Chapter 7
Cognitive Ergonomics in Smart Manufacturing: Aligning Technology With Human Capabilities

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ABSTRACT

The rise of smart manufacturing under Industry 4.0 demands a harmonious integration between advanced technology and human cognitive abilities. This paper explores the role of cognitive ergonomics in ensuring that complex systems, automation, and artificial intelligence are designed to support, rather than overwhelm, the human operator. By focusing on cognitive load, decision-making processes, mental models, and user interfaces, this study emphasizes the importance of human-centred design in smart work environments. Through a review of empirical research and case studies, the paper highlights the psychological challenges and opportunities arising from human-technology interaction in manufacturing settings. Practical recommendations are provided for optimizing task design, reducing mental fatigue, and improving performance and well-being in technologically advanced workplaces. The paper argues that aligning technological innovation with psychological capabilities is critical to achieving sustainable productivity and employee satisfaction in smart manufacturing systems.

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1. INTRODUCTION

Smart manufacturing is reshaping the global industrial landscape, driven by the convergence of automation, data analytics, and interconnected systems collectively termed Industry 4.0. In Malaysia, this technological revolution is guided by initiatives such as the National Policy on Industry 4.0 (Industry4WRD), which aims to transform the manufacturing sector into a digitally driven and people-centric industry. While much of the focus has been placed on technological innovation and automation, an equally critical factor, the cognitive capacity of human operators has often been underemphasized.

Cognitive ergonomics, a key subfield of human factors psychology, offers a lens through which the interaction between humans and complex systems can be examined and optimized (Wickens, 2008). It emphasizes the design of technologies and environments that align with human mental processes such as perception, memory, decision-making, and attention (Vicente, 2006). In high-stakes manufacturing environments, these mental processes are often taxed by the pace and complexity of operations, leading to cognitive overload, performance errors, and psychological fatigue.

Malaysian manufacturing industries, particularly in Penang, Selangor, and Johor, have seen rapid adoption of smart technologies, including robotics, automated quality inspection, and IoT-enabled machinery. While these innovations boost efficiency, they also demand a high degree of cognitive agility from operators who must interpret complex data, make time-sensitive decisions, and maintain situational awareness in digital control environments. For example, a case study from an electronics plant in Penang revealed that machine operators struggled with interpreting multi-screen dashboards, resulting in increased error rates and delayed response times (Mayer, Schneider & Braun, 2020).

This paper argues that the sustainable success of smart manufacturing depends on how well these systems are aligned with the cognitive capabilities of their users. Neglecting the human component risks undermining technological investments and jeopardizing both productivity and well-being. The integration of cognitive ergonomics into manufacturing practices ensures that technological complexity does not exceed human limitations and that workplaces are designed to enhance mental performance rather than diminish it.

Accordingly, the objectives of this paper are threefold:

1. To define cognitive ergonomics and its relevance in the context of Malaysian smart manufacturing.
2. To examine the psychological challenges and opportunities arising from human-technology interaction.