

# Research on a Low-Code Platform-Based Supply Chain Collaborative CRM System for Discrete Manufacturing: A Case Study of the Pump and Valve Industry

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**Abstract:** The pump and valve manufacturing industry is characterized by significant discrete features, including "high variety, small batch sizes, and high customization." In the deep waters of digital transformation, small and medium-sized enterprises (SMEs) are often constrained by traditional Customer Relationship Management (CRM) systems, which suffer from high development costs, long delivery cycles, and severe disconnection from backend supply chain operations. These limitations lead to challenges in configuring non-standard products, opaque order fulfillment processes ("black boxes"), and inefficient after-sales traceability. Based on empirical research involving 48 typical pump and valve enterprises, this paper proposes a supply chain collaborative CRM architecture based on the low-code development paradigm. Incorporating Model-Driven Engineering (MDE) principles, the study leverages the agile modeling and heterogeneous integration capabilities of low-code technologies to achieve real-time mapping of backend ERP/MES data to frontend interactive interfaces. This approach constructs a collaborative mechanism integrating intelligent configuration and quoting, transparent order progress tracking, and closed-loop service management. The findings not only validate the architectural elasticity and engineering feasibility of low-code technologies in complex discrete manufacturing scenarios but also provide theoretical foundations and practical references for resource-constrained SMEs in the equipment manufacturing sector to explore low-cost, high-adaptability cross-organizational collaboration pathways.

**Keywords:** Low-Code Development; Supply Chain Collaboration; Customer Relationship Management (CRM); Pump and Valve Industry.

## 1. Introduction

As a typical discrete manufacturing sector, the pump and valve industry has long adhered to Engineer-To-Order (ETO) and Make-To-Order (MTO) production paradigms. Taking the Wenzhou pump and valve industrial cluster in China as an example, the highly non-standardized nature of its products imposes stringent requirements on the business flexibility and data interoperability of information systems, far exceeding those of standard product manufacturing. Against the macro backdrop of intensifying global competition and normalized supply chain volatility, traditional passive CRM systems—focused primarily on lead recording and sales funnel management—struggle to meet the urgent market demands for delivery agility and cross-organizational data transparency.

Through in-depth surveys of 48 representative SMEs in the pump and valve sector, this study identifies three structural pain points currently faced by enterprises in customer collaboration and order fulfillment:

### (1) Logical Complexity in Technical Configuration and Quoting

The material selection and sealing configurations of pump and valve products often undergo customized changes in response to minor adjustments in parameters such as medium type and temperature. Survey data indicates that approximately 75% of enterprises lack dynamic calculation tools, relying heavily on engineers' personal experience for Bill of Materials (BOM) breakdown and cost accounting. Generic CRM systems struggle to accommodate the engineering constraint logic involving multi-parameter coupling, resulting in prolonged quoting cycles and persistently high error rates in orders.

### (2) Delivery Opacity Caused by "Information Silos"

Pump and valve manufacturing encompasses multiple discrete processes, including casting, machining, assembly, and pressure testing. About 62.5% of enterprises experience severe data fragmentation between the sales frontend (CRM) and backend Manufacturing Resource Planning/Manufacturing Execution Systems (ERP/MES). Customers are unable to access accurate order milestone information. Frequent passive "order chasing" not only deteriorates service experience but also significantly elevates internal communication and coordination costs.

### (3) Lack of Closed-Loop After-Sales Traceability

Industrial equipment has a long service life, and its maintenance relies heavily on the original configuration BOM and inspection reports generated at the time of shipment. Constrained by outdated historical archive management methods (with over 70% of SMEs still relying on paper-based document flows), the efficiency of spare parts matching during equipment failures is extremely low, making it difficult to establish a full lifecycle service closed loop.

Faced with these challenges, the high threshold of traditional hard-coded custom development deters SMEs, while standardized SaaS products fail to adapt to the highly dynamic business flows inherent in ETO models. Consequently, this paper proposes a lightweight collaborative CRM system architecture based on a low-code development platform, aiming to resolve these dilemmas.

## 2. Literature Review

### 2.1. Digitalization of Discrete Manufacturing and the System Adaptability Paradox

The digital transformation of the manufacturing industry is undergoing a paradigm shift from localized point automation to a global data-driven model (Zhong et al., 2017). However, research by Masood and Sonntag (2020) focusing on SMEs highlights that due to weak IT infrastructure and high sunk costs, SMEs face significant resource constraints when adopting Industry 4.0 technologies. Particularly in ETO modes, the highly customized nature of products makes standardized ERP/MES systems with pre-set logic extremely difficult to adapt to dynamically changing production flows, thereby posing enormous challenges to the agile response capabilities and flexible reconfiguration mechanisms of information systems (Aslan et al., 2012).

### 2.2. Paradigm Shift from Isolated CRM to Supply Chain Collaboration

In the dimension of information system evolution, the focus of both academia and industry has shifted from customer relationship management (CRM) confined within single enterprise boundaries to supply chain collaboration networks spanning across organizations. There is a growing emphasis on the deep integration of CRM and supply chain management to achieve visibility throughout the entire order lifecycle, thereby eliminating "black box" phenomena in manufacturing and delivery processes. Concurrently, the rise of low-code technology offers a new path for technical empowerment, breaking down traditional system barriers and enabling low-cost, agile collaboration across enterprises.

## 3. System Architecture Design

To overcome the inherent defects of traditional hard-coded models, such as long development cycles and difficulty in coping with high-frequency business requirement changes, this study introduces Model-Driven Engineering concepts to design a five-layer distributed system architecture characterized by high cohesion and low coupling.

### 3.1. Overall Architecture and Low-Code Empowerment Mechanisms

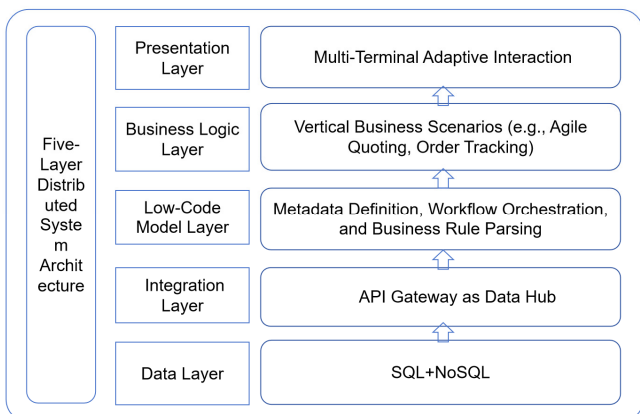


Fig 1. Five-Layer Distributed System Architecture

The system is logically divided into five layers from top to bottom: the **Presentation Layer** provides a multi-terminal adaptive interactive environment; the **Business Logic Layer** encapsulates vertical business scenarios such as agile quoting

and order tracking; the **Low-Code Model Layer**, serving as the core driving engine, provides metadata definition, workflow orchestration, and business rule parsing; the **Integration Layer** acts as a data hub via API gateways to break heterogeneous system boundaries; and the **Data Layer** adopts a hybrid storage strategy of relational and document-oriented databases (SQL + NoSQL) to accommodate both structured order data and unstructured engineering drawings.

This architecture reshapes system scalability through two core mechanisms:

- **Visual Data Modeling:** Addressing the complex attribute definitions of non-standard products, the system allows business personnel to dynamically expand data dictionaries through visual Entity-Relationship (ER) diagrams. For instance, when adding a new fluid medium standard, the underlying table structure and frontend UI can be synchronized and iterated merely through graphical drag-and-drop operations.
- **Componentized UI Interaction and Micro-Frontend Architecture:** High-frequency functions such as configuration tables and BOM calculation sheets are encapsulated as independent, reusable UI components. Page rendering is completed through modular assembly. This approach not only minimizes frontend development workload but also ensures consistency and responsiveness of the system interface.

### 3.2. Design of Core Collaborative Business Modules

To eliminate "information silos," the system architecture extends to the upstream and downstream of the supply chain. By introducing Role-Based Access Control (RBAC) technology, it creates permission-isolated collaborative portals for external distributors and outsourced processing factories. Core functional modules include:

- **Intelligent Configuration and Quoting Configurator:** Equipped with an engineering constraint rule library. The system calls APIs to retrieve dynamic raw material costs from the ERP in real-time and combines them with preset mathematical models for machining rates to achieve automated cost verification and one-click quote generation for non-standard orders.
- **End-to-End Collaborative Order View:** Highly specialized underlying process routes from the backend MES are mapped and transformed into "order milestones" understandable by non-technical personnel on the frontend, achieving progress transparency for both customers and sales teams.
- **"One Item, One Code" After-Sales Traceability Closed Loop:** A digital identity containing a unique Serial Number (SN) is generated for each shipped device. Upon scanning the code for repair requests, the system automatically parses and retrieves the original factory BOM and inspection records to precisely locate required spare part models, thereby significantly improving the First-Time Fix Rate (FTFR).

## 4. System Implementation and Cross-System Integration

This study focuses on overcoming the challenges of visual reconstruction of complex business logic and deep interoperability of heterogeneous systems.

### 4.1. Low-Code Reconstruction of Complex Business Logic

Addressing the "one order, one discussion" non-standard characteristics of the pump and valve industry, the system utilizes conditional gateways in its underlying configuration to handle asymmetric logical branches. In the low-code visual canvas, implicit engineering experience is abstracted into executable sets of Boolean expressions and event listening mechanisms. When configuration parameters are perturbed, the event bus triggers updates to the cost accounting model in real-time, enabling the business side to completely break away from the previous inefficient and error-prone modes reliant on Excel formulas and manual calculations.

### 4.2. Heterogeneous Data Integration Mechanisms and Loose Coupling Strategies

Deep interoperability between this system and existing ERP/MES environments is achieved primarily through API gateways and loose coupling architectures:

- **Dynamic Synchronization of Inventory and Lead Times:** The system periodically requests spot and in-transit inventory status from the ERP via RESTful APIs. During the CPQ (Configure, Price, Quote) configuration phase, algorithms verify the availability of core components (e.g., valve stems, sealing rings). Combined with procurement lead time models, the system automatically calculates and outputs Estimated Time of Arrival (ETA) to customers.
- **Master Data Mapping and Price Threshold Response:** A master data mapping middleware is established to synchronize standard BOMs to the CRM module. When market prices for bulk raw materials (e.g., stainless steel, cast iron) fluctuate beyond preset thresholds, a Webhook mechanism actively triggers the cost recalculation engine within the system. This mechanism effectively supports the business department's transition from "experience-based decision-making" to dynamic "data-driven decision-making."

## 5. System Evaluation and Discussion

The proposal and prototyping of this architecture not only provide a new perspective for the informatization construction of discrete manufacturing enterprises but also reveal the theoretical significance and technical boundaries of low-code technologies in specific industrial scenarios.

### 5.1. Theoretical and Practical Implications

At the theoretical level, this study enriches the application paradigm of cross-organizational information systems in the SME context. The research indicates that low-code application platforms effectively delegate partial system

construction authority to the business side, reshaping the Business-IT Alignment mechanism.

At the practical level, this study proposes and validates a "Bimodal IT" architectural path—pairing a lightweight low-code frontend with backend core ERP/MES systems. This evolutionary path offers a high cost-performance best practice for capital-constrained and IT-talent-scarce SMEs in the equipment manufacturing sector to resolve the dilemma of "excessively high costs for heavy customization and poor fit of standardized software."

### 5.2. Technical Challenges and Limitations

While low-code architectures excel at handling CRUD (Create, Read, Update, Delete) operations and business flows, they possess underlying architectural shortcomings when dealing with complex computations. Therefore, future engineering practices should adopt a hybrid architecture: business flows are carried by low-code platforms, while core physical simulations and algorithms are encapsulated as independently deployed Python/C++ microservices, invoked in real-time via APIs to circumvent platform performance limitations.

## 6. Conclusion and Future Outlook

Against the macro backdrop of the global discrete manufacturing industry accelerating its transformation towards agility, customization, and servitization, this study addresses the three typical pain points in the pump and valve sector—"inefficient non-standard quoting, opaque delivery processes, and after-sales data fragmentation"—by proposing a low-code-driven supply chain collaborative CRM system architecture. Theoretical analysis and prototype testing demonstrate that this architecture can break down data barriers between heterogeneous systems at a lower trial-and-error cost, achieving real-time mapping of front-end and back-end data and business closed loops. In this context, low-code is not merely an efficient software engineering tool but a strategic technological engine driving the leap in organizational agility for traditional equipment manufacturing enterprises.

Looking ahead, low-code-based manufacturing collaborative platforms possess vast space for intelligent evolution. Future research will focus on the deep integration of **Generative Artificial Intelligence**: specifically, exploring the embedding of **Multimodal Large Language Models (MLLMs)** as intelligent Agent plugins into low-code workflows. By leveraging visual understanding and Natural Language Processing (NLP) technologies, the system will automatically parse unstructured engineering drawings and inquiry sheets in PDF or image formats sent by customers. This will enable the intelligent extraction of key manufacturing feature parameters and the automatic generation of preliminary BOMs. Ultimately, this will propel CRM systems to achieve a leapfrog development from the traditional "process-collaboration driven" mode to a "data and AI dual-driven assisted decision-making" mode.

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