



# Understanding Lean—Statistical Analysis of Perceptions and Self-Deception Regarding Lean Management

Antony Pearce<sup>1</sup> · Dirk Pons<sup>1,2</sup> · Thomas Neitzert<sup>3</sup>

Received: 7 March 2021 / Accepted: 30 January 2023 / Published online: 28 March 2023  
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## Abstract

Despite the benefits of a lean business system, many organisations struggle to implement and sustain lean initiatives. The purpose of this work was to explore in what way a leader's deeper knowledge or different understandings of lean affects the lean implementation and its outcomes. The research methodology incorporated a survey of 757 participants. How respondents understood lean was assessed and later correlated to their extent of lean knowledge and specific understanding. This was supported by exploratory factor analysis and structural equation modelling. What caused participants to pursue lean knowledge was also assessed. Low lean knowledge and experience correlated with a system, tools and processes perspective of lean that was perceived to provide a low competitive advantage. Those of high lean knowledge had a much more holistic view of lean that encompassed both socio and technical aspects and also perceived greater competitive advantages from lean. Results showed 88% of people were (are) not at all familiar with lean, 9% of low knowledge and 3% of high knowledge. This paper promotes the importance of management knowledge in establishing a lean business system and exposes that many are actually self-deceived regarding their knowledge of lean. It identifies the need to develop lean education and recommends further research in this area. It also provides a conceptual framework for the implementation of lean with an emphasis on leadership learning. This paper contributes statistical evidence and a new perspective on the cause of lean success and failure.

**Keywords** Lean · Production · Management · Implementation · Structural equation · PLS · SEM

## 1 Introduction

Lean management is said to be the standard for systematic productivity improvement [1–3], enhancing productivity through the minimisation of wasteful action. The lean principles arose in manufacturing, specifically automobile production and assembly [4–6],

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✉ Dirk Pons  
dirk.pons@canterbury.ac.nz

Extended author information available on the last page of the article

but have subsequently been applied to business practice universally [7] consequently lean is seen as a management system [8] and called lean management [9]. Lean benefits have extended beyond manufacturing into service industries, being applied in universities and the general public sector as examples [10–12]. While the principles of lean are simple, the implementation is not always straightforward, and organisations fail to realise or sustain the desired outcomes [13–16]. This makes clear the importance of change leadership and the need to identify the critical factors for success.

The failed instances of lean have caused it to suffer various critiques and reinforced workers views of lean as a repackaging of previous improvement methods and another management fad [17–19]. While some early attempts at lean raised concerns of it being high pressure and exploitative of staff [20–22], notably these are somewhat isolated cases from lean in its infancy and have received little further comment. The critiques related to success factors for application beyond mass production have lingered longer. These specifically relate to Womack and Jones [7] claims of the universal applicableness of lean [23] going beyond automobile mass production [24]. Although going beyond mass production models and enabling flexibility are key to effective lean practice [8, 25], critiques on this line are not restricted to lean [26] and are considered examples of researchers neglecting to understand what lean success is contingent on [27]. Reviews of the literature show the critiques themselves predate 2003 [11, 28] and there continue to be reports of success in a wide variety of fields [11, 14, 24]. Yet the need to understand the critical factors of success has not been forgotten [29, 30]. The theory for lean success needs further quantitative work [31] in order to understand how practitioners can more readily achieve the benefits of lean.

Pearce et al. [17] asked the question, ‘is there a single overriding factor that could be considered the root cause for the success or failure of an implementation?’. The lean-change literature specifically points to leadership needing an attitude that promotes permeable change versus a quick-fix mentality and piecemeal application of lean tools [32–34]. This is balancing the technical execution with the softer side of management. These matters are well discussed in the literature, with practitioners encouraged to address strategic and human factors through leadership rather than merely the tools, technology and processes of lean [35–37]. These concepts are not entirely new, and echo the Toyota Way; that is focusing not merely on waste elimination but also respect for people [5]. Management commitment in a general sense has also been emphasised as ‘a’ or ‘the’ critical factor for lean success [35, 38–41] and that leadership behaviour has a moderating effect on the success of lean process improvement [42].

## 1.1 Gap in the Literature

The literature clearly showed that the elementary knowledge for sustaining lean implementations has been available for practically two decades [7, 36, 39, 43]. The a question that remained was: ‘Why do managers (1) not embark on or (2) embark on substandard, tool focused and unsustainable lean implementations?’ [17]. The 60 to 90% failure rates stated [13, 44] indicate that if the knowledge for a successful lean

implementation did in-fact exist, it has been underutilised. The case studies of Pearce et al. [17] identified that commitment by management in a general sense was not the deciding factor. It concluded that, management understanding clearly what they should commit to (in a more tangible and specific sense) might be the real key to achieving lean success. Specifically, a commitment to knowledge and learning was required. So it was postulated that that ‘the primary answer to why managers do not embark on or embark on substandard implementations, lies in inadequate knowledge and further a passivity towards acquiring new knowledge’ [17]. Increased familiarity with lean through exposure of leadership to information sources has been shown to have an impact on commitment and commitment to impact lean thinking in an organisation [45]. However, ‘the direct relationship between external information sources and lean thinking’ was not yet supported. It was proposed that a further development of these studies, supported with a larger data set from a web-based survey distribution, would help identify significant relationships between lean knowledge and lean outcomes. This could more solidly address this gap in the body of knowledge, i.e. the understanding of how lean knowledge affects lean thinking and the success of its application.

## 2 Purpose and Approach

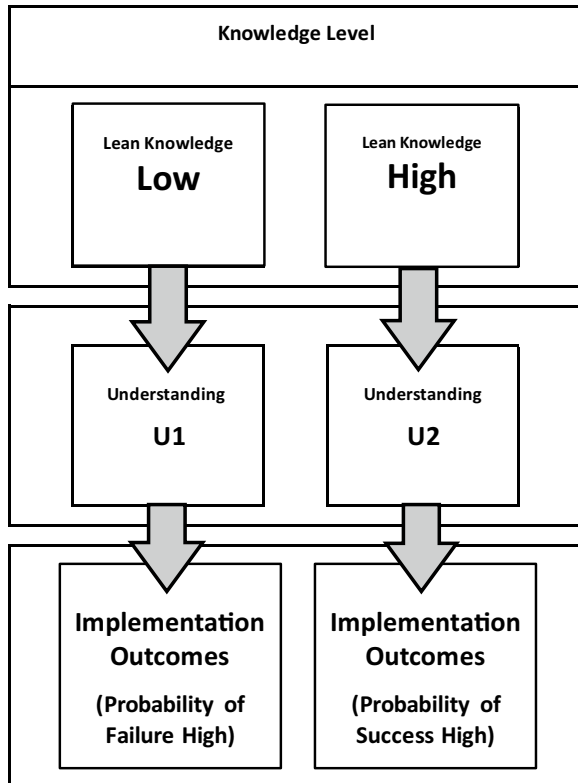
### 2.1 Purpose

The purpose of this work was to explore how a manager’s knowledge of lean affects the successful implementation of lean practices. Specifically, it was expected that managers who implement lean successfully might have a fundamental difference in their understanding of lean and its implementation compared to those who fail. In other words, the problematic implementation of lean may have less to do with the deficiencies of lean, as some would suppose, but rather the inadequacies of the manager’s understanding.

It is logical that the level of lean knowledge and particularly leadership knowledge affects implementation outcomes. The more knowledge is possessed regarding a thing, the more wisdom or skill and ability can be applied in handling that thing. This concept is not particularly novel in itself. The novel premise in this work exists in showing diverging understanding, i.e. proposing that the benefit of increased lean knowledge is not merely associated with a general increased understanding of the matter but rather a fundamentally different understanding. In alternative terms, the definition of lean differs significantly with increased lean knowledge. It was believed these different definitions or understandings formed a kind of mediating relationship with success and failure as illustrated in Fig. 1 with different understandings U1 and U2.

The proposition here (Fig. 1) was that the major success factor for lean lies in the area of leadership knowledge; with the postulation for this work being, that fundamentally different understandings or ways of defining lean exist amongst those of lower knowledge than those with higher knowledge, who have a definition which is more holistic and associated with success.

**Fig. 1** Divergent understanding model: the developing construct of lean knowledge for lean success



## 2.2 Approach

A survey experiment was chosen for this investigation. Recent systematic reviews show over half (54%) of lean articles take an entirely conceptual or descriptive approach, meaning less than half have any empirical basis [31, 46, 47]. Until recently, the research methodologies in lean were not challenged leaving room for weakness in the body of knowledge. The lean work was based on more subjective qualitative methods, pointing to the need to further investigate these findings quantitatively [47]. Statistical analysis of survey data is a common quantitative approach in managerial sciences [48, 49] and survey based empirical works do exist in lean, but verification of theory only made up 5% of the research [46]. And the majority of this work addressed superficial factors rather than the core theory for lean success [47]. There is a need for this kind of quantitative work to fill this gap.

## 2.3 Design of Experiment

The purpose of the survey (questionnaire) experiment was to investigate the differences in how lean is understood. That is the different ‘definitions’ or constructs of lean within the population and how they correlate with the different levels of lean knowledge and the

perceived advantages of lean. For this purpose, the population sampled embodied more than just lean practitioners but also those with low or no knowledge of lean. Though the study was very much exploratory, questions were formulated based on the conceptual constructs from literature review, building specifically on the concepts of Pearce et al. [17].

The literature review took a narrative approach based on a prior 8-year study in lean management. The literature searches typically took 'lean' as the primary keyword combined with 'implementation', 'success', 'manufacturing', 'production' and 'management'. Databases searched included Ei Compendex, Scopus and eventually Google Scholar to increase the breadth of the search [50, 51]. This research aligns itself with the view that lean principles, methods and challenges of change apply across industries [7, 11, 52, 53]. Therefore literature research was not restricted to a specific industry, even though it acknowledges the roots of lean in manufacturing [4–6].

The survey covered basic demographics including the participant's country, training, field of study, industry, role and business size. It then followed with series of self-report questions that utilised a 5-point ordinal text response. In order to aid some analyses, the 5 point ordinal responses of 1 & 2 (were grouped and defined as 'Low', 3 & 4 as 'High' and 0 was 'Not at all'. The ordinal survey questions asked the extent of participants' familiarity and implementation experience with lean and related methods and then focused on lean specifically. These core survey questions asked regarding the participants understanding of lean and whether lean was a competitive advantage. How these core questions of this study were developed from the literature can be seen in the following literature section and is summarised in Table 1. Additionally, to find common drivers and inhibitors in the pursuit of knowledge, participants were categorised into low or high knowledge level of lean, based on their own responses and asked respectively why they had or had not pursued lean knowledge. Further ancillary questions were asked to help understand the participant's responses and develop further work. These questions, though not the focus of this study, are included in the Appendix with a results summary for reference and were discussed where relevant through the study. They include mainly questions regarding various methods and their perceived relevance to the participants' organisations. Questions included an "other" option or "don't know" and frequent room was left for textual responses in order to explain answers and allow freedom of response.

A total of 757 survey responses were gathered with less than 1% expressing any concern that the survey design was found restricting.

Fundamental and advanced statistical methods were used in the analysis of data, utilising the 5-point scales as Likert type scales. This is a common method in management sciences, although a particular understanding of the data and its limitations is necessary [54–58]. Descriptive statistics, ANOVA, exploratory factor analysis (EFA) and partial least squares structural equation modelling (PLS-SEM) [47, 59, 60] were utilised to extract core insights. EFA was used to explore the data, identify the underlying constructs in the data set and in effect reduce dimensionality [61, 62]. Statistically discrete constructs could in that way be formed, and once clearly identified, hypothetical model for the relationships between these could be further crystallised and those relationships tested. PLS-SEM is a powerful method for analysing the relationships between factors. Its critics [63] neglect to differentiate between cases of misuse and appropriate use [64, 65] nor provide adequate scientific

**Table 1** Question summary-statements representing the common understanding of lean (ordered by variable id)

<i>Variable ID</i>	<i>Question: Do the following statements match your understanding of lean?</i>	<i>Ref.</i>
(V050) Repacking of JIT/Qual. Sys	Lean is simple repacking of JIT and quality systems, nothing new.	[17]
(V051) Tools, processes	Lean implementation is of tools and processes for improving productivity.	[34, 37]
(V052) Process Eng.	Lean is tools or methods primarily for process or industrial engineers.	[14, 86]
(V053) Waste Elimin.	Lean means eliminating waste.	[5, 7]
(V054) Train & Empower	Lean gives workers training and empowerment to solve problems.	[14, 36]
(V055) Fragile/Unbuffered	Lean means fragile (i.e. without buffers).	[4, 75]
(V056) New Systems/Ways	Lean is implementation of new systems and ways of doing things to improve productivity.	[14, 36]
(V057) Respecting People	Lean means respecting people.	[5, 9]
(V058) Philos./Strategy	The implementation of a company-wide philosophy and strategy.	[8, 36]
(V059) Needs regularity and focus	Lean implementation process needs regularity and focus for sustained success.	[14, 17, 37]
(V060) New label-Industrial Eng.	Lean is a new label for industrial engineering and the work of industrial engineers.	[75, 86]

evidence [66]. The software Smart PLS 2.0 [67] was used for SEM analysis and Statistica 11 [68] for ANOVA and EFA. R [69] was used for addressing endogeneity [70]. The outcomes of the analysis were combined in a graphical model that encapsulated the findings of the study.

### 3 Literature

#### 3.1 Lean Management and Its Definitions

Although lean has been operationalised to an extent [71], it is difficult to crystallise an accurate definition [72–74]. Yet one's definition and understanding of lean could have profound effects on the advantages that are perceived and realised [47]. Initially, lean was coined as a system that was without buffers and fragile in the positive sense of promoting change [4, 75]. Superficially, lean has been considered as a set of tools and techniques (VSM, Kanban, 5S, TPM, SMED, etc.) with a typical lean implementation involving their successive implementation to define a journey of improvement [34, 76]. The early works on lean [7, 77] although not entirely neglecting the softer side, tended to focus mainly on these technical aspects. The tools and methods are also most visible when observing a lean system and also technically logical to implement [37]. The problem appears when lean systems are adopted in traditional organisation i.e. it requires widespread transformational change [78]. Neglecting the human component of change results in resistance [39, 79, 80] and jeopardises the permeability of the initiative [14, 32, 34]. Although the respect for people aspect was considered equal with the technical aspects in the Toyota Production System [5], it is only a little over a decade ago, with the background of failed implementations, that the lean literature began pointing more emphatically at the softer side of management. It began moving beyond seeing lean as mere set of tools [34] to the engagement and empowerment of staff [14] that is developing the human and cultural aspects of lean [81, 82]. Because of this change in emphasis, it seems that the definition of lean began shifting [83].

True or real lean [84] is said to set a focus on the people of an organisation, the empowerment of staff at all levels to make change, creating a dynamic and flexible learning organisations of emergent change [36, 85]. In practice, lean is more commonly associated with the technical aspect and the respect for humans component is more neglected [34, 37]. A popular representation of this problem is the iceberg-model [37], depicting the technical aspects of lean being visible or above the waterline and the unseen supporting functions and human aspects being less visible, hidden below the waterline. Practitioners may associate the tool approach with the work of specialist consultants or industrial engineers [86] whom previously fulfilled this role [75]. In research, the way lean is operationalised also tends towards a leanness or production perspective that is weighted towards the tools and methods of lean [71, 74], such operationalising provides an easy vehicle for analysis but has issues [87]. The operationalising of lean appears to have affected the majority of quantitative lean research to the extent that lean is now commonly addressed as a mere set of production methods [47] this has resulted in an unsatisfactory body of quantitative work.

### 3.2 Various Definitions

It is clear there is a range of views or understandings of lean and how it is defined. Lean is most commonly associated with eliminating waste [5, 7]. More obscurely, lean was coined as a fragile system, one without the buffers that hid waste [4, 75]. Lean may be considered an implementation of new systems and ways of doing things to improve productivity, reducing waste [14, 36]. Lean has an aspect of tools and processes for improving productivity [34, 37] and is viewed by some as a simple repackaging of JIT and quality systems, rather than something new [17], not considering there to be any advancement in how these systems have been understood or applied. For some, lean is heavily associated with particular tools or methods used by process or industrial engineers [14, 86]. To others it is a new label for industrial engineering and the work of industrial engineers [75, 86]. Besides these above tools and process centric views, the softer side includes an emphasis on the principle of respecting people [5, 9], and giving workers training and empowerment to solve problems [14, 36]. Lean is said to require a company-wide philosophy and strategy [8, 36], with implementation needing the regularity and focus for sustained success [14, 17, 37]. At this, arguably more up to date, end of the spectrum of understating lean, it is essentially no longer about an implementation in the sense of a step change, but rather focusing on continuously striving to solve problems, becoming a learning organisation that is constantly improving [36, 85].

### 3.3 Survey Questions

These above aspects and understanding of lean, while not exhaustive provide main components of the existing understandings of lean and were used as the basis of the core questions of the survey experiment. In simplistic terms these statements and the resultant questions addressed either of two standpoints — a technocratic view or alternatively a more holistic, humanistic view. However, multiple questions were used to address each of these standpoints and attempt to identify any major ancillary views. The questions with survey variable ID and source references are listed here in Table 1. Participants were asked to respond to the question ‘Do the following statements match your understanding of lean?’ rating each on a 5 point scale from 0= ‘not at all’ to 4= ‘very great extent’

## 4 Results

### 4.1 Distribution

A small pilot study and a slow release of the survey gave confidence in the survey design. All pilot data was proven valid for inclusion in the data set (757 responses); screening of all text responses and communication with participants gave confidence that questions were understood correctly.



The predominant means of distribution was personal communication with a satisfactory 18% return [88–90] which compares well with similar large-sample operations surveys e.g. 11% [45] and 7% [91]. The majority of participants were sourced from posts in LinkedIn.com discussion groups with 229 responses from Business Groups (30%) and from Small Business Groups 81 (11%), The Association for Manufacturing Excellence 46 (6%), Doctoral Students and Practitioners Group 38 (5%) and New Zealand Specialised Manufacturing 12 (2%). As the previously mentioned sources were heavily business and manufacturing biased, and a cross section of the general public was desired. For this, the survey was also distributed via posts on three Facebook accounts. The accounts belonged to one male user 31 years, New Zealand based; one female 32 years of age, New Zealand based but recently migrated from the USA; and one female 50+ years of age based in the USA. Facebook posts provided 83 responses (11%) A local manufacturing service business also made available their customers and suppliers details who were emailed the survey. These emails gathered 197 responses (26%) direct from industry. Other direct personal communication gave 47 responses (6%). The main countries represented were New Zealand (55%), Australia (16%), the USA (14%) and the UK (8%) as driven by the sample groups chosen. Although the manufacturing industry was most represented (21%), there was a large range of other engineering and service industries represented. Work experience showed an appropriate distribution, although weighted towards intermediate (15–25 years, 28%) and senior levels (25 plus years, 42%). The majority of participants (66%) had higher education (bachelors or postgraduate level). Future studies could gather lower qualification levels and industry positions also. Survey responses from lower levels of hierarchy were less likely; there is less interest in online networking and lower access to business email. Additional responses from lower levels of hierarchy would broaden the study even though the focus was the effects of knowledge on leadership. This limitation was recognised at the outset of the study.

## 4.2 Data Characteristics

The data set was sufficiently dense, with few missing responses. The data had a natural drop out point at which those who were not familiar with lean could not answer any further. No cases were insufficiently filled and there were not any specific insights from missing data. The advanced statistical methods (EFA and SEM) used case-wise deletion of data [92]. Standard deviation of these Likert responses was reviewed by case. Only one case had a standard deviation less than 0.7 i.e. 0.44 and therefore no cases were removed due to lack of variation [92]. Screening of the data was by visual inspection of plots, typically histograms. Visual inspection was deemed more appropriate and pragmatic than statistical tests disconnected from reality [62]. A basic assumption across many of the statistical methods is linearity and normality. Most of the data came from textural ordinal variables arranged as 5-point Likert scales. Likert scales do not lend themselves to perfect normal distributions but the data set was reasonably large so the central limit theorem supported normality and visual inspection of the data [62] showed acceptable levels of skew. ANOVA and factor analysis with PLS-SEM are also robust to these moderate deviations [59, 60, 62].

As both predictor and criterion variables come from the same participant common-method variance (CMV) warrants consideration [93]. EFA showed significant variance, being much less than 50% by individual variables, meeting Harman's single factor test [94]. Further tests are available [95] and recommended for some circumstances [96] but post-hoc methods have drawbacks [97, 98], and are not necessary for this research design nor do they threaten typical research findings and reliabilities [96] as observed in this study. Self-reports were a necessary part of this research.

### 4.3 Lean Knowledge

The data was analysed according to various subsets including data source. The Facebook source was used to give a relatively unbiased representation of the general public. It achieved a sufficient mix of adult respondents from various professional fields and educations. Countries in this group were United States 46%, New Zealand 37%, UK 5% and Australia 5%. This subset of data indicated lean knowledge is practically non-existent in the general public. Of the 78<sup>1</sup> participants in this group, Familiarity with lean was self-reported as "not at all" in 88%, low<sup>2</sup> in 9% and high in 3% (Fig. 2).

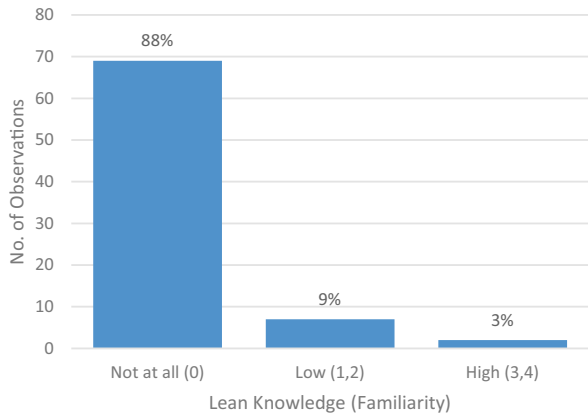
A review of lean knowledge (familiarity) in the manufacturing sector was conducted. Bias to a high-level lean knowledge was adjusted for by removing data sources that did not represent a random sample of the manufacturing sector. The Specialised Manufacturing and AME (Association for Manufacturing Excellence) groups and business consultants were removed. They did not represent the general manufacturing population let alone business population and were over represented in the sample. Since lean was born in manufacturing, it is natural that many more participants from that field have some familiarity with lean. However, one in six (17%) of those in the manufacturing industry answered that they had no familiarity with lean. Knowledge of lean was observed low in 46% of manufacturing industry participants and considered high in 38% of manufacturing industry participants (Fig. 3).

Comparing familiarity by role in manufacturing showed different data distributions. The distribution for senior management was a relatively normal form (Fig. 4). Owner operator familiarity (Fig. 5) showed skew towards no familiarity (43%), this was a concerning yet expected distribution, representing a focus on getting the job done as opposed to learning and development. Middle management familiarity showed a non-normal distribution, seemingly bi-modal (Fig. 6). Similar non-normal distributions appeared for familiarity in technical roles, although response numbers were much lower ( $n=13$  cf.  $n=29$ ). It is believed the non-normal distributions may reflect how the organisation's knowledge is dependent on leaders' knowledge or pursuit of lean; the lower levels of hierarchy introduction to and familiarity with lean is highly dependent on leadership. If top leadership pushed heavily for lean, by default the staff would develop their own familiarity. If top leadership did not promote lean, lower hierarchy staff would exhibit a low familiarity. Hence, leadership knowledge and attitude becomes a moderating factor.

<sup>1</sup> Five participants in this sample of 83 did not respond to this question leaving 79.

<sup>2</sup> Responses of ordinal value 1 & 2 were grouped and defined as 'low', 3 & 4 as 'high' and 0 was 'Not at all'. See Sect. 2.2.

**Fig. 2** Lean knowledge in general public (Facebook sample,  $n = 78$ )



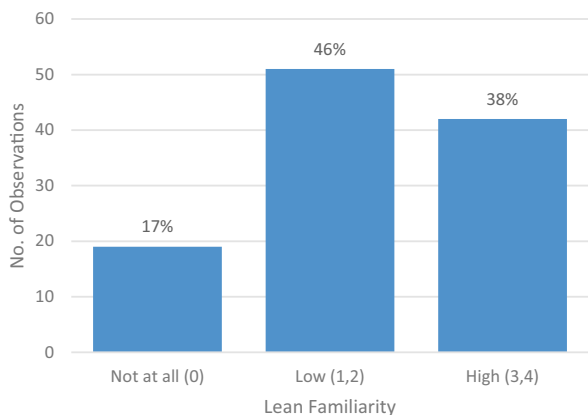
This could tend towards a bi-modal distribution of essentially two distinguishable populations, one of employees whose leadership pursued lean and the other whose leadership did not. A study with a larger sample of middle managers would be needed to confirm and investigate this apparent bi-modal distribution.

Differences between countries were explored. The only statistically significant relationship observed was that the manufacturing sector participants from the USA, when compared with those in New Zealand, were observed to have a significantly higher familiarity i.e. 3.6 out of 4 compared to 1.8, i.e. 50% higher. ANOVA showed this result to be strongly significant,  $F(1,87) = 19.2, p = 0.00003$ . However, as there were only 10 responses from the US manufacturing sector, compared with 82 from New Zealand, further responses from the US manufacturing sector would further increase confidence in this observation.

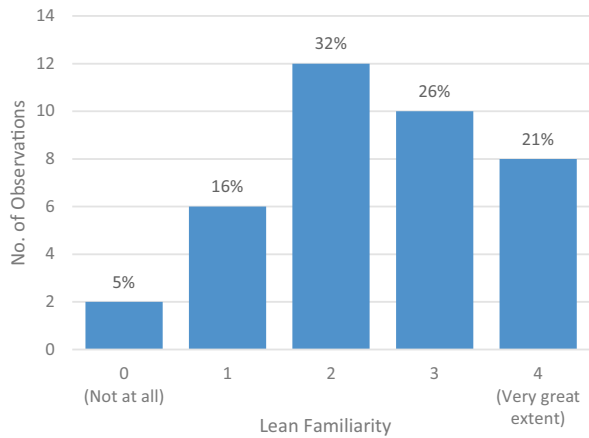
#### 4.4 Influences on Knowledge

Participants were asked to provide free text comments for why they had or had not pursued lean knowledge. The analysis addressed 77 free text comments for “why” and 217

**Fig. 3** Lean knowledge level in manufacturing industry ( $n = 112$ )



**Fig. 4** Familiarity with lean of senior management in manufacturing ( $n=38$ )



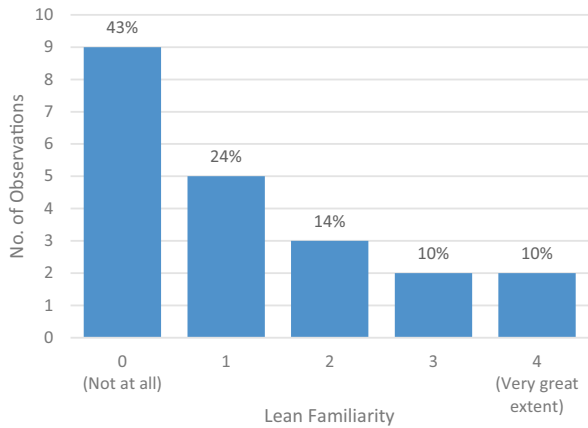
comments for “why not” that were coded according to similarity and tallied for frequency. The reasons why lean was pursued, or the drivers for lean knowledge, exhibited both active and more passive attitudes. The most proactive reasons were seeking business performance gains (30%<sup>3</sup>) or personally pursuing excellence or improvement (18%). Others desired to empower staff, improve process or just felt lean is logical and essential (~5% each). Less proactive pursuits were because of employer introduction (29%) and through other education (7%). Some pursued lean merely because it was a known skill for consulting or employment opportunities (9%). These later categories of employer introduction, other education and required skill show less personal passion for improvement, excellence or a “kaizen spirit” but are associated with passive external exposure. It would be interesting to investigate if this passive introduction to lean correlates less with the development of a sound knowledge of lean. In some cases, greater interest may be sparked through these introductions. The relationships between these categories and other variables could be investigated in future research.

The top reason given for not pursuing lean knowledge was “Lean is not relevant to my field” (74 or 34%). It is understandable that lean is simpler for and delivers results that are more significant in certain situations. It is hard to believe that lean is not relevant to the fields represented in this study (or arguably any field). Lean is now commonly used in many areas beyond manufacturing and mass production including service industries, healthcare and education (lean universities) as well as lean government. Investigating the participants who answered “Lean is not relevant to my field” showed many (30%) were from engineering and manufacturing categories.

Other responses included “I am not required by my employer” (8%) showing passivity. Many responses indicated a lack of understanding of lean and its application and especially beyond manufacturing and mass production. And three had avoided lean because of others’ bad experiences. These are further indications of lack of knowledge, including misunderstandings that negatively impact lean success.

<sup>3</sup> This is the percentage of participants who gave this response. Percentages do not add up to 100% as some participants gave more than one reason.

**Fig. 5** Familiarity with lean of owner operators in manufacturing ( $n = 21$ )



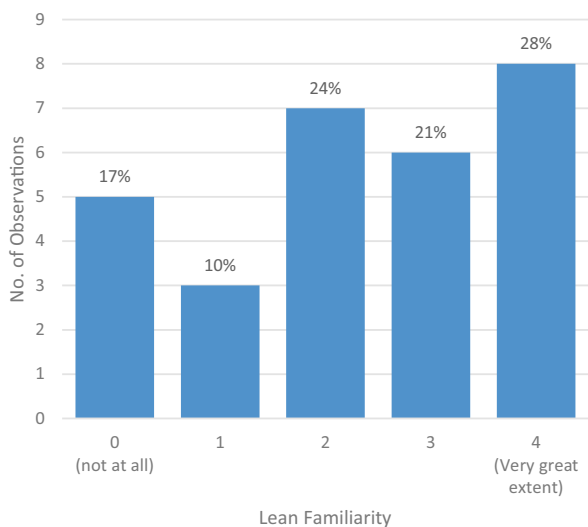
### 4.5 Self-Deception

It was apparent that many participants were deceived about their knowledge of lean. Assessment showed actual knowledge levels were clearly below what was reported. A striking indicator of self-deception was that 46% of the 74 participants who stated lean is not relevant to their field also reported they had no familiarity with lean. This was also evident where participants who reported to having great familiarity with lean actually had no knowledge of basic lean principles or methods (see Table 2).

### 4.6 Construct Analysis—Different Understandings

The principal analysis was the investigation of the different understandings of lean (Table 1). Exploratory factor analysis (EFA) was first used to identify the underlying

**Fig. 6** Familiarity with lean of middle management in manufacturing ( $n = 29$ )



**Table 2** To what extent would the following be relevant to your organisation? — responses of participants reporting Great Familiarity with lean

	<b>5 S System</b>	<b>Just in time</b>	<b>Pull systems</b>	<b>Total productive maintenance</b>	<b>Continuous improvement culture</b>	<b>Become a Lean learning organisation</b>
<b>No. of obs.</b>	78	79	77	79	77	79
<b>I don't know this</b>	10%	1%	12%	5%	0%	0%
<b>Not at all</b>	5%	23%	12%	20%	0%	4%
<b>Small extent</b>	14%	14%	12%	11%	1%	11%
<b>Moderate extent</b>	9%	14%	21%	18%	8%	15%
<b>Great extent</b>	32%	25%	27%	27%	40%	34%
<b>Very great extent</b>	29%	23%	17%	19%	51%	35%

A normal amount of variance was observed across this subset of participant responses

constructs and in effect reduce dimensionality [61, 62], statistically grouping the measured variables into common constructs. An orthogonal approach to EFA was confirmed appropriate after trialling oblique rotations uncovered no special insights [61]. Initially, an r-matrix (correlation matrix) was produced and no variables were found correlating 'too high' for inclusion i.e.  $r > 0.8$  or  $p < 0.05$  [92]. For this initial EFA, Varimax, arguably the best and most common orthogonal rotation [61, 99] was utilised. Three factors were extracted based on scree plot examination [62, 92, 100]. The two main factors were factor 1 which showed a more holistic view of lean and factor 2 showing the view of lean as tools and processes, the repacking of old methods. Factor 3 referred primarily to the knowledge of lean. Variables loading both factors 1 and 2 (i.e. being non-discriminant) gave good insight to the different understandings or definitions of lean. V051 Tools or processes and V056 New Systems/Way were found highly cross loading and implicated in both constructs/understandings of lean. Other factors cross loaded but were all typically less than 0.19 (not impactful).

Table 3 shows the resultant factors extracted following iterations for adequacy and construct validity. This final iteration showed the same constructs (factors) held through to an adequately discriminant solution. The key variables of the study such as V033: *To what extent are you familiar with the following? [Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)]*, V043: *To what extent have you implemented the following? [Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)]* and particularly V062: *To what extent does Lean provide a competitive advantage?* were shown to have a cross loading, indicating relationships between the constructs that were not adequately understood. V062 was not strongly loading in any factor and mildly increased the cross loading of other factors, but is included in the analysis table due to its importance and reference in the following structural equation modelling (SEM) which addressed the factor relationships. The three factors extracted explained 52% of the variance in the data. This is borderline, but adequate [92], particularly considering this is primarily an exploratory analysis used to unveil the key underlying constructs as particularly represented by factors 1 and 2.

**Table 3** Exploratory factor analysis—factor loadings by varimax raw extraction: principal axis factoring (bold loadings are > 0.3 and loadings < 0.18 were removed). Analysis included 264 cases after case wise deletion of missing data (explained variance 52%)

	<i>Factor (1)</i>	<i>Factor (2)</i>	<i>Factor (3)</i>
V043 Lean Impl. Exp.	0.21		<b>0.83</b>
V033 Lean Familiarity	0.26		<b>0.83</b>
V062 Comp. Advantage	<b>0.36</b>		<b>0.31</b>
V054 Train and Empower	<b>0.77</b>		0.28
V057 Respecting People	<b>0.72</b>		0.29
V058 Philos./Strategy	<b>0.71</b>		
V059 Needs regularity and focus	<b>0.58</b>		0.29
V053 Waste Elimin	<b>0.55</b>		
V052 Process Eng..		−0.70	
V060 New label Indus. Eng.		<b>−0.81</b>	
V050 Repacking of JIT/Qual. Sys		<b>−0.54</b>	
Explained variance	2.5	1.47	1.79
Proportion of total	0.23	0.13	0.16
Description Assigned	1. Holistic lean	2. Lean is tools & a repackaging of methods	3. Knowledge

#### 4.7 Construct Relationships—Structural Equation Model

Structural equation modelling (PLS-SEM) was used to investigate relationships between lean knowledge and the perceived competitive advantage of lean. EFA identified the constructs but not specific relationships between them. From the identified discrete constructs, and supported with the logic from literature, a hypothetical model for the relationships between the constructs could be built. There was specific interest in the mediation of advantages by the different understandings of lean:

- The holistic view of lean (factor 1) was expected to support the advantages of lean, achieving a learning organisation [14, 85].
- Knowledge (factor 3) was expected to indirectly affect the advantages perceived, developing the holistic view. This is in line with the knowledge-based view [101, 102] and the proposal for deliberate learning [103].
- The alternate view of lean as merely tools and processes (factor 2) was believed to be unsatisfactory [7, 32] not providing advantage but rather being detrimental in the long term.

The latent constructs for SEM, as established from the above theory and consolidated by the EFA are recorded in Table 4.

Lean knowledge is represented by participants' familiarity and experience. The construct Holistic Lean included the remaining indicators of factor 1. These all reference a holistic view of lean. *V059 Needs regularity and focus* could have arguable remained there but was removed as tended towards the actual application more than the understanding of lean. The Tools/Repack construct was extracted from factor

**Table 4** Construct indicators for SEM of lean understanding

Lean knowledge	Holistic lean
V033 Familiarity with lean	V054 Train and Empower
V043 Experience with lean implementation	V057 Respecting people
	V058 Philosophy/strategy
	V053 Waste elimination
Tools/repack	Perceived advantage
V052 process engineering	V062 Comp. advantage
V060 New label for industrial eng.	
V050 Repacking of JIT/Quality sys.	

2. Perceived Advantage was not a developed construct but was represented by one indicator (V062 - to what extent lean was considered a competitive advantage), which for the purposes of this exploratory analysis was considered adequate.

### 4.8 Hypothesis Model

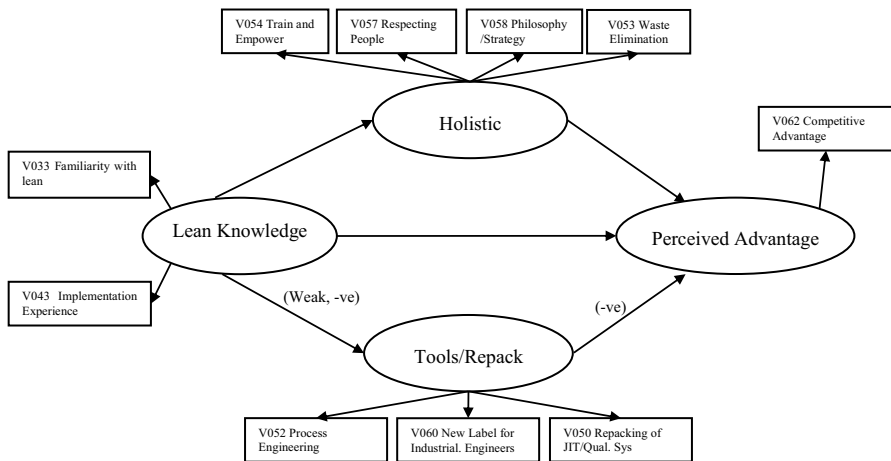
A hypothetical model (Fig. 7) was developed to test the relationship between the above identified constructs of lean knowledge and its perceived advantages.

The model can be described by three hypotheses that it tests:

H1: The positive effect of lean *Knowledge* on the *Perceived Advantage* of lean is mediated by the *Holistic* view of lean.

H2: The view of lean as tools and repackaging of other methods, *Tools/Repack* has a negative relationship with *Perceived Advantage* of lean.

H3: The view of lean as tools and repackaging of other methods, *Tools/Repack* has a weak negative relationship with lean *Knowledge*.



**Fig. 7** Hypothesis path model for the impact of lean knowledge on understanding and perceived advantage



The models were run using the path weighting scheme [104]. Incomplete cases were removed from the analysis resulting in 193 cases being included. A minimum of 30 samples is recommended for this model by the 10 times paths rule [60] indicating the data set of 193 is substantial and supports consistency at large. Cross comparison with a sample of 90% complete data [105] showed negligible differences. SEM outputs were tested to determine model quality. Specific assessment was for loadings in the outer (measurement) model, construct reliability, convergent validity, discriminant validity, inner model path coefficients (size and significance) and variance explained by target endogenous variables.

## 4.9 Model Validation

### 4.9.1 Validation of Outer Model Quality

Loading of measurements on latent variables were all 0.64 or greater (Table 5). A basic standard for indicator validity is  $>0.7$  although indicator loadings as low as 0.6 are considered acceptable in exploratory research [60].

Traditional reliability assessment is Cronbach Alpha  $>0.7$  [106]. PLS is able to compute the more advanced composite reliability which allows for differences in factor loadings [107]. For exploratory research, composite reliability greater than 0.6–0.7 is recommended and greater than 0.7–0.9 is recommended for more advanced theory testing [60]. For convergent validity, average variance explained (AVE) should be greater than 50% i.e. 0.5 [108]. This means *the latent variable is able to explain more than half of the variance of its indicators on average* [107]. See others also [105, 109]. These criteria are comfortably met for the model in discussion, see Table 6.

Discriminant validity implies there are significant differences between each construct i.e. the constructs are discriminant [107]. Fornell–Larcker criterion [108] has been called the best method for assessing of discriminant validity [110, 111]. Fornell–Larcker criterion is commonly represented as the square root of the AVE for a latent variable being greater than any loadings between it and the other latent

**Table 5** Outer (measurement) model indicator loadings on constructs

	Holistic	Knowledge	Perceived advantage	Tools/Repack
V050 Repacking Of JIT/Qual. Sys				0.79
V052 Process Engineering				0.82
V060 New Label For Industrial Eng.				0.72
V053 Waste Elimination	0.64			
V054 Train And Empower	0.82			
V057 Respecting People	0.64			
V058 Philosophy/Strategy	0.70			
V062 Competitive Advantage			1.09	
V033 Lean Familiarity		0.89		
V043 Lean Implementation		0.64		

**Table 6** AVE, composite reliability and discriminant validity by Fornell–Larcker criterion (Fornell and Larcker 1981) for SEM of lean knowledge

	AVE	Composite reliability	Holistic	Knowledge	Perceived advantage	Tools/repack
<i>Significance criteria</i>	> 0.5	> 0.6	Fornell–Larcker criterion, $\sqrt{(AVE)} >$ factor loading, Bold = $\sqrt{(AVE)}$ , plain text = factor loadings			
<b>Holistic</b>	0.64	0.88	<b>0.80</b>			
<b>Knowledge</b>	0.87	0.93	0.49	<b>0.93</b>		
<b>Perceived Advantage</b>	1.00	1.00	0.43	0.41	<b>1.00</b>	
<b>Tools/Repack</b>	0.62	0.83	0.00	−0.17	−0.15	<b>0.79</b>

variables [107, 111]. Confirmation of discriminant validity by this criterion is seen in Table 6. An alternative check is that the indicator loads on its construct are higher than on all other constructs [60, 107] as seen in Table 7. Although additional validity methods have become available [112] the above methods are widely accepted and deemed more than adequate for this case.

Significance of paths was tested by bootstrapping to 5000 iterations [60], although 500 iterations [113] converged to near identical solution. The individual sign changes option was used to diminish the risk of reduced *t*-value due to an arbitrary sign change during bootstrapping analysis as recommended [107]. Significance levels or criteria by *t*-values are 1.65 for 10% ( $\alpha=0.1$ ), 1.96 for 5% ( $\alpha=0.05$ ) and 2.58 for 1% ( $\alpha=0.01$ ) for this sufficiently large sample (degrees of freedom greater than 30). All measurement model paths showed high significance. The indicator paths Tools/Repack were the weakest in the outer model but still highly significant *t*-values from 4.3 to 5.8, much greater than 2.58 ( $\alpha=0.01$ ).

### 4.9.2 Validation of Inner Model Quality

Inner model paths between latent variables for Knowledge  $\geq$  Holistic  $\geq$  Perceived Advantage and Knowledge  $\geq$  Perceived Advantage were strongly significant,  $p > 0.01$  (bootstrapped).

**Table 7** Cross loading matrix for review of discriminant validity

	Holistic	Knowledge	Perceived Advantage	Tools/Repack
<b>V050 Repacking of JIT/Qual. Sys</b>	−0.01	−0.04	−0.18	0.72
<b>V052 Process Eng.</b>	−0.02	−0.22	−0.11	0.89
<b>V053 Waste Elimination</b>	0.68	0.29	0.24	0.05
<b>V054 Train and Empower</b>	0.90	0.47	0.44	−0.03
<b>V057 Respecting People</b>	0.85	0.45	0.34	−0.01
<b>V058 Philosophy./Strategy</b>	0.77	0.33	0.34	0.00
<b>V060 New label Industrial Eng.</b>	0.05	−0.08	−0.04	0.75
<b>V062 Competitive Advantage</b>	0.43	0.41	1.00	−0.15
<b>V033 Lean Familiarity</b>	0.46	0.94	0.39	−0.19
<b>V043 Lean Implementation</b>	0.46	0.93	0.37	−0.12

The significance level of  $\text{Knowledge} \geq \text{Tool/Repack}$  was exactly  $p=0.01$ . Allowing for individual sign changes gave the highest significance value for  $\text{Tool/Repack} \geq \text{Perceived Advantage}$ ,  $t=1.5$ , not meeting the lowest  $\alpha$  significance level, 0.1.

The variance explained ( $R^2$ ) are categorised as substantial, moderate and weak. One scale is 0.67, 0.33 and 0.19 [107, 114] and a similar alternative 0.75, 0.50 or 0.25 [market research 60]. Moderate values are deemed acceptable if only a few latent variables are exogenous. If several latent variables are acting, substantial values are suggested [107]. This criterion is dependent on context, e.g. in consumer behaviour 0.2 is considered high [60]. That said, a minimum of 0.1 is a reasonable guideline [113, 115].

The model here is exploratory, has early stage constructs and one variable acting endogenously. The  $R^2$  values of 0.24 for holistic and 0.25 for perceived advantage could be taken as moderate if not substantial i.e. 0.2 = high in consumer behaviour [104]. Tools/Repack however was very weak at  $R^2=0.03$  i.e.  $<0.1$  [113]. A goodness of fit (GoF) of 0.35 was achieved for the model. The minimum GoF recommended is 0.31 [113, 116]. But strictly, GoF needs to be interpreted with the support of other tests [117]. Ultimately, the effects through Tools/Repack were small but beneficial to be left in the model for discussion. See Table 8 and Fig. 8.

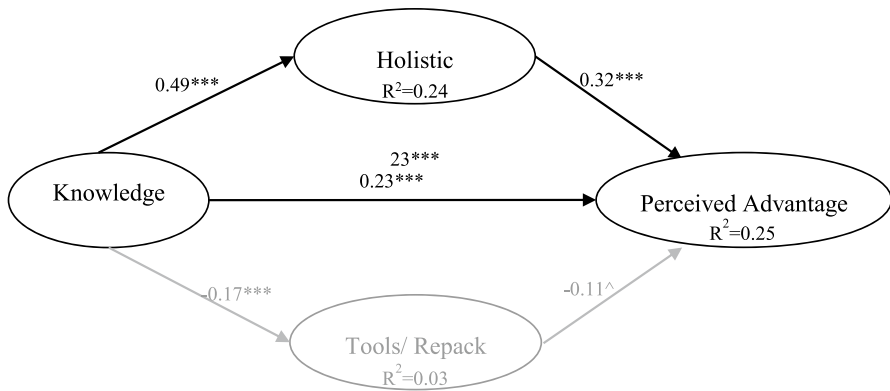
#### 4.10 Addressing Endogeneity

Problem of endogeneity occurs where a predictor variable correlates with dependent variables error term [118]. Common causes of endogeneity include omitted variables, omitted selection, common-method variance, simultaneity and measurement error. A comprehensive approach to addressing endogeneity in PLS-SEM has been developed [70, 119, 120]. As this research is explanatory and prior research had not ruled out the possibility of endogeneity, it needed to be addressed. An instrumental variable-free approach using Gaussian copula [70, 119] was followed using the R Code provided by Hult et al. [70] incorporating R Package REndo [121] with Boot [122] for bootstrapping. The correlation between the error term and the endogenous independent construct in the regression model is controlled for by the copula as an additional independent variable.

The Gaussian Copula approach assumes the variables in question are non-normally distributed. Standardised latent variable scores for the constructs were extracted from Smart PLS [67]. Kolmogorov–Smirnov test with Lilliefors correction [70, 123] were run using R Package KScorect [124] and showed that none of these scores were normally distributed (Table 9).

**Table 8**  $R^2$ , communality and goodness of fit for the impact of lean knowledge on its understanding and perceived advantage

	$R^2$	Communality
<b>Holistic</b>	0.24	0.64
<b>Knowledge</b>		0.87
<b>Perceived Advantage</b>	0.25	N/A (single item)
<b>Tools/Repack</b>	0.03	0.62
<b>Average</b>	0.17	0.71



$\alpha$  levels: \*\*\* = 0.01, \*\* = 0.05, \* = 0.1, ^ = Not Significant  
 $\alpha$  levels are the significance levels (p) achieved in testing paths.  $R^2$ =variance explained in that variable by exogenous (preceding) latent variables. Path coefficients are analogous to regression beta values i.e.  $y=\beta x+\epsilon$

**Fig. 8** Structural model for the impact of lean knowledge on understanding and advantage.  $R^2$  is variance explained by incoming paths

Table 10 shows the results of the Gaussian copulas where copulas are denoted “C” for example  $C_{Holistic}$  is the copula for the Holistic construct. The copula coefficients were not significant that is there is no critical endogeneity issues affecting the regression results.

#### 4.10.1 Resultant Structural Model

The resultant structural model is shown in Fig. 8. The path Knowledge  $\geq$  Perceived Advantage has  $\beta=0.23$ . Stronger  $\beta$  are observed by the moderating effect. Knowledge  $\geq$  Holistic,  $\beta=0.49$  and Holistic  $\geq$  Perceived Advantage,  $\beta=0.32$ .<sup>4</sup> All are significant to  $\alpha=0.01$ . This supports H1.

**Accept H1** The positive effect of lean *Knowledge* on the *Perceived Advantage* of lean is mediated by the Holistic view of lean.

A small negative relationship  $\beta = -0.11$  was observed between Tools/repack and perceived advantage of lean. This relationship was insignificant. The constructs are not fully developed but the data set is reasonably large and all other paths converged to high  $\alpha$  of 0.01. Lack of consistency at large is not likely to be a factor and if so, the relationship ( $\beta$  value) would still be weak. Therefore, H2 is rejected.

**Reject H2** The view of lean as tools and repackaging of other methods, *Tools/Repack* has a negative relationship with *Perceived Advantage* of lean.

<sup>4</sup> Relationships between the competitive advantage construct and other factors would have been stronger if different question terminology or additional scale items were used, e.g. some considered lean as being essential for their industry, a necessity rather than a competitive advantage.

**Table 9** Kolmogorov–Smirnov test with Lilliefors correction for latent variable scores

	<i>p</i>
<b>Holistic</b>	0.0004
<b>Knowledge</b>	0.0004
<b>Perceived Advantage</b>	0.0002
<b>Tools/Repack</b>	0.0004

No relationship was found between the tools/repack view of lean and perceived advantage, i.e. negative or positive.

A negative relationship  $\beta = \geq 0.17$  was observed between the tools/repack view and knowledge. Although weak, the relationship was significant to  $\alpha$  of 0.01 exactly ( $t$ -value = 2.6).

**Accept H3** The view of lean as tools and repackaging of other methods, *tools/repack* has a weak negative relationship with lean *knowledge*.

The weakness of this relationship was highlighted by a small  $R^2$  (0.03). Although goodness of fit for the model was acceptable, only 3% of the variance of tools/repack was explained by lean Knowledge. For this reason, tools/repack has been displayed grey in the model (Fig. 8). Other exogenous factors influencing the tools/repack construct are unknown and need further investigation. A trial was conducted using a work experience categorical variable as a pseudo 5-point Likert scale. This was to investigate both work experience and by inference age but showed no significant relationship. Further investigation is required.

The holistic understanding of lean correlates with lean being a competitive advantage and develops with knowledge i.e. mediating between knowledge and perceived advantage. The view of lean as tools and repackaging of other methods did not correlate to perceived advantage. Its relationship with knowledge, although statistically significant was negative and weak describing insignificant variance.

These results could be extrapolated to the outcomes of lean implementation. That is the way lean is understood has significant effect on the outcomes as represented by the advantages perceived.

#### 4.11 Two Definitions of Lean

To better understand and communicate the findings, two definitions (understandings or views) of lean were extracted from the data. The factor analysis showed that as knowledge develops a different understanding of lean develops towards a holistic view. A secondary construct, lean as tools processes and repacking of old methods (Tools/Repack) was also present in the data set but it was in an alternate plane. It was determined that:

- Two definitions for lean were expected, one at low knowledge and one at high.
- The construct Tools/repack describes an alternative view.
- Tools/repack does not expressly describe the understanding at low levels of lean knowledge.

**Table 10** Results of the Gaussian copulas showing no critical endogeneity issues

	Model 1 (endogenous variable: holistic)		Model 2 (endogenous variable: knowledge)		Model 3 (endogenous variable: tools/ repack)		Model 4 (endogenous variable: holistic, knowledge)		Model 5 (Endogenous variable: Holistic, Tools/Repack)		Model 6 (Endogenous variable: Knowledge, Tools/Repack)		Model 7 (All variables endogenous)	
	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p
<b>Holistic</b>	0.3581	0.001	0.3191	0.0001	0.3175	0.0001	0.3557	0.0014	0.3722	0.0006	0.315	0	0.369	0.0007
<b>Knowledge</b>	0.2324	0.003	0.2531	0.0274	0.233	0.0032	0.2464	0.0382	0.2322	0.0034	0.271	0.0331	0.27	0.0346
<b>Tools/repack</b>	-0.1051	0.119	-0.1060	0.1143	-0.1801	0.4417	-0.1058	0.1207	-0.2386	0.3254	-0.2170	0.41	-0.2750	0.3053
$C_{Holistic}$	-0.0241	0.6201					-0.0229	0.6477	-0.0356	0.4779			-0.0355	0.4833
$C_{Knowledge}$			-0.0111	0.8061			-0.0077	0.8703			-0.2090	0.693	-0.0208	0.6944
$C_{Tools/Repack}$					0.0888	0.7434			0.158	0.5724	0.131	0.672	0.1994	0.5236

- In order to define the different understanding by knowledge level, an alternative approach was needed.

The alternative approach involved considering not just the main construct. Linear investigation considering all the *lean understanding* variables was required and undertaken with ANOVA. Four variables were removed from consideration. V052 (process engineering) and V060 (new label for industrial engineering) were removed because they were weighted towards a job description of who implemented lean rather than the understanding of lean itself. Additionally, less than 13% of participants associated these highly with Lean. V055 (lean is fragile) was removed as it represented an obscure concept recognised by only a few practitioners. It is no surprise that V055 had dropped out in the EFA. V050 (repackaging of JIT/quality systems) showed weak effects ( $F [1,305]=8.8, p=0.0032$ ) but only 7% of participants associated V050 with lean to a high extent (39% not at all, 57% to low extent), it clearly did not contribute to the lean definitions. The lean definitions' phrases were then formed by modifying the text of each variable question. This was a subjective interpretation but one based on the mean magnitude of responses. Table 11 shows mean Likert values by knowledge level i.e. low and high familiarity with lean. The ANOVA shows the effect size ( $F$ ) and significance ( $p$ ).

It was determined that to form part of the definition a Likert value should tend towards highly related to the understanding. Therefore, any variable with a Likert not in the order of 2.5 or higher was to be discarded. The only exception was V056 new systems and ways in the low knowledge definition, which was borderline for rejection, being 2.4 and reasonably included. Which variables formed the major differences between views was confirmed by the most significant ANOVA effects. Variables that showed little difference (small statistical effects) between knowledge levels formed the baseline view of lean associated with low knowledge levels. The baseline understanding included lean as waste elimination, new systems and ways of doing things and needs a level of regularity and focus for sustained success. It also impacts business strategy and philosophy. This view was termed the baseline as the holistic factors are added to it in order to form the higher view of lean.

For those of lower knowledge, lean was defined:

- Lean impacts the business strategy and philosophy; it involves waste elimination and includes new systems and ways of doing things for improving productivity. It needs regularity and focus (consistency) for sustained success.
- The higher, holistic understanding of lean is much more emphatic describing definitely what lean is and has; it was:
- Lean is a business strategy and philosophy. It focuses on waste elimination but with a high level of respect for people. This is seen in a very strong focus on worker training and empowerment to solve problems. It incorporates new systems and ways of doing things and also has tools and processes for productivity improvement. It needs a great level of regularity and focus, a consistent effort, for sustained success.

This second definition is considered as a higher and holistic view because it presents lean as a philosophy and strategy that encompasses all of an organisation.

**Table 11** The systematic formation of the two definitions of lean

Variable	Low knowledge (low familiarity)		ANOVA (low to high)		High knowledge (high familiarity)		
	Likert mean	Interpretation	dF	F	Likert mean	Interpretation	
Philos./Strategy (V058)	2.6	Lean ... Impacts the business strategy and philosophy,	353	33.9	0	3.3	Lean ... Is a business strategy and philosophy.
Waste Elimin (V053)	2.5	It involves waste elimination and	363	51.2	0	3.3	It focuses on waste elimination but with
Respecting People (V057)	1.8	(~ Moderate - not significant for this variable to be included)	331	54.4	0	2.9	A high level of respect for people.
Train & Empower (V054)	2.3	(~ Moderate - not significant for this variable to be included)	356	80.7	0	3.3	A very strong focus on worker training and empowerment to solve problems.
New Systems/Ways (V056)	2.4	includes new systems and ways of doing things for improving productivity	361	12.5	0.0005	2.8	It incorporates new systems and ways of doing things for improving productivity
Tools, processes (V051)	2.3	(~ Moderate - not significant for this variable to be included)	359	8.7	0.0033	2.7	It also has tools and processes for productivity improvement.
Needs regularity and focus (V059)	2.7	It needs regularity and focus (consistency) for sustained success	346	56.6	0	3.5	It needs a very great amount of regularity and focus, a consistent effort, for sustained success
Competitive Advantage (V062)	2.5	Provides some competitive advantages	356	42	0	3.1	Provides a great competitive advantage

Likert values: 0 = not at all, 4 = very great extent; ANOVA typical form  $F(df \text{ effect}, df \text{ Error}) = F; p < 0.05$  is significant. 'df error' is indicative of total "sample" size for compared groups (n-2 in this case)



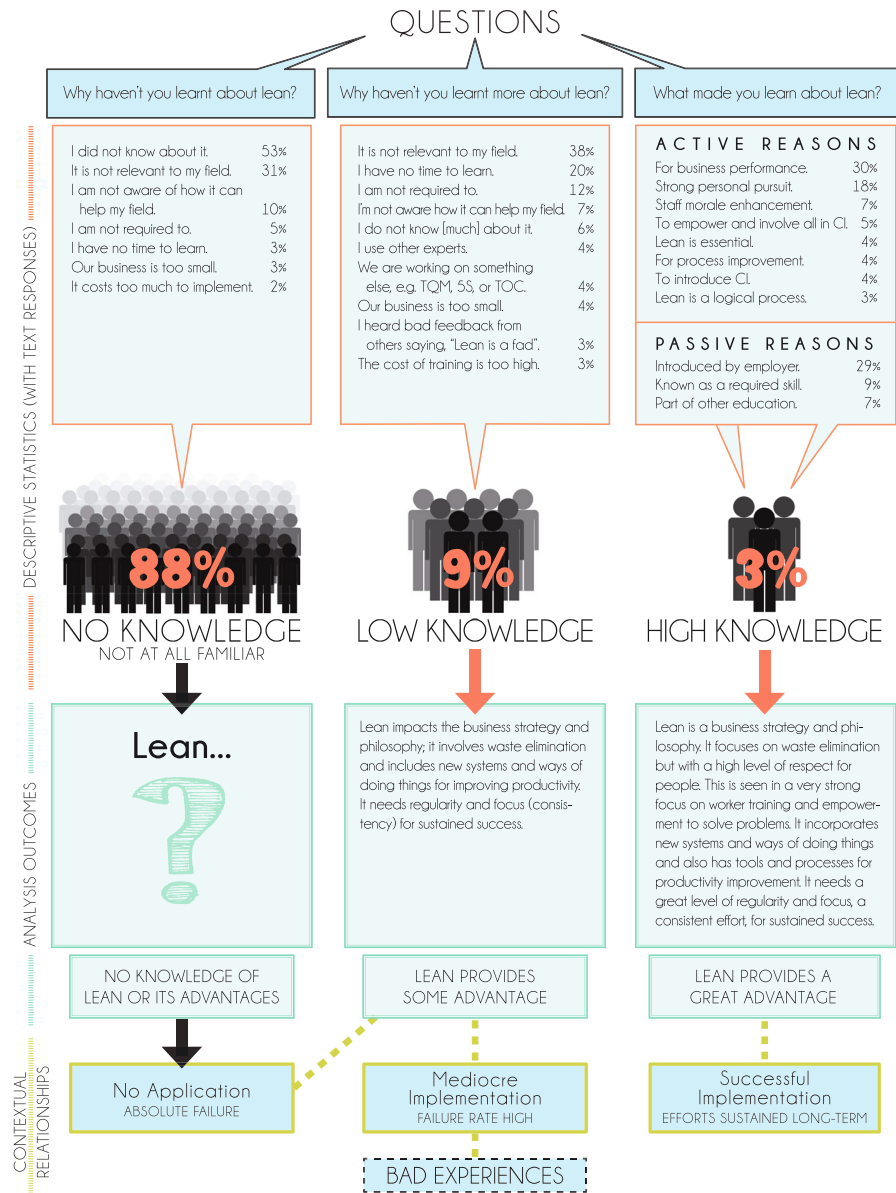
Two concepts that could have also been included in the understanding lean questions were (1) value creation, instead of just waste elimination, and (2) becoming a learning organisation. Whether value creation should have been included more emphatically in the survey questions is debatable. Truly defining waste requires understanding the customer perspective of value to avoid mere cost reduction and minimisation of value. In a proper sense, waste elimination is relative to value and implies that it is understood. Four participant's text comments (of 123 comments on Lean's advantage and its implementation) did address value creation. These comments were "efficiency is relative to current state and there comes a point when improvement actually diminishes eventual value", "understand the end-to-end value for the customer", "lean creates a value stream and focuses on the customer" and "Do the easiest first. Find something of value that will definitely work". The frequency of these comments being low seems to indicate that this was not missing in the definition formed i.e. the common understanding of lean and the survey adequately covered the key concepts. It was the researchers' view that waste elimination implies value and is implicit in the above definition. Future research could confirm this, investigating the understanding of lean as focusing on value creation as opposed to purely waste elimination, to see how much this concept has infiltrated at the practitioner level. Adding the matter of a becoming a learning organisation and its various facets into the "understanding lean" questions could have also expanded further the definition of holistic lean and the way in which continuous improvement is achieved although participants did not bring this into their comments. Learning cycles were mentioned in one comment but not learning organisations. Further research could consider this.

## 5 Discussion

The different understandings of lean were analysed towards addressing leadership knowledge as a success factor for lean management. Although this analysis did not expressly address different levels of leadership, inference can be made to the effect of knowledge on leaders' understanding and their achieving lean's advantages. In some variables, differences in opinion were only small, e.g. very great extent of compared with great extent of. However even these small differences in opinion will alter choices, adjust priorities and have a significant bearing on success.

### 5.1 Framework Interpretation Graphic

The results were combined for a systematic interpretation of the data in Fig. 9. Model of lean knowledge, a systematic interpretation of the data, which presents the differences by knowledge level, starting with the influences on lean knowledge. A total of 88% of people had no knowledge of lean. Their reasons for not pursuing lean knowledge include simply not knowing about it (53%) and not being aware how it can help (10%). These are logical responses. More surprising is the 31% who said lean was not relevant to their field, even though they indicated being not familiar with lean (46%



**Fig. 9** Model of lean knowledge, a systematic interpretation of the data. The framework shows the influences on lean knowledge, the different understandings of lean and the relationship with success. Cross References: Sect. 4.3 Influences on knowledge; Fig. 2 for knowledge levels of lean; and Table 11 for the formation for lean definitions

of all who commented lean was not relevant). This implies self-deception. This 88% who do not know about lean, are totally unaware of its advantages and therefore would never apply lean i.e. an absolute failure to receive the benefits of a lean system.

Persons of low lean knowledge made up 9% of the general population or 75% of those with lean knowledge. Although they knew about lean, 38% felt it was not relevant to their field. They typically define lean as tools and processes, new systems and ways for productivity improvement. They do not see the more holistic side of lean and only associate it with some, moderate benefits. If they apply lean, it is likely to be with mixed levels of success. Participants in the low knowledge category, who may think that they understand lean, are likely misguided without a proper and holistic view of true lean. This may be considered a generalisation but it is based on the significant correlations of lean familiarity with the variables for the understanding of lean. According to a poor definition of lean, lean would be applied in a misguided form. These implementations may be driven by a consultant and have a tools focus. The outcome may be initial success but ultimately failure to sustain is likely. Some may then seek improvement on their failed approach and in time shift towards the more balanced and holistic approach to lean [17]. Unfortunately, bad attitudes toward lean and other similar organisational changes develop [125]. An outcome is the thought that lean does not work and is just a fad, as came out in text responses.

In the high knowledge category, lean is viewed holistically. The focus is systems and ways for process improvement, but strongly taking lean as the business philosophy and strategy and respecting people, as well as strongly focusing on training and empowerment of employees. Lean provides great benefits in the eyes of these people i.e. a great competitive advantage. Their understanding is in line with the lean iceberg model and the development of a learning organisation, one that is self-propelling [35]. A self-propelling or self-improving organisation has the advantages of a culture of ongoing improvement (supported by systems). This does more than sustain an initial improvement; it achieves continuous improvement with emergent change. Unfortunately, it is only a small 3% of the public or 25% of those with lean knowledge that were associated with this view. It is only this portion that sees the advantages, and by inference are in line to reap the true benefits of lean management.

In the high knowledge category, the active reasons for pursuing lean knowledge included seeking business performance gains (30%) and strong personal pursuit of excellence (18%). Alternatively and more passively, exposure from employment made up 29%, and 9% picked up lean merely as a required skill, without signs of passion or drive for improvement. Only 7% of these were introduced to lean through general education. Others sought after lean to provide staff morale, empowerment and continuous improvement (CI). Lean was seen as essential by 4% and as a logical process by 3%.

Potentially, the percentage given here for low knowledge could have been moderated up and percentages for high knowledge level down due to the identified error in self-report i.e. self-deception regarding level of knowledge. Forty-six percent of the 74 participants who stated lean is not relevant to their field also reported they had no familiarity with lean. Their response to relevance of lean had no basis according to their self-report. It is possible, they may have gleaned the tiniest amount of information on lean enabling a response, but not enough to assume a level of familiarity. The survey's title, *Knowledge Survey (Productivity Systems)*, and the questions asked, may have enticed the response "lean is not relevant". But it is believed many of these comments were made in an insular way, by participants who assume they know all there is to know regarding their field. Either way, this shows a significant

barrier to lean uptake. If this exists amongst those with no familiarity with lean, similar unfounded resistance is assumed to exist at other levels of knowledge. This again exhibits self-deception amongst participants.

Self-deception was also evident in participants who self-reported to having a great extent of familiarity with lean but had no knowledge of basic lean principles or methods (Table 2). A total of 19% of those reporting familiarity to a great extent describe that 5S, a highly popular tool and arguably relevant tool, was not at all relevant or only a small extent relevant to their business and 10% did not know of it at all, similarly and respectively for Just in Time (JIT) 37% and 1%, for pull systems 24% and 12% and total productive maintenance 31% and 5%. Although JIT may be difficult to know how to apply in certain low volume environments, it is very hard to believe that someone with a high familiarity with lean would not know of it and likewise for the other basic methodologies and their application. Additionally, and arguably more telling of self-deception, is that of these participants, 9% also felt continuous improvement was only small or moderately relevant to their organisation and to 4% becoming a lean learning organisation was considered not at all relevant and only small to moderately relevant to 25%. This presents a dilemma, although a leader may believe that a high level of understanding is crucial in implementing a change they may be self-deceived into thinking they have an adequate level of knowledge, when in fact they do not have knowledge of even basic matters.

Decision making is prone to error with self-deceived leaders. The implications of this to lean seem significant. One is not appreciating the benefits of lean and therefore not embarking on a lean implementation at all and therefore a failure to receive the benefits of lean. Another embarking on a substandard implementation that is prone to failure. And, although a leader may believe that a high level of understanding is crucial in implementing lean, they may be self-deceived into thinking they have the adequate knowledge, and their implementation would head for an event of poor change management. These bad experiences then affect employee impressions of lean, seemingly confirming lean as another fad and increasing their resistance to future change.

## 5.2 Implications

### 5.2.1 Knowledge Management

Exploratory factor analysis (EFA) identified the holistic view of lean; seeing lean not only as tools and processes for eliminating waste, but as a business philosophy and strategy involving training and empowerment with respect for people. Hypothesis H1 implied that increasing knowledge develops a different understanding of lean, a holistic view. And this understanding mediates between knowledge and the benefits of lean. By SEM there was a strong relationship observed between lean knowledge and the holistic view of lean ( $\beta=0.49$ ,  $p<0.01$ ,  $R^2=0.24$ ). There was also a significant relationship between the holistic view and perceived advantage ( $\beta=0.32$ ,  $p<0.01$ ) as well as a weaker direct relationship between lean knowledge and perceived advantage

( $\beta=0.23$ ). This outcome confirmed H1: The positive effect of *lean knowledge* on the *perceived advantage* of lean is mediated by the *holistic view* of lean.

The interpretation is that increasing lean knowledge develops a different understanding, the holistic view of lean. It is this understanding that mediates between lean knowledge and the perception of its benefits. The relationship between knowledge, understanding and perceived advantages is extrapolated to represent the outcomes of implementation (Fig. 9).

The research, showing that increasing lean knowledge develops a holistic understanding of lean which promotes sound leadership decisions, implicates the importance of deliberate learning [103], a *resource-based view* [126] in which the knowledge of an enterprise is seen as the preeminent resource [101], and similarly the general importance of knowledge management [127, 128]. The concepts of the learning organisation [129, 130] with double-loop learning [131] have been adopted in lean texts already [14, 36] in order to promote a collaborative learning environment [132]; management intervention for continuous learning [133] and for continuous improvement. But the matter of learning, especially among management, needed and still needs strengthening as to its importance and its direct link to implementation outcomes.

The view of lean as a repackaging of old methods was also observed and had weak negative correlations with lean knowledge. The weakness of the correlation indicates that it is not only practitioners with low levels of lean knowledge that have this understanding, but even some of those more familiar with lean also hold to this unhealthy view. This view brings with it a tools and processes approach, which is correlated with industrial engineering, and is associated with a top down management-centric implementation. These top down implementations are likely to be in more command-and-control mechanistic organisations, where leadership understand lean as a system but may miss the higher philosophical aspects that benefit the long term, developing people and achieving a learning organisation. It is healthier to have a holistic outlook, taking lean as a philosophy and a strategy in itself. Although lean systems utilise many methods [8] and these may take certain businesses to a certain level of improvement, their benefits are amplified by the way they are combined and integrated in a holistic lean business system. In this holistic application, lean may provide a significant competitive advantage beyond the popular methods and previous method focused attempts at decoding the Toyota Production System. This view of lean as repackaging old methods is akin to viewing lean as a fad. For the advancement of lean success, these negative perceptions need to be addressed.

In contrast to an overly tools based approach to lean, those with a bias to the softer side of lean management need to also be balanced. The importance of culture to success is emphasised in contemporary literature. Because of this, there was an expectation that the view of lean as tools and processes would have had a negative correlation with lean knowledge. Respondents did not reflect this. Rather, lean as *tools and processes* was moderate in both low and high knowledge levels of lean. The extent that lean was considered as tools and processes actually increased with lean familiarity ( $F[1,359]=8.7, p=0.0033$ ) and competitive advantage ( $F[1,327]=4.4, p=0.036$ ) being represented stronger in higher knowledge levels. Similar increases

were observed for lean as *new systems and ways*. This indicates although true lean has a focus on staff training and empowerment, which is important, the process side of it should not be neglected. There are still significant advantages in using the tools and processes of lean. There is clearly a balance to be found between focusing on tools, methods and systems versus developing the inherent human potential. Even the systems themselves should promote a culture of continuous improvement by supporting scientific thinking with lean behaviours. Although the tools and processes may have been deemed insufficient, lean practitioners need to be careful in taking an entirely soft-skills view of lean. As lean's more technical aspects are not sufficient in themselves, neither are the cultural aspects. These two sides are equally important and can work synergistically.

Showing that the perceptions of lean's advantages increased as knowledge and experience increased, indicates that lean is not merely a fad but provides a true advantage over traditional ways when it is properly understood. On one hand, with almost any effective managerial approach, the more experience one has in its application, the more proficient they are at achieving the desired results. On the other hand, if significant shortcomings existed in an approach like lean, knowledge and especially experience would decrease perceptions of lean's benefits by further highlighting shortcoming. However, it was clear that increased lean knowledge and experience did not decrease the perception of lean's effectiveness but the opposite. It rather indicated that the advantages that leaders may be struggling to achieve can be secured by developing a further and proper understanding of lean through increased knowledge and experience. This further indicated that lean is failing to deliver not because lean itself is flawed but because of the way it is understood and applied.

Because managers miss the holistic view of lean, they may delegate leadership inappropriately and expect lean to be led from lower levels without comprehending what a successful lean implementation entails. They, not recognising for themselves the gap in their knowledge, may also quickly hire consultants to perform lean process improvement and focus on a tools based approach to seek quick wins but neglect the development of a lean learning organisation. Practitioners do not realise that their approach has been the problem, not the lean methodology. The problem with lean is not that it has a weak methodology or is just another fad; rather the problem is that it is being misunderstood and misapplied. The real fad is for managers to embark on lean poorly, self-deceived that they know what true lean is.

### 5.2.2 In-Depth Knowledge for Risk Management

It is clear that lean is not only about maximising benefits by applying methods to improve processes, but it is also about mitigating the detriments of implementation [134]. There are risks of setting back progress and ultimately failing through poor leadership decisions. To mitigate these detriments and maximise the benefits, an in-depth knowledge is required. Risk management results in a decision analysis based on an accurate understanding of the forces at play. An adequate knowledge of true, holistic lean and up-to-date knowledge of the context is essential to maximise the

benefits and minimise the detriments with implementation. With lean, there will be significant situational challenges faced according to different business structures, existing cultures, product mixes, geographic locations and other situational specific factors. Lean leadership becomes a decision making process which demands continual gathering of knowledge within the context of the implementation that is continual learning and participation in the implementation.

### 5.3 Practitioner Implications

Those who perceived the greatest advantage from lean held a higher understanding of lean. Unfortunately, the majority viewed lean as systems and ways related to a set of tools and processes or even a regurgitation of old methods. Practitioners need to see that taking lean as a business philosophy and strategy provides benefits that can take an organisation further than the common technical systems, tools and processes approach. If practitioners see these benefits exist, firstly, they will be more likely to implement lean, and secondly they will tend to implement lean in a proper holistic way, that is more likely to succeed at reaping those benefits.

The typical managers' lethargic attitude towards learning needs to be broken down, along with the self-deception that "we know what lean is" and "lean is not relevant." To re-educate the first step may be to make it plain to leaders that there is a systemic deficiency in the way lean is understood. Although they may think they have a high level of understanding of what lean is, in all likelihood their knowledge and application is lacking. Managers need to recognise that there is a need for education or re-education on lean. There may be benefits to lean that they do not see. Despite of what they think, a holistic lean approach could be applied to improve their business activities or solve other problems in their field. The results indicated it is highly likely the majority of leaders do not really understand lean and therefore how it should be applied. But rather, they are self-deceived regarding their knowledge of lean. The gap in knowledge somehow needs to be bridged. Overcoming this self-deception is the challenge.

Finding an appropriate sensei to *get the knowledge* has long since been recommended [7]. The problem with this is if there is a detachment of management from the implementation leading to inappropriate delegation, without leadership adequately understanding lean. The use of consultants needs careful consideration and further research would also shed light on this area.

#### 5.3.1 Small Business and Owner Operator Economies

The familiarity of owner operators in manufacturing was skewed towards not at all familiar with lean systems (43%), this was a concerning yet expected distribution, representing a focus on getting the job done as opposed to learning and development.

The survey results indicate that New Zealand manufacturing is well behind the USA in lean knowledge. The lack of knowledge itself could be attributed to the prevalence of small business in New Zealand, with owners and managers time constrained

and focusing on the daily running of the business, more than the development of leadership and bringing in of new knowledge. This result would be relevant to countries of similar social, economic and geographic conditions. Findings from further investigation in these economies would help support similar economies and specifically small businesses worldwide. It is apparent that the smaller businesses need further support with education in lean systems as they have less resources to spend or expertise available in-house. Unfortunately, many would feel themselves sufficient (as indicated by text responses) but in doing so are self-deceived and miss their businesses true potential.

### 5.3.2 Education and Re-education for Lean Success

A persons' development of a holistic view of lean was associated with high familiarity and extensive experience. This needs to change. The holistic view is not especially complicated as a concept. Although internalising it and learning to apply it may take some time, a proper education can get someone moving in the right direction quickly and help them recognise what kind of approaches they should expect of an expert consultant or sensei that they might seek out to support their journey. A difficulty exists in that the critical mass in industry is moving the wrong way and what is needed is some to make a turn through a proper and well-rounded education. Government support through education would seem much more advantageous than merely funding of consultants as has been the case. There is the dire need for promotion of lean thinking and an overcoming of the lethargy and self-deception for the development of true lean capability within industry. The education of someone such that their awareness of holistic lean is well developed will be a solid step for them to begin their lean journey in the right direction.

Governing bodies should take the initiative to build lean into the education of professionals by including lean and related *systems thinking* in the standard curriculum. Although lean thinking has proven beneficial and considered essential for some businesses, it is not built into general education. Only 12% of the general population were familiar with lean. Of these, the majority (seen in the 75% with low knowledge) were associated with the tools and processes view of lean. Of those with a good level of lean knowledge, the study showed that personal drive or business needs motivated 68% to actively pursue lean knowledge, whereas only 29% noted introduction through employment, and less than 7% indicated exposure through general education. Although specialised lean training needs to be developed, there also needs to be general inclusion in other courses of study, especially where long term careers have a leadership function e.g. engineering, business and medical degrees. Rather than being merely taught the technical skills of their field, students should be brought to think critically about the way they work and how their role affects the whole organisation as an integrated system. That is, professionals should not only offer their field's skills and knowledge but also their continued improvement and productive application with the aid of lean systems thinking.



### 5.3.3 Practitioner Framework: A Learning Approach to Lean

In order to support practitioners a framework was developed. The graphical model constructed draws from the existing body of knowledge [17, 35, 37, 78, 82], particularly taking well established concepts from transformational lean change models [35, 78] and incorporating a time axis for emphasising ongoing leadership learning. The resultant framework interprets the findings of this research and provides an overview of the initial lean change process; giving practitioners a generalised approach to lean [135]. This approach is particularly relevant to SME managers with limited resources.

The model includes the two major sections of Preparedness and Enterprise Deployment & Development. There is also a supporting line of Alignment with Consultants.

The emphasis of this research is on the preparedness aspect with the stress of on-going learning. The framework emphasises that the real lean journey can begin when leadership both desires and begins to develop a deeper understanding of lean and its application. Their pursuit of knowledge could include external training, support groups and an emphasis on self-study. After the initial period of learning, the development or adjustment of strategy with planning will become more significant, and as changes begin to be initiated (deployed) the on-going learning by doing becomes much more significant. The emphasis is still the active participation of management but the experiential learning will be more significant. The strategising and planning will also continue with regular review of progress. For this Plan Do Check Act cycles are emphasised.

Becoming lean is a transformational change that is a journey towards perfection [78], strictly speaking not an implementation that is done for a limited period of time only. However, practically there will be a time when the developing lean thinking will transition from affecting a small team, e.g. a group of managers or key employees planning, to affect the whole organisation in a significant way. This is the beginning of an enterprise wide deployment. While the enterprise deployment is not the focus of this research, it is needed to complete the framework for the sake of practitioners. In deployment, supporting a successful organisational change is argued to be the most important [14, 78]. Literature points to the importance of the process of on-going management communication [17, 40] which would be lead by management but become reciprocal. Presenting of the vision, motivating for change, making first steps clear, developing employee identity & behaviours, aligning employees with enterprise goals, supporting and empowering them in their initiative to make change, and producing small wins are all considered relevant in this first section of deployment [78]. It is advised that as the change progresses and gains momentum with employees being engaged, the improvement methods themselves could become more and more an emphasis, i.e. the tools, techniques and processes used by trained, engaged staff to improve performance. The change ultimately does not affect the organisation only but customers and suppliers also. Ideally, the feeling of a management centric deployment of lean should fade quickly as the organisation progresses into a stage of continual development lead from all levels. This has been referred to as becoming a kind of self-propelling lean learning organisation [35, 131, 133]. This

above approach with changing emphasis in deployment is depicted in the Enterprise Deployment & Development section of the framework.

Consultants are commonly relied upon for carrying out lean initiatives. Alignment with consultants is shown dashed at the bottom of this model. Remembering the emphasis on the learning of leadership, if a consultant is desired their selection must be carried out carefully. The long-term positive effects of a consultant would come through their coaching. The framework continues to stress the view of learning, emphasising the relationship with a consultant should be that of a coach or a sensei rather than a programme manager or an external expert or industrial engineer. It points to consultants providing a supporting presence, a consultant should help to maintain and establish the learning organisation [35, 133], but the implementation should not be driven solely by them but with the leaderships continual learning. The managers themselves need to show their commitment, gain staff trust and be able to make the right decisions in the context of their organisation [17].

#### 5.4 Further Work –Addressing Limitations

In principle, the analysis had an exploratory nature which provides many implications for further research. The sample was necessarily broad. Further samples could be more refined identifying important participant characteristics e.g. recipients who are managers active in a lean environment, and accessing specific qualitative and quantitative performance data. Such characteristic could be used as control variables. When building the questionnaires, relevant factors were contextualised from a narrative review of the literature. It is always possible that some aspects could be missed (omitted variables and problems of endogeneity), and a further systematic analysis of the literature could be warranted. However, results showed only a small amount (1%) of respondents felt restricted by the ordinal scale and no significant or new insights were identified by the free text responses, therefore justifying the approach by the data. Although the resultant structural models (PLS SEM) were sufficient, they were still of exploratory nature, with the number of indicators for constructs typically small (in one cases one). Further development of scales for lean knowledge would be advantageous. The questions were based on current contextual knowledge of lean. However, these factors need further study. In this study, perceived advantages were extrapolated to represent the outcomes of implementation, but the actual relationship between managers' knowledge and the outcomes require further experiment. The study also presents that the knowledge for successful implementation of lean does in fact exist. Further work by multiple case studies is recommended to investigate all the currently identified factors and more.

The study identified the need for increased practitioner knowledge and the common reason given for not seeking out new knowledge was not having enough time. This needs to be addressed in further work. Besides further clarifying critical success factors, the findings need to be readily accessible to practitioners at the forefront of the information available on lean. Practitioner models of findings from new

empirical research would be a step to address this including the further development of the framework in Fig.10.

Reasons for pursuing lean were captured. The responses categorised under employer introduction, other education and required skill, imply less passion or personal drive or knowledge seeking. The relationships between the way someone is introduced to lean and their resultant attitude to lean change could be investigated in future research along with what kind of approach to lean they were educated in.

The low level of lean knowledge in New Zealand versus the USA and other country comparison should be investigated further, and especially the characteristics that explain the observed effect in this and other regions of similar socio-economic conditions. The presence of more inhibitors of lean knowledge, less drivers for lean knowledge or specific national characteristics could explain the effect.

Most importantly, how to carry out the most effective lean education and re-education needs active research. This includes how to accomplish sufficient learning amongst leadership prior to their initial experience of implementation. While it is generally accepted that the real learning cannot happen without the doing or practical experience, there is still room to improve the success rate of first time implementations with prior education.

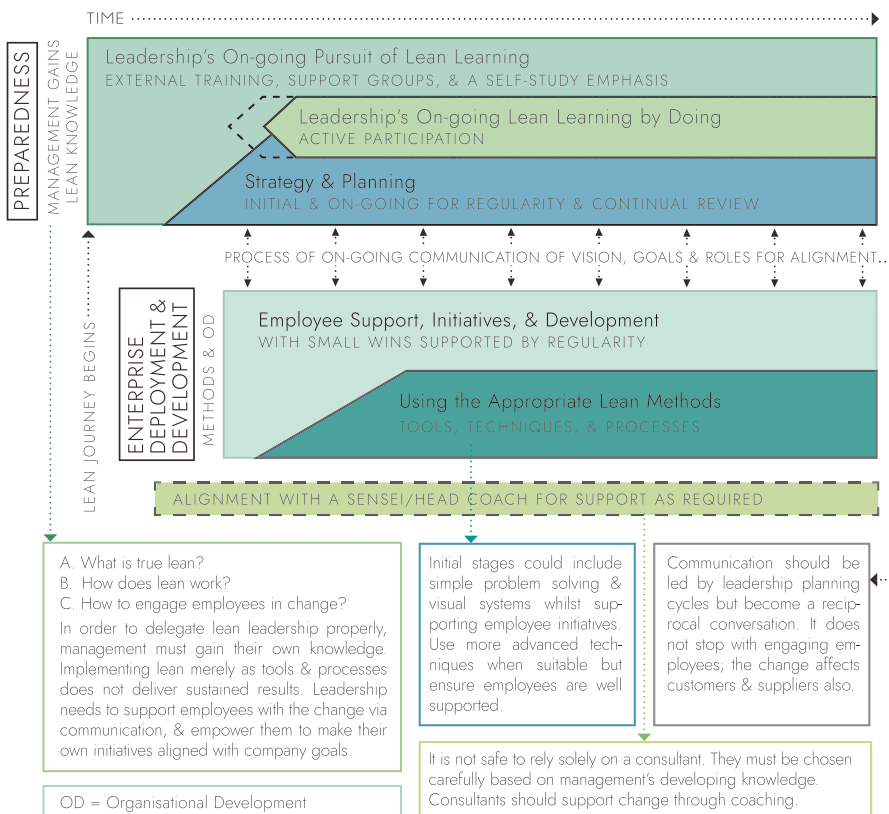


Fig. 10 A learning approach to lean. This model gives an overview of the initial change process

Business partnerships, support groups, internships and expert support (coaches) will aid in someone's necessary experiential learning but it is the researchers' view that an initial education is critical in starting a practitioner on the right path and especially enabling them to more effectively identify what of the various types of help will propel them forwards in holistic approach to lean for sustained continuous improvement.

## 6 Conclusion

The basic proposition was that the major success factor for lean is in the area of leadership knowledge and that fundamentally a different understanding or definition of lean exist amongst those of lower lean knowledge than higher. The literature on lean implementation and causality for success has been predominantly qualitative and contextual. This work took an empirical approach with a survey of 757 responses and statistical exploration including factor analysis and structural equation modelling (SEM) from questionnaire data. This enabled an analysis of both the public and practitioners' understanding of lean and the relationship between the understanding and their perception of its advantages. The results identify how a manager's cognitive construct of lean can affect the success of the implementation. An understanding of the relationship between lean knowledge and lean success was developed and a framework incorporating statistical analysis was built to represent the insights (Fig. 9). Results indicated that lean provides a competitive advantage but is failing to deliver, not because lean itself is flawed but because of the way it is understood and applied.

Lean knowledge saturation was shown to be very low. 88% of the public were not at all familiar with lean. And of the remaining 12% with lean knowledge, only one quarter of these (3% of the public) indicated a high familiarity with lean. Even in the manufacturing sector knowledge of lean was low in 46% of participants. Logically persons who do not know about lean and are not aware of its benefits would never apply lean nor receive the benefits. The analysis also showed, of those familiar with lean, only the small number with high knowledge properly understand lean and are likely to succeed at gaining its benefits. Also many were considered self-deceived with, 46% of the 74 who said lean was not relevant to their field ironically at the same time affirmed they were not familiar with lean at all. Similarly, many that reported a great familiarity with lean yet later recorded they were not familiar with basic lean practices.

Those at a higher knowledge level of lean did not merely possess more knowledge but actually had a different definition of lean. The basic (low) definition correlated with those of low knowledge was "lean impacts the business strategy and philosophy; it involves waste elimination and includes new systems and ways of doing things for improving productivity. It needs some regularity and focus (consistency) for sustained success." At the high knowledge level, a higher much more holistic and definitive view of lean was described:

**Lean is a business strategy and philosophy. It focuses on waste elimination but with a high level of respect for people. This is seen in a very strong focus on worker training and empowerment to solve problems. It incorporates new systems and ways of doing things and also has tools and processes for productivity improvement. It needs a great level of regularity and focus, a solid consistent effort, for sustained success.**

This view also correlated with a greater perceived competitive advantage. By inference, the significant benefits of lean are not being realised because of the lack of understanding. A learning approach to lean implementation should be taken.

Development of the holistic view is currently associated with high familiarity and extensive experience. This needs to change. The holistic view (referred to as true or real lean) is not especially complicated as a concept and, although it requires some internalising and practice, it need not take a long time to learn at least conceptually. Unfortunately, the majority take lean purely from the systems, tools and process perspective. This inadequate tacit knowledge is proliferated through industry. There has been a critical mass of inadequate knowledge moving practitioners in the wrong direction. To the authors it is apparent that lean education needs further development and propagation. It is viewed that government support through education would be more advantageous than merely providing funding for consultants as it will enable practitioners to make better decisions from the start and more effectively identify what or who of the various types of help (partnerships, support groups, internships and consultants) will best guide them in a balanced experiential learning process. This area of education was identified as the most important point for future research.

Additionally, although culture has been emphasised in the current literature, the extent that lean was considered as tools and processes actually increased with lean familiarity ( $F[1, 359]=8.7, p=0.0033$ ) and competitive advantage ( $F[1,327]=4.4, p=0.036$ ). Similar increases were observed for lean as *new systems and ways*. True holistic lean has a focus on staff training and empowerment, which is important, but it is clear that the process side should not be neglected and both can work synergistically to develop a lean learning organisation.

In summary, this work contributed an advancement of the body of knowledge for lean organisational change. Lean is very valid and practitioners, particularly managers, need to re-think their definition. The problem with lean is not that it is a weak methodology but rather it is being misunderstood and misapplied. Business leaders are prone to embark on lean poorly, under improper guidance, self-deceived that they understand what true lean is. The main message of the framework (Fig. 9) was to illustrate the desperate situation and need for leaders to start their journey in the right direction by gaining an adequate base of knowledge of the holistic approach to lean. Results indicated lean provides a competitive advantage and is failing to deliver not because lean itself is flawed. The vast majority of people simply do not know about lean and therefore receive no benefit from it. And of the small number who do know about lean, the majority misunderstand and misapply it. The significant benefits of lean are simply not being realised because of the way lean is being understood and applied by leadership.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s43069-023-00198-4>.

**Author Contribution** All authors contributed to the development of the paper.

**Funding** Open Access funding enabled and organized by CAUL and its Member Institutions. This research was partly funded by the Ministry of Science and Innovation Education Funding of the New Zealand Government, and this is acknowledged and appreciated.

**Data Availability** Participants of this study did not agree for their data to be shared publicly. Reasonable requests related to the data that support the findings of this study can be made to the corresponding author.

**Code Availability** The software Smart PLS 2.0 [67] was used for SEM analysis and Statistica 11 [68] for ANOVA and EFA.

## Declarations

**Ethics Approval** HEC 2012/78/LR, Human Ethics Committee, University Of Canterbury.

**Consent to Participate** All participants consented for their responses to be used as part of this research study.

**Consent for Publication** The information sheets provided as part of the participant consent processes explicitly identified publication.

**Conflict of Interest** The authors declare no competing interests.

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## Authors and Affiliations

Antony Pearce<sup>1</sup>  · Dirk Pons<sup>1,2</sup>  · Thomas Neitzert<sup>3</sup> 

Antony Pearce  
antonypearce@leanapproach.co.uk

Thomas Neitzert  
thomas.neitzert@aut.ac.nz

<sup>1</sup> University of Canterbury, Christchurch, New Zealand

<sup>2</sup> Department of Mechanical Engineering, University of Canterbury, Private Bag 4800, Christchurch 8020, New Zealand

<sup>3</sup> Auckland University of Technology, 55 Wellesley Street East, Auckland Central, Auckland 1010, New Zealand