your dinners, you made the dish exceptional.

Dear Jannes, I’m forever grateful that you initiated me in the world of science. At our weekly meetings you helped me really understand my research field, and you also taught me the nuts and bolts of doing academic research. I clearly remember your doubts about me being a good researcher or a good writer! Thanks to your support, specifically the ‘fish’-model, I hope this will make you reconsider your initial judgement. And though your creativity could sometimes be overwhelming, it led me to ideas and methods crucial to achieve this substantive result.

And dear Roel, you really complemented my research team. You were present from my Pre-PhD program onwards. You helped me understand the importance and process of scientific reasoning. Back then and since, numerous versions of the different papers and chapters passed your desk. Ever patient, you always pointed out those areas and sentences that might have made sense in my head, but did not to anyone else. Moreover, you taught me that doing academic research is no excuse not to have a lot of fun. Thank you!

Many thanks also to the other colleagues (in addition to Roel) who contributed to my Pre-PhD program. Thank you, Allard, for co-hosting this invaluable program and for helping the other prospective PhD candidates and myself to understand the ways of conducting scientific research, academic writing, and publishing in academic journals. And thank you Hubert and Stephan for helping us understand different research paradigms, research methodologies, and research methods.
I’m convinced that my work would have been only a shadow of itself if I hadn’t followed your program.

In addition, thank you Antoine and Hilde for helping me along the way. The first year’s bi-weekly Fridays were among the highlights of my trajectory, and they wouldn’t have been if we hadn’t been there together. And also my thanks for our ‘irregular’ follow up meetings. Thank you, Antoine, for your unparalleled coaching skills. And thank you Hilde for your indisputable faith in my research abilities. I hope these meetings will continue so we can further share our experiences, highs and lows, while achieving our intellectual ambitions. Slightly more distal but no less crucial are all the professors and researchers that contributed to (parts of) my manuscript. Thank you Professor Ache and Dr Kremser for providing the invaluable feedback that helped me find focus in my research. It would have taken me a lot longer if it hadn’t been for your constructive comments.

Thank you very much Professors Benders, Pentland and Van der Heijden for taking part in my manuscript committee and providing me with critique and directions to continue my research in the future. I very much look forward to following this advice and hope to meet and discuss this with you in the future. And thank you Professors Riezebos, Dul and De Weerd-Nederhof for being part of my doctoral examination board and providing me with important feedback. In addition, thank you Professor Dul for helping me with all the questions I had on taking the necessary perspective, and for helping me with the NCA tools and techniques in Operations Management. They turned out to be a large and valuable part of my work.

On a more day-to-day basis, thanks to all my present and former colleagues of the HAN World Class Performance/Lean research group. The innumerable talks and many discussions we had about my research, especially those discussing the implications of my results for practice, helped me focus on the true meaning of my work.

Thank you, colleagues of the Radboud University Organizational Design and Development research group. Our many talks and discussions provided me with perspectives on my research from outside of my specific field and on a more academic level. These perspectives have proven crucial to my work. Thank you Martijn and Jochem for hours and hours of transcribing my interviews and the time it provided me to improve the quality of my research.
Thank you Roswitha for your great effort to turn my manuscript into this beautiful book. My planning was a bit optimistic, but the result is all that counts and it is amazing.

And thanks to all the remaining colleagues and students with whom I’ve had the pleasure of discussing my work in conferences and classes. All of these talks contributed to my understanding of the different research fields, the different research methods, and the art of academic writing: this all helped me achieve this wonderful milestone.

And, a big thanks to the managers and employees that helped me gather the data necessary. First, to all the managers and employees that took part in one of the many self-assessments in as many organizations - thanks. Not only did these provide me with the data for the first two and several remaining studies, these visits and discussions also helped me understand the nature and setting of the managerial questions I was trying to answer. Interacting with practice has added great value to my research, as well as to my enjoyment while conducting this programme.

A special thanks go to Axel, Bas, Jelle, Michel, Pascal, Shakeel, Stefan and Ron. Thank you for giving me the opportunity to study the lean implementations in your organizations and for sharing your own experiences and ideas on my research questions. And thanks to all the interviewees I was able to meet and talk to while doing the case studies. Furthermore, I’m grateful to the numerous managers and employees with whom I had the pleasure to discuss the countless case site observations. All of these many perspectives helped me to better understand the complexity of the subject at hand.

And yet another special thanks goes to Maarten and colleagues. You provided me with the opportunity to apply the first translation of my initial research findings in an intervention at your organization. As Lewin said, “If you want to truly understand something, try to change it.” This intervention helped me to understand the true complexity and interplay of all the different concepts. This wouldn’t have been possible without your enthusiasm and openness.

And a warm thanks to all the attendees of my Key notes, Masterclasses, Webinars, and Guest lectures at HAN and several other universities. These sessions not only forced me to explain the added value of my research to you as professionals - your questions and comments also helped me improve my focus in general, and specifically in relation to practical contributions.
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CURRICULUM VITAE

Wilfred Knol (1986) works as a researcher and teacher at the research group World Class Performance/Lean, Academy Engineering and Automotive, HAN University of Applied Science, in the Netherlands. In 2011 he received his Master of Science in Technology Management *with distinction* (Dutch ‘cum laude’) from Faculty of Economics and Business, University of Groningen, the Netherlands. For his master thesis, he studied setup time reduction at a medium sized offset printing company. After managing and advising on IT systems at KPN (Dutch telco) he started at HAN University of Applied Science to initiate his PhD research at the research group Organizational Design and Development at Nijmegen School of Management, Radboud University, the Netherlands.

His work is published in *International Journal of Operations & Production Management*, *International Journal of Production Economics* and *International Journal of Production Research*. He presented papers at international conferences on operations management and management and organization, such as the *Annual Meeting of the Academy of Management*, the *European Operations Management Association Conference*, the *European Lean Educators Conference* and the *International Process Symposium*. In 2020, his submission was nominated for best student paper of the Operations and Supply Chain Division at the *80th Annual meeting of the Academy of Management: Broadening our sight*, Vancouver, Canada. His findings are also shared through Keynotes, Masterclasses and Webinars. He received grants to conduct his own PhD research as well as three research projects on smart industry, lean management and product development.
LIST OF PUBLICATIONS

Journal papers and book chapters


Conference papers


GRANTS AND AWARDS

2022  Research Grant from Sia (RAAK MKB): Beheersbare productvariëteit realiseren in het productie mkb. 2 years, €300,000.-.

2020  Nominated for best student paper of the Operations and Supply Chain Division at the 80th Annual meeting of the Academy of Management: Broadening our sight, Vancouver, Canada.

2018  Research Grant from Sia (KIEM): De synergie tussen smart industry en lean binnen het high-variety/low volume productie-mkb. 1 year, €30,000.-.

2017  Research Grant from Sia (KIEM): De synergie tussen smart industry en lean binnen het procesproductie-mkb. 1 year, €30,000.-.

2015  Research Grant from HAN University of Applied Science (PhD): Developing improvement strategies for manufacturing SMEs. 4 years €140,000.-.

2011  Master of Science in Technology Management with distinction (Dutch ‘cum laude’) from Faculty of Economics and Business, University of Groningen.

FOR PRACTITIONERS

MOOC Lectures and Webinars


Invited talks


Knol, W.H. (2017, October 23) *Continuous improvement routines for Lean [Continu Verbeterroutines voor Lean]*. Masterclass, HAN Lean-QRM Centre, Arnhem, the Netherlands.


To implement lean production, the literature identifies two approaches; 1. Implement lean operating structures to develop local improvement routines later on, or 2. Develop local improvement routines in order to implement lean operating structures. This dissertation studies this issue through three different perspectives.

The first study (Chapter 3) takes an infrastructural perspective to test the criticality of success factors for lean practices (related to lean operating routines). The second study (Chapter 4) takes a practical perspective to explore the relative importance of improvement routines for lean practice implementation. The third study (Chapter 5) takes an organizational routines perspective to zoom in on the interplay between lean operating and improvement routines.

The fourth study (Chapter 6) prototypes an intervention for a manufacturing SME to implement lean production consisting of a series of hands-on improvement exercises for team leaders’ and employees’ daily work. The final chapter (Chapter 7) aggregates the findings of the four studies.

Wilfred Knol (1986) works as a researcher and teacher at the research group World Class Performance/Lean at HAN University of Applied Science, the Netherlands. In 2011 he received his Master of Science in Technology Management with distinction (cum laude) from University of Groningen, the Netherlands. He previously worked as consultant at KPN (Dutch telco).