

# **From Lean Manufacturing to Lean Enterprise 4.0: Intergration of theoretical foundations emerging with Grounded Theory Method**

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## **Abstract**

Today, the world is involved in a cyber-physical technology revolution that is called Fourth Industrial Revolution or Industry 4.0. However, Lean Manufacturing and Lean Thinking are theoretical-practical approaches that still have a 25 years old framework.

We started with a primary assumption: the emerging of cyber-physical systems and robots; additive and nano manufacturing, high interconnectivity and interoperability; biotechnologies and integrated ecosystems; have established an urgent re-formulation of the “lean thinking” foundations.

This research seeks for answers to what theoretical principles must to be changed in “lean thinking” using a Grounded Theory design with hermeneutical analysis of qualitative data and theoretical saturation in different lean enterprises located in Costa Rica, Central America.

We conclude that classic lean manufacturing must to evolve to a “lean enterprise 4.0” approach with a new framework of theoretical foundations. The adding value process must to open to environmental and social purposes and the “value stream” is not a chained system anymore; this implies hat the concept of MUDA must to be aligned not only with “cost reduction” but with customer needs and sustainable return on investment. In addition, MUDA re-conceptualization implies the analysis of new categories related with data management, machine learning and software architecture.

## **Keywords**

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

## **Biographies**

**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)