Environmental Engineering and Management Journal

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

AN UNSUPERVISED MACHINE LEARNING APPROACH TO ASSESSING ENTERPRISE GREEN CAPABILITIES: AN SME PERSPECTIVE

Gülşen Akman, Ali İhsan Boyacı*

Kocaeli University, Industrial Engineering Department, Kocaeli, Turkey

Abstract

Small and medium-sized enterprises (SMEs) have a critical importance in terms of environmental impact. However, especially in the context of developing countries, there are limited studies on the evaluation of the green capabilities of SMEs, and available data on a regional basis are quite insufficient. This study aims to fill these gaps and contribute to the literature by assessing SMEs in the manufacturing industry with respect to their green capabilities. The required data were collected from 278 SMEs operating in Türkiye using a questionnaire designed based on 11 measurement variables, administered through e-mail and face-to-face interviews. An unsupervised machine learning approach consisting of Principal Component Analysis (PCA) and K-Means clustering algorithm was employed to analyse the data. While PCA was used to reduce 11 measurement variables to 3 key dimensions of enterprise green capability, which are green manufacturing capability, green design capability, and green innovation capability, K-means algorithm was used to divide 278 SMEs into three classes: (1) good, (2) medium, and (3) bad, according to their greenness level. Clustering results and performance were measured and assessed by using two metrics, namely silhouette score and Adjusted Rand Index. The distribution of companies for each cluster was examined according to industry, age, number of employees, and capital structure characteristics. The findings of the study provide empirical support for understanding the greenness levels of SMEs in the manufacturing industry in Türkiye and form a basis for comparison with companies in other regions.

Key words: green capabilities, green innovation, machine learning, unsupervised learning

Received: May, 2024; Revised final: March, 2025; Accepted: March, 2025

* Author to whom all correspondence should be addressed: e-mail: ali.ihsan@kocaeli.edu.tr; Phone: +90 5399216189; Fax: +90 5399216189