

# **Re-formulating the theoretical principles of lean manufacturing in the Fourth Industrial Revolution: A Grounded Theory Approach**

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## **Abstract**

Lean Manufacturing and Lean Thinking are theoretical-practical approaches that have been consolidating over the last 25 years extending throughout the world with different emphases and ways of applying their most common tools. This article presents the first findings and conclusions about an investigation that seeks the theoretical analysis and re-construction of conceptual nuclei that revolve around these approaches within the framework of the tendencies of change associated with what has been called the Fourth Industrial Revolution (Industry 4.0), ie the revolution of cyber-physical systems of production and delivery, high interconnectivity and artificial cognition, biotechnologies and additive manufacturing, as well as integrated ecosystems. The research follows the Grounded Theory method with hermeneutical analysis of qualitative data collected through in-depth interviews and theoretical saturation in different lean manufacturing contexts in transnational industries located in Costa Rica, Central America. We conclude that lean thinking must evolve according to the technological tendencies of Industry 4.0, especially in the conceptualization of value, value stream and MUDA (waste); as well as the need to more aggressively integrate human-robot collaborative techniques in their implementation. As a future line of research is the theoretical modeling of integration "lean-cyber-physical systems" and its implications in service sectors.

## **Keywords**

Lean Manufacturing, Lean Thinking, Grounded Theory, Fourth Industrial Revolution, Cyber-physical Systems

## **Biography**

**Eldon Caldwell** is "Outstanding Service Award" of the Industrial Engineering and Operations Management Society, USA; full professor (Cathedraticus) University of Costa Rica with over 25 years of teaching and research experience. After his Bachelor and Master degree in Industrial Engineering at University of Costa Rica, he obtained several Master degree (MBA, Health Systems, Social Marketing, Operations Engineering) and finally a Ph.D. in Industrial Engineering at the University of Nevada, USA/Autonomous University of Central America, CR. Currently he serve as Chairman of Industrial Engineering Department at University of Costa Rica and his research interests include smart, lean and cognitive systems, robotics, cyber-physical systems and intelligent technologies for educational systems implementation in workplace for equitable employment of people with disabilities. Contact: [eldon.caldwell@ucr.ac.cr](mailto:eldon.caldwell@ucr.ac.cr)