The Application of Measures of Lean Production for Services

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Purpose – The purpose of this paper is to explore how lean can be measured for services, inventorying existing assessment tools and demonstrating the applicability to the domain under research.

Design/methodology/approach – To identify examples and alternative questions on the measures of lean production for services, we employed a combination of observation and brainstorming using a focus group of Lean Six Sigma Black Belts who have experience in both manufacturing and services.

Findings – This research shows that most lean constructs for production can be used to assess the degree of lean for services. Typical production-related constructs such as product maintenance are not applicable, but most of the constructs are, thus creating an adapted instrument which can be applied to services.

Research limitations/implications – An adapted instrument to assess lean for services is proposed, which has to be tested and validated.

Practical implications – To assess the degree of lean constructs in an organisation, depending on whether physical products or intangible services are produced, the degree of lean constructs can be determined with a measurement instrument based on the same constructs.

Originality/value – The yield of quantitative instruments for assessing lean is low and even lower for evaluating lean for services. This research is the first to adapt validated lean constructs for production to service and propose an abbreviated version of the instrument of Shah and Ward (2007).

Keywords: Lean production, scale development, lean services, lean survey.

Paper type – Research paper.

1. Introduction

Lean arose from the Toyota production system (TPS; Chiarini et al, 2018; Dahlgaard & Dahlgaard-Park, 2006; Holweg, 2006) and was popularised by the bestselling books *The Machine That Changed the World* (1990) and *Lean Thinking* (1996). While traditional production systems focus on economies of scale, lean and the (TPS) focusses on maximising value and diminishing waste (Antony et al, 2017).

Lean, which assumes every organisation is the sum of all their processes (Douglas et al, 2015) and delivers added value for an internal customer, external customer or society, is based on five principles. These five principles are value, value streams, flow, pull and perfection (Womack & Jones, 2003). Value is defined by the customer, and this concept shifted traditional thinking from a shop floor focus on waste and cost reduction (Hines et al, 2004) to value creation and continuous improvement – basically the goal of the fifth principal, ‘perfection’.

The TPS originated in the automotive industry, and lean was first coined by John Krafcik (1988) in his article on the research at the Massachusetts Institute of Technology’s International Motor Vehicle Program. Holweg (2006) described in ‘The genealogy of lean production’ how this system evolved in automobile manufacturing from just-in-time (JIT) manufacturing to a benchmarking methodology, applicable to any industry (Roos et al, 1990). Some say that lean is only applicable to the automobile industry (Cooney, 2002); they raise the question that if TPS was so successful, then why had this system not been extended to other industries in Japan (Pettersen, 2009).

Over the years, there has been a debate on whether production systems are applicable to services, from being completely applicable (Levitt, 1976) to completely non-applicable (Bowen & Youngdahl, 1998). The debate is ongoing among scholars; some scholars state that lean production applies to services (Piercy & Rich, 2009; Malmbrandt & Åhlström, 2013) and others advocate that lean production does not (Procter and Radnor, 2014; Seddon et al, 2011).

Despite the ongoing debate, the prevailing opinion seems to be that the lean principles are applicable to any sector and any industry (Gijo et al, 2019), whether or not it is related to service. Removing waste and optimising value is relevant for any process and industry (Alexander et al, 2019; Lu et al, 2017). The disputes about lean seem to focus more on the dark side (Salentijn et al, 2021), where lean is synonymous to worker exploitation.

From a quality management perspective, although waste and value are created in any process, the nature of manufactured goods is different from services (Douglas et al, 2015). Still, waste is created in any process, regardless of whether it is from manufacturing or services.

Table 1. Differences between manufactured goods and services based on Douglas et al. (2015)

Manufactured goods	Services
Goods are manufactured in a different place than where they are consumed	Services are produced and consumed simultaneously
Manufactured goods can be stored	Services cannot be stored
Manufactured goods are tangible	Services are intangible

Manufactured goods are constant	Services are variable

Lean brings tools and techniques aimed at reducing waste and lead times and improving the overall process flow (Antony, 2011). It has evolved (Bhamu and Singh Sangwan, 2014) from a ‘hard’ set of tools (Shingo and Dillon, 1989) and steps (Dennis, 2015) to a systems approach that combines both hard and soft factors (Bortolotti et al., 2015; Langstrand, 2016; Muraliraj et al., 2020; Salentijn et al., 2021). The transition to lean involves implementing interrelated strategies concerning not only processes, but also deployment, training, drivers, engagement and aspects of culture (Sisson & Elshennawy, 2015).

When assessing the degree of ‘leanness’ in an organisation, the prevailing opinion is to distinguish between manufacturing and services (Alsmadi et al. 2012; Gupta et al. 2016); however, there is a growing understanding that most tools are used for both manufacturing and services, and specific tools have to be differentiated (Bouranta, 2020). The question is how to measure the extent of lean practices in either manufacturing or services. Basically, the principles are the same, and the general notion seems to be that lean applies to any sector and context.

Our objectives in this paper are exploring how lean can be measured for services, inventorying existing assessment tools and demonstrating the applicability to the domain under research. Following this introduction, an overview of the literature and an evaluation of existing assessment tools are presented (Section 2). The findings of this literature review and assessment tools’ evaluation are used to produce focussed research questions. Section 3 deals with the methodology used for this research. The results are presented in Section 4, followed by the key findings in Section 5. The discussion, implications and limitations are discussed in Section 6, followed by the conclusion and directions for further research in Section 7.

2. Literature review and evaluation of the existing assessment tools

After lean was popularised by the bestsellers *The Machine That Changed the World* (1990) and *Lean Thinking* (1996), the question arose how to measure the degree of lean and assess progress on different variables when implementing lean (Karlsson & Åhlström, 1996). Lean was characterised as a number of best practices in improvement programmes in different company departments such as process and equipment, manufacturing planning and control, human resources, product design, supplier relationships and customer relationships (Panizzolo, 1998).

In the nineties, continuous improvement initiatives increased due to lean, Six Sigma, Total Quality Management (TQM) and quality management systems like EFQM (European Foundation for Quality Management) and ISO 9000 (Zwetsloot, 2003). The need for assessing the progress on continuous improvement initiatives emerged. Self-assessment tools were developed for testing the application by practitioners (Caffyn, 1999; Martínez Sanchez & Pérez Pérez, 2001) and the progress on the implementation (Doolen & Hacker, 2005; Horacio Soriano-Meier & Forrester, 2002).

However, conceptual researchers were urged to take multiple dimensions of lean production programs into consideration (Shah & Ward, 2003) instead of unidimensional ones in an effort

to determine the degree to which aspects of lean had been implemented. Considering lean as a multi-dimensional system in which elements are interrelated, Shah and Ward (2007) developed a measurement instrument with 48 items which empirically identifies 10 underlying components. Although this study was empirically validated, the underlying theoretical groundwork was not fully supported in the literature (Pettersen, 2009).

In defining and developing measures of lean production, one could run the risk of oversimplifying the complexity of a new way of working, involving aspects of culture and change. Considering lean as a journey, Bhasin (2011) developed an audit to determine whether an organisation had adopted lean as a philosophy and deduce the phase of the transition it was in.

Recognizing that measurement instruments were production orientated, the question arose whether the degree of leanness could be assessed for services evolving to an instrument containing 34 items (Malmbrandt & Åhlström, 2013). This instrument includes 9 enablers, 19 practices and 6 performance indicators. For each enabler and practice, 5 statements are given, of which the respondent has to select the most appropriate one. An adapted version was introduced by Psomas, Antony and Bouranta (2018), indicating the adoption of lean principles on a five-point Likert scale: level 1 – no adoption, level 2 – general awareness, level 3 – systematic approach, level 4 – ongoing refinement, and level 5 – exceptional approach.

Surveys are a valuable method for collecting data on measuring the degree of leanness. Answers to a survey often could be subjective. Using indicators like the number of scraps, the annual inventory costs, transportation costs, non-value-added time, setup time and data on the orders and delivery times should lead to an ‘objective’ measurement instrument (Behrouzi & Wong, 2011). Additionally, other assessments based on objective indicators were developed in an effort to overcome the relative subjectivity of a survey (Vinodh & Chintha, 2011; Wan & Chen, 2008), or a mixed form was proposed (Pakdil & Leonard, 2013).

Even so, the success of the lean implementation can be measured not only by typical performance-based outcomes but also by typical ‘soft’ outcomes like empowerment, engagement and commitment to quality (Bortolotti et al, 2015; Danese et al, 2015). These outcomes concern the worker and their perceived perceptions or even the users' cognitive or emotional state about lean and its changes to day-to-day work. Disregarding these aspects could enable the dark side when negative soft outcomes out rule the positive effects of lean implementation (Alcadipani et al., 2018; Jones et al., 2013).

Since using surveys assumes a degree of subjectivity due to the perceptions of the respondents (e.g., how they perceive the questions), Cronbach alpha (Cronbach, 1951) is used to determine the internal consistency of items which form a unidimensional outcome construct (Heo et al, 2015). Using surveys for determining the degree of leanness for soft factors seems inevitable, while hard factors can be measured by more objective indicators.

There are few studies in the literature on leanness assessment compared to the number of publications on lean initiatives (Narayanamurthy & Gurumurthy, 2015). Of the tools mentioned in the literature, 13 have been discussed in this section – 10 were developed for manufacturing and three have been proposed as models (Behrouzi & Wong, 2011; Karlsson & Åhlström, 1996; Pakdil & Leonard, 2014).

The self-assessment tool by Caffyn (1999) determines the degree of continuous improvement, while the audit by Bhasin (2011) assesses the lean maturity in the organisation. The instruments by Martínez Sanchez & Pérez Pérez (2001), Horacio Soriano-Meier & Forrester (2002) and Doolen & Hacker (2005) assess the implementation of lean by the presence of its indicators such as JIT.

The instrument by Shah and Ward (2007) considers the system and the relationships among factors and other companies' characteristics. The instrument by Malmbrandt & Åhlström (2013) is recognised as suitable for services; however, this instrument uses Likert-type scales, which have predefined statements to compensate for the lack of a clear Likert scale. Psomas et al. (2018) adapted this instrument to a Likert scale, but the data collection suffered limitations.

Table 2 (1). Review studies

year	author(s) and year	kind of tool	orientation	what is measured?	validation
1996	Karlsson & Åhlström	assessment	manufacturing	operationalizes the determinants of a lean production system by changes in functional areas based on <i>The Machine that Changed the World</i>	proposed model
1998	Panizzolo	assessment	manufacturing	determines the degree of adoption of improvement programmes and practices in several areas (process and equipment, manufacturing planning and control, human resources, product design, supplier relationships and customer relationships)	empirically at 27 companies
1999	Caffyn	self-assessment	any industry	determines the degree of continuous improvement (CI) in the organisation, by evaluating the extent to which key behaviour indicators for CI are present	pilot tested at 3 companies
2001	Martínez Sanchez & Pérez Pérez	assessment	manufacturing	assesses the manufacturing changes towards lean production by analysing which lean production indicators are more often used to assess the companies improvements in its production systems	tested by a sample of manufacturing companies
2002	Horacio Soriano-Meier & Forrester	survey	manufacturing	The first questionnaire is used to measure different operational measures like 'the degree of adoption of lean production principles'. The second questionnaire is used the variables related to the managerial commitment to lean production like 'commitment to JIT'. The questionnaire are for operations managers and MDs/CEOs, respectively.	the survey was completed by over 30 firms in the UK ceramics industry
2005	Doolen & Hacker	survey	manufacturing	to assess the implementation of lean practices within an organisation, like 'Does your organization make an effort to reduce setup times?' If Yes is answered, there is a follow-up question to assess several practices like 'Encourage employees to find ways to reduce setup times'	13 companies were included in this analysis, five companies were identified as having fewer than 100 employees, and the remaining eight companies had more than 100 employees.

Table 2 (2). Review studies

year	author(s) and year	kind of tool	orientation	what is measured?	validation
2007	Shah & Ward	survey	manufacturing	to assess the state of lean implementation in firms and to test hypotheses about relationships between lean production and other firm characteristics that affect firm performance.	confirmatory factor analysis (CFA) using a calibration sample ($n = 140$) and a validation sample ($n = 140$)
2008	Wan & Chen	data envelopment analysis (DEA) technique	manufacturing	extracted from the data envelopment analysis (DEA) technique, the value-added investments from a production process are measured to determine the leanness frontier as a benchmark. A linear program based on slacks-based measure (SBM) derives the leanness score that indicates how lean the system is and how much waste exists.	proposed model
2011	Bhasin	audit	manufacturing	The audit consists of 12 distinct sections and respective indices which have to be scored by the appraiser, with a maximum score of 1,040 points which stands for the highest stage in lean, namely 'ideological' while a score of less than 155 represents the lowest stage, namely the 'planning' phase	The audit has been tested in 20 manufacturing organisations.
2011	Behrouzi & Wong	quantitative model using fuzzy membership functions	manufacturing	4-step measurement model based on the lean performance attributes like waste elimination and Just-in-Time (JIT) and the connection with the related performance categories and metrics, like cost, quality and time	proposed model
2013	Malmbrandt & Åhlström	assessment	service	operational measures of lean service for assessing the level of adoption of lean service, consisting of 34 items on enablers, practices and performance of lean service adoption which have to be assessed on five statements from which the best fit has to be chosen (Likert-type scales)	the instrument was validated qualitatively in four ways throughout the development process
2014	Pakdil & Leonard	assessment	manufacturing	Leanness assessment tool (LAT) consisting of a qualitative section with five performance dimensions measured by 51 items on a Likert scale and a quantitative section with eight performance dimensions: time effectiveness, quality, process, cost, human resources, delivery, customer and inventory along with detailed sub-performance indicators	proposed model
2018	Psomas, Antony and Bouranta	assessment	SMEs	adaptation of the tool by Malmbrandt & Åhlström by adding questions referring to TPM and supplier involvement and using a Likert scale in stead of the 'Likert-type scale' in the original instrument.	Nine Greek food Small and Medium Enterprises (SME) certified according to the ISO 9001 quality management system (QMS) and the ISO 22000 food safety management system (FSMS) were

Despite three decades of lean literature and practices, the yield on assessing the degree of lean is small. The instrument developed by Shah and Ward (2007) considers the system and the relations among items, gaining knowledge on the system as a whole instead of assessing

items separately. However, the instrument was primarily developed for manufacturing. The instrument by Malmbrandt & Åhlström (2013) assesses the degree of leanness for services but has issues due to the scaling it uses. The question remains whether separate instruments are necessary for manufacturing versus services given the understanding that most of the lean instruments and tools are applicable in any sector, while some tools fit better with manufacturing (Alaskari et al. 2016) and others with services (Bouranta, 2020; Gupta et al, 2020).

This leads to the following focussed research questions:

RQ1. Which elements used in assessing the degree of lean are applicable for services?

RQ2. Which elements used in assessing the degree of lean are not applicable for services?

3. Methodology

A sample of eight Lean Six Sigma Black Belts with experience in both production and services was assembled with the aim of identifying examples for the measures of lean production for services. All of them were invited to attend a session in February 2021 on the preselected subject under research. The ideal sample for a focus group is ideally six to eight participants (Allen, 2017). The group has more than 80 years combined experience in applying Lean Six Sigma to both services and production.

In the session, questions based on Shah and Ward's questionnaire were asked in a menti. A menti is an interactive session based on the Mentimeter application, developed for interactive questioning in groups. The participants had to generate examples for services from their own experience. Participant observation as a data collection methodology is widely used in many branches of social science research (Arumugam et al., 2012; Douglas et al., 2015). After answering all the questions, a group discussion was facilitated where the outcomes were discussed.

For each question on the questionnaire developed for manufacturing, an example was asked for services. Asking for examples for services determined the applicability of the questions for services. Each participant had to answer the questions on their own. After conducting the group session in the menti, the results were discussed in a focus group to get a better understanding of the answers and be able to abstract them to general conclusions. Focus groups are widely used in lean and Lean Six Sigma research (Chiarini & Bracci, 2013; Nascimento et al., 2019; Timans, et al., 2014). They effectively for narrow results, expand results, or both, including the validation for proposing a final instrument (Sfakianaki & Kakouris, 2019).

The research was qualitative. To be sure that the researcher had correctly written down the conclusions of the participants, the findings and proposed questions were sent for feedback. The research was conducted in three phases (Figure 1).

Figure 1. Research phases

4. Results

In Table 3, the results of the session's first phase with the application Mentimeter are shown. Similar answers were grouped into one answer.

Table 3. Results of the group session

Prompt	Examples given
1. We are frequently are in close contact with our suppliers	Discussing service-level agreements (SLAs) with our IT suppliers. Visiting our IT supplier and discussing our SLA and improvement project.
2. Our suppliers seldom visit our plants	Our IT suppliers regularly visit our organisation for participation and consultation in projects. Our partners for temporary workers regularly visit our organisation.
3. We seldom visit our supplier's plants	We visit our consultancy firms regularly. We visit our IT suppliers regularly. We visit bankers and other service suppliers to learn from them.
4. We give our suppliers feedback on quality and delivery performance	We provide feedback on our suppliers' backlog. There are meetings on a regular basis to address the performance and areas for improvement with our partners and (IT) suppliers. We only complain if the quality is poor.

5. We strive to establish long-term relationships with our suppliers	Our intention with our (IT) suppliers is always on the long-term relationship. We have relationships with all our suppliers, accountancy, etc.
6. Suppliers are directly involved in the new product development process	Suppliers, or as we prefer to say 'partners', are directly involved in our development teams, mostly run by scrum. Our suppliers of partners are inhouse with us.
7. Our key suppliers deliver to plant on JIT basis	No, we have our suppliers involved in our development teams, but they make slow progress because of the sprint agenda and IT adjustments. Yes, our data suppliers provide these at the time needed, for instance, after the opening of the stock market.
8. We have a formal supplier certification program	We do not have a formal certification program: suppliers have to be ISO certified; otherwise, they cannot do business with us. No bells ringing.
9. Our suppliers are contractually committed to annual cost reductions	Wish it was like that. No bells ringing.
10. Our key suppliers are located in close proximity to our plants	No, also not necessary.
11. We have corporate-level communication on important issues with key suppliers	Only for escalations. It is under development due to the implementation of Industry 4.0 with our IT suppliers. Yes, on a strategical, tactical and operational level.
12. We take active steps to reduce the number of suppliers in each category	Always. Never. Yes, yearly we benchmark our (IT) suppliers.
13. Our key suppliers manage our inventory	Does not apply.
14. We evaluate suppliers on the basis of total cost and not per unit piece	We evaluate per license. Yes, total maintenance costs and development for IT. Yes, we evaluate based on total cost.
15. We frequently are in close contact with our customers	Yes, all the time.
16. Our customers seldom visit our plants	No, we visit the customer, and mostly it's digital.
17. Our customers give us feedback on quality and delivery performance	Yes, they do. Customer surveys and net promotor scores are part of our process.
18. Our customers are actively involved in current and future product offerings	Yes, customers are directly involved in the development teams. Yes, we actively engage our customers in product development.
19. Our customers are directly involved in current and future product offerings	Yes, they are in close contact with our product management department.

	Yes, as part of customer relations, we involve them directly.
20. Our customers frequently share current and future demand information with marketing department	No. Only when asked by the marketing department.
21. We regularly conduct customer satisfaction surveys	Yes, we do.
22. Production is pulled by the shipment of finished goods	No, in general that is not in place.
23. Production at stations is pulled by the current demand of the next station	No, not applicable.
24. We use a pull production system	No, not really.
25. We use kanbans, squares or containers of signals for production control	We use kanban boards in our scrum teams. Not for regular services, only development.
26. Products are classified into groups with similar processing requirements	Yes, sometimes; it depends. We have lines of services.
27. Products are classified into groups with similar routing requirements	Routing is different depending on the services or business line.
28. Equipment is grouped to produce a continuous flow of families of products	Does not apply.
29. Families of products determine our factory layout	Does not apply.
30. Pace of production is directly linked with the rate of customer demand	No, not really, when compared to production. In services, you start working when asked.
31. Our employees practice setups to reduce the time required	New software is tested regularly to work more efficiently. No. Always.
32. We are working to lower setup times in our plant	This question feels the same as the previous one. No. Yes, all the time.
33. We have low setup times of equipment in our plant	Does not apply.
34. Long production cycle times prevent us from responding quickly to customer requests	Yes, there are a lot of steps and a lot of waiting times.
35. Long supply lead times prevent responding quickly to customer requests	Yes, they do. Especially since we cannot produce to stock.

36. Large numbers of equipment/processes on shop floor are currently under SPC	Does not apply. One answer: Yes, they are.
37. Extensive use of statistical techniques to reduce process variance	That's correct; it's all about the statistics. No, not yet; a lot of data are available but not connected to statistical tooling. No use yet.
38. Charts showing defect rates are used as tools on the shop floor	No, they are available for management but not on the shop floor.
39. We use fishbone-type diagrams to identify causes of quality problems	Yes, we are using cause and effect diagrams. Only in projects.
40. We conduct process capability studies before product launch.	Only for service introduction. Only in projects. No, not at all.
41. Shop floor employees are key to problem-solving teams	Yes, they are. In our organisation, opinions differ.
42. Shop floor employees drive suggestion programs	Yes, they do. One answered: Sometimes.
43. Shop floor employees lead product/process improvement efforts	Yes, they do. Partly. They are involved but not leading.
44. Shop floor employees undergo cross-functional training	Yes, they do. Sometimes.
45. We dedicate a portion of each day to planned equipment maintenance-related activities	Yes. No.
46. We maintain all our equipment regularly	We do not. Our IT department does.
47. We maintain excellent records of all equipment maintenance-related activities	Everything is recorded. No.
48. We post equipment maintenance records on our shop floor for active sharing with employees	No.

Participants could not answer the following questions in relation to services: 9, 10, 13, 16, 22, 23, 24, 28, 29, 30, 33, 46 and 48.

In the group discussion, the Lean Six Sigma Black Belts said that developing suppliers (9-14), pull (22-25), flow (26-30) and TPM (45-48) do not apply to services and that if they gave an example, they made the transfer from their experience in production.

The questionnaire from Shah and Ward is based on the supplier, customer and internally related questions (Castro De et al, 2010). In the group discussion, the participants said that the major difference they see between services and production is that flow and pull do not typically apply to services unless the services are IT-related and (mostly) automated. The customer has, according to the Black Belts, more impact on services than on production.

This would mean that 29 questions of the typical production-orientated survey also apply for services, while 19 are more appropriate for ‘hardcore’ production. The questions regarding developing suppliers, pull, flow and productive maintenance do not apply to services.

Figure 2. Lean production factors (Shah and Ward [2007])

The Black Belts further suggested that for the questions which also apply to services, it would be better to replace some words for more neutral or service-related terms. The suggestions are shown in Table 4.

Table 4. Proposed words

Word used in the questionnaire	Proposed word(s)
Suppliers	Partners
Plants	Offices
The new product development process	Product development
On JIT basis	When we need it
Equipment	Systems
Production	Services
SPC	Statistical Process Control
Shop floor employee(s)	Employee(s)

For one prompt – ‘our key partners deliver to plant when we need it’ – the word ‘us’ was proposed as an alternative for ‘plant’. This is due to the use of ‘we’ in the sentence. For two prompts, the singular of ‘plant’ was used to refer to the setup of the process. For these two prompts, ‘processes’ was used instead of ‘plant’. The clarification ‘on the shop floor’ in prompts 36 and 38 was considered unnecessary, and the participants proposed to omit it from the prompt.

Based on the results, we propose a questionnaire consisting of 29 items to reflect a comprehensive set of lean practices for services; it is presented in the appendix. Both the findings and the proposed questionnaire were sent to the participants. The participants approved both the findings and adapted questions.

5. Key findings

The objective of this paper is to explore how to measure lean for services. This is done by inventorying existing instruments and selecting one of them to demonstrate the applicability for services. The instrument by Shah and Ward (2007) has been selected since it considers the

system and the relations among items. Even though the items were developed for manufacturing, operational measures for services were validated by using group techniques.

We consider lean production the main concept, while the underlying constructs are supplier, customer or the internal (process) orientation. All of the underlying constructs are applicable to services, but not all of the operational elements which determine the measures for services apply. With regard to the elements used in assessing the degree of lean for services (RQ1), the following constructs apply to both production and services: supplier feedback, JIT delivery, involved customers, low setup, controlled processes and involved employees. Developing suppliers, pull, flow and productive maintenance are too exclusive to production to apply for services (RQ2).

Table 5. Applicability of the constructs based on Shah and Ward (2007)

Construct	Production	Services
1. SUPPFEED (supplier feedback): provide regular feedback to suppliers about their performance	x	x
2. SUPPJIT (JIT delivery by suppliers): ensures that suppliers deliver the right quantity at the right time in the right place.	x	x
3. SUPPDEVT (supplier development): develop suppliers so they can be more involved in the production process of the focal firm.	x	
4. CUSTINV (customer involvement): focus on a firm's customers and their needs.	x	x
5. PULL (pull): facilitate JIT production, including kanban cards, which serves as a signal to start or stop production.	x	
6. FLOW (continuous flow): establish mechanisms that enable and ease the continuous flow of products.	x	
7. SETUP (setup time reduction): reduce process downtime between product changeovers.	x	x
8. TPM (total productive/preventive maintenance): address equipment downtime through total productive maintenance and, thus, achieve a high level of equipment availability.	x	
9. SPC (statistical process control): ensure each process will supply defect free units to subsequent process.	x	x
10. EMPINV (employee involvement): employees' role in problem solving, and their cross-functional character.	x	x

6. Discussion, implications and limitations

Although there is a general consensus that lean is applicable to both manufacturing and services, there is a discussion on how to measure the degree of lean. The yield on quantitative assessment instruments for lean is scant. The yield on quantitative instruments for lean services is even more scarce. Since not all the constructs and elements in lean apply to services, the question is 'Which of them do apply?'. There is an understanding among the practitioners who participated in this study that constructs such as flow and pull are not suitable for services. However, creating balanced processes and flow should be applicable for services (Gupta et al., 2016; Staats et al., 2010). Pull should also be applicable for services as this is already used at call centres (Laureani et al., 2010), thus creating a paradigm with the practitioners' experiences.

There are many misconceptions regarding the applicability of lean for services (Sunder et al., 2018). This research creates a foundation for discussing and developing strategies when assessing lean in terms of services.

As with any research, this study has limitations too. First, this research concentrates on lean for services; however, over the years, especially since 2008, the number of articles on Lean Six Sigma has increased (Muraliraj, 2018), thus implying that the focus in research is shifting from lean or Six Sigma to the merged Lean Six Sigma. Second, only Lean Six Sigma Black Belt practitioners were invited for this research who had at least three years of working experience in both manufacturing and services. They were all from the Netherlands, so there was no representation from other countries. Third, Shah and Ward's original instrument consists of 10 constructs. In the adapted version for services, only six constructs apply. There is a question of whether the results are still valid and reliable when using an abbreviated questionnaire.

7. Conclusion and directions for further research

This paper set out to determine whether constructs for lean production are applicable to lean services. Translations were provided for the semantic meaning of lean constructs to make them better suited for services, and examples for each of them were provided. An adapted version of the instrument of Shah and Ward (2007) is proposed. This means that besides the current version to assess lean for production, an adapted version for services is also available, and both are based on the same constructs. In this way, the effect of the lean implementation in organisations, whether production or services, can better be compared. Additionally, for mixed organisations having both a manufacturing and a service component, the degree of their lean practices can be better compared.

The next step for the adapted instrument is to test the scales for validity and reliability and to assess lean constructs for services. In future research, the instrument could be extended to include soft factors that capture the behavioural aspects involved in assessing lean. Distinguishing between hard and soft factors would help understand the variance in the organisation's outcomes after lean implementation, ranging from positive to negative.

Appendix. Scales adapted for services

		Please indicate the extent of implementation of each of the following practices in your organisation. (1) no implementation, (2) little implementation, (3) some implementation, (4) extensive implementation, or (5) complete implementation
Suppfeed_01	1	1. We frequently are in close contact with our partners
Suppfeed_02	2	2. Our partners seldom visit our offices (reverse coded)
Suppfeed_03	3	3. We seldom visit our suppliers' offices (reverse coded)
Suppfeed_04	4	4. We give our partners feedback on quality and delivery performance
Suppfeed_05	5	5. We strive to establish long-term relations with our partners
SuppJIT_01	6	6. Partners are directly involved in product development
SuppJIT_02	7	7. Our key partners deliver to us when we need it
SuppJIT_03	8	8. We have a formal supplier certification program
Custinv_01	9	15. We frequently are in close contact with our customers
Custinv_02	10	16. Our customers seldom visit our offices (reverse coded)
Custinv_03	11	17. Our customers give us feedback on quality and delivery performance
Custinv_04	12	18. Our customers are actively involved in current and future product offerings
Custinv_05	13	19. Our customers are directly involved in current and future product offerings
Custinv_06	14	20. Our customers frequently share current and future demand information with the marketing department
Custinv_07	15	21. We regularly conduct customer satisfaction surveys
Setup_01	16	31. Our employees practice setups to reduce the time required
Setup_02	17	32. We are working to lower setup times in our processes
Setup_03	18	33. We have low setup times of systems in our processes
Setup_04	19	34. Long services cycle times prevent responding quickly to customer requests (reverse)
Setup_05	20	35. Long supply lead times prevent responding quickly to customer requests (reverse coded)
SPC_01	21	36. Large number of systems/processes are currently under statistical process control
SPC_02	22	37. Extensive use of statistical techniques to reduce process variance
SPC_03	23	38. Charts showing defect rates are used as tools
SPC_04	24	39. We use fishbone-type diagrams to identify causes of quality problems
SPC_05	25	40. We conduct process capability studies before product launch.
Empinv_01	26	41. Employees are key to problem-solving teams
Empinv_02	27	42. employees drive suggestion programs
Empinv_03	28	43. Employees lead product/process improvement efforts
Empinv_04	29	44. Employees undergo cross-functional training

The questions are numbered from 1 to 29, while in the questions, the original number from Shah and Ward's questionnaire is mentioned.

SUPPFEED (supplier feedback): provide regular feedback to suppliers (partners) about their performance

SUPPJIT (JIT delivery by suppliers): ensures that suppliers (partners) deliver the right quantity at the right time in the right place.

CUSTINV (customer involvement): focus on a firm's customers and their needs.

SETUP (setup time reduction): reduce process downtime between product changeovers.

SPC (statistical process control): ensure each process will supply defect-free units to the subsequent process.

EMPINV (employee involvement): employees' role in problem solving and their cross functional character.

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