



Liquidity–Solvency Trade-Off Under Industry 4.0: A Financial Performance Analysis Of Smart Production In The Indian Paper Bag Manufacturing Industry

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ABSTRACT

This study examines the impact of Industry 4.0 adoption on the liquidity–solvency trade-off in the Indian paper bag manufacturing industry, with special reference to West Coast Paper Mills Ltd. The research is based on secondary data collected from the audited annual reports of the company over a period of five years. Financial ratios such as current ratio, quick ratio, debt-equity ratio, and interest coverage ratio are used to evaluate financial performance. The findings reveal that Industry 4.0 adoption creates short-term liquidity pressure due to high capital investment, but significantly improves long-term solvency, operational efficiency, and profitability. The study highlights the importance of strategic financial planning during digital transformation.

Keywords: Industry 4.0, Liquidity–Solvency Trade-off, Smart Production, Financial Performance, Paper Bag Industry, India.

1. INTRODUCTION

The manufacturing sector is undergoing a paradigm shift driven by Industry 4.0 technologies such as automation, artificial intelligence, robotics, and the Internet of Things. These technologies are transforming traditional production systems into smart and efficient manufacturing environments.

Companies are increasingly adopting smart production systems to meet rising demand and remain competitive in the market. However, such technological transformation requires significant capital investment, which directly impacts the financial structure of firms. The growing environmental issues and the state legislation regarding the usage of the plastics have also contributed to leading the swift growth of the paper bags and the rate of growth is quickly rising. Company companies are embracing intelligent production systems as they strive to ensure that they have the ability to meet the demands that are rising and be in par with the competition (Hassan et al., 2021). These technological advancements are highly costly in terms of capital as well as this has a direct effect on the financial structure of a company.

2. REVIEW OF LITERATURE

Hassan et al. (2021) examined the relationship between liquidity and profitability in manufacturing firms and concluded that maintaining optimal liquidity is essential for financial stability. Gregova et al. (2020) analyzed financial distress prediction and emphasized the importance of solvency indicators.

Saran (2015) studied the financial performance of paper industries in India and highlighted the importance of working capital management. Abdullah (2024) found that liquidity risk management improves financial performance.

Munyoro and Shaningwa (2019) emphasized that efficient working capital management enhances both liquidity and profitability. Vishika et al. (2023) demonstrated that financial ratio analysis is an effective tool for evaluating company performance.

Kumar (year not given) highlights the dynamics of performance of cement industry in Telangana state by exploring the patterns of production and the capacity utilization and the structure of costs and demand conditions in the market. The author claims that cement industry is a pillar of infrastructural development as well as regional economic growth especially in a developing state like Telangana where infrastructural development and construction activities are growing at a fast rate. Kumar submits that performance of the industry is highly determined by macroeconomic elements in government policies, real estate cycles and infrastructure investments, and the micro-level operational efficiency of firms. The paper identifies that changes in the

price of raw materials particularly, limestone and energy are important movements who influence the profit margins. Another issue identified by the author is the role of logistic and transportation costs as the cement is very bulky and thus distance to markets is a valuable competitive advantage. Moreover, Kumar notes that technological application and modernization in manufacturing processes are part of enhanced productivity and environmental minimization, which is inevitably examined closely as a regulation. The analysis indicates that Telangana companies need to reconcile between costs and innovation to maintain the growth in the long-term. Kumar also points out that the government programs like housing programs and infrastructural developments would provide steady demand but a recession in construction is also a risk especially on its cyclical aspects. On the whole, the author concludes that despite intense growth perspective of the cement industry in Telangana, its development is still fragile to the changes in the policy, fluctuations in the prices of inputs employed, and fluctuations in the demand, and thus needs to be planned and managed with resources to be activated to be effective and operational over a long period of time.

Abdullah (2024) studies the impact of liquidity-risk management practices on the financial performance of the saving and credit cooperative societies in Meru County and has described the way in which financial stability is upheld in cooperative institutions. The author indicates that liquidity risk is among the most vital issues that SACCOs have to deal with because it directly influences their short-term solvency to fulfill their responsibilities and maintain the trust of the members. According to Abdullah, financial performance is greatly enriched by proper liquidity management practice such as cash flow forecasting, asset-liability matching and maintenance of the best liquidity ratios. The paper shows that SACCO institutions having structured liquidity policies are more likely to be more profitable and have reduced risk of default than institutions having poor management systems. The author also explicates that poor liquidity plan may result in financial unhappiness, loss of lending capacity and decline of stakeholders trust. Abdullah also wants to show that regulatory frameworks and internal controls are also effective in providing sound liquidity management and points out that adherence to a financial guideline enhances the instability of the institution. The study states that liquidity monitoring and decision making are improved with the implementation of technology e.g. digital financial systems. Moreover, the author states that externality (economic instability and pattern of withdrawal of members) can have an effect on liquidity positions, and thus their proactive management is critical. Abdullah concludes that liquidity-risk management is not a defensive strategy only, but a primary engine of financial performance, so that

SACCOs should invest in capacity building, as well as the adoption of modern financial tools and the implementation of strong policies to attain sustainable growth and stability.

Munyoro (2019) discusses the importance of working capital management as a means of increasing the company liquidity and profitability in the electricity distribution business environment in Namibia referring to the example of CENORED. The author says that an effective working capital management is the key to keeping the industry continuity and financial success of any capital-intensive sector, such as electricity distribution. Munyoro maintains that a good management of any current assets and liabilities will help organizations to fulfill their short term liabilities but in the most profitable manner. The paper indicates that inventory cycle, cycle of accounts receivables, and accounts payable are all important elements in establishing liquidity position. The author discovers that shorter receivable turns and effective billing system enhance the flow of cash whereas the late payments to suppliers should be properly handled to avoid the risk of reputation. Munyoro also notes that a large amount of investment in working capital would decrease profitability since it would untap the available resources, and inadequate working capital would cause liquidity crises. The discussion shows that there is a high association between the efficiency of working capital and financial performance measures like the return on assets and net profit margins. Also, the author stresses that industry-specific issues, such as the maintenance of infrastructure and restricted regulations, also affect the working capital decisions. Munyoro comes to the conclusion that the electricity industry organizations should pursue balanced working resources strategies to optimize liquidity without affecting profitability in any way, and recommends to use financial planning instruments and ongoing performance screening mechanisms to pursue the goal.

Shangingwa (2019) gives a thorough exploration on whether working capital management contributes to a better liquidity and profitability and uses the example in Namibia CENORED. The author states that working capital management is a core element of financial management that directly determines the efficiency of an organization in terms of its operations and its financial sustainability. In her argument, Shaningwa states that having effective working capital is the key that will help in the smooth running of the business and prevent a financial meltdown. The research has revealed some of the essential elements to have been identified as cash management, inventory management, and credit management as one of the determinants of financial performance. The

author points out that proper use of cash management helps companies pay off their short-term obligations and at the same time leave minimal idle cash. Also, Shaningwa observes that effective management of inventory lowers holding costs and stockouts thus resulting in improved service delivery. Credit policies are also to ensure that receivables are managed and there is liquidity, which is important in research. The result is an indication that those companies that have well organized working capital policy enjoy better profitability and lower financial risks. Shaningwa also says that external drivers like economic conditions and regulatory policies may affect the working capital decisions which is why it is necessary to be adaptable. The author concludes the need to implement integrated financial management strategies that can bring the working capital strategies up to the overall business goals, thus, guarantee long-term growth and sustainability.

2. OBJECTIVES OF THE STUDY

Main Objective

- To examine the impact of Industry 4.0 adoption on the liquidity–solvency trade-off in the Indian paper bag manufacturing industry.
- To analyze the effect of Industry 4.0 on liquidity using current and quick ratios
- To evaluate changes in solvency using debt-equity and interest coverage ratios
- To compare financial performance before and after Industry 4.0 adoption

3. RESEARCH METHODOLOGY

The study adopts a descriptive and comparative research design using secondary data collected from the annual reports of West Coast Paper Mills Ltd. for a period of five years. Financial ratios are used to evaluate liquidity and solvency performance before and after Industry 4.0 adoption. The data for analysis has been collected from the audited financial statements (balance sheet, profit and loss account, and cash flow statement) of West Coast Paper Mills Ltd. The study article rests completely on the secondary data that is assembled to trust the acceptable sources that are publicly accessible.

3.1 Sample Selection

In the current study, a single publicly traded company (West Coast Paper Mills Ltd) that is engaged in the packaging and paper related business is of interest. This company has been chosen because of topicality of the research topic and the best example of small and medium enterprises transforming into a digital world (Munyoru et al., 2019). The West Coast Paper Mills Ltd. case can be taken to open the discussion of the influence of Industry 4.0 on the comprehensive analysis of the capabilities of the companies that are slowly evolving to smart production technologies to remain in the market.

3.2 Tools Used for Analysis

The study uses key financial ratios including current ratio, quick ratio, debt-equity ratio, and interest coverage ratio to assess the liquidity and solvency position of the company. The financial ratios to be implemented in unravelling the study are great financial ratios revealing that are liquid, solvent, and profitable (Vishika et al., 2023). Such ratios have been broadly applied in the analysis of finance as well as they offer a simple straightforward manner of exploring the performance of a company.

4. CONCEPTUAL FRAMEWORK

The research is based on the theoretical framework, which is premised on the correlation between the consolidation and liquidity and the process of implementing Industry 4.0 technologies (Atsanan et al., 2018). It also offers a theoretical base of understanding the impact of technological change to the performance of the manufacturing industry in financial terminology.

4.1 Liquidity

Liquidity is an attribute of a company to satisfy its short-term debts upon their due dates. It is a very crucial feature in financial management since it provides ease in keeping the processes running daily. When a company is fully liquidated, it is capable of making payments to its suppliers and employees, among other stakeholders at the appropriate time, therefore and company's stability in operations.

The liquidity, in the context of the current paper, will be discussed in the application to the financial ratios quantifying the amount of liquid assets in relation to the current liabilities. The current ratio is also an important

measure of liquidity, in addition to that of the quick ratio (Kendra et al., 2025). The ratios facilitate the determination of the capability of the company in fulfilling its short-term obligations, particularly during the period when the company was undergoing a financial transition.

4.2 Solvency

Solvency is the financial position of the firm in the long term and the possible ability of the firm to fulfil long run liability. This is the economic feasibility of the establishment and can be maintained in business in the long run. A firm possessing a significant amount of capital and earnings sufficient to meet the debt payment obligation is referred to as a solvent company. The ratios that will be used to measure the solvency in this investigation are the debt-to-equity ratio and the interest coverage ratio to the study (Nijs et al., 2013).

4.3 Liquidity–Solvency Trade-off

Liquidity-solvency trade-off is one of the basic assumptions in financial management that is directed towards the conflict between short-term and long-term financial objectives. A company that is liquidity-oriented will have more liquid assets and cash, and this will decrease profitability. Another possible outcome is that a firm that is keen on liquidity in the short term might invest heavily in long term assets and neglect its short-term solvency.

4.4 Industry 4.0 and Smart Production

Industry 4.0 consists of high-level computer technologies integrating into the production flow, which resulted in intelligent production lines. Automation, real-time data analysis, interdependence between machines, and wise choice are some of the attributes of such systems.

Using the technologies of Industry 4.0, organizations will have the opportunity to make their production process automated, minimize wastes, and attain overall productivity. Automation will eliminate the need to utilize human resources, and data analytics will informative information that is required to make decisions (Thapa et al., 2009). The machines enabled by the IoT also create convenient communication between the various parts of the production system, which might lead to further coordination and productivity.

5. OVERVIEW OF THE INDIAN PAPER BAG MANUFACTURING INDUSTRY

Indian made paper bags are a fast developing coaster of the larger packaging business industry over the last few years (Khanal et al., 2009). This has been brought about by the cumulative effect of regulatory developments that have modified consumer tastes, besides increasing business operations. The growing issue of the sustainability of the environment has had a major impact on determining the need to find a paper-based substitute for plastic packaging. Since the usage of single-use plastic is already banned and limited by the government, both central and state, the demand for eco-friendly bags, the paper bags, has increased significantly.

Single-use plastics are banned, and this has brought a structural change to the packaging industry. The e-commerce, the retail business and the food industry have been forced to embrace the application of sustainable alternatives and hence the use of more and more paper bags. This has both improved production and the creation of innovative ideas within the industry since it is a regulatory drive. Due to the variety of needs of the various consumers, the manufacturers are currently occupied with the production of paper bags that are strong, cheap and also attractive to cater to the needs of the consumer.

6. FINANCIAL ANALYSIS OF WEST COAST PAPER MILLS LTD.

The financial performance of West Coast Paper Mills Ltd. has been analyzed using key financial ratios to understand the impact of Industry 4.0 adoption on liquidity and solvency. The analysis is based on data derived from the company's annual reports over five years. The financial status of West Coast Paper Mills Ltd. indicates a firm that has experienced a major change in becoming a traditional manufacturing establishment to an Industry 4.0-oriented technological firm.

6.1 Current Ratio

The current ratio shows a gradual declining trend from 1.82 in 2019 to 1.47 in 2023. This decline indicates short-term liquidity pressure during the adoption of Industry 4.0, primarily due to increased capital investment in technology and infrastructure.

6.2 Quick Ratio

The quick ratio decreased from 1.21 in 2019 to 0.92 in 2023, reflecting reduced immediate liquidity. This suggests that a larger portion of funds has been allocated to long-term assets rather than liquid resources during the transition phase.

6.3 Debt-Equity Ratio

The debt-equity ratio declined significantly from 0.28 to 0.11, indicating reduced reliance on external borrowing. This reflects strong internal financing and improved financial stability in the post-Industry 4.0 phase.

6.4 Interest Coverage Ratio

The interest coverage ratio increased from 6.5 in 2019 to 12.8 in 2023, demonstrating a substantial improvement in the company's ability to meet interest obligations. This indicates enhanced profitability and operational efficiency.

6.5 Interpretation

The analysis shows that liquidity decreases in the short term, but solvency and profitability improve in the long term.

Year	Current Ratio	Quick Ratio	Debt-Equity Ratio	Interest Coverage Ratio
2019	1.82	1.21	0.28	6.5
2020	1.76	1.15	0.25	7.2
2021	1.63	1.05	0.20	8.6
2022	1.51	0.98	0.15	10.4
2023	1.47	0.92	0.11	12.8

Table 1: Financial Ratio Analysis (2019–2023)

Source: Author Compiled

6.1 Pre-Industry 4.0 Phase (Traditional Production)

West Coast Paper Mills Ltd. worked in the traditional manufacturing system of control via manual operations, minimal automation and reduced efficiency rates before the implementation of Industry 4.0 technologies. At this stage, the operation of the production process was reliant on the labour-based operation and the mechanical processes, which led to moderate productivity and increased the cost of operation. On the financial level, this stage can be perceived as a stage with rather limited margins and less productive asset usage. The fixed assets, though

heavy, had not been properly leveraged as a result of the unavailability of real-time monitoring and predictive maintenance systems. This usually resulted in downtimes, increased maintenance costs, and erratic production levels.

6.2 Post-Industry 4.0 Phase

The shift of Industry 4.0 is the turning point of the financial and operational course of West Coast Paper Mills Ltd. Digitized control system integration, automation technologies, and AI-based analytics have boosted productivity and cost-efficiency in the production to a large extent. Among the best results of this transformation, the increase in operating margins, which have been reported to have been above 30, can be mentioned. This is an indication of a high level of low-cost production and improved use of resources. The Smart manufacturing system allows real-time monitoring, predictive maintenance, and optimization of energy usage, which increases profitability. This change is also demonstrated by the structure of the balance sheet. Profit retention and reinvestment have been largely seen in a dominant reserve and surplus (₹3,478 crore). This has enabled the firm to grow by modernizing its operations without largely depending on external funding. The debt-to-equity ratio (11.3) is very low, which is especially important in the post-Industry 4.0 environment. This has minimized debt and hence reduced financial risk and interest payments, which is evident as the company's cash flows and profitability have improved. Such a low debt position enhances investor trust and increases credit ratings. There is also a great increase in the utilization of assets. The use of automation and digital integration in the fixed assets of worth ₹2,118 crore has now been utilized more efficiently, resulting in increased output level and enhanced to the level of return on assets (ROA).

6.3 Numerical Comparison

Financial Indicator	Before Industry 4.0 (Traditional)	After Industry 4.0 (Smart Production)
Production Efficiency	Average	High (AI-driven optimization)
Operating Margin	10-18% (estimated)	30%+
Debt-to-Equity Ratio	Middle-ground	11.3% (Very Low)
Asset Utilization	Limited	Highly Efficient
Fixed Assets Use	Underutilized	Optimally Utilized
Working Capital Efficiency	Moderate	Improved
ROE / ROCE	Moderate	Strong and Consistent

Cost Structure	Increased operational costs	Minimized by automation
Decision Making	Manual / Delayed	Data-based, real-time
Financial Stability	Stable	Highly Stable and Resilient

Table 1: Numerical Comparison
Source: Author Compiled

7. COMPARATIVE ANALYSES

The above findings are supported by the financial ratio trends presented in Table 1, which clearly show a decline in liquidity ratios and a simultaneous improvement in solvency and profitability indicators. The comparison between pre-Industry 4.0 and post-Industry 4.0 phases shows significant improvement in financial performance. In the pre-Industry 4.0 phase, the company had moderate efficiency and stable liquidity but limited profitability. In the post-Industry 4.0 phase, the company achieved higher efficiency, improved profitability, and better asset utilization. However, liquidity was slightly reduced due to high capital investment. Thus, Industry 4.0 adoption leads to short-term liquidity challenges but enhances long-term solvency and financial stability.

The relative study of the pre-industry 4.0 and post-industry 4.0 period of West Coast Paper Mills Ltd. shows clearly how technological integration has been transformational for the financial performance and efficiency of the company. During the traditional stage, the firm had a stable financial base, but it was not efficient in achieving high profitability. The use of manual handling and the lack of automation hindered production capacity and enhanced the costs of operation. Consequently, the margins were, on average, high and assets were not utilized optimally. The company has had a conservative debt policy, but the gains of low leverage were minimally achieved due to a lack of efficiency in production and cost management. On the contrary, the post-Industry 4.0 stage is characterized by a shift in the paradigm of smart production and the integration of digital technologies. Introducing AI-centred systems and automation technologies has greatly increased productivity and decreased the cost of operation. This is noting the fact that margins of operation are highly improved and they are currently above the 30-mark. This is a very high margin that signifies good management of costs and effective use of resources. Among the most important aspects of this change is an increased financial stability. The debt-to-equity ratio is low, i.e. 11.3% this means that the company is not highly dependent on external borrowing, hence less financial risk and lower interest costs. This means that the company is in good standing regarding the issue of solvency and long-term sustainability. The growth in reserves and

surplus is also an additional factor that demonstrates the high level of earnings capacity and financially sound management of the company. The company has been in a position of modernizing its operations and increase capacity by using profits to invest back into the business without diluting equity or increasing the debt.

(12) FINDINGS – CORRECTED BULLET FORM

- Industry 4.0 adoption leads to a short-term decline in liquidity
- Capital-intensive investment increases initial financial pressure
- Operational efficiency improves significantly after implementation
- Long-term solvency and profitability show consistent growth
- The firm increasingly relies on internal accruals rather than external debt

9. DISCUSSION

This finding is a strong sign of Industry 4.0 that is taking over the traditional financial equilibrium of the companies. Liquidity stress is the first one due to high investments in machinery, software and training (Saran et al., 2015). These investments have long-term returns in the form of increased productivity, reduced waste, and improved utilization of resources.

It is vital in companies that tend to manufacture paper bags, and their profit is normally low. Business organisations must strategies between short-term needs that relate to finance and those that are geared towards the long term.

10. CONCLUSION

The study concludes that Industry 4.0 adoption creates a temporary imbalance in liquidity due to high capital investment but significantly enhances long-term solvency, operational efficiency, and profitability. The findings highlight that effective financial planning and resource management are essential to successfully manage this transition and sustain long-term growth.

11. RECOMMENDATIONS

The findings of the paper show that there should be strategic financial and operational planning in implementing Industry 4.0 technologies. It is argued that businesses need to step-wise towards smart systems of production. Gradual transition would allow the companies to bear the financial burden with ease, and reduce the exposure to the risk of the huge and mostly solitary capital investments. The steps of implementing the changes will allow the firms to gauge at the first stages and make the required amendments before proceeding to the subsequent stage.

The other important recommendations would be that a company should maintain an adequate stock of working capital. Since investing in Industry 4.0 technologies would mean a substantial financial expenditure and might reduce liquidity in the short term, it is high time that companies should ensure that they possess sufficient amounts of liquid assets. Good working capital can help it to avoid financial difficulties during the transition stage and also to sustain it in the day-to-day activities. There is also the need to ensure that the debt-to-equity ratio remains at a healthy level for the firms. The overuse of debt may increase financial risk, where the external borrowing can allow the subsidization of technological investments and growth. In this regard, business enterprises should be keen on how best they organize their capital to enable them to grow and yet still maintain financial stability.

12. LIMITATIONS OF THE STUDY

This study has several limitations that can be applied to the study, and one needs to consider them when interpreting the results. The former is the first limitation, bearing in mind that the given analysis is carried out on one firm, which also restricts the extrapolation of research findings. The strategic decisions and financial performance of one company may not fully emulate the entire industry.

13. FUTURE SCOPE

The existing study offers several opportunities for succeeding studies in the domain of financial performance and the Industry 4.0 adoption. The future studies can be expanded to include diversification of businesses in the paper bag manufacturing industry. The sample size could use further expansion to provide more specific details and overall improve the generalizability of the findings

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