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**LEAN MANAGEMENT LITERATURE REVIEW
2009–2013: THE INFLATION PHASE AND
SETTING THE PACE TOWARDS AGILITY**

Abstract: The adoption of Lean Production practices by growing numbers of organizations and the tangible benefits in applying them, highlights the vast potential of operational and economic gains that companies can achieve by implementing Lean Management. Following Stone's [2012] segmentation of Lean literature into time phases, we titled the five-year period 2009–2013 as the "inflation" phase, since about 50% of the total count of academic articles on the phenomenon ever published were during this period. The author also reviews recent literature regarding the concepts of "agile manufacturing", often seen as the next step after "lean manufacturing" in the evolution of Operations Management and of lean supply chain and agile supply chain management, being closely relevant to both.

Keywords: lean management, lean production, lean manufacturing, agile manufacturing, lean-six sigma (LSS), quick response manufacturing (QRM), lean supply chain; operations management.

JEL Classification: C44, D24, L11, L14, L15.

**ANALIZA PIŚMIENNICTWA POŚWIĘCONEGO SZCZUPŁEMU
ZARZĄDZANIU W LATACH 2009–2013: FAZA „NADMUCHI-
WANIA” I PODĄŻANIE W KIERUNKU ZWINNOŚCI**

Streszczenie: Wdrażanie praktyk szczupłej produkcji (*lean production*) do coraz większej liczby przedsiębiorstw oraz korzyści, o charakterze operacyjnym i ekonomicznym, jakie dzięki temu one odnoszą, świadczą o ogromnym potencjale, jaki niesie ze sobą szczupłe zarządzanie (*lean management*). Przyjmując systematykę etapów rozwoju piśmiennictwa proponowaną przez Stone'a [2012], pięcioletni okres 2009–2013 nazwano okresem „nadmuchiwanian”, jako że ok. 50% wszystkich publikacji naukowych poświęconych

szczupłemu zarządzaniu zostało opublikowanych właśnie w tym okresie. Przedmiotem artykułu są także koncepcje zwinnego wytwarzania (*agile manufacturing*), które postrzegane jest jako kolejny po szczupłym wytwarzaniu krok w rozwoju wiedzy w zakresie zarządzania operacjami. Właściwą ekspozycję w tekście zyskała także tematyka szczupłych i zwinnych łańcuchów dostaw.

Słowa kluczowe: szczupłe zarządzanie, szczupła produkcja, szczupłe wytwarzanie, zwinne wytwarzanie, lean-six sigma, quick response, szczupły łańcuch dostaw, zarządzanie operacjami.

Introduction: Lean Management

“Lean” business process management is a relatively new field of research within Operations Management (OM), and its role in business, government, and civil society is growing. Applications of “lean production” (LP) principles are common nowadays not only in manufacturing but also in a wide range of non-manufacturing industries, e.g. project management, healthcare, construction, information systems, entrepreneurship (lean start-up), military, banking, insurance, education, logistics, procurement, and supply chain management (lean SCM), to mention but a few. Literature relates to “lean production”, “lean manufacturing”, “lean thinking”, and “lean management” as synonyms. However, in the context of this literature review, the author finds the generic term “lean management” (LM) more suitable than the others, since the application areas discussed cover manufacturing as well as a variety of non-manufacturing industries.

The main objective of this paper is to review the current relevant academic literature, while demonstrating the growth in the number of LM-related publications, together with a growing spread of both geographical relevance and of the areas of variety in the application. The review is limited, however, only to peer-reviewed academic publications in English. Clearly, publications in many other languages discuss the phenomenon with an increasing amount of publications in open-source electronic journals not subject to peer-review and practice. In addition, several leading not-for-profit institutions (e.g. The Lean Enterprise Institute with Womack and Shook, in the US, and the Lean Enterprise Academy with Jones, in the UK) publish numerous non-academic LM-related papers in ever growing numbers.

The fundamental concept of LM is to provide products and/or services of superior quality, at a competitive cost and within a competitive lead-time for the customer and/or the consumer. Although “nothing is new under the

sun” with LM, as per Ohno, some of its building blocks are counter-intuitive. An example is the issue of overproduction: producing more products than those needed for immediate use. According to LM overproduction is not necessary (and therefore is a “waste”), as long as market demand is met. Machines and operators do not always need to be fully utilized [Arnold, Chapman and Clive 2011]. This surge capacity changes dramatically both cost accounting and performance measurement. Another example is the “total productive maintenance” approach (TPM) to manufacturing assets which is counter-intuitive to the common “if it’s not broken, don’t fix it” approach.

Although of minor significance critiques on and debates around LM take place, including documented failures to “transform” from traditional production (normally mass, but also craft-production) to LM and in applying LM principles in non-manufacturing industries. Evidence of the negative influence on workers’ work satisfaction, stress, and on labour relations, exists as well (see for example [Hasle et al. 2012] and [Seddon and O’Donovan 2010]).

Academic research of the LM phenomenon is also growing and the quantity of publications in academic journals in the past five years reviewed (2009–2013) contains about 50% of the total existing LP literature. This phenomenon is the reason for naming the period of LM literature reviewed (years 2009–2013) as “the inflation phase”.

In the past 60+ years, LM has evolved to encompass several concepts to include quality, process management and problem-solving techniques such as Total Quality Management (TQM) and Six-Sigma, Total Productive Maintenance (TPM), and the Theory of Constraints (TOC), into a holistic approach focused on achieving operational excellence (see for example [Friedli et al. 2010] and [Moyano-Fuentes and Sacristán-Díaz 2012]).

Significant amounts of evidence shows that adopting LM principles improves business results at firm/organization level (see for example [Womack and Jones 1996] and more recently [Fullerton and Wempe 2009]). However the common perception of LM nowadays in the western world is three-fold (see for example [Arnold, Chapman and Clive 2011] and [Vollmann et al. 2011]), and in the eyes of most scholars it is far more than a cost reduction fad:

- a philosophy preaching for total elimination of all waste and optimization of resources used,
- a toolbox of process improvement and problem-solving tools and techniques, and

- an organizational culture and eco-system through which organizations and their business partners gain superior quality and customer satisfaction whilst continuously improving.

1. Lean Management definitions and terms

As mentioned above both manufacturing and non-manufacturing industries adopt LM principles. However since its origins started with the car assembly lines at Toyota, much of the basic terminology of LM has its origins at Toyota [Vollmann et al. 2011]. The author believes that one cannot grasp the concept of LM without realizing the development of its perception outside Toyota, from a highly efficient production and inventory control system, to a holistic management culture. The following paragraphs therefore briefly describe the three phases of the development – “Just-In-Time” (JIT), “lean production”, and “lean thinking”.

Just-In-Time (JIT). The first factor easy to observe when looking at Toyota was LM’s JIT building block. The American Production and Inventory Control Society (APICS, aka “Advancing Productivity Innovation and Competitive Success”) definition for JIT as “a philosophy of manufacturing is “A philosophy of manufacturing based on the planned elimination of all waste and on continuous improvement of productivity. The goal is to have only the required inventory when needed; to improve quality to zero defects; to reduce lead times by reducing setup times, queue lengths, and lot sizes; to incrementally revise the operations themselves; and to accomplish these activities at minimum costs” [Blackstone 2010].

Lean production (LP). Whilst JIT concentrates on timing, LP outlines the means to achieve it. The definition of APICS for LP as a philosophy of production is “A philosophy of production that emphasizes the minimization of the amount of all the resources (including time) used in the various activities of the enterprise. It involves identifying and eliminating non-value-adding activities in design, production, supply chain management, and dealing with customers. Lean producers employ teams of multi-skilled workers at all levels of the organization and use highly flexible, increasingly automated machines to produce volumes of products in potentially enormous variety. It contains a set of principles and practices to reduce cost through the relentless removal of waste and through the simplification of all manufacturing and support processes” [Blackstone 2010].

Lean thinking. In their book “Lean Thinking” Womack and Jones [1996], the two pioneers took the LP concept a step forward to present a broader approach and summarized ‘lean thinking’ in the following five principles. The definitions are from Blackstone [2010]:

1. Precisely specifying value by specific product/service: value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer: „the worth of an item, good, or service”.
2. Identify the value stream for each product/service: value streams are the specific activities required to design, order, and provide a specific product/service: „the processes of creating, producing, and delivering a good or service to the market. For a good, the value stream encompasses the raw material supplier, the manufacture and assembly of the good, and the distribution network. For a service, the value stream consists of suppliers, support personnel and technology, the service »producer« and the distribution channel. The value stream can be controlled by a single business or a network of several businesses”.
3. Make value flow without interruption: flow is the progressive achievement of tasks along the value stream so that a product proceeds from design into the hands of the customer with no stoppages, scrap, or back-flow: „a system in which work flows over a stationary path, usually with little variance in the rate of flow. This is known as repetitive manufacturing if discrete units are produced and otherwise is referred to as continuous manufacturing”.
4. Let the customer pull value from the producer: pull is a system of cascading production and delivery instructions bottom-up, from downstream to upstream activities. APICS define pull systems as „(1) in production, the production of items only as demanded for use or to replace those taken for use. (2) In materials control, the withdrawal of inventory as demanded by the using operations. Material is not issued until a signal comes from the user, and (3) In distribution, a system for replenishing field warehouse inventories where replenishment decisions are made at the field warehouse itself, not at the central warehouse or plant”.
5. Pursue perfection: perfection is a state of the complete elimination of waste („Muda”), so that all activities along a value stream create value.

As mentioned above the author finds the generic term “lean management” (LM) more suitable to name the lean phenomenon than JIT, LP, “lean manufacturing”, “lean thinking”, or simply “lean”, since the areas discussed cover both manufacturing and non-manufacturing industries. Moreover the

author aims at an audience including researchers and practitioners not only from the field of OM, but also from research fields in business management and economics and does not wish to narrow the discussion either to „production” or to „manufacturing”.

2. Early research (up to year 2009) and Stone’s “Four Decades of Lean: a Systematic Literature Review” [Stone 2012]

As an academic discipline operations management (OM) is, almost by definition, close to practice [MacCarthy et al. 2013]. Being an emerging OM research field, LM follows as well, and LM academic literature is therefore largely one of case studies [Vollmann et al. 2011].

Reading recent LM literature reviews (see for example [Camacho-Miñano, Moyano-Fuentes and Sacristán-Díaz 2013] and [Moyano-Fuentes and Sacristán-Díaz 2012]) the author finds Stone’s review inspiring. Stone argues that since the introduction of the term “lean production” [Krafcik, 1988a, 1988b] and [Womack, Jones and Roos 1990], the majority of LM literature stems from OM and from Industrial Engineering (IE) disciplines, with few from social sciences and divides LM literature published up to year 2009 chronologically into five typical periods or maturity phases:

- Discovery phase (1970–1990): Contains more books written by practitioners than academic articles. Early publications are from [Drucker 1971], describing some ‘Japanese management practices’, and from [Sugimory, Kusunoki and Uchikawa 1977], being the first article in English exploring the ‘Toyota Production System’ (TPS) and introducing it to the western world.
- Dissemination phase (1991–1996): Labour relations related articles followed the early LM publications identifying threats to unionized firms from more flexible ones. Articles named “LP” and “LM” as synonyms, explored the benefits from applying LM principles also to non-production processes.
- Implementation phase (1997–2000): Articles noted Womack and Jones’ [1996] book as being influential in helping firms to better understand the strategic approach to LM transformation. Empirical studies employed quantitative and qualitative methods contributing to the required LM knowledge base.
- Enterprise phase (2001–2005): Womack and Jones [1996], and Jones and Womack [2003] inspired the expansion of LM outside the shop floor and

LM literature during the enterprise phase significantly shifted to other areas of the enterprise, e.g. R&D, marketing, finance and human resources development (HRD).

- Performance phase (2006–2009): An increase in the quantity of LM related articles published in the year 2006 (26 articles, compared to 15 in 2004, as per Stone's sample), influenced Stone's decision to split the decade into two phases. A possible reason for that is the dramatic new positioning of Toyota, taking the lead from GM as the world automotive industry's leader.

3. Recent research (2009–2013): the LM research inflation phase

Utilizing EBSCO and the Thomson-Reuters web-of-science search tools the author identified the following leading LM-related academic journals, searching for “lean management”, “lean manufacturing”, “lean production”, or “lean thinking” in the title, abstract, or as a subject or key term:

1. International Journal of Production Research (Taylor & Francis, UK)
2. Journal of Manufacturing Technology Management (Emerald, UK)
3. Management Services (The Institute of Management Services, UK)
4. Production Planning & Control (Taylor & Francis, UK)
5. International Journal of Operations & Production Management (Emerald, UK)

In the following sections the review covers recent research published in these top-5 journals in the past five years (2009 – beginning of 2014). This convenient sample amounts to 99 papers, containing 43% (99 out of 232 articles) of the publications in the top-20 journals published during the period and therefore representing it well.

The author finds five key points that characterize LM research during the inflation phase compared to previous phases: First, the quantity of LM peer-reviewed academic articles is growing significantly and not linearly. Second, the range and variety of areas of application of LM and research fields is growing. Third, the geographical spread of LM research is growing. Fourth, a reasonable proportion (80:20) tends to exist between empirical and descriptive LM research and fifth, healthy critiques exist. The author decided to classify the “inflation phase” reviewed articles reviewed into four typical bundles, sub-grouped into descriptive vs. empirical research sub-groups.

4.1. Descriptive research – LM literature reviews

The sample holds only two pure literature reviews both suggesting ways to classify the un-structured LM literature. Trying to construct the un-structured current LM literature, Hoss and ten Caten [2013] presented the concept of “lean schools of thought” and identified seven “schools of thought”: (1) systems engineering; (2) systems architecture; (3) operations research; (4) organizational development; (5) contingency systems; (6) socio-technical systems, and (7) evolutionary.

Complementary to this and exploring LM research areas and opportunities for future studies, Marodin and Saurin [2013] suggested a classification into six research areas: (1) structure/scope of LM systems; (2) factors influencing LM implementations; (3) methods for implementing LM systems; (4) LM assessment methods; (5) results of implementing LM systems; and (6) adaptation of LM to particular sectors.

4.2. Descriptive research – LM philosophy/theory/paradigm/models

The sample contains 17 papers dealing with LM conceptually. Researchers deal with advanced LM models and assessment tools, decision-supportive frameworks and tools, LM transformation paths with manufacturing cells and look at OM research methods in the post-LM era.

Addressing LM assessment models Camacho-Miñano, Moyano-Fuentes and Sacristán-Díaz [2013] concluded that models considering financial and operational indicators and contextual factors find a positive and significant impact of LM on financial performance. Similarly, Wong et al. [2014] constructed a “lean index” suggesting a way to quantify “leanness” using a multi-criteria approach i.e., “analytic network process” (ANP).

Various decision-supportive frameworks and tools are given, for example, by Hallgren and Olhager [2009] and by Ramesh and Kodali [2012]. LM transformations are also addressed by Taylor, Taylor and McSweeney [2013], and by Deflorin and Scherrer-Rathje [2012], looking at the LM environment from the point of view of long-term stability and sustainability and at different LM paths of transformation from both mass- and craft-production to lean-managed environments.

Manufacturing cells (MCs) are addressed, for example, by Saurin, Morodin and Ribeiro [2011], Deif [2012] and by McDonald et al. [2009], assessing their specific LM best practices, the way they deal with uncertainty and the optimal way workers should be assigned, emphasizing the importance of rotation in a cross-trained workforce.

Arguing that as an academic discipline operations management (OM) is almost by definition close to practice, MacCarthy et al. [2013] suggested that some fresh research approaches must evolve to reflect the new LM realities, enhancing OM as a theoretically sound and practically relevant discipline. In an exceptional paper Seddon [2011] states that LM fits with the current management paradigm and offers to solve problems that managers think they have. However many of them disappoint when results fail to come up to expectations and the improvements do not benefit the bottom line.

4.3. Empirical research – LM human resources development (HRD), and cultural aspects

The sample contains fifteen papers dealing with LM cultural and human resources development (HRD). Researchers look at various HRD aspects, at cultural and HRM aspects, at managerial lessons and at LM simulation games.

Human resources development (HRD) aspects are addressed by Lucey [2009] and by Longoni et al. [2013]. Researchers are looking at employees' engagement, commitment and participation, dealing with a temporary workforce, and with employees' health, safety and well-being. An exceptional publication from Hasle et al. [2012] concludes that there is strong evidence for the negative impact of LM on both the working environment and on employees' health and well-being in cases of manual work with low complexity.

Cultural and HR management related aspects are addressed by Badurdeen, Wijekoon and Marksberry [2010], and by Atkinson and Nicholls [2013]. Researches look at a range of cultural and HR management (HRM) related aspects, cover the roles of culture and of HRM in LM transformations, culture change process, the issue of corporate culture, success-related cultural factors and address the issue of trans-nationality. The complementary effects on operational performance (OP) of two of the main LM bundles of practice, namely JIT and TQM, were presented by Furlan, Vinelli and Pont [2011], emphasizing that only plants characterized by a significant adoption of HRM practices enjoy the effects of TQM and JIT on OP.

Todd, Maika and Jan [2011] addressed the role of management exposure to external information sources, i.e. training sessions, plant visits, and conferences in helping to achieve LM goals. Their research results confirm that this management exposure and commitment to LM both have positive influence on "lean thinking". In a joint paper, Ballé and Bouthillon [2011] exchange LM-related academia and practice managerial lessons they have learned. Ozelkan and Galambosi [2009] introduce a simulation game,

named the “Lampshade Game”, aimed at educating students and industry professionals on LM principles. The game enables the comparison of craft, mass, and Lean manufacturing methods using different operational and financial metrics.

4.4. Empirical research – various LM application areas, tools, and case studies

The majority of publications in the sample (sixty-five) present various application areas, tools and case studies. For convenience the author sub-divided the contents into five main sub-groups: research and development (R&D), manufacturing execution, supply chain management, services and country specific studies.

- Research and development (R&D). The sample contains only two (2) papers dealing with research & development, presenting practical applications of LM principles in the field. Wang et al. [2012] present a systematic implementation framework for “lean product development” (LPD), whilst Pullan, Bhasi and Madhu [2013] developed a “concurrent engineering” (CE) based decision support tool.
- Manufacturing execution. The sample contains ten (10) papers dealing with manufacturing execution and supportive IT applications. Researchers deal with the way ERP and MES systems support LM, quantity control and with the adoption of demand-pull strategy in non-traditional LM environments.
- Supply chain management (SCM). The sample contains nine (9) papers dealing with supply chain management (SCM) and with the related issues of procurement and material handling. Researchers deal with strategic ‘lean SCM’ issues, the relationships with customers and with vendors, managing LM in material handling operations and with managing knowledge in the SC (see section 5 for a more detailed review of lean supply chain management).
- Service industries. The sample contains thirteen (13) papers dealing with service industries, most of them (eight papers) relate to the UK. Researchers deal with ‘lean services’ methodology and measurement, case studies in the public sector in Mexico, in the private sectors in Portugal and in the US and discuss the public sector in the UK as well as call centres in the private sector.
- Country/economy specific case studies. The sample contains thirty-one (31) papers dealing with various country/economy specific case

studies. India has the largest number of publications (eight papers), followed by the US (six papers) and the UK (five papers). Within the rest of the publications, whilst the developed economies are modestly represented (Ireland, Japan, Spain and Sweden), the author found that most of publications represent developing economies (Brazil, China, Indonesia, Pakistan, Taiwan, Thailand, Trinidad & Tobago and Turkey).

Common to all the case studies is that the adoption of LM practices and the tangible benefits of applying them highlight the vast potential of operational gains companies can achieve by implementing LM. Prominent benefits are higher inventory turnover, better quality, decreased costs, less production and warehousing areas required, improved employee satisfaction, improved customer service and growth in market share and profitability.

5. Supply chain management (SCM)

A closely related subject and research field to operations management and manufacturing is the concept of supply chains (SCs), or supply chain management (SCM). Therefore, not surprisingly, one of the first application areas to adopt LM is the “supply chain” with the relatively new concept of “lean supply chain” or “lean supply chain management” [Martin 2008].

Coincidentally the leading professional organizations addressing the two closely related research areas, APICS and the Supply Chain Council (SCC), announced a merger in May 2014. „The merger takes two recognized leaders in supply chain research, education and professional certifications and creates a comprehensive source for corporations and individuals seeking to improve performance” [Eshkenazi 2014, pp. 6]. It is solid evidence of the complementary nature of the two research areas and it justifies the diffusion of LM principles from manufacturing throughout the entire SC.

The supply chain is „the global network used to deliver products and services from raw materials to end customers through an engineered flow of information, physical distribution, and cash”, and it is based on Porter’s concept of the ‘value chain’. Supply chain management (SCM) is „the design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally” [Blackstone 2010].

Womack and Jones [1996] defined the “lean supply chain” as the “lean enterprise”. The following is its definition from APICS: „A group of individuals,

functions, and sometimes legally separate but operationally synchronized organizations. The value stream defines the Lean Enterprise. The objectives of the Lean Enterprise are to specify correct value to the ultimate customer and to analyze and focus the value stream, so that it does everything from product development and production to sales and service by removing actions that do not create value. Actions that do create value proceed in a continuous flow, as pulled by the customer. Lean Enterprise differs from a »virtual corporation« in which the organizational membership and structure keeps changing” [Blackstone 2010].

As mentioned above the sample contains nine (9) papers dealing with the adoption of LM principles in supply chain management (SCM) and with the related issues of procurement and material handling. However, searching specifically for ‘lean supply chain’ in the titles, abstracts, or as key or subject terms, the author examined some 24 articles published during the inflation phase (2009 – October 2014). Some of the articles are already in the sample, but more articles are to be found in journals other than the leading five sampled, especially in “supply chain management”, from Emerald.

Strategic lean SC issues are addressed by Godsell [2009], and by Soni and Kodali [2012], looking at LM principles and their adoption in the consulting industry and challenging the LM concept with some other popular SC systems, i.e. agile, leagile, resilient and green SCs.

Covering three concepts, namely the principles of strategic alignment, the philosophy of LM, and the output derived from the Cranfield University Innovative Manufacturing Research Council (IMRC) project, Godsell [2009] describes the adoption of a customer driven supply chain strategy by a “lean enterprise consultancy” (S.A. Partners). He argues that it is possible to obtain enterprise-wide alignment and competitive advantage applying LM in a supply chain context.

At the same time, whilst looking at Indian manufacturing industry, Soni and Kodali [2012] evaluated the reliability and validity of LM, agile and leagile SC competitive strategies (CSs), in the three SC strategies (SCSs) evident in SCM literature: cost efficiency, time responsiveness and a hybrid of the two. The authors propose a framework for selecting LM, agile or leagile CS, based on the foundations of each supply chain strategy. The relationships with customers and vendors are addressed by Moyano-Fuentes et al. [2012] and by So and Sun [2011]. Research deals with the impact of the level of the cooperation, the effect of LM on the SC with Lean procurement and with the role of electronic integration as a Lean SC enabler.

Reviewing a large sample of manufacturers in Spanish industry, Moyano-Fuentes, Sacristán-Díaz and Martínez-Jurado [2012] examined the impact of the level of cooperation with suppliers and customers on LM adoption. Results show that greater levels of cooperation with suppliers do not affect the intensity of LM adoption, but the greater the cooperation with customers, the higher the intensity of LM adoption becomes. .

Similarly, by means of a theoretical model based on the ‘innovation diffusion theory (IDT), So and Sun [2011] examined the relationship between electronic-enabled SC integration and the adoption of LM. Results show that IDT could explain LM adoption and that electronic-enabled SC integration positively influences the perceived relative advantage of LM and consequently leads to its long-term adoption.

In order to manage LM in material handling operations in a petroleum drill bit manufacturing company, Green, Lee and Kozman [2010] developed a methodology that provided the operations group with a tool to assist them in defining the objectives of their LM transformation. The case demonstrates success although top-level management dictated LM as a mandatory waste reduction tool.

A decision-focused knowledge management framework, presented by Liu et al. [2013], supports collaborative decision making for Lean SCM. They developed a multi-layer knowledge model to capture the know-why and know-with, together with the know-what and know-how, a knowledge matrix for knowledge elicitation and a decision tree for the design of the knowledge base.

6. Agile manufacturing and agile supply chains

On reviewing LM literature one cannot ignore the term “agile”. In this paper the term is mentioned several times, (excluding in the abstract and the key words), in conjunction with manufacturing and with supply chain. The following, therefore, is a short discussion on “agility”, derived from the discussion on “leanness”.

In the context of operations management, agility is “the ability to successfully manufacture and market a broad range of low-cost, high-quality products and services with short lead times and varying volumes that provide enhanced value to customers through customization. Agility merges the four distinctive competencies of cost, quality, dependability, and flexibility”. Respectively, ‘agile manufacturing’ is “the ability to respond quickly

to unpredictable changes in customer needs by reconfiguring operations” [Blackstone 2010]. A popular synonym for agile manufacturing is ‘quick response manufacturing’ ([Suri 2010]).

Analyzing the above definitions and comparing them to those of LM, the author observes the following:

1. Both approaches share the four distinctive competencies of cost, quality, dependability and flexibility. They also share short lead times and varying production volumes.
2. While demand stability is key for a LM environment to operate smoothly, an agile environment would successfully deal with unpredictable changes in customer needs.
3. Flexibility within a LM environment would normally be between different products in one product family (flexibility within a family), while flexibility in an agile environment would be between products from different product families (flexibility between families).
4. The two approaches do not contradict but rather complement each other. Moreover a facility can be both lean and agile at the same time. In that case the terms “leagile”, or “agilean”, or “hybrid lean-agile”, (see [Elmoselhy 2013]), are used.
5. Agility would fit best when based on LM principles and practice and therefore we could consider it as an evolutionary step in the field of operations management.

Reviewing the literature from the past three years (2012–2014) utilizing EBSCO and the Thomson-Reuters web-of-science search tools, gathered 24 articles searching for ‘agile manufacturing’ or ‘agile supply chain’ in the title, abstract, or as a subject or key term were collected. Two articles are already in the sample, since they address both key words “lean” and ‘agile’. For the rest, the author refers to the most cited ones, as far as could be tracked.

Agile manufacturing systems and their respective agile supply chains are addressed by Frei and Whitacre [2012], Hasani, Zegordi and Nikbakhsh [2012] and by Costantino et al. [2012] dealing with the contingency of agile manufacturing systems, with supply chain network designs and suggesting operational models for agile supply chains.

Introducing new principles for improving upon the design and implementation of agile manufacturing and assembly systems, Frei and Whitacre [2012] focus on challenges that arise while dealing with current novel conditions. They describe an important mechanism by which biological systems can cope with uncertainty through properties described as degeneracy and

networked buffering and review some evidence from simulations using evolutionary algorithms that support some of their conjectures.

Proposing a general, comprehensive model for strategic closed-loop supply-chain-network-design under interval data uncertainty, Hasani, Zegordi and Nikbakhsh [2012] consider various assumptions such as multiple periods, multiple products and multiple supply chain echelons, as well as uncertain demand and purchasing cost. Parameters' The uncertainties of the parameters are handled by means of a robust interval optimization technique and the model matches with the decision-making environments of the food and high-tech manufacturing industries.

Assuming that the manufacturing system is composed of different stages, Costantino et al. [2012] present a technique for the strategic management of the chain, addressing supply planning and allowing the improvement of the MSC agility in terms of ability to reconfigure in order to meet performance. A case study describes the optimal MSC configuration of an Italian manufacturing firm, the results showing that the design method provides managers with key answers to SC agility issues.

Conclusion and recommendations

Reviewing LM literature provides sound evidence as to the positive effect that LM adoption has on the competitiveness of firms and organizations up to corporate level. Evidence from the field documents benefits gained from LM adoption all over the globe, in both developed and developing economies. Empirical research includes LM human resources development (HRD) and cultural aspects, and the range of application areas in the selected sample is wide and it covers, in addition to manufacturing, fields such as R&D, supporting information technologies and systems, supply chain management, purchasing and various service industries, in both the public and private sectors, to mention but a few.

However the author could not find much research investigating the relationships between the level of adoption of LM principles in economies and nations and their competitiveness (as assessed, for example, by the GCI). Closing this gap is the main recommendation for further research in the field of LM.

An exception, however, exists. In "Lean Supply Chains and the Competitiveness of Emerging Market Firms", Mefford [2013] addresses the issue of whether the type of supply chain can have a significant effect on the pace and

tenor of economic development of an economy, using several case studies to illustrate these effects.

Mefford argues that the spread of LM/TPS and its derivatives could improve technology transfer to an economy and diffuse it more widely than traditional forms of production systems and supply chains. The result is faster economic development through a more rapid transition to higher value-added manufacturing and more export-competitive industries in terms of price, quality and flexibility. The mechanisms for technology transfer in LM are the emphasis on soft technology (that is, process and management skills) and the fuller development of human resources in firms. The spread of these capabilities through the supply chain accelerates the effects on economic growth and development.

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