Integrating Lean Manufacturing and Energy Management for Sustainable Efficiency

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Abstract

In the contemporary industrial landscape, energy efficiency has evolved from being a discretionary objective to an imperative for both competitiveness and sustainability in manufacturing. Excessive energy consumption is increasingly becoming the "eighth waste" in lean manufacturing. As such, policymakers and industrial leaders are prioritizing strategies to optimize energy use across sectors. The integration of lean manufacturing principles with energy management practices has emerged as a critical strategy for achieving sustainable industrial efficiency. This study introduces a unique methodology that quantifies the energy consumption associated with each component within a given manufacturing process. Beyond direct energy consumption, the research also explores opportunities for measuring and reducing indirect energy use. These strategies contribute to a comprehensive, energy-efficient manufacturing ecosystem. By combining Value Stream Mapping (VSM) with specific energy consumption (SEC) metrics, the proposed approach facilitates systematic identification, measurement, and rectification of energy inefficiencies. This framework provides a structured pathway toward enhancing energy efficiency, thus advancing sustainable manufacturing practices. Ultimately, this paper presents a scalable and adaptable framework that manufacturing firms can implement to align operational productivity with sustainability objectives, thereby promoting a more energy-conscious and resource-efficient industrial environment.

Keywords
Lean manufacturing, Energy management, Specific Energy Consumption (SEC), Sustainable manufacturing, Energy efficiency

Biographies
Michael Dahamah is a graduate student at Michigan Technological University pursuing a Master of Science in Manufacturing Engineering. With a strong foundation in mechanical engineering and engineering management, he is passionate about innovation, efficiency, and continuous improvement in the manufacturing sector. He has industry experience in planning, maintenance, and process optimization, coupled with expertise in computational modeling and data-driven decision-making. Dedicated to lifelong learning and problem-solving, he strives to bridge the gap between engineering principles and real-world industrial challenges. He is a member of the Society of Manufacturing Engineers (SME) and the National Society of Black Engineers (NSBE), reflecting his commitment to professional growth, collaboration, and the advancement of modern engineering practices.

Dr. Anis Fatima is an accomplished academician in the Department of Manufacturing and Mechanical Engineering Technology at Michigan Technological University, with over seventeen years of experience in academia, including eight years of post-doctoral higher education teaching. Dr. Anis Fatima has a proven track record as both a team leader and collaborator, with expertise in bridging the gap between traditional manufacturing practices and modern advancements such as digitalization, sustainable manufacturing, and circular economy principles.

Dr. John Irwin is a tenured Professor, Mechanical Engineering Technology and Chair of the Manufacturing and Mechanical Engineering Technology Department in the College of Engineering, at Michigan Technological University. In addition, he is Director of the Research and Innovation in STEAM Education (RISE) Institute at Michigan Tech. He has a Doctorate in Curriculum and Instruction from Wayne State University, Detroit, Michigan. Dr. Irwin is PI for an NSF S-STEM grant until 2025. He is experienced in the manufacturing industry as well as the teaching profession, with five years in engineering design, several years of part-time consulting in the industry and over 30 total years of teaching. Dr. Irwin's research focus is on teaching and learning in computer-aided design, analysis, & manufacturing subjects. Areas of teaching expertise are Parametric Modeling, FEA Methods, Computer Aided Manufacturing, Statics, Strength of Materials, and Product Design and Development.