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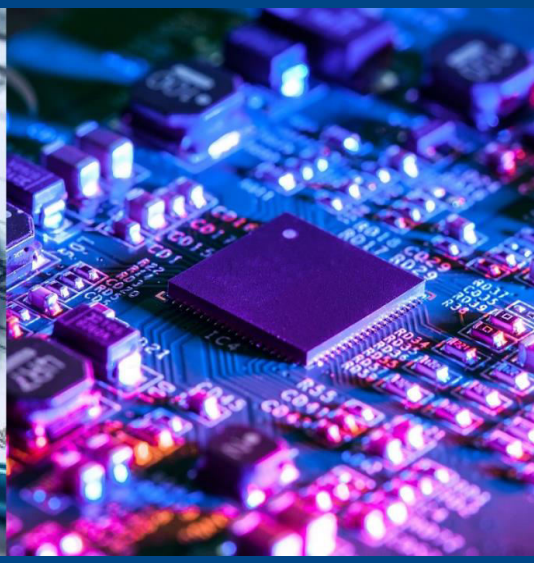

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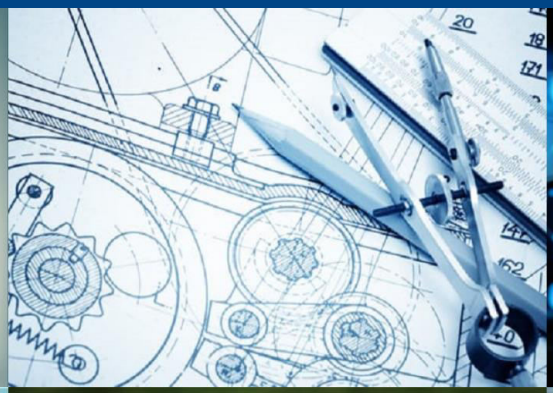

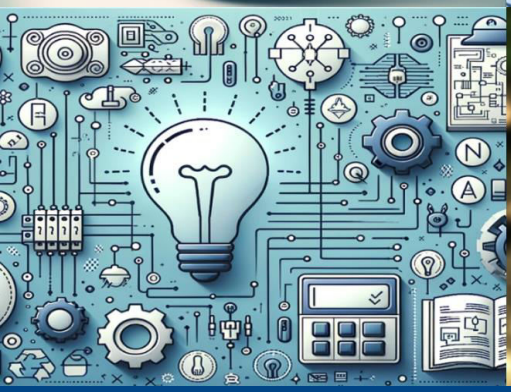

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Barriers of Industry 4.0 for Supply Chain Decarbonisation in Paint Industry

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ABSTRACT: The global imperative to combat climate change has intensified the focus on decarbonising industrial supply chains, particularly in high-emission sectors such as paint manufacturing. Industry 4.0, characterized by advanced digital technologies like the Internet of Things (IoT), artificial intelligence (AI), big data analytics, cloud computing, and cyber-physical systems, offers transformative potential to reduce carbon footprints across the supply chain. However, the implementation of these technologies is not without challenges. This study aims to identify and evaluate the barriers to Industry 4.0 adoption for supply chain decarbonisation in the paint industry, with Asian Paints Limited serving as the primary case for analysis. To systematically assess and prioritize these barriers, the study employs the Failure Mode and Effect Analysis (FMEA) framework.

KEYWORDS: Industry 4.0 adoption, paint industry, supply chain decarbonisation, barriers, technological challenges, cybersecurity, data management, organizational barriers, financial constraints, skilled workforce, infrastructure readiness, policy support, green supply chain management, Internet of Things (IoT), Artificial Intelligence (AI), big data analytics, cloud computing, Failure Mode and Effect Analysis (FMEA), Step-wise Weight Assessment Ratio Analysis (SWARA),

I. INTRODUCTION

The paint industry is a critical component of the manufacturing sector, supporting construction, automotive, and consumer goods. However, it is also resource-intensive and contributes significantly to environmental emissions through its supply chain operations. In recent years, the adoption of Industry 4.0 technologies—including IoT, AI, cloud computing, and robotics—has emerged as a potential enabler of supply chain decarbonisation. Despite its transformative potential, the implementation of Industry 4.0 in the paint industry remains limited due to various technical, financial, and organizational barriers. Barriers to Industry 4.0 adoption in general manufacturing sectors (Kamble et al., 2020; Dalenogare et al., 2018), and some have discussed its role in enhancing environmental sustainability (Bongomin et al., 2020; Sahoo & Yadav, 2022).

II. LITERATURE REVIEW

The integration of Industry 4.0 (I4.0) technologies within the supply chain is seen as a vital step toward achieving decarbonisation goals. However, the paint industry faces numerous challenges in this transformation. Several studies have evaluated the barriers that hinder the effective implementation of Industry 4.0, especially in sectors with high environmental footprints like paints and coatings. **Mittal et al. (2018)** discussed the organizational and infrastructural readiness of Indian manufacturing sectors for I4.0 adoption. **Kamble et al. (2018)** studied the technological readiness and barriers of I4.0 in Indian industries and pointed out cybersecurity concerns, lack of reliable internet connectivity, and insufficient employee training

III. RESEARCH METHODOLOGY

To investigate the barriers to Industry 4.0 implementation for supply chain decarbonisation in the paint industry, this study adopts the*Step*-wise *Weight Assessment Ratio Analysis Method (SWARA).* Step-wise Weight Assessment Ratio Analysis (SWARA) was developed by Kersuliene et al. (2010) to calculate the weight of selection criteria based on expert's knowledge and experience. One criterion may be higher or lower in significance than other. The significance ratio of criteria is determined in this method for making decisions. Pair-wise comparison is reduced in this method in comparison to others method, AHP, BWM.

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IV. DATA COLLECTION AND ANALYSIS

A questionnaire was emailed to ten executives from **a paint company**, a leading player in the global paint and coatings industry. They were asked to rate the barriers in terms of their relative (expected) significance using linguistics terms. Respondents are coded as DM1, DM2,…, DM10. The analysis is done in following steps: *Step 1:* Barriers expected significance rating (p_i) was done by group of 10 DMs. *Step 2*: Aggregate fuzzy expected significance rating was obtained using mean.

V. DISCUSSION

The analysis highlights that barriers B3 and B7 are the most critical challenges hindering the adoption of Industry 4.0 for supply chain decarbonisation in the paint industry. Their top ranking reflects significant obstacles—possibly related to technology integration or data management—that require urgent attention. Barriers B5 and B1 follow, indicating moderate challenges that could slow progress if not addressed. Lower-ranked barriers, such as B4 and B6, while less severe, still contribute to overall inefficiencies in decarbonisation efforts.

VI. CONCLUSION

The data analysis clearly identifies barriers B3 and B7 as the most significant obstacles to Industry 4.0 adoption in the paint industry's supply chain decarbonisation efforts. These top-ranked barriers likely represent critical issues such as technological integration and data management challenges. Lower-ranked barriers, while less impactful individually, collectively affect the overall implementation process. Addressing these barriers through focused strategies—such as investing in advanced digital infrastructure, improving workforce capabilities, enhancing collaboration among stakeholders, and developing supportive policies—will be essential for successful Industry 4.0 adoption.

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