

# Research on Logistics Tracking System for Intelligent Manufacturing Workshop in Shipbuilding based on Digital Twin Automata

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## Abstract

Aiming at the problem of low efficiency in logistics management of shipbuilding enterprises in China, this paper proposes an intelligent manufacturing workshop logistics tracking system based on digital twin technology. The system utilizes Internet of Things (IoT) technology, RFID tags, and sensing devices to achieve real-time monitoring and visual management of the entire process of materials from procurement, warehousing, and outbound to production. Application results show that this system can significantly improve the logistics efficiency of shipbuilding enterprises, reduce operational costs, and provide a feasible technical solution for the construction of intelligent shipyards.

## Keywords

Ship Intelligent Manufacturing, Digital Twin, Logistics Tracking, Internet of Things (IoT), RFID.

## 1. Introduction

Shipbuilding, as a comprehensive large-scale equipment manufacturing industry, is characterized by complex product structures, long production cycles, and a wide variety of materials. Currently, shipbuilding enterprises in China generally face problems such as inefficient logistics management, difficulty in tracking materials, and lack of information transparency, which restrict the improvement of their competitiveness. In the context of Industry 4.0 and intelligent manufacturing, how to use new generation information technologies to enhance the level of logistics management in shipbuilding has become an important topic<sup>[1]</sup>.

Digital twin, as a key enabling technology for intelligent manufacturing, can provide comprehensive data support and visual control means for manufacturing systems through the bidirectional mapping and real-time interaction between physical and information spaces<sup>[2]</sup>. This paper, combining the practical needs of shipbuilding workshops, designs a logistics tracking system architecture based on digital twin, and elaborates on the implementation path of its key technologies, aiming to provide a reference for the intelligent transformation of shipbuilding enterprises.

## 2. Current Situation and Challenges of Logistics Management in Ship Intelligent Manufacturing

### 2.1. Characteristics of Logistics Management in Shipbuilding

Logistics management in shipbuilding involves the coordination and cooperation of thousands of material types and hundreds of processes, with the following significant characteristics:

- Wide variety of materials: A single ship may require tens of thousands of material types, including steel plates, pipes, electrical equipment, etc.
- Complex processes: Involves multiple links and departments from material procurement, warehousing, storage, distribution to workshop consumption.
- Wide spatial distribution: The shipyard area is vast, with materials distributed in different warehouses and work areas.
- High real-time requirements: Production progress is closely dependent on the timely delivery of materials<sup>[3]</sup>.

## 2.2. Analysis of Existing Problems

Currently, most shipbuilding enterprises in China still face the following problems in logistics management:

- 1) Lack of information transparency: Material status updates are lagging, making it difficult to grasp accurate locations and quantities in real time.
- 2) Low efficiency: Reliance on manual recording and inventory counting leads to high error rates and low efficiency.
- 3) Difficult coordination: Severe information silos among departments, lacking a unified collaborative platform.
- 4) Insufficient decision support: Lack of data analysis and forecasting capabilities, making it difficult to optimize logistics processes<sup>[4]</sup>.

## 3. Architecture of Logistics Tracking System based on Digital Twin

### 3.1. Overall Architecture Design

The proposed logistics tracking system for ship intelligent manufacturing workshops based on digital twin adopts a four-layer architecture design:

#### 3.1.1. Physical Layer

The physical layer consists of various hardware devices, including:

- RFID tags and readers/writers: Attached to materials, pallets, and equipment for identification and tracking.
- Sensor network: Includes temperature, humidity, position sensors, etc., to collect environmental parameters.
- Mobile terminals: Used for field data collection and query.

#### 3.1.2. Data Layer

The data layer is responsible for storing and managing various types of data, including:

- Material basic data: Material codes, specifications, supplier information, etc.
- Real-time status data: Location, quantity, environmental parameters, etc.
- Historical data: Material circulation records, consumption patterns, etc.

#### 3.1.3. Digital Twin Layer

The digital twin layer is the core of the system, realizing:

- 3D Modeling: Constructing virtual models of workshops, equipment, and materials.
- Data Mapping: Establishing real-time correlation between physical entities and virtual models.
- Simulation Analysis: Simulating and optimizing logistics processes.

#### 3.1.4. Application Layer

The application layer provides specific business functions, including:

- Material Tracking Management: Real-time monitoring of material location and status.

- Intelligent Scheduling Optimization: Automatically generating distribution plans based on production schedules.
- Visualization Display: Displaying the overall logistics picture through dashboards, charts, etc.

**Table 1.** Description of Main System Functional Modules

Functional Module	Main Functions	Technical Implementation
Data Acquisition Module	RFID information reading, sensor data collection	RFID Readers/Writers, ZigBee Technology
Material Management Module	Inbound, outbound, inventory management	Web Services, Database Operations
Online Query Module	Material data query and display	Web Client, Mobile APP
Material Tracking Module	Material circulation path tracking	Algorithm Optimization, Real-time Positioning
Decision Support Module	Logistics optimization analysis	Big Data Analysis, Machine Learning

### 3.2. System Workflow

The system workflow mainly includes the following links:

- 1) Material Inbound Process: Newly arrived materials are affixed with RFID tags, automatically identified by readers, entered into the system, and assigned storage locations; the digital twin model is updated synchronously.
- 2) Outbound and Distribution Process: Distribution tasks are generated based on the production schedule; AGVs or workers pick and distribute materials according to system guidance, with real-time tracking throughout the process<sup>[5]</sup>.
- 3) Workshop Consumption Process: When materials arrive at workstations, their status is updated via workshop readers, and the system records consumption time and quantity.
- 4) Exception Handling Process: When the system detects anomalies (e.g., wrong material, shortage), it automatically alarms and generates handling suggestions.

## 4. Implementation of Key System Technologies

### 4.1. Material Identification and Positioning Technology based on RFID

RFID technology is the core for material tracking. The system adopts the following scheme:

- Tag Selection: Select different types of RFID tags (anti-metal, high-temperature resistant, etc.) according to material properties.
- Reader Deployment: Deploy a network of readers at warehouse entrances, workshop passages, key workstations, etc.
- Positioning Algorithm: A multi-point fusion positioning algorithm based on Received Signal Strength Indication (RSSI) and phase difference, with an accuracy of 1-3 meters.

### 4.2. Digital Twin Modeling Technology

The construction of the digital twin model includes:

- Geometric Modeling: Using 3D modeling software to build workshop layout, equipment, and facility models.
- Physical Modeling: Defining the physical attributes of materials (weight, dimensions, storage requirements, etc.).
- Behavior Modeling: Establishing logical relationships such as material flow rules and constraints.

- Data Driving: Updating the model status through real-time data to ensure consistency between the virtual and physical worlds<sup>[6]</sup>.

### 4.3. Data Integration and Processing Technology

Facing the massive data generated in shipbuilding workshops, the system adopts the following processing technologies:

- Edge Computing: Preliminary filtering and processing at the data acquisition end to reduce server load.
- Cloud Computing Platform: Utilizing elastic cloud computing resources for big data analysis and simulation tasks.
- Data Fusion: Correlating and integrating RFID data, sensor data, and business system data.

**Table 2.** Main System Performance Indicators

Performance Indicator Target	Value	Measured Result
Material Identification Accuracy	99%	99.5%
Position Update Real-time Performance	<5 seconds	3 seconds
System Response Time	<3 seconds	2 seconds
Data Query Efficiency	<2 seconds	1.5 seconds
System Stability	99.9%	99.95%

## 5. Analysis of System Application Effects

After applying this system in a shipbuilding enterprise, significant results were achieved:

### 5.1. Efficiency Improvement

- Material Search Time: Reduced by over 75%, from an average of 30 minutes to 7 minutes.
- Inventory Counting Efficiency: Improved by 90%, full inventory counting that originally took 2 days now only takes 2 hours.
- Staff Efficiency: Logistics management personnel reduced by 40%, while processing capacity increased by 50%.

### 5.2. Cost Reduction

- Inventory Costs: Through precise control and optimization, inventory turnover rate increased by 25%.
- Error Costs: Distribution error rate reduced by 95%, reducing production interruptions caused by material errors.
- Labor Costs: Reduced 15 dedicated inventory counting and management personnel, saving about 1.5 million RMB annually in labor costs.

### 5.3. Management Level Enhancement

- Information Transparency: Achieved visual management of the entire material lifecycle<sup>[6]</sup>.
- Decision Support: Logistics optimization suggestions based on data analysis support scientific decision-making by management.
- Collaboration Efficiency: Broke down departmental information silos and improved overall collaboration efficiency.

## 6. Conclusion and Outlook

This paper addressed the pain points in logistics management of shipbuilding enterprises and proposed an intelligent manufacturing workshop logistics tracking system based on digital twin. Through the integrated application of RFID, IoT, and digital twin technologies, real-time tracking and visual management of the entire material flow process were achieved. Application practice has proven that the system can significantly improve logistics efficiency, reduce operational costs, and provide an effective path for the intelligent transformation of shipbuilding enterprises.

Future research will focus on the following directions: First, deepening the application of artificial intelligence technology in logistics prediction and optimization; Second, exploring the potential of 5G technology in enhancing system real-time performance; Third, expanding the integration depth of the system with other links in shipbuilding (such as production scheduling, quality control) to promote the comprehensive construction of intelligent shipyards.

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