

An Instrument for Measuring the Degree of Lean Implementation in Manufacturing

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Despite lean thinking being a broadly accepted approach, there is still some confusion within present terminology regarding 'lean' and its issues. This paper presents the results of a research survey carried out within 72 medium and large-sized Slovenian manufacturing companies. The sample selection criteria adopted, together with the research items investigated, ensured a generic framework for our research. Eight crucial areas were identified based on a synthesis of 'lean' literature for assessing and measuring the degree of lean implementation within existing manufacturing systems: value concept and customers, value stream mapping (VSM), pull/kanban and flow, waste elimination, productive maintenance, just-in-time (JIT), employee involvement and the development of excellent suppliers (lean suppliers). Variables were constructed within these areas using Likert scales, and statistical validity and reliability analyses. For example, when measuring the developments of excellent suppliers the focus should be on three variables: on time deliveries, supplier relationships, and a skilled and loyal supplier. The results show that the developed variables can be important both for understanding 'lean' and measuring the degree of lean implementation within existing manufacturing systems.

Keywords: lean manufacturing, lean implementation, survey research, reliability, validity, new variable design

0 INTRODUCTION

According to available literature it could be said that lean concepts are on the agenda again [1] to [3], particularly because of high quality requirements, generally known as six sigma as launched in the Motorola company and later expanded in General Electric and world-wide that urge companies to focus their knowledge and activities on higher operational excellence.

Lean thinking [4] is broadly accepted as an approach linked to superior performance (excellence), and for its ability to provide competitive advantage. Despite its broad acceptance there is still some confusion within present terminology and a lack of common conceptual definitions regarding lean and its issues.

In 1996, the Slovenian economist Ursic [5] determined that 'Slovenian companies poorly understand and master those procedures, approaches, tools and methods that could enable greater competitiveness. In the following year the same author, together with his colleagues, published further research [6] exposing prevalent management methods within Slovenian companies' strategic management, benchmarking, such as the TQM, ISO 9000 and 20 Keys methods. What about 'lean' or 'six-sigma' or even 'lean six sigma' and 'design for six-sigma'? Knowledge about lean tools and techniques is available in university textbooks or can be acquired at several conferences and external education institutions that offer their services daily. But do companies practise

these methods? As there is no evidence about the presence of lean concepts within Slovenian companies the above questions were the basic motivators for the presented research.

The first reflections from the performed research were positive and showed the presence of lean concepts within Slovenian companies. Experiences with six-sigma were however rarer and mostly limited to companies with foreign ownership. Therefore further analyses were made for only those research aspects dealing with 'lean'. Based on a survey's research results, an attempt was made to address the confusion within present terminology that leads to certain difficulties when measuring the level of lean implementation.

In reviewing the literature, the following major issues important for 'lean' could be identified:

1. The definition of 'lean'. An attempt was made to review the more important aspects of 'lean' through existing definitions.
2. Tools and techniques. A short overview is presented of the essential tools and techniques for 'lean'.
3. Pull/kanban and flow. Managing flow is at the heart of 'lean', based on a pull-system and operationalised using kanban.
4. Waste elimination. The elimination of waste is central to lean approaches.
5. Employee involvement. Motivation, education and above all responsiveness are discussed as the conditions for being 'lean'.

6. Lean suppliers and lean design. The importance of external issues is examined.

This paper aims at clarifying these lean-areas and issues using a wider-range of items in respect to previous studies.

This instrument can be useful, simple, and precise for accessing and measuring the degrees of lean implementation within existing productive systems or in connection with new lean programmes.

1 LITERATURE REVIEW

Lean manufacturing goes back as far as 1978 when Ohno (1978) wrote his book on the Toyota Production System (TPS) in Japanese. It could be said that the 'lean' principles resulted from the broader community outside Japan, as a response to the mass-production system that was practised in most American and European companies after the Second World War. The first ideas of TPS were focused mainly on waste elimination through the simplification of manufacturing processes [7] to [8]. The basic idea of TPS is to produce the kind of units needed, at the time needed and in the quantities needed. These goals can be achieved through different concepts such as JIT, automation, flexible workforce, work standardisation, links between suppliers and customers, and many others.

1.1 The Definition of 'Lean'

Lean manufacturing was, for a long time, equated with JIT and thus it is difficult to make a clear distinction between lean and JIT. Similarly to its origin JIT lean aims to meet demand instantaneously, with perfect quality and no waste. Several authors have provided different interpretations of lean. Starting with Womack [9] lean manufacturing is defined as an integrated set of socio-technical practices aimed at eliminating waste along the whole value chain within and across companies. On the other hand, lean can also be seen from the practical perspective as a set of management practices, tools, or techniques for effective lean management [10] and [11].

1.2 Tools and Techniques

In general, lean manufacturing is described from two points of view, either from a philosophical perspective related to guiding principles and goals [4] and [10], or from the practical perspective as a set of management practices, tools, or techniques that can be observed directly [12].

1.3 Pull/Kanban and Flow

In the pull system, typical for lean manufacturing, the job is pulled to successive workstations instead of being pushed by its preceding workstation. In other words, in a pull system the material is only moved when the next stage requires it. The flow of parts throughout the production line can be controlled by kanban cards. The primary advantage of the pull system is the reduced inventory and therefore the associated cost of inventory reduction [13].

1.4 Waste Elimination

Identifying waste is the first step towards eliminating it. It could be said that waste is anything that does not directly add value to the final product or contribute to the product's transformation [14]. Toyota identified seven types of waste, which have been found to apply in many different types of operations – both service and production – and which form the core of lean philosophy: over-production, waiting time, transport, processing, inventory, motion, and defectives.

1.5 Employee Involvement

Various studies have concluded that without the total commitment of senior management, a company-wide project or change of programme could never succeed. Top management commitment with the active cooperation of all employees can be expounded as the more important success factor. As any change in operations usually presents a certain level of stress for employees, training about the roles of cooperation and preparedness for changes is the next essential element for success.

1.6 Lean suppliers and lean design

The main focus of lean enterprise is to reduce waste and simultaneously increase value to the customer. Nowadays the customer is a 'king' as he will buy only the products that satisfy his needs and wants [15]. As the production of a high percentage of value-added components during most manufacturing – and non-manufacturing organisations are outsourced, it is insufficient to be just the most efficient firm without having the most efficient network.

A collaborative relationship between organisations and suppliers should be established in order to reach this goal. The same concept should be used to establish lean design [16] to [18]. Two-way communication and cooperation from product design

to delivery to the end-user is essential for effective lean manufacturing.

2 PREVIOUSLY PERFORMED SURVEYS

In order to obtain a transparent set of issues (dimensions or variables) that must be practised for achieving effective lean manufacturing within a business unit, the results of previous studies were examined that dealt with the systematisation of 'lean'. Due to space limitation only those selected representative writings from the last two decades are briefly summarised below.

Karlsson and Ahlstrom [19] tried to assess those changes towards lean production. Following the ultimate goal of implementing lean production within an operational (increase productivity, enhance quality, shorten lead times, reduce cost etc.), they developed a model for operationalising the determinants of a lean production system (actions taken, the principles implemented, and the changes made to achieve the desired performance). The principles of 'lean' were presented through nine determinants as follows: elimination of waste, continuous improvement, zero defects, JIT, pull, multifunctional teams, decentralised responsibilities, integrated functions, and vertical information systems.

Through a multiple case-study approach Panizzolo [20] explored how the lean production model was adopted by 27 excellent firms operating throughout international markets. He defined six characteristic areas of a 'lean' company: process and equipment, manufacturing planning and control, human resources, product design, supplier relationships, and customer relationships.

Sanchez and Perez [21] developed and tested an integrated check-list for assessing manufacturing changes towards lean production. Within the lean production model they combined six groups of indicators from common basic lean production practices: elimination of zero-value activities, continuous improvement, multifunctional teams, JIT production and delivery, supplier integration, and a flexible information system.

Shah and Ward [12] tried to establish a distinction between the system and its components through a literature review from the earliest publications relating to the Toyota Production System to the more recent. They realised that many descriptions exist about lean production and its underlying components, with a few conceptual definitions. Following the results of an extended survey research was performed at 280 companies by developing ten distinct dimensions

of a lean system: supplier feedback, JIT delivery, developing suppliers, involved customers, pull, flow, low set-up, controlled processes, productive maintenance, and involved employees.

Based on a synthesis of literature reviews and available resources, nine lean issues were designed for our investigations (Table 1), listed in the first column on the left. Nine lean issues were checked for reliability and validity – this will be discussed later in Chapter 4, 'Results analyses and variable construction'. Whilst it is certainly true that other sets of critical factors could be developed, this set appears to capture most of the important aspects of effective 'lean'.

Table 1. Internal consistency analysis results for the critical factors of lean manufacturing

Lean issues	Cronbach α
1. The value concept + customers	0.546
2. VSM	0.691
3. Pull/kanban + flow	0.768
4. Waste elimination	0.760
5. Productive maintenance	0.670
6. Just-in-time	0.667
7. Employee involvement	0.800
8. Lean suppliers	0.642

3 METHODOLOGY

An exploratory survey research methodology was adopted for considering the presented problem [22] to [24]. The research was divided into the following phases (Fig 1):

- an analysis of existing literature was made to determine the major dimensions of lean manufacturing;
- a questionnaire was designed, pre-tested on experts and pilot-firms (as suggested by Dillman, [25]). The questionnaire contained 59 items, designed according to the Likert scales, ranging from 'strongly disagree' to 'strongly agree';
- the resulting data were examined through reliability and validity analyses, and then analysed using uni- and multi-variate statistical techniques.

The unit of analysis was the individual company and specifically the lean projects within the individual company.

3.1 Data Collection and Measurement Analyses

The research was carried out at 72 Slovenian companies within the mechanical, electro-mechanical,

and some other industries. The criterion for the choice of sample was the size of the company. It was limited to medium (from 50 to 249 employees and revenue from 8.8 to 35 million), and larger sized companies (from 250 upwards employees and revenue from 35 million EUR upwards).

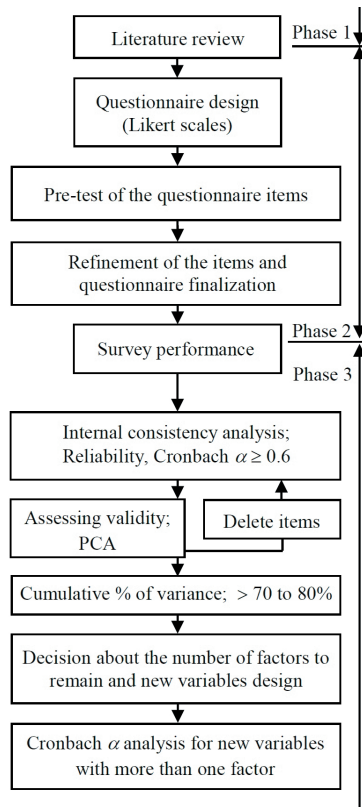


Fig. 1. New variable construction process

The response rate was very good for the post-contact methodology (18.6%), and showed the firms interest in the subject. Included in the firms that responded to the survey were some of the more successful Slovenian companies [26]. The subsequent statistical analysis was, therefore, carried out on the results from those 72 companies that returned the questionnaires correctly filled in.

A five- point Likert scale [27] was used to indicate the degree or extent of each item, ranging from 'strongly disagree' to 'strongly agree'. For each of the eight crucial areas statements were designed with positive or negative connotations (to keep the attention). For the Value concept + Customer 10 statements were designed, e.g. as follows: 1. The value of a product can be measured in terms of customer satisfaction, 2. Higher product quality caused higher satisfaction, 3. The ratio between quality and costs does not essentially influence customer satisfaction,...

When determining the measurement properties of the constructs used within the statistical analysis, reliability and construct validity were assessed [28], using Cronbach's alpha and principal components analysis (PCA) respectively.

3.2 Reliability

Reliability is a statistical measurement of how reproducible the survey instrument's data are [29] to [31]. Reliability is commonly assessed in three forms: test-retest, alternate-form and internal consistency. Internal consistency reliability is the commonly used psychometric measure in assessing survey instruments and scales and it is an indicator of how well the different items measure the same issue.

As variables were being developed for the first time Cronbach's alpha for measuring internal consistency was used. According to Nunnally and Bernstein [30] the newly-developed measurements can be accepted with $\alpha \geq 0.6$, otherwise $\alpha \geq 0.7$ should be the threshold. With $\alpha \geq 0.8$ the measurement is very reliable. In our research all of the multi-item variables had a Cronbach's alpha of at least 0.6, thus well exceeding the guidelines set for the development of new variables.

3.3 Validity

Besides determining survey reliability we must also assess the validity of a measurement. It refers to the extent to which it measures what it was intended to measure [31] and [32]. Three different types of validity are typically measured: content validity, criterion related validity, and construct validity.

Content validity is a subjective measurement of how appropriate the items are. Content validity was derived from several extended reviews of recent literature about lean manufacturing [12], [19] to [21].

In order to establish criterion validity, each item of the questionnaire was reviewed and also by three general managers from different manufacturing companies. Following the pre-tests of the items, 65 items remained appropriate for conducting research.

Construct validity was checked through the use of PCA. PCA was carried out in order to uncover the underlying dimensions, eliminate problems of multicollinearity and reduce the number of variables to a limited number of orthogonal factors. Each multi-item variable was factor-analysed separately: for the items loaded on more than one factor, the items responsible for the other factors beyond the first were eliminated (or considered in another variable) and

Cronbach's alpha was re-calculated. The presented variables are all in their final versions.

The same procedure was then adopted to group several variables in order to obtain a more manageable set of variables. Rotation was applied to aid interpretation.

4 RESULTS ANALYSES AND VARIABLE CONSTRUCTION

An internal consistency analysis was performed separately, using the PASW Statistics 18 program package for the items of each eight scales on Lean manufacturing (Table 1). This table shows that the reliability coefficients or Cronbach's α ranged from 0.546 to 0.800. According to instructions [30] measurements for the most critical factors (except for 'Value concept + Customers') are very reliable.

The initial reliability value of 'Value concept + Customers' stayed on 0.546 even though several combinations of the defined items' eliminations were tried for improving reliability. As this was the only criteria that didn't fulfill reliability conditions completely, it was decided to continue with PCA for all eight scales. For value concept + customers the three factor solution was generated with eigenvalues 1.7, 0.9 and 0.8 explaining 88.8% of variance (Table 2).

Table 2. Value concept + customers

Items on Value concept + customers	1 st factor	2 nd factor	3 rd factor
High product quality	0.814	0.194	0.209
Product quality for customer satisfaction	0.899	-0.043	0.037
Warranty	0.148	0.069	0.983
Quality in perceiving customer needs and demands	0.078	0.988	0.068
Eigenvalue	1.779	0.952	0.805
Proportion of variance explained [%]	44.466	23.799	20.129
Cumulative variance explained [%]	44.466	68.265	88.394
Re-calculated Cronbach α	0.666	-	-
Name given to the new variable	VAR 1	VAR 2	VAR 3

The first variable consists of 'high product quality' and 'product quality for customer satisfaction', with re-calculated Cronbach's α 0.666. The first variable, VAR 1 was named 'Customer satisfaction' and the other two 'Perceiving customers demands' and 'Warranty'.

Similar procedure as used for new variable construction as 'Value concept + customers' was then used for all eight scales on Lean manufacturing. The final set of lean variables constructed is presented in

Table 3. As reported in Table 3, the 24 Lean variables proposed are grouped in 8 issues or areas.

Table 3. Summary of lean variables constructed

Lean issues	New variables	New Cronbach α
The value concept + Customers	1. Customer satisfaction	0.666
	2. Perceiving customers demands	
	3. Warranty	
Value stream mapping	4. Process mapping	0.763
	5. Waste evidence	
	6. Cost reduction	
Pull/kanban + Flow	7. Early information on customer needs	0.730
	8. Customer involvement during product design	
	9. Flexible response on customers' demands	
	10. Planning and control	
	11. Parts standardization	
Waste elimination	12. Inventory management	0.676
	13. Capacity utilization and working conditions	
Productive maintenance	14. Total preventive maintenance	0.670
	15. First-pass quality	
Just in time	16. On-time deliveries	0.627
	17. Cooperation with suppliers	
	18. Parts reduction	
	19. Order and cleanliness in the plant	
Employee involvement	20. Employee cooperation	0.833
	21. Team working	
Development of excellent (lean) suppliers	22. On-time deliveries by the suppliers	0.775
	23. Supplier relationships	
	24. A skilled and loyal supplier	

The *value concept* is represented by three variables: customer satisfaction level, degrees of warranties, and capacity to perceive the customers' demands.

Another group of variables concerns *Value Stream mapping (VSM)* i.e. the visualisation of value during the firm's processes; also here three variables have been developed by the presenters for covering this theme: the presence of process mapping, the evidence of waste, and the cost reduction.

Five variables regarding the Womack's principles of *flow & pull*: early information on customer needs (the starting point of each process, the client being external or internal), customer involvement since product design, flexibility in responding to customers, parts standardisation/modular products (which evidently allow flow and pull), an adequate planning and control system [33].

The *waste elimination for perfection*, which is a dogma of the lean, is realised through the variables of

inventory management (concept of “standard work-in-progress” i.e. the only material needed by a pulled pipeline) and capacity utilisation.

Productive *maintenance* being the sustainability of a model is realised by two other variables: Total Productive Maintenance -TPM and first-pass quality (the latter meaning that the system should be able to guarantee an acceptable production at the first shot).

Just-in-time is another issue typically ascribed to lean and would result in measurements by four variables: the existence of on-time deliveries, cooperation with the suppliers, a reduced number of parts, and order cleanliness inside the plant.

The other two variables (employee cooperation and teamwork) state that a crucial factor for lean success is the *employee involvement* i.e. lies in the human resources of a company.

For *development of excellent suppliers* on-time deliveries are crucial along with good relationships and a skilled and loyal supplier.

5 DISCUSSION AND CONCLUSIONS

Lean management has become the main managerial initiative for improving firms' performances, leading to excellence within the context of sustainable competitive advantage. Due to the present markets' crises and especially for companies with production systems in higher cost areas, Lean management is central and crucial.

This paper has covered a wider range of items in respect of previous studies, collating many of them. Starting from 59 items 24 'lean' variables were constructed and tested. A rigorous method for obtaining or confirming these variables was the other main contribution of the presented work.

The substantial questionnaire utilised was based on literature reviews and experts' interviews, and covered, in our opinion, all the most representative “lean” aspects at the moment expect lean design. Lean design was initially a part of the questionnaire but since we received too different answers we estimated that specific investigation would be of benefit in the future.

Table 3 assumes that the variables proposed, for each of them had been constructed and justified according to the described statistical methodology, so this presentation of Lean is quite unique in its rigour in respect of many other contributions that do not adopt a statistical survey method such as this.

Although the survey was performed in Slovenian companies the results of the survey can be generally used.

Besides the consideration that the presented work can be useful for studies aimed at a more “objective” approach to lean management, this wide and rigorous contribution has led to a *concrete* managerial instrument for usage.

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