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A UNIFIED ETL FRAMEWORK AND A PREDICTIVE ANALYTICS SYSTEMS FOR DEAL-LEVEL RISK ASSESSMENT IN MANUFACTURING

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ABSTRACT

In India, MSMEs are still facing significant challenges in utilizing operational data for predictive and analytical purposes, with cash flow management being a major concern. India's monthly UPI transactions amount to roughly 8 billion, but the extent to which MSMEs use digital tools is limited. A significant proportion of micro-SMEs, around 82%, are not acquainted with implementing or integrating modern data analytics and AI solutions into their operations, and they often lack basic knowledge of available digitisation support. Variable customer payment behaviours, different credit terms, and the lack of predictive financial analytics frequently cause working capital issues and delay management responses.

The focus of this research is on MFG360, an AI-driven ETL solution that utilizes the Spindle Finance module as a tool for assessing accounts receivable risks at the transaction level in manufacturing settings. Predictive models are built on the basis of past billing records, payment histories, delay trends, and contract details to help users estimate receivable collection periods and forecast future cash inflows. By examining the payment reliability and cash-flow risk, it categorizes deals by scrutinizing their consistency of payment, delays, and credit conditions.

In contrast to traditional dashboard-based systems, MFG360 incorporates an AI-driven financial intelligence layer that provides additional insights beyond typical descriptive analytics. Upon examination of multiple sources of operational and financial data, the system

generates a root-cause explanation for each identified issue by connecting financial deviations with operational factors and using AI. The data is prioritized and comprehensible in terms of their specific faults, locations, and operational factors that may have caused the financial impact.

KEYWORDS: Financial Management System, Invoice Management, Accounts Receivable Tracking, Instalment Payment Processing, Cash Flow Monitoring, Credit Risk Assessment.

INTRODUCTION

Efficient cash flow management is crucial for the financial health and ongoing operations of small manufacturing businesses. Even companies with consistent production and steady order flow can face cash flow challenges due to late customer payments, lengthy billing cycles, and unpredictable trends in accounts receivable. These issues are particularly evident in manufacturing, where variations in credit terms, contract arrangements, and customer payment habits create uncertainty in the timing of cash inflows. Although recent studies indicate that digital financial tools and predictive analytics can enhance forecasting precision, many small and medium-sized manufacturing enterprises still lack adequate analytical resources. Conventional accounts receivable management relies mainly on descriptive reports and static ageing assessments, which offer limited insight into anticipated cash inflows. From a data science perspective, these methods fail to fully leverage the growing volume of transactional data generated by contemporary digital processes. Disparate data sources, such as daily operational logs and outdated financial documents, often hinder finance teams from obtaining a cohesive understanding of receivable risks. Consequently, financial responses tend to be reactive, occurring only after Liquidity issues have begun to disrupt business activities.

To address these challenges, this research introduces MFG360, a comprehensive ETL and predictive analytics framework tailored for finance in manufacturing. Utilising actual billing and payment data from a manufacturing unit in Pune, this system integrates diverse data sources into a single analytical framework. By employing temporal feature engineering and analysing invoicing and payment behaviours at the deal level, the framework uncovers trends in customer payment dependability and receivable risks. MFG360 transforms raw transactional data into predictive financial insights, enabling proactive cash flow management.

I. LITERATURE REVIEW

The increasing use of Artificial Intelligence and digital technologies is leading to an increase in data-driven and intelligent financial management systems. Traditional financial forecasting methods often involve the use of historical summaries and manual analysis, but these methods may not be sufficient to accurately predict future fluctuations in business conditions. Recent research has emphasized the use of AI models, ERP systems and digital transformation strategies to improve financial forecasting, operational efficiency, and decision-making in organizations.

Numerous studies have examined technologies such as LSTM-based time-series forecasting, AI-led financial automation (see Digital Transformation in Enterprises), and Industry 4.0 frameworks. By utilizing advanced analytics, financial performance and business planning can be enhanced through these studies. These works can be analyzed to determine their strengths and weaknesses, and then utilized to develop better systems. The proposed MFG360 has been influenced by the outcomes of these studies. The Predictive Analytics Framework and ETL for managing risk at a manufacturing-based level.

1. AI-Driven Cash Flow Forecasting in ERP Systems: Integrating Economic Indicators and Real-Time Transaction Data Using LSTM-Based Time-Series Models (Vinay Kumar Singh, 2025)

The study aims to improve cash flow forecasting by utilizing time-series models with Long Short-Term Memory (LSTM) and combining real-time ERP transaction data with external economic indicators. The ability of LSTM models to learn intricate patterns in sequential financial data results in more accurate prediction than traditional statistical methods. By integrating data from internal financial institutions with general economic indicators, the study suggests that more comprehensive financial forecasts are achievable and accurate. The results indicate that this combined approach can improve forecasting accuracy by almost 30 percent, enabling organizations to make more informed financial planning choices. Nevertheless, the study concentrates mainly on forecasting performance and does not fully address issues related to integration of data from various operational systems or deal-level financial risk analysis, especially for small and medium-sized manufacturing companies.

2. Digital Transformation and Financial Performance in India (Manju Sharma & Bhushan Singh, 2012–2024/25)

This research examines how digital transformation impacts financial performance in Indian

companies. From 2012 to 2024, the researchers examined data from companies listed on the NSE. According to their research, the implementation of digital technologies can significantly enhance Total Factor Productivity (TFP), leading to better financial performance and operational efficiency.

Additionally, the study indicates that firms who embrace digital platforms are more equipped to optimize their business operations and streamline decision-making processes. The research indicates that digital transformation can have a more significant impact on non-family-owned businesses than family–owned companies, which is interesting.

While there are clear advantages to digital adoption in this study, it is primarily targeted at large corporations that are listed on the stock exchange.

3. The "Autonomous CFO" and Agentic AI Trends (M. Vasarhelyi & J. K. M. Smith, 2026)

The Autonomous CFO concept, which involves the use of artificial intelligence systems to assist organizations in performing advanced financial analysis and strategic decision-making, is introduced by this research. Automated financial tasks like forecasting, risk assessment, and strategic planning can be achieved through the use of Agentic AI technologies.

The research highlights the impact of modern ERP systems and AI-driven advancements on financial management. The real-time processing of large amounts of financial data by these systems provides organizations with valuable insights that help them make more efficient and informed decisions.

How These Studies Were Utilized in My Project

This work was important to the design of the proposed system.

Paper 1 (Vinay Kumar Singh, 2025) introduced the notion of using AI-based time-series models for financial forecasting. This was followed by this concept in 2018. This notion inspired the use of predictive analytics in the project, which uses data from billing records and payment history to forecast cash flows.

According to Paper 2 (Sharma & Singh, 2024/25), the study highlighted the significance of digital transformation in improving financial performance. By incorporating digital financial data and analytical tools, the MFG360 system can be developed to enhance decision-making, which is supported by this insight.

The intelligent analytics layer was derived from the concept of AI-led systems for financial

management that were introduced in Paper 3 (Vasarhelyi & Smith, 2026). This project is unique.

The fourth paper emphasized the importance of data visualization and financial monitoring through dashboards. Management can easily understand intricate financial data using visual dashboards, as demonstrated in the study. An interactive Power BI dashboard was created for the MFG360 project, which utilized this concept to present financial data in a visually engaging manner, aiding management in making quick decisions and monitoring their performance. This research contributed to the development of the proposed system's module for visualization and reporting.

What My Project Adds Beyond These Works

1. The suggested approach involves a comprehensive ETL system that unifies financial and operational information from various sources in manufacturing-based businesses.
2. This tool provides an assessment of financial risks at the deal-level, examining transaction patterns, credit terms, and payment behavior to identify potential receivable risks.
3. The system includes a financial intelligence layer that is powered by artificial intelligence and can generate forecasts while pinpointing the causes of financial mishaps.
4. By presenting interactive dashboards that display real-time visualizations of expected cash flow, overdue accounts, and transaction-level risk levels, organizations can take proactive financial action.

A. Traditional Methods for Cash-Flow and Receivable Management

Financial management of small and medium manufacturing enterprises has traditionally used descriptive reporting methods, including static aging reports, manual spreadsheet tracking, and periodic financial summaries. The usual way in which these methods operate is to divide outstanding receivables into specific time frames, such as 30-day, 60-day or 90- day aging buckets. Although they provide a general overview of pending payments, these reports primarily describe past financial activity rather than forecasting future cash flows.

Deployed systems like manual trackers, CSV files, or isolated accounting software are commonly used by SMEs to store billing and transaction records. Financial teams often rely on retrospective analysis and intuition when making decisions regarding liquidity. This is the case. Consequently, they are unable to detect behavioral payment patterns or predict delays in accounts receivable due to the absence of integrated analytics. Therefore, companies that have high production output and satisfied customers may face financial difficulties due to

delayed payments and unpredictable cash inflows.

B. Challenges with Traditional Financial Analysis Models

Even with digital invoicing and payment systems, traditional financial management in manufacturing SMEs still has several drawbacks. Due to the fact that financial reports are mostly reactive, and delays in payments only reveal problems afterward, it is challenging to manage liquidity risks proactively. Often, financial information comes from multiple sources (billing systems, payment platforms and manual records) Without a shared structure, integration is difficult. The traditional aging reports only present company-level summaries and do not account for deal- level or customer-specific payment behaviors. In addition, the absence of advanced visualizations and predictive analytics in these systems means that financial decisions are frequently made manually, rather than through data-driven insights.

C. Emergence of Data-Driven Financial Analytics and Predictive Modeling

The use of data science and financial analytics can provide solutions to problems in traditional financial management systems. The use of time-series models allows for the prediction of cash flows by analyzing past billing and payment patterns to identify potential payment delays or liquidity risks.

Financial data is gathered and processed in a central analytical warehouse using modern data engineering methods, such as ETL pipelines that combine financial information from various sources for efficient analysis. By utilizing interactive dashboards or visualization tools, organizations can gain real-time insights into crucial financial metrics like payment delays, deal level risk scores, and predicted receivable timelines, which helps them make proactive financial decisions.

D. Application of Predictive Analytics in Manufacturing Financial Systems

The use of predictive analytics in financial data systems enhances accounts receivable management and cash-flow forecasting within manufacturing organizations. By examining past billing and payment patterns, machine learning models can identify factors that contribute to delayed payments. Why? Using the MFG360 framework, a single ETL pipeline is used to collect financial data from multiple sources and process it using predictive algorithms to predict receivable timelines. Deal-level indicators such as delay predictions and risk scores are displayed through interactive dashboards, providing managers with insights into identifying high-risk receivables and taking proactive financial measures.

E. Identified Research Gaps

The research on digital transformation and predictive analytics in financial management is ongoing, there are significant gaps in data available, particularly for manufacturing businesses. A lot of these systems prioritize company-level forecasting over deal- level transaction behavior, making it hard to identify specific customer payment patterns. The absence of ETL pipelines in existing financial tools is a hindrance to efficient handling and merging of financial data from various sources. Furthermore, advanced analytics solutions are often expensive and complex, making them less suitable for small and medium-sized enterprises. Lack of transparency and visualization in traditional financial reporting systems makes it difficult to interpret predictive insights. To provide manufacturing SMEs with deal-level financial intelligence, the proposed MFG360 framework integrates a scalable ETL architecture, predictive analytics, and interactive dashboards, alleviating these challenges.

A significant research gap has been identified due to the absence of real-time financial monitoring systems in manufacturing SMEs. The majority of studies currently on the topic concentrate on historical financial analysis rather than real-time data processing and alerts. It also makes it difficult for organizations to respond quickly to financial risks, such as late payment charges or other cash flow problems, when implementing changes.' In order to address this shortcoming, the MFG360 project suggests a system that can accommodate near-real-time data updates, automated financial alerts, and continuous monitoring via dashboards. By promoting proactive decision-making, management can enhance the overall effectiveness of financial planning and risk management.

A lack of integration between financial and operational data in manufacturing organizations. In most systems currently in use, financial data is analyzed separately, without any consideration for production, sales, or inventory data. Incomplete financial forecasts and poor strategic decision-making are the consequences. By consolidating financial and operational data into a single analytics platform, the MFG360 system seeks to address this gap and improve decision-making and business performance analysis.

II. METHODOLOGY

This study proposes MFG360, an integrated data engineering and predictive analytics framework that can improve the visibility of cash-flow and reduce risk in manufacturing small enterprises. It transforms disorganized financial trecords into actionable insights by utilizing data ingestion, temporal feature engineering, predictive modeling, and visualization.

A. Preparation of Dataset and Preprocessing

During phase I, firstly, financial data is taken from a manufacturing environment; this includes billing records, invoice information, payment transactions, and deal-level customer data extracted from operational systems and historical CSV files. Manual trackers, digital billing records, and payment systems are all necessary to process the data provided. This involves removing duplicate or incomplete entries, standardizing the format of these tables, converting dates into time-series variables, and normalizing payment values to ensure that data is clean (or well-structured) and ready for predictive analysis.

B. Feature Engineering

An ETL (Extract, Transform, Load) process combines dispersed financial data sources into a cohesive pipeline. The data is retrieved from operational trackers and legacy CSV records, processed through cleaning, normalization, and feature generation, before being loaded into a centralized PostgreSQL data warehouse All items are then stored in XML-based databases.

C. Temporal Feature Engineering

Patterns are extracted from past billing to be used in analyzing customer payment behavior using temporal feature engineering. The main components of the system are payment delay timeframe, invoice age, deal size, payment frequency, customer payment consistency, and historical delay patterns.

The inclusion of these features enables the analysis at the deal-level and enhances the predictability of payment risks.

D. Predictive Modeling for Cash-Flow Forecasting

The analysis of past financial data is used to create predictive models that estimate receivable timelines and forecast cash flow. Identifying payment trends and possible delays is achieved through the use of time-series forecasting techniques, such as moving averages and exponential smoothing, weighted delay scoring, and trend analysis. By using these models, businesses can better anticipate payment dues and manage liquidity risks.

E. Financial Performance Metrics

Financial analytics models, such as Accounts Receivable Aging, Days Sales Outstanding (DSO), and the Cash Conversion Cycle (CCC), are used to evaluate payment behavior and working capital efficiency. These models can categorize invoices based on payment delays or orderly processing of invoice payments. The measurement of receivable risk and liquidity

performance is facilitated by these metrics.

F. Interactive Dashboard and Visualization

Through the use of an interactive Streamlit dashboard, analytical findings are presented in the form of cash-flow trends, payment delay predictions at the deal level, risk categorization (including buyer preference), and key KPIs such as DSO and aging distribution.

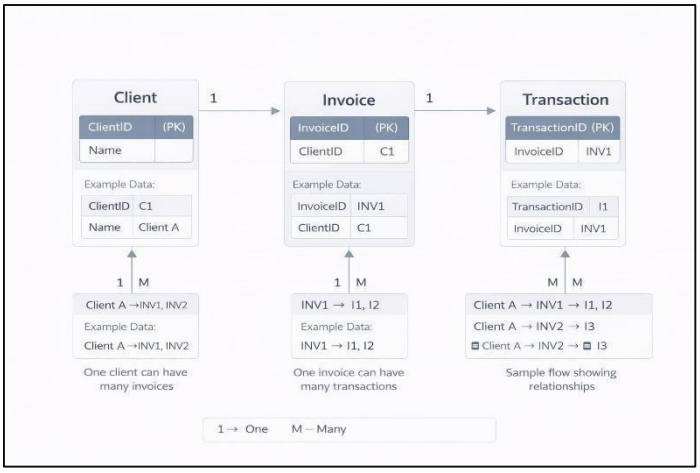

Fig 2.1: Finance Data Model.

This finance data model is part of the MFG360 project and describes how different types of financial institution are linked to effectively manage and analyze business transactions. It commences with the client, who is the customer, associated with one or more Invoices produced for services or purchases. Transactions are linked to each invoice and contain information on actual payments made. Tracking the complete flow from customer interaction to payment completion is made possible by this structure, which enables the organization, tracking and traceability of financial information for analysis related to cash flows or payments behavior.

- Your client is essentially your customer, with each person having their own unique ID and name.
- A client may have multiple invoices, but each bill is unique to a particular client.
- A bill for a client and its own ID with an associated client ID is the same as an invoice.
- Each invoice can contain multiple transactions, such as payments and adjustments.
- An occurrence is the recording of financial transaction and is always associated with an identifiable invoice.
- This Linkages clinet, invoice and transaction to help analyse the behavior of customers' payments, outstanding balances and cash flow patterns.

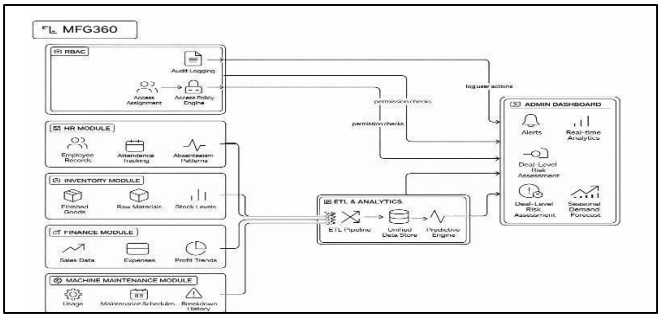

Fig 2.2: System Architecture Flow Diagram.

An integrated manufacturing management system, MFG360 (Manufacturing 360), is designed to provide a comprehensive view of production, inventory, and business operations. A single platform is used to integrate raw material management, production planning and tracking of stocks as well as admin control. By using the system, users can keep track of material inventory, stock levels, and product delivery throughout the manufacturing lifecycle. The architecture incorporates a central user interface that facilitates access to relevant functionality for both admin and operational users. The data is transmitted between modules such as raw materials, finished goods, and stock balance, ensuring real-time updates and consistency. Admin dashboard: View stock trends, usage patterns and performance metrics to make better decisions. In general, MFG360 enhances efficiency, reduces manual errors, and improves process transparency.

- An integrated solution for end-to–end manufacturing operations is provided by the proposed MFG360 system. It provides real-time monitoring and control over raw materials, production methods, and inventory levels.
- It also uses role-based access control to ensure user management is secure. The use of automatic stock updates based on production activities reduces the need for manual intervention.
- The inventory module maintains detailed records that include the quantity, inward date, and expiry date of materials. The system facilitates the seamless flow of data among modules, thereby enhancing operational coherence.
- It uses an analytical dashboard to show stock trends and the use of resources by. Automation helps improve data accuracy and reduces human errors. Real-time and structured data are provided by the system, leading to improved decision-making. Generally, MFG360 improves productivity and operational efficiency in manufacturing settings.

III. RESULTS AND DISCUSSION

A. The deal-level financial data sets are not readily accessible.

A significant research gap was identified due to the lack of structured deal-level financial datasets for manufacturing SMEs. The primary focus of datasets that are publicly available is on the overall financial performance of a company, with no emphasis on invoice or transaction levels. The difficulty in building precise predictive models for payment behavior is attributed to this limitation. In order to address this gap, the MFG360 framework employs a financ Neha Pokale ial data model and ETL pipeline to manage the organization of invoice and transaction-level data.

B. The absence of Integrated Financial and Operational Analytics

Another research gap is that operational data production, inventory and sales are not correlated with financial transactions in traditional systems of financial analysis. The inability to integrate hinders the execution of comprehensive business analysis. The MFG360 system merges financial and manufacturing data to create a single platform, which facilitates better analysis and decision-making.

C. The requirement for interpretable predictive models in financial systems

A lot of advanced predictive models are black-box systems that don't offer precise explanations for predictions. Transparency and transparency in analytics are crucial for financial decisions. As a result, the MFG360 predictive framework not only addresses accuracy in predicting outcomes but also generates interpretable analytical insights into customer payment patterns and various risk categories, making the system more useful to financial managers.

D. The influence of ETL pipelines on data quality and processing time is significant.

According to research, the ETL pipeline made a significant contribution to the data quality, consistency and processing time during the introduction of the MFG360 framework. A structured format was used to collect and store data from different sources, including billing systems, payment records, and inventory data. Financial reporting errors were reduced and predictive models were made more accurate.

E. Dashboard-Based Decision Support System.

The MFG360 system developed Power BI dashboards that offered users the opportunity to interact with financial and operational data. Management was assisted by a dashboard to keep

track of key KPIs like cash flow, invoices on hold and outstanding balances, stock levels, and payment delays. This facilitated quicker decision-making and enabled management to take proactive steps based on predictive insights instead of relying on conventional reports.

IV. CONCLUSION

In the finance module of the MFG360 framework, predictive analytics and ETL processes are utilized to enhance cash-flow forecasting and accounts receivable management. This module uses data from billing, invoices and transactions to form a well structured financial dataset. Through the use of temporal feature engineering and predictive modeling, it uncovers customer payment patterns, predicts payment delays, and estimates receivable realization timeline. The proposed finance module offers a more prospective perspective than the conventional financial analysis of aging, rather than solely reporting from historical events. It enables financial managers to make more accurate decisions about cash-flow planning, risk assessment, and risk management.

The finance module's experimental outcomes demonstrate that it enhanced financial visibility, decreased uncertainty in managing receivables, and facilitated proactive financial planning. As a result, the proposed finance analytics framework can be considered an effective means for manufacturing SMEs to improve financial performance, manage liquidity risks, and improve overall financial decisions through data-driven insights.

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