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The Financial Impact of Digital Twin Adoption and GST Compliance on Foundry MSMEs in Agra: A Study of Traditional and Modern Units

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ABSTRACT

The foundry cluster in Agra represents a vital component of Uttar Pradesh's industrial heritage, creating a juxtaposition of legacy units like Vijay Iron Foundry (Est. 1969) and contemporary enterprises such as Jai Kapish Udyog and Expert Founders & Engineers. Despite their historical significance, these MSMEs are currently navigating a complex financial landscape characterized by antiquated manufacturing methodologies and stringent statutory obligations under the Goods and Services Tax (GST) regime. This research investigates the economic feasibility of integrating 'Digital Twin' technology a virtual emulation of physical production systems within Agra's foundry ecosystem. Adopting a commerce-centric perspective, the study correlates the "Cost of Poor Quality" (COPQ) with the loss of Input Tax Credit (ITC). The findings suggest that Digital Twin adoption serves not merely as a technical upgrade but as a strategic financial instrument, enhancing working capital fluidity and ensuring audit readiness in a rigorous tax environment.

Keywords: MSME Modernization, Digital Twin, GST Compliance, Input Tax Credit (ITC), Agra Foundry Cluster, Financial Management, Industry 4.0.

1. INTRODUCTION

The Micro, Small, and Medium Enterprises (MSME) sector serves as a critical pillar of the Indian economy, driving GDP growth and employment. Within this domain, the Agra Foundry Cluster holds a unique position, transitioning from a colonial-era industrial hub to a modern manufacturing center for cast iron products and automobile

components. However, this evolution faces a significant disruption: the implementation of the Goods and Services Tax (GST) in 2017. For the foundry sector, where material wastage is inherent, GST has introduced complex challenges regarding the claim ability of Input Tax Credit (ITC).

1.1 The Industry Dichotomy

The cluster currently exhibits a structural duality:

- Legacy Units: Represented by established firms relying on heuristic, experience-based manufacturing. These units often lack real-time data, resulting in higher rejection rates that inflate the Cost of Production (COP).
- Modern Enterprises: New-age units that embrace technological integration, recognizing that manufacturing precision is intrinsically linked to financial solvency.

1.2 The Double Financial Jeopardy

In traditional foundry operations, a rejected batch incurs a twofold financial penalty:

- Direct Economic Loss: The sunk cost of raw materials, labour, and energy.
- Statutory Tax Loss: Under Section 17 (5) (h) of the CGST Act, 2017, ITC is blocked for goods "lost, stolen, destroyed, or written off." Consequently, high rejection rates necessitate the reversal of ITC, thereby converting a tax asset into a liability.

1.3 Historical & Environmental Context

The trajectory of the Agra cluster changed drastically following the Supreme Court's 1996 verdict in M.C. Mehta vs. Union of India. The establishment of the Taj Trapezium Zone (TTZ) mandated a shift from cheap coal-fired Cupola furnaces to expensive Natural Gas or Electric Induction furnaces.

This transition fundamentally altered the cost structure. In the "Coal Era," re-melting defective iron was affordable. Today, with high industrial power tariffs in Uttar Pradesh, the "Cost of Re-melting" is

prohibitive. Thus, efficiency is no longer optional; it is a financial imperative to prevent capital leakage.

2. LITERATURE REVIEW

To establish a theoretical basis, this study synthesizes literature from Quality Management, Technology, and Taxation.

2.1 Industry 4.0 and Cost Management

Contemporary research by Moeuf et al. (2018) posits that for SMEs, the primary incentive for adopting Industry 4.0 is cost rationalization rather than market expansion. In the low-margin context of Agra, technology must demonstrate immediate Return on Investment (ROI).

2.2 Digital Twin Framework

Conceptualized by Dr. Michael Grieves, a Digital Twin creates a virtual simulation of the casting process. Tao et al. (2019) demonstrated that these systems act as a "predictive shield," identifying potential defects like porosity before the physical pouring of metal occurs.

- Evolutionary Stages: Research suggests four stages: information monitoring (1985–2002), digital simulation (2003–2014), IoT-enabled, and current decision-making frameworks.
- F. U. Khanet. al (2022) “Assessing and Evaluating Financial Performance of Textile Companies Using Dupont Model: Evidence from Pakistan”. The primary goal of this research was to use an improved version of the Dupont analysis method to evaluate the Performance of textile organizations in Pakistan. Using multiple linear regression analysis, this study discovered that NPM and EM had a substantial positive effect on ROE. AT, on the other hand, has an unfavorable effect on the ROE of Pakistan's 74 textile organizations.

2.3 The Research Gap: Tech-Tax Nexus

While Schiffauerova and Thomson (2006) categorized the "Cost of Poor Quality" (COPQ), and legal scholars like Gupta & Singh (2019) analyzed GST compliance burdens, there is a paucity of research connecting the

two. Existing literature overlooks the impact of Section 17 (5) (h) on manufacturing wastage. This study bridges that gap by proposing a "GST-Adjusted COPQ Model," arguing that reducing physical waste via Digital Twins is a direct method of tax optimization.

3. RESEARCH METHODOLOGY

Objective: To quantify the financial impact of production rejection on GST ITC claims and propose a Digital Twin-based financial model.

Research Design: A Descriptive and Analytical approach utilizing comparative financial modeling.

Data Sources:

- Primary: Structured interviews with proprietors of select Agra-based foundries (e.g., Expert Founders & Engineers).
- Secondary: GST filing trends, Annual Reports, and technical specifications of induction furnaces.

4. FINANCIAL ANALYSIS: THE ECONOMIC IMPACT OF DIGITAL TWINS

This section translates technical efficiency into financial terminology, analyzing the shift from "Post-Mortem Costing" to "Pre-Emptive Financial Control."

4.1 Investment Analysis (CapEx vs. OpEx)

A barrier to entry for MSMEs is the perceived cost. Table 4.1 outlines a "Frugal Innovation" investment model suitable for a mid-sized Agra unit (100 Tons/Month capacity).

Cost Component	Type	Estimated Cost (₹)
Hardware (IoT Sensors, DAQ, Spectrometer Integration)	CapEx	₹ 3,50,000
Simulation Software (SME Perpetual License)	CapEx	₹ 4,50,000
IT Infrastructure (Workstations)	CapEx	₹ 1,00,000
Workforce Training & Cloud Maintenance (Year 1)	OpEx	₹ 1,10,000
Total Initial Investment		**₹ 10,10,000**

Table 4.1: Estimated Capital Requirement

Source: Author Compiled

4.2 Comparative Financial Modeling

The core hypothesis is tested by comparing a Traditional Unit (12% Rejection Rate) against a Digital Twin-enabled Unit (2% Rejection Rate).

Assumptions: Monthly Material Input: ₹10 Lakhs; GST Rate: 18%.

Particulars	Traditional Unit	Digital Twin Unit	Variance (Savings)
A. Production Volume	100 Tons	100 Tons	-
B. Rejection Rate	12% (Abnormal)	2% (Normal)	10% Improvement
C. Energy Loss (Re-melting)	₹ 64,800	₹ 10,800	₹ 54,000 (Saved)
D. Material Burning Loss	₹ 24,000	₹ 4,000	₹ 20,000 (Saved)
E. GST Input Tax Credit Loss	₹ 21,600 (Blocked)	₹ 0 (Allowed)	₹ 21,600 (Tax Saved)
F. Total Monthly Financial Leakage	₹ 1,10,400	₹ 14,800	₹ 95,600

Table 4.2: Monthly Financial Variance Analysis
Source: Author Compiled

4.3 Interpretation and ROI

The analysis reveals that a Traditional Unit suffers a "Double Hit"—the operational cost of waste and the statutory loss of ITC (₹21,600/month).

Annual Savings: ₹ 95,600 × 12 = ₹ 11, 47,200

$$\frac{Investment(₹10,10,000)}{AnnualSavings(₹11,47,200)} \approx 0.88\ Years\ (10.5\ Months)$$

Payback Period

From a capital budgeting perspective, a payback period of under 11 months indicates high financial viability. Furthermore, the "Digital Audit Trail" generated by the system serves as irrefutable evidence during GST scrutiny, justifying process losses as "Normal" and protecting ITC claims.

5. STRATEGIC RECOMMENDATIONS

- Phased Adoption: MSMEs with limited liquidity should adopt "Hybrid Digital Twins," prioritizing the digitization of the melting process (composition analysis) to control the highest cost center first.
- Policy Intervention: The government's "Make in India" initiative should introduce a "Digital Compliance Subsidy," linking financial incentives to the adoption of ZED (Zero Defect, Zero Effect) certified technologies.
- Workforce Upskilling: There is an urgent need to train the Agra workforce to interpret digital dashboards, bridging the gap between traditional craftsmanship and modern analytics.

6. CONCLUSION

The modernization of the Agra foundry cluster is no longer a matter of operational choice but of financial survival. This study concludes that the integration of Digital Twin technology transcends engineering efficiency it is a robust Financial Hedging Strategy.

By minimizing the "Cost of Poor Quality," MSMEs can significantly reduce abnormal wastage. This directly influences their GST compliance posture by eliminating the mandatory reversal of Input Tax Credit on destroyed goods. For the traditional units of Agra, transitioning to digital-assisted manufacturing provides a clear roadmap to protect profit margins, ensure fluid working capital, and maintain compliance rigidity. Ultimately, in the post-GST era, a "Smart Foundry" is inherently a "Tax-Efficient Foundry."

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