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How much does Lean Manufacturing need environmental and information technologies?

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A B S T R A C T

This paper analyses the role played by Environmental and Information Technologies (ET\&IT) in the capability of Lean Manufacturing (LM) to achieve improved industrial performance. In contrast to seminal literature about lean practices, and in view of increasing consumer requirements regarding response times and environmental concerns, we suggest that shop-floor technologies are crucial for transforming lean routines into enhanced performance. Hypotheses were tested in a multisectoral sample of 763 manufacturing plants (NACE codes 15–37) from five different European countries. Results confirm total mediation by both technologies between lean routines and industrial performance, which entails that LM establishes efficient conditions on the shop floor for developing technology-enabled capabilities that can be leveraged to improve industrial performance. From a managerial perspective our findings highlight the need for avoiding short-sighted attitudes and for internalising plant technologies within lean transformation projects. This is important not only because such technologies are determinant for maximising the potential of organisational routines in current manufacturing systems but also because of their intrinsic benefits.

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1. Introduction

This paper addresses how Lean Manufacturing (LM) can leverage technology-enabled capabilities to achieve improved industrial performance. Over the last 30 years, competitive pressures in the business environment have focused attention on organisational efficiency popularising management theories such as LM [1]. Increasingly, however, market developments, with sudden changes in preferences and growing environmental concerns, force companies to reconfigure their management strategies to reduce the complexity [2,3]. In order to maintain their competitiveness, firms have to incorporate new resources to meet such demands without harming efficiency, or even, where possible, improving it.

Accordingly, this paper analyses the role played by environmental and information technologies (ET\&IT) in the capability of LM to achieve improved industrial performance. The analysis of these resources was considered not only because these are two of the most widespread technologies on shop floors, but also because they are closely related to the fulfilment of these customer demands [4,5]. The technology-enabled capabilities of both resources can constitute therefore powerful mechanisms through which lean routines reinforce their contributions to manufacturing efficiency and also, because of their nature, help meet these changing client requirements and concerns (e.g., environmental challenges) in which lean principles seem weaker [6,7].

On the one hand, although the application of IT and LM principles have long been seen as mutually exclusive (e.g., [8,9,10]); it is increasingly claimed that both approaches may be interdependent and complementary [11,12,13]. While lean practices can be conducted adequately in a simple manner without using IT, recent academic and business evidence highlights the increasing importance of technology for managing the huge amount of real-time data and enhance the firm’s absorptive capacity to respond to the variation in client requirements [14,15].

Scholars increasingly consider IT resources to be decisive for leveraging organisational practices, which then lead to further improvement in industrial performance [16]. Similarly, many lean manufacturers have begun adopting IT to support daily process management and new product development (NPD) to respond
with greater speed and flexibility to changes in customer demands [17,4].

There are, however, some discordant opinions which must be considered to avoid wasted time and resources; including the automation of muda (non-value added activities). This is probably one of the best examples of how a technocentric view can increase waste just by getting caught up in the newest technological fads. Classic authors such as Sugimori et al. [18] and Ohno [9] had already warned that the use of IT could entail a certain dehumanisation of processes and, more importantly, gave rise to unnecessary costs associated with surplus information. Similarly, Toyota [8] stated that receiving a huge amount of information could damage workers’ capacity to think and, therefore, their problem-solving skills. Along the same lines, Liker [19] advocates using “only reliable, thoroughly-tested technology that serves your people and process”, whereas Riezebos et al. [20] and Hendricks et al. nuance this posture suggesting that introducing IT could add value in specific areas such as production planning or in supply chain management (SCM), among others.

On the other hand, social awareness about global warming, or water and land contamination, also makes a difference in how operations should be run. After all, according to a recent survey by Nielsen, 55% of consumers will pay extra for products and services from companies committed to pursuing a positive social and environmental impact. Designing tense flows under a Just-in-Time (JIT) inspiration, for instance, should be taken into account how these are going to affect CO2 emissions. Shorter product life cycles and sudden changes in preferences, analogously, should have some influence on how product design, industrialisation and logistics affect the firm’s environmental impact. The issue at stake is that the efficiency and sustainability approaches to operations are not always aligned, so additional resources are required to achieve “green goals” [21,22,23]. Environmental technologies (ET) thus come into play as a valuable resource to develop and complement lean initiatives. The ET approach to waste and energy reduction, together with lean principles and tools, should enable firms to find new opportunities for waste elimination and thereby improve their industrial performance. However, despite of the enormous development of the Lean-Green topic in recent years, the absence of studies that analyse the relationships among lean principles, ET and industrial performance is striking [21].

Against this background, the contribution of this paper is not only to clarify and extend the literature on the relation between LM and ET&T, but also to do so while studying multiple mediators of industrial performance in an integrated model. Bono and McNamara [24] emphasised the need of this type of exercises when an area of research becomes more mature and when the causal relation between variables A and B—in our case LM and industrial performance—can be taken for granted. In these situations, choosing the right mediators to describe and measure the process by which variable A affects variable B becomes essential, but treating them separately, as is usually with Lean-ET and Lean-IT, when in fact they coexist in the vast majority of industrial environments, can be a sign of omitted variable bias.

Here, precisely, lies the main contribution of this paper. Moving away from the usual separate analysis, and bearing in mind the characteristics of most manufacturing systems today, we propose a comprehensive model that is closer to reality and allows for evaluation of the relationships among technological and organizational resources. We attempt to evaluate how LM establishes the right conditions for developing technology-intensive environments, and how shop-floor technologies can subsequently be leveraged to enhance the contribution of lean practices to industrial performance. This allows us to extend the current Lean-Green and Lean-IT knowledge in three areas: (1) we widen the conventional lean wisdom by drawing attention to the need to explicitly inter-

2. Theoretical background and hypotheses

2.1. Lean routines, environmental technologies and industrial performance

Lean practices did not initially include the idea of protecting the environment. However since LM pursues the “systematic elimination of waste”, it is considered by many authors as the most adequate paradigm to balance the trade-off between efficiency and sustainability [25,7]. Although we recognise the appropriateness of LM for this purpose, it is also true that efficiency and sustainability approaches are not always aligned, and additional resources are required to achieve the “green goals” [21,23]. Thus, ET appear here not only as the necessary resource for developing lean routines consistent with the environmental commitment, but also to articulate and reinforce their contribution to manufacturing efficiency. We shall evaluate this issue empirically, equating it with the mediating role (H1) that can be played by ET between lean routines (LR) and industrial performance (IP). This approach requires analysing, firstly, the causality between LR and ET (H1a) and then, between ET and IP (H1b) as shown graphically in Fig. 1.

Although we analyse both sub-causal links, we do not propose the sub-hypotheses separately because they have already been extensively studied in the literature [26,27]. Similarly, the direct effect (LM on performance) is not tested because numerous studies have already proven the positive link between LM and productivity results.

Regarding the first part of the mediation (H1a, Fig. 1), which evaluates the link between LR and the level of ET implementation, ample evidence suggests that many LM principles (e.g., waste reduction, supplier collaboration and continuous improvement) precede and serve as the foundation for numerous environmental practices and technologies implementation. King and Lenox [28], for instance, cite different cases in which firms developed their environmental and technological initiatives by following the same basic lean principles. Similarly González-Benito and González-Benito [29] note the need to have JIT-based programs and Total Quality Management (TQM) programs to develop truly efficient environmental initiatives and standards. Florida [30] argues that
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