Energy xxx (2017) 1–8

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Lean-Green models for eco-efficient and sustainable production

M. Florentina Abreu, Anabela C. Alves*, Francisco Moreira

Centro ALGORITMI, Department of Production and Systems, University of Minho, Guimarães, Portugal

ARTICLE INFO

Article history:
Received 15 October 2016
Received in revised form
8 February 2017
Accepted 2 April 2017
Available online xxx

Keywords:
Lean production
Lean-Green
Eco-efficiency
Sustainability

ABSTRACT

Lean-Green is a concept that associates value aggregation and efficiency in operational and environmental terms. This concept arises as a corollary effect of companies' challenges for rethinking their goals and strategies in order to add more value while contributing to social equity and prevent environmental burdens. The eco-efficiency concept translates the idea of "creating more with less", in order to reduce ecological impacts and resource intensity. Lean is a strategy that encompasses a wide variety of management practices, in an integrated system, to streamline business processes, minimize waste and improve financial performance. When Lean and Green are associated in the so called Lean-Green link, many of those savings also result in environmental benefits. This paper reports the ongoing effort to provide models for the Lean-Green integration. A comparative analysis of the few models identified is provided, and the most frequently used KPI acknowledged. Findings show the existence of a limited number of Lean-Green models, published from 2012, denoting a narrow breadth of dissemination. The fundamental goal of Lean-Green models was mostly found to be related to improve the systems productivity while reducing the environmental impacts. Integrate Lean-Green initiatives constitute a valuable approach to sustain and endure a greener industrial activity.

1. Introduction

Nowadays, for a company to remain competitive and thrive on the long run, it has to focus on an enduring quest for providing value for its customers. This is achieved by doing timely deliveries of products and services, at the right price, that are truly beneficial and do not embody environmental burdens. Some fundamental pre-conditions to achieve that are the use of effective strategies and operations, enabled by energy and other resources savings rationale, adequate technology, human capabilities and an effective organizational setting.

Lean Production is recognized for its persistent goal of banishing waste from the industrial shop floors and service providers. Lean organizational model is rooted on the Toyota Production System, from the Toyota Motor Company, which, under highly restrained circumstances, was able to provide an approach that enabled the company to remain competitive and even thrive on the automobile highly competitive marketplace [1]. Some innovative thinking pushed forward the provision of solutions, which returned more value in more effective ways, i.e. by using less human effort, time and inventories, less energy, fewer resources and less residues. Present day challenges, however, require not only highly productive and responsive production systems, but also eco-efficient ones, i.e. systems that provide more value with lower environmental impacts. Both concepts are concerned on minimizing all sorts of waste, on all its shapes and appearances, including the most hard to deal with, i.e. the invisible ones. This must be achieved without raising the production costs, with no hidden external environmental consequences in the short and on the long run, so that sustainability is genuinely pursued and truly accomplished [2]. Uncovering the synergetic relationship among the Lean and Eco-efficiency approaches, normally, called Lean-Green [3], is therefore an imperious endeavour.

The literature is rich in publications on Lean, sustainability and eco-efficiency, but still there is a research gap on the literature on the Lean-Green synergy, as highlighted by Alves et al. [4]. In this publication the authors conducted a systematic literature review on 83 papers, over the 2001–2015 time-frame, whose main results revealed that the Lean-Green link was not explicitly recognized by most papers. Overall, only a small percentage (7%) of them reports a relation among Lean, eco-efficiency and sustainability. Others similar researches could be found but addressing others concerns, not explicitly the Lean-Green link [5,6] or considering other related

* Corresponding author.
E-mail addresses: florentinaabreu@netcabo.pt (M.F. Abreu), anabela@dps.uminho.pt (A.C. Alves), fmoreira@dps.uminho.pt (F. Moreira).

http://dx.doi.org/10.1016/j.energy.2017.04.016
0360-5442/

techniques [7] [8] [9]. The corollary effect of the above is that few researchers study this link and develop suitable models. Even a special volume of the Journal of Cleaner Production devoted to examining the interrelationships among lean, green, and sustainability, encompassed only nine papers, from the 43 identified to contain models, frameworks and methodologies [10]. It is common to find companies concerned with wastes reduction without taking into consideration all the benefits that a Lean-Green approach could bring. For example, when a company is interested in reducing transports, considered by Ohno [11] one of the seven wastes, it reduces energy consumption, that is an environmental waste [12]. All production wastes are causes of weak environmental performance [13], thereby reducing these wastes puts the companies in the eco-efficient pathway, but it seems that, most of the time, they are unaware of that. This motivates the authors to research this issue.

Attending to the above mentioned motivation, this paper intends to present and compare different models for the Lean-Green integration. This comparison allows estimating the levels of acceptance of the Lean-Green concept, to identify the most used performance indicators, to identify the level of applicability to real contexts and reveal its benefits. The study is based on a systematic literature review that the authors previously conducted, that was published in Alves et al. [4]. For the purpose of the current paper the authors selected and analysed the papers that presented models and/or frameworks. This selection returned 27 models that were analysed in detail aiming at identifying the ones that could be considered a Lean-Green model.

The paper is structured in five sections. After a brief introduction, section two provides the study background, namely the concepts of Lean, Eco-efficiency and Lean-Green. Section 3 explains the research methodology, and the fourth one presents the results, accrued from the analysis and classification of the 27 models, comparison of five models selected and highlighting the main findings, in terms of the most used performance indicators, benefits and applicability of the models. In the last section some conclusions are drawn.

2. Background

This section presents some concepts on the Lean Production methodology, the Eco-efficiency concept, and the Lean-Green model which integrates them both.

2.1. Lean production

Lean production is a shop floor-related management methodology, stirred on the works of Taiichi Ohno, Shigeo Shingo, and other Toyota Motor Company officials, that devised and perfected the Toyota Production System (TPS) in the post Second World War period [14] [11], which, in itself, imposed a number of particularly demanding challenges on the Japanese economy. The Lean methodology became a successful approach, and even a reference, for shop floor improvement, and has been spreading globally and across many sectors of economic activity thereafter. The TPS tried to perform well in what mass production excelled, i.e. the smallest use of resources to actually make things, while enabling for greater production flexibility along with quality assurance and timely deliveries [1]. The success of the TPS was studied and its features described in a number of MIT based research work, that disseminated the concept and became the groundwork for many more publications [15].

Toyota engineers designed the TPS so that fewer and fewer resources would be required for delivering the right products at the right time at the shortest timeframes possible, by eliminating all types of wastes, therefore requiring less human effort, fewer inventories and facilities space. Ohno [11] considered wastes all of activities that do not add value to the products and classified them in seven categories: 1) overproduction; 2) over processing; 3) transportation; 4) defects; 5) motion; 6) inventory and 7) waiting. An extra waste, i.e. untapped human potential, was later on identified [16].

According to Womack and Jones [17] Lean holds five principles: 1) Value; 2) Value Stream; 3) Flow; 4) Pull production and 5) Pursuit of Perfection. These principles are cyclical, and the later gives the mote for a new cycle of continuous improvement, also known as *kaizen*. This is enabled by people seriously committed with Lean and always unsatisfied with the *status-quo*. They become thinkers [18]. However, even the best results achieved by Lean companies all over the world have not convinced the most skeptical. For instance, Cowger [19] wonders in a short paper in the Mechanical Engineering Magazine: “What’s taking so long?”, meaning that is taking ages for manufacturers to implement Lean (namely SME enterprises), while attributing this lack of sense of urgency, and even skepticism, to confusing definitions of Lean, too much information and lack of human resources, time and money to adopt Lean initiatives. Nevertheless, it seems only a matter of time for a larger adoption of Lean, with so many studies and reports pointing out the benefits of Lean and advocating that Lean implementation is a major enabler for moving manufacturing operations from overseas and remain competitive [20].

2.2. Eco-efficiency

The Business Council for Sustainable Development (BCSD) defined eco-efficiency as: “The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impact and resource intensity throughout the life cycle, to a level at least in line with the Earth’s estimated carrying capacity.” [21]. This concept was introduced by Stephan Schmidheiny and the BCSD in the 1990s and was intended to foster a new kind of development, the sustainable development, which wants to contribute truly to a better world, including to human and nature well-being. The Eco-efficiency concept, along with other similar and dissimilar ones, represent an active set of assets that can be used to deal with the most fierce consequences of a number of pressing challenges of contemporary societies, namely the depravation of ecosystems and of the atmosphere, and of the respective provision of fundamental services (e.g. freshwater, fertile soil, adequate climate for human settings, etc.).

The eco-efficiency concept is grounded on the safeguarding of nature by providing conservation on its resources, namely with [22]: a) reduction on materials intensity b) reduction on energy intensity; c) reduction on the quantity and level of toxicity of substances; d) promotion of closed cycles and use of meaningful end-of-life strategies; e) promotion of renewables, abundant and local resources; f) improvement of the durability of the products; g) intensifying the use of services.

Providing more value with less impact requires innovation efforts, both at the product and production processes, and a distinct perspective on the assessment of products’ environmental performance. Since, the worst impacts of products may dwell on any stage of the full lifecycle, a system strategy is highly advised to avoid unintended armful relocations among lifecycle stages, and simultaneously, to identify gains opportunities, which would be hard to devise otherwise. A continuous improvement process may be used to achieve successive marginal gains, along with more substantial gains, normally achieved by way of radical innovation, which may include as well, green logistics and alternative ownership models,

Please cite this article in press as: Abreu MF, et al., Lean-Green models for eco-efficient and sustainable production, Energy (2017), http://dx.doi.org/10.1016/j.energy.2017.04.016