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J. Paulo Davim *Editor*

Progress in Lean Manufacturing

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Preface

Lean thinking was a concept developed by James P. Womack and Daniel T. Jones to capture the essence of Toyota Production System. Therefore, it is current report lean thinking as a lean way of thinking allows companies to '*specify value, line up value creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively*'. This declaration leads to the five principles of lean thinking: *Value*, *Value Stream*, *Flow*, *Pull* and *Perfection*. The concept of lean thinking presents great importance in the context of modern manufacturing.

The purpose of this book is to present a collection of chapters exemplifying progress in lean manufacturing. The first chapter of the book provides leanness assessment tools and frameworks. The second chapter is dedicated to lean supply chain management (a systematic literature review of practices, barriers and contextual factors inherent to its implementation). The third chapter describes a literature review on lean manufacturing in small manufacturing companies. The fourth chapter contains information on application of structural equation modelling for analysis of lean concepts deployment in healthcare sector. Finally, the last chapter is dedicated to association between lean manufacturing teaching methods and students' learning preferences.

The current book can be used as a research book for final undergraduate engineering course or as a topic on management and industrial engineering at the postgraduate level. Also, this book can serve as a useful reference for academics, engineers, managers, researchers, professionals in management and industrial engineering and related subjects. The interest of scientific in this book is evident for many important centers of the research and universities as well as industry. Therefore, it is hoped this book will inspire and enthuse others to undertake research in management and industrial engineering.

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Aveiro, Portugal J. Paulo Davim
January 2018

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About the Editor

J. Paulo Davim received the Ph.D. degree in Mechanical Engineering in 1997, the M.Sc. degree in Mechanical Engineering (materials and manufacturing processes) in 1991, the Mechanical Engineer degree (MEng-5 years) in 1986, from the University of Porto (FEUP), the Aggregate title (Full Habilitation) from the University of Coimbra in 2005 and the D.Sc. from London Metropolitan University in 2013. He is Eur Ing by FEANI-Brussels and Senior Chartered Engineer by the Portuguese Institution of Engineers with a MBA and Specialist title in Engineering and Industrial Management. Currently, he is Professor at the Department of Mechanical Engineering of the University of Aveiro, Portugal. He has more than 30 years of teaching and research experience in Manufacturing, Materials and Mechanical Engineering with special emphasis in Machining & Tribology. He has also interest in Management & Industrial Engineering and Higher Education for Sustainability & Engineering Education. He has guided large numbers of postdoc, Ph.D. and masters students. He has received several scientific awards. He has worked as evaluator of projects for international research agencies as well as examiner of Ph.D. thesis for many universities. He is the Editor in Chief of several international journals, Guest Editor of journals, books Editor, book Series Editor and Scientific Advisory for many international journals and conferences. Presently, he is an Editorial Board member of 25 international journals and acts as reviewer for more than 80 prestigious Web of Science journals. In addition, he has also published as editor (and co-editor) more than 100 books and as author (and co-author) more than 10 books, 70 book chapters and 400 articles in journals and conferences (more than 200 articles in journals indexed in Web of Science core collection/h-index 43+/5500+ citations and SCOPUS/h-index 52+/7500+ citations).

Leanness Assessment Tools and Frameworks

Omogbai Oleghe and Konstantinos Salonitis

Abstract This chapter presents the most recent developments with regards the assessment of leanness in manufacturing organizations. Leanness is the measure of the performance of lean manufacturing practices. It is tracked for improvement using assessment frameworks. This chapter reviews prevalent frameworks in order to organize the knowledge, extract the typical and potential uses, establish strengths and weaknesses and reveal ways of improving the extant frameworks. Prevailing frameworks are identified through a search of literature, together with those developed by lean consultants, as well as award-based frameworks. Two main classification schemes are used to organize and compare the frameworks namely the leanness indicators (input data type) used in the frameworks and the applications of the frameworks, representing the inputs and outputs respectively of the frameworks. The key findings of this work can be summarized into: First, most frameworks are generated using either a quantitative or qualitative set of leanness indicators; meanwhile there is a paucity of frameworks that use both types of indicators simultaneously to take advantage of their individual strengths and overcome their respective weaknesses. Second, the frameworks have been used mainly for current-as-is audits, whereas the assessment of proposed improvements is rarely considered. Third, majority of frameworks do not emphasize the interactions between lean practices and the trade- offs between their improvements.

Keywords Leanness · Leannes assessment · Lean maturity · Lean indicators · Performance measurement

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1 Introduction

Lean manufacturing (LM) takes its roots from manufacturing best-practices that were implemented in the Toyota Motor Corporation, such as Just in Time (JIT) management, Quality Management (QM), Total Productive Maintenance (TPM). LM has evolved over the years to include a variety of management values related with Employee Involvement, Supplier Management, Cross-functional Teams, Training, Customer Engagement and many others (Shah and Ward 2003, 2007), with a variety of tools such as Six Sigma, Statistical Process Control, Poka-Yoke, Jidoka.

Lean practices have been proven to improve manufacturing and organizational performance. The practices are intended to achieve multiple objectives for an organization, chiefly to improve customer responsiveness through continuous improvement and identification/elimination of all types of activities and processes that do not add to customer value. A collection of lean practices constitutes a lean system: the practices cannot be individually adopted on their own if an overall lean state is to be attained (Hallam 2003a; Rymaszewska 2014). There is in fact limited positive impact on performance when lean practices are introduced in isolation (Bonavia and Marin 2006).

Leanness is a concept that unifies the various practices of promoting lean (Bayou and De Korvin 2008). Leanness assessment is the measure of the adoption of lean manufacturing practices (Susilawati et al. 2013; Vimal and Vinodh 2013). Leanness assessment refers to the structured approach taken to assess leanness level as represented in Fig. 1.

The hierarchical structure shown in Fig. 1 represents the key components of the methodological steps, as well as the sequence and levels of assessment. In the configuration, the various lean practices and their measurement items are singled out and assessed using one or a set of tools and instruments, from which

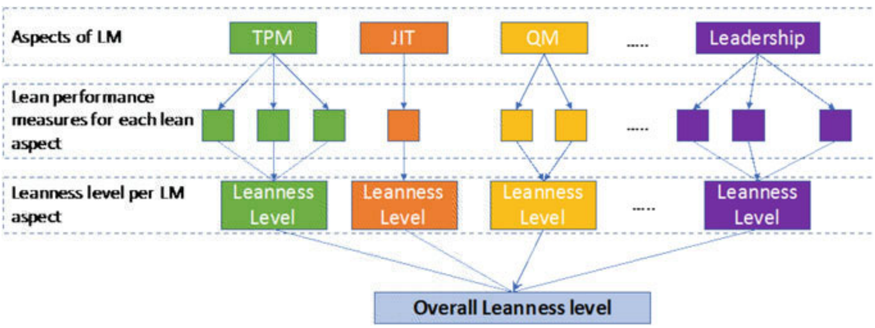


Fig. 1 Generic structured approach to leanness assessment

information about the lean state of the system can be generated. Lean Enterprise Self-Assessment Tool (LESAT) is a good example. Aspects of lean transformation are set apart in three sections under the LESAT framework namely Leadership, Processes and Infrastructure (LAI 2012). The indicators of leanness are the 54 measurement items under each of the three sections, for example, one measurement item under Leadership is the extent to which the organization integrates enterprise transformation into its strategic planning process. The analysis of the gap between the current and desired levels of performance for each measurement item is indicative of the leanness level for the measured practice (Perkins et al. 2010). The final tallies, ranges, patterns and averages provide information about the state of leanness of the enterprise (Perkins et al. 2010). Majority of methods can be described using this generic format also depicted in Fig. 1. The structured approach of leanness assessment helps to reduce chaos in terms of which lean practices to implement (Cil and Turkan 2013), where improvement efforts should be focused (Vinodh and Balaji 2011; Vimal and Vinodh 2013) and assist in the decision-making process (Chhabi et al. 2014).

The critique of leanness assessment methods has been undertaken in the past by various authors (Ray et al. 2006; Wan and Chen 2008; Mahfouz 2011; Anvari et al. 2013; Cil and Turkan 2013; Chhabi et al. 2014; Azadeh et al. 2015; Ali and Deif 2016). Most of these reviews have been limited in scope whereby only a handful of methods are appraised. If previous reviews have been done scantily, it implies that there is limited knowledge about what the expansive range of methods have accomplished. If there is limited knowledge about what leanness assessment methods can achieve, then lean practitioners and academics are not fully aware of what is available for them to use. Meanwhile, a number of tools and instruments have been developed for the leanness assessment. They have been applied singly and in a mixed manner. They have been validated to show the multiple benefits that can be derived from their use. Yet the knowledge is not organized. Meanwhile, it could be argued that the literature is representative of what is used in industry, since majority of the study methods were validated in real life cases. In addition, some methods coming from lean groups and consultants share similarities with what is available in the literature. For example, the Gemba Academy (Gemba 2010) have developed a lean enterprise self-assessment tool that is similar to methods used in various studies (Vinodh and Balaji 2011; Vimal and Vinodh 2013). The Strategos LAT developed by Quaterman Lee (Strategos 2010) has been used in multiple studies (Taj 2005; Ihezie and Hargrove 2009). The Association for Manufacturing Excellence (AME) LAT is based on the Iwao Kobayashi's 20 Keys to workplace improvement (AME 2016).

The current chapter aims to survey leanness assessment methods that prevail in literature. The survey will focus on the key aspects addressed by the methods. In addition, the survey will investigate the key instruments and data types that are used in the methods. The intention is to reveal common themes and trends as well as gaps, to provide directions where future advancements can be made in the methods.

2 Search Strategy to Generate List of Leanness Assessment Tools

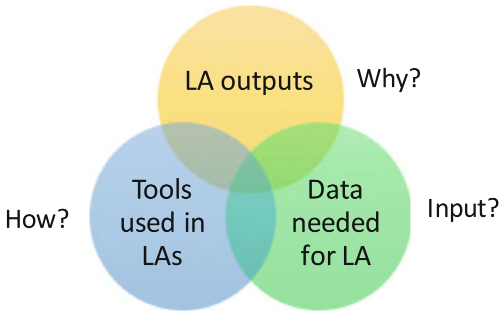
Various academic databases and search engines such as Springerlink, Google Scholar, ABI/Inform Complete, EBSCO, Elsevier, Emerald Full Text, Science Direct, Scopus, and Taylor and Francis were consulted to extract relevant articles from which the methods were set apart. Search keywords included leanness, manufacturing leanness, leanness assessment and lean assessment tools. The relevant articles covered the period between 2000 and 2016, and did not limit the search to high impact journals only, in order to capture as many studies that are relevant as well as current. In fact, some studies with interesting results were found from journals with low to average impact factor. The adopted search strategy generated 64 relevant research publications from which a comprehensive list of leanness assessment methods was extracted.

The relevant articles were surveyed in three parts (Fig. 2). The first part was used to summarize the key uses of the methods. The second part was used to outline the tools/instruments that were used in the methods. The final part details the data types used in the assessment.

3 Key Uses and Outputs of the Leanness Assessment Methods

The uses of leanness assessment methods have been varied even though past researchers/users all make reference to assessing leanness. An uninformed and casual observer at first glance of the literature will be overwhelmed or confused with the variety of the studies, study outcomes and uses of the methods. In this section, the generic study outcomes (those concerned with assessing manufacturing leanness) are revealed to provide details of the typical uses of the various methods that have been advanced. Seven general or common uses have been found for the methods namely: quantification of leanness level, gap analysis, impact analysis, degree of adoption of lean practices, benchmarking, scenario analysis and dynamic analysis (Fig. 3).

Fig. 2 Leanness Assessment (LA) analysis structure



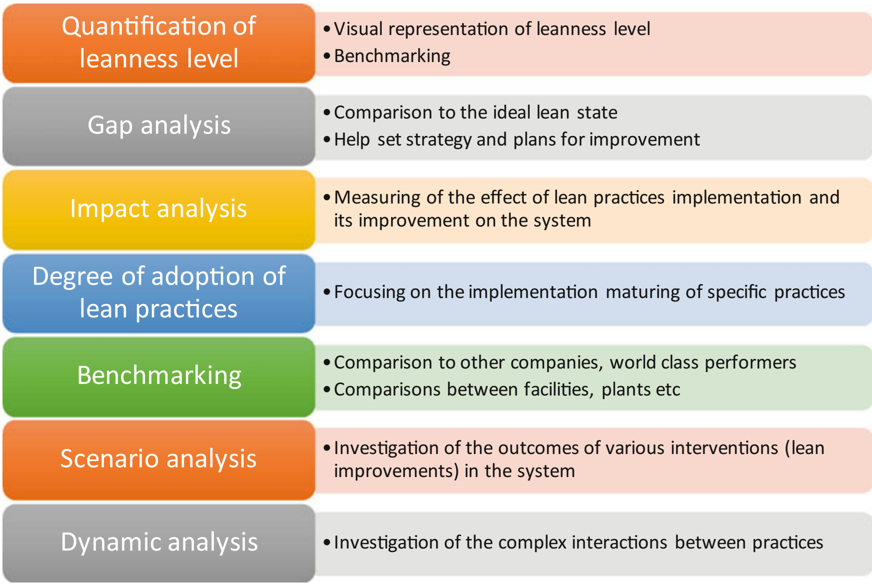


Fig. 3 Why lean assessment methods and tools are used

- **Quantification of leanness level**

Leanness level has been measured, quantified and represented by numbers. The quantification of leanness has been achieved using scoring methods, made possible through multi-level grading schemes (Taj 2005; Shetty et al. 2010). Leanness quantification has also been realized using the lean index (Ray et al. 2006; Wan 2006; Deif 2012; Vinodh and Vimal 2012; Berlec et al. 2014; Pakdil and Leonard 2014; Oleghe and Salonitis 2016a, b). The lean index can be defined as the weighted summation of the lean metrics that define performance of various variables representing lean practices within a system (Oleghe and Salonitis 2015). It is a single indicative score for overall lean performance (Searcy 2009).

Multiple benefits are derived from leanness quantification. The quantified leanness can be tracked using line graphs, statistical process control charts and radar charts (Taj 2005; Ray et al. 2006; Pakdil and Leonard 2014; Wong et al. 2014; Oleghe and Salonitis 2016a, b). The lean index can be used to drive organization-wide behaviour towards improving the metric (Searcy 2009; Wong et al. 2014), in a collaborative manner (Vimal and Vinodh 2012; Wong et al. 2014). Leanness quantification also enables objective benchmarking (Srinivasaraghavan and Allada 2006; Ray et al. 2006; Bayou and De Korvin 2008).

There are some limitations associated with leanness quantification. If a single metric is used to quantify leanness level, organizations may be tempted to use it exclusively (Wong et al. 2014). Rather, the metric should be decomposed for better understanding of its components i.e. the individual measures of lean (Searcy 2009).