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# The joint use of resilience engineering and lean production for work system design: A study in healthcare

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ABSTRACT

Although lean production (LP) has been increasingly adopted in healthcare systems, its benefits often fall short of expectations. This might be partially due to the failure of lean to account for the complexity of healthcare. This paper discusses the joint use of principles of LP and resilience engineering (RE), which is an approach for system design inspired by complexity science. Thus, a framework for supporting the design of socio-technical systems, which combines insights from LP and RE, was developed and tested in a system involving a patient flow from an emergency department to an intensive care unit. Based on this empirical study, as well as on extant theory, eight design propositions that support the framework application were developed. Both the framework and its corresponding propositions can contribute to the design of socio-technical systems that are at the same time safe and efficient.

## 1. Introduction

In many countries, lean production (LP) has emerged as a widely used approach for improving healthcare systems (D'Andreamatteo et al., 2015). However, there is still skepticism in some circles, given that: (i) much evidence from LP success in healthcare has been collected and disseminated by consultants (Hartzband and Groopman, 2016; Leggat et al., 2015); (ii) lean practices often adopt oversimplified assumptions about work-as-done (Sheps and Cardiff, 2017); and (iii) undesired side-effects arising from LP have been reported in healthcare, such as slack reduction (Radnor et al., 2012).

Disappointing results of LP can be partially due to the lack of consideration of the complexity of healthcare (Dobrzykowski et al., 2016). Complex socio-technical systems are plagued by uncertainty, diversity, and non-linear interactions (Perrow, 1984). By contrast, LP has been criticized for overemphasizing technical tools and neglecting the implementation context (Netland, 2016).

Resilience Engineering (RE) can play a role in addressing the gaps in LP when applied to healthcare. RE has been a topic of increasing academic and practical interest in healthcare (Fairbanks et al., 2014). This led to the coining of the resilient health care concept, which is defined as the "ability of the healthcare system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required performance under both expected and unexpected conditions" (Hollnagel et al., 2013, p. xxv). RE in healthcare has shed light on the gap between work-as-imagined and work-as-done, as well as on new approaches for patient safety, which rely on learning from every day work, instead of only from adverse events (Clay-Williams et al., 2015). RE is based on complexity science and, in contrast to lean it recognizes that the performance variability of front-line practitioners is essential to safe care of patients (Hollnagel, 2012).

While RE and LP seem to be in conflict, commonalities between them have been identified (Azadeh et al., 2017; Saurin et al., 2017). Some recent case studies, although not taking an RE perspective, have also provided piece of empirical evidence that LP can be used synergistically with safety management, either in healthcare (Crema and Verbano, 2015) or manufacturing plants (Gnoni et al., 2013). Furthermore, the joint use of RE and LP can be an effective approach for balancing the efficiency-thoroughness trade-off (Hollnagel, 2009), which is ubiquitous in complex socio-technical systems. On the one hand, RE is strongly concerned with the study of safety (a proxy of thoroughness), although the more recent literature has moved towards a resilience per se emphasis (Patriarca et al., 2018). On the other hand, the study of LP is historically associated with the control of wastes (Liker, 2004), which suggests a strong concern with efficiency.

Regardless of the potential synergies between LP and RE, there are no practical tools for their integrated use, and these relationships are not yet well understood. Partially, these gaps can be due to the lack of

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wide dissemination of RE in practice. Thus, practical examples of jointly applying RE and LP are unusual, which hinders empirical investigation. In this context, this study addresses two research questions (RQ). RQ1 is stated as "how can work system design be supported by combining insights from RE and LP?" As for RQ2, it is stated as "which are the insights of RE into LP and vice versa?"

In order to answer RQ1, we developed a framework for supporting the work system design, inspired by concepts from both LP and RE. Then, the framework was tested in the flow of critically ill patients from an emergency department to an intensive care unit. The results of this field study, as well as extant theory, set a basis for the identification of mutual insights between RE and LP, thus answering RQ2. These insights are presented in this study as "design propositions" (Van Aken et al., 2016), which offer theoretical guidance for the integrated use of RE and LP, playing a complementary role to the framework.

The adopted methods and findings of this study are also relevant for other sectors, not only healthcare. However, the empirical focus on healthcare has practical relevance, due to the recent dissemination of LP in this sector. Healthcare is also an adequate environment for investigating whether LP principles, which were originally conceived for more linear systems, can benefit from approaches tailored for complexity, such as RE.

## 2. Resilience engineering: design guidelines

RE aims at the "deliberate design and construction of systems that have the capacity of resilience" (Fairbanks et al., 2014). However, designers should not focus on designing resilience itself. Rather, designers should be concerned with the creation of conditions that support resilient performance, since it is an emergent phenomenon (Hollnagel, 2014).

The main dimensions of resilient systems have been defined by seminal authors of RE. For instance, Hollnagel (2015) recommends the development of four resilient potentials: anticipation, monitoring, responding, and learning. These four potentials should be developed at the level of systems, rather than individuals. Woods (2015) argues that resilient systems have the abilities to: rebound from disrupting events; to bring extra adaptive capacity to bear, when surprise events challenge the system boundaries; and to sustain adaptability, which means to adapt to future surprises as conditions continue to evolve.

A core RE assumption, which permeates the aforementioned guidelines, is that individuals and organizations are always adjusting to current conditions and constraints (Hollnagel, 2014). Due to these adjustments, work-as-imagined tends to differ from work-as-done. The former corresponds to what designers, managers, regulators and authorities believe occurs, or should occur. The latter refers to what actually occurs in the workplace (Hollnagel, 2014).

In line with the principles set by seminal RE authors, six guidelines for the management of complex socio-technical systems were compiled by Saurin et al. (2013). These guidelines are: give visibility to processes and outcomes; monitor unintended consequences of improvements and small changes; encourage diversity of perspectives when making decisions; design slack; monitor and understand the gap between prescription and practice; and create an environment that supports resilience. The guidelines address important dimensions of system design when facing complexity – e.g. slack absorbs variability, and certain types of diversity, such as of skills and functions, may be an asset for devising innovative solutions. These guidelines were used in a previous study (Righi and Saurin, 2015) for assessing the same emergency department that was focused on by the research reported in this paper.

## 3. Lean production: some concepts relevant for this study

Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently minimizing supplier, customer, and internal variability (Shah and Ward, 2007). As result of this ambitious intent, LP permeates all elements of a socio-technical system, thus making its implementation difficult and slow (Liker, 2004).

In fact, the healthcare organization focused on by our study adopted LP principles introduced by the researchers, instead of having a structured lean management system. Mature lean systems are rare even in the manufacturing sector and the situation we faced in our study (i.e. the isolated use of some lean principles) is the most common in healthcare (Radnor et al., 2012).

Thus, rather than going deep in the myriad of lean principles and practices, which have been discussed by a vast literature (e.g. see Liker, 2004 for a good overview), in this Section we are limited to define two key lean concepts used in this research study. These are: (i) value, which corresponds to outputs that derive from a production system, which are required by clients, who are keen on paying for them (Bolviken et al., 2014); and (ii) waste, which accounts for activities that consume time and resources but fail to add value to the final service or product (Shingo, 1989). Waste may also be an unwanted physical functionality, an unwanted output, or the use of more resources than is needed (Bolviken et al., 2014). Thus, value and waste are inseparable concepts, and what is waste to a client may be value to another – it depends on what counts as value to the client. A well-known classification of wastes was proposed by Shingo (1989). This classification is applicable to healthcare, involving waste of defects, overproduction, transportation, waiting, inventory, motion, over processing, and talent (Graban, 2011).

Concerning the lean principles, a compact account is given by Womack and Jones (1998): (a) specify *value* from the standpoint of the end customer; (b) identify the *value stream*, by eliminating steps that do not create value; (c) *flow*, by creating interruption-free processes across the value stream; (d) *pull*, by producing in response to customer demand; and (e) pursue *perfection*, by continuously improving processes through the plan-do-check-act cycle (PDCA).

## 4. Research design

### 4.1. Epistemological approach

This study is framed as an application of Design Science Research, in which all or part of the investigated phenomenon may be created as opposed to naturally occurring. This approach has been recently adopted in resilience engineering, such as in the proposal of a framework for the analysis of slack in healthcare systems (Saurin and Werle, 2017).

The epistemology of design science stresses knowing through making, involving the development of an innovative artifact to solve a practical problem, and simultaneously making a prescriptive scientific contribution (Holmstrom et al., 2009). In this research, the artifact is a framework for supporting the work system design, inspired by concepts from both LP and RE. As for the practical problem, from the lean view it can be defined as how to make lean interventions more compatible with the nature of complex systems, which is a gap identified by Soliman and Saurin (2017) in a recent review. From the RE perspective, the problem is how to carry out an intervention based on RE theory, which has been criticized for a paucity of empirical evidence from practical implementation (Anderson et al., 2016).

The development of the framework was based on the extant literature of LP, RE, and complex socio-technical systems. A tentative design was developed and then tested and refined in a field study. While the framework is supported by theory, it is worth noting that, in design science research, the development of artefacts cannot logically be deduced from the problem it is to solve, nor from extant theory; the design is to some extent a creative step (Van Aken et al., 2016).

In fact, the framework should be interpreted as a generic design, which is intended to be used as a "design model by well-trained and experienced designers to make their own context specific design" (Van