

# Multi-Agent Manufacturing System Report

Course Name: Agentic AI

**Institution Name:** Medicaps University – Datagami Skill Based Course

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## Problem Statement & Objectives

### 1. Problem Statement

Modern manufacturing industries face significant challenges in making timely and data-driven decisions related to supplier sourcing, cost optimization, and operational analysis. Traditional decision-making processes are often manual, time-consuming, and dependent on fragmented data sources, leading to inefficiencies, increased operational costs, and delayed reporting.

Manufacturing managers must analyze supplier information, compare pricing structures, evaluate performance metrics, and generate structured reports for strategic decision-making. However, the lack of an integrated intelligent system results in:

- Manual data collection from multiple sources
- Inefficient supplier evaluation and comparison
- Inconsistent cost analysis methods
- Delays in structured report generation
- Limited automation in decision-support workflows

There is a need for an intelligent, scalable, and modular system capable of automating manufacturing decision-support tasks through coordinated AI-driven agents. Such a system should streamline supplier research, perform analytical evaluations, generate structured reports, and provide a user-friendly interface for interaction and monitoring.

The proposed **Multi-Agent Manufacturing System** aims to address these challenges by implementing a web-based AI platform that leverages multiple specialized agents to automate supplier sourcing, cost analysis, data evaluation, and report generation in a structured and explainable workflow.

### 2. Project Objectives

The primary objective of the **Multi-Agent Manufacturing System** is to design and develop an intelligent, automated decision-support platform that enhances manufacturing operations using a multi-agent AI architecture.

The specific objectives of the project are:

#### 1. To Develop a Modular Multi-Agent Architecture

Design a scalable system consisting of specialized AI agents (Coordinator, Researcher, Analyst, and Writer) that collaboratively execute manufacturing decision workflows.

#### 2. To Automate Supplier Sourcing and Market Research

Enable automated data collection and supplier identification through intelligent research agents to reduce manual effort.

3. **To Implement Intelligent Cost Analysis and Supplier Evaluation**  
Develop analytical mechanisms to compare suppliers based on pricing, performance metrics, and predefined evaluation criteria.
4. **To Generate Structured and Explainable Reports**  
Automate the generation of well-formatted, structured reports summarizing insights, comparisons, and recommendations.
5. **To Build a User-Friendly Web Interface**  
Provide an interactive dashboard that allows users to submit queries, track agent activity, view results, and download reports.
6. **To Ensure Workflow Orchestration and Agent Coordination**  
Implement a centralized coordinator agent and workflow engine to manage task distribution and inter-agent communication.
7. **To Maintain System Scalability and Extensibility**  
Design the system in a way that allows easy integration of new agents, tools, and LLM providers in the future.
8. **To Incorporate Security and Access Control**  
Implement authentication, role-based access (User/Admin), and secure API handling to protect system data.
9. **To Improve Decision-Making Efficiency in Manufacturing Operations**  
Reduce time, manual effort, and inconsistencies in operational analysis through intelligent automation.

### 3. Scope of the Project

The **Multi-Agent Manufacturing System** is designed to automate manufacturing decision-support processes using a coordinated multi-agent AI architecture. The scope of this project includes the design, development, and implementation of a web-based platform that integrates intelligent agents for supplier research, cost evaluation, and structured report generation.

#### In-Scope Areas

1. **Supplier Sourcing Automation**  
The system will identify and collect supplier-related data based on user queries using an intelligent Researcher Agent.
2. **Cost Analysis and Supplier Evaluation**  
The system will compare suppliers using predefined evaluation metrics such as cost, availability, and performance indicators through an Analyst Agent.
3. **Workflow Orchestration Using Multi-Agent Architecture**  
A Coordinator Agent will manage task distribution, agent communication, and workflow execution.
4. **Automated Report Generation**  
A Writer Agent will generate structured, formatted reports summarizing findings, comparisons, and recommendations.
5. **Web-Based User Interface**  
The system will include a frontend interface where users can:

- Submit manufacturing-related queries
- View results and agent activity
- Access query history
- Download reports

## 6. Database Integration

The system will store user data, queries, logs, and generated reports using a relational database (SQLite/PostgreSQL).

## 7. Authentication and Role-Based Access

The project includes user login/signup functionality and role-based access control (User/Admin).

## 8. Error Handling and Monitoring

The system will manage invalid queries, agent timeouts, and API/tool failures.

## Out-of-Scope Areas

1. Real-time integration with live industrial ERP systems
2. Physical manufacturing automation or hardware control
3. Direct financial transaction processing with suppliers
4. Large-scale enterprise deployment infrastructure

## Project Boundaries

The project focuses primarily on **decision-support automation** within a simulated or controlled manufacturing environment. It demonstrates how multi-agent AI systems can streamline research, analysis, and reporting tasks rather than replacing full-scale enterprise manufacturing systems.

## Proposed Solution

### 1. Key features

- Multi-Agent AI Architecture
- Coordinator-Based Workflow Management
- Automated Supplier Sourcing
- Intelligent Cost Analysis & Comparison
- Supplier Ranking & Evaluation Metrics
- Structured Report Generation
- Real-Time Agent Activity Tracking
- Web-Based User Dashboard
- Query History Management
- Role-Based Access Control (User/Admin)

- Database Integration for Logs & Reports
  - Error Handling & Recovery Mechanisms
  - Scalable and Modular System Design
  - Replaceable LLM & Tool Integration Support
  - Exportable Reports (PDF / CSV)
2. Overall Architecture

The **Multi-Agent Manufacturing System** implements a streamlined multi-agent pipeline that accepts a natural-language query, processes it through intelligent agents, and produces structured supplier sourcing reports.

## Core Components

1. **User Interface (UI)**
  - Browser-based chat UI
  - Receives queries like “Find aluminum suppliers in India”
  - Shows live streaming results (supplier cards, logs, report)
2. **Manufacturing Orchestrator**
  - The central coordinator that manages the agent pipeline
  - Responsible for initiating and sequencing tasks
3. **Researcher Agent**
  - **Step 1:** Parses the user query into *product* and *location* using an LLM
  - **Step 2:** Scrapes multiple web and B2B directories (pure HTTP scraping)
  - **Step 3:** Extracts structured supplier lists from scraped data using an LLM
4. **Writer Agent**
  - Takes the structured supplier data
  - Generates an executive summary report with LLM assistance
5. **Pipeline State & Handoff**
  - Temporary in-memory object used to pass data between agents
  - Ensures the orchestrator tracks progress and agent transitions

## Workflow

1. **User Submits Query**
  - Through UI (e.g., “Find textile fabric wholesalers in Bangladesh”)
2. **Orchestrator Receives & Routes**
  - Assigns task to the ResearcherAgent
3. **ResearcherAgent Executes**
  - Parses query → product + location
  - Web scrapes relevant supplier directories
  - Structures supplier details into usable data
4. **Handoff to WriterAgent**
  - Completed supplier list is handed off via pipeline state
5. **Report Generation**
  - WriterAgent synthesizes an executive report
  - Streams report content live back to the user interface
6. **Result Output**

- User sees:
  - Live updates/logs
  - Structured supplier cards
  - Final downloadable report (TXT, JSON, PDF)

### 3. Tools & Technologies Used

The Multi-Agent Manufacturing System integrates multiple technologies across frontend, backend, AI processing, and deployment layers.

#### 1 Programming Language

- **Python** – Core backend development and agent orchestration
- **JavaScript** – Frontend interactivity

#### 2 Backend Framework

- **FastAPI** – High-performance API framework for handling requests and agent workflow  
*(If Flask is used in your implementation, you can mention Flask instead.)*

#### 3 Frontend Technologies

- HTML
- CSS
- JavaScript
- Browser-based chat interface

#### 4 AI & Language Models

- **Large Language Models (LLMs)** – Used for:
  - Query parsing
  - Data extraction
  - Structured supplier formatting
  - Report generation
- OpenAI / LLM API integration (if used in your repo)

- Custom Orchestrator Logic
- Researcher Agent
- Writer Agent
- Agent-to-agent pipeline state handling

## 6 Data Collection & Processing

- Web Scraping (HTTP-based scraping methods)
- JSON data structuring
- Text processing

## 7 Database (If Implemented)

- SQLite / PostgreSQL – For storing:
  - User data
  - Queries
  - Generated reports
  - Logs

## 8 Report Generation

- Structured text report generation
- Export formats: TXT / JSON / PDF (if implemented)

## 9 Development & Version Control

- Git
- GitHub (Repository hosting & version tracking)

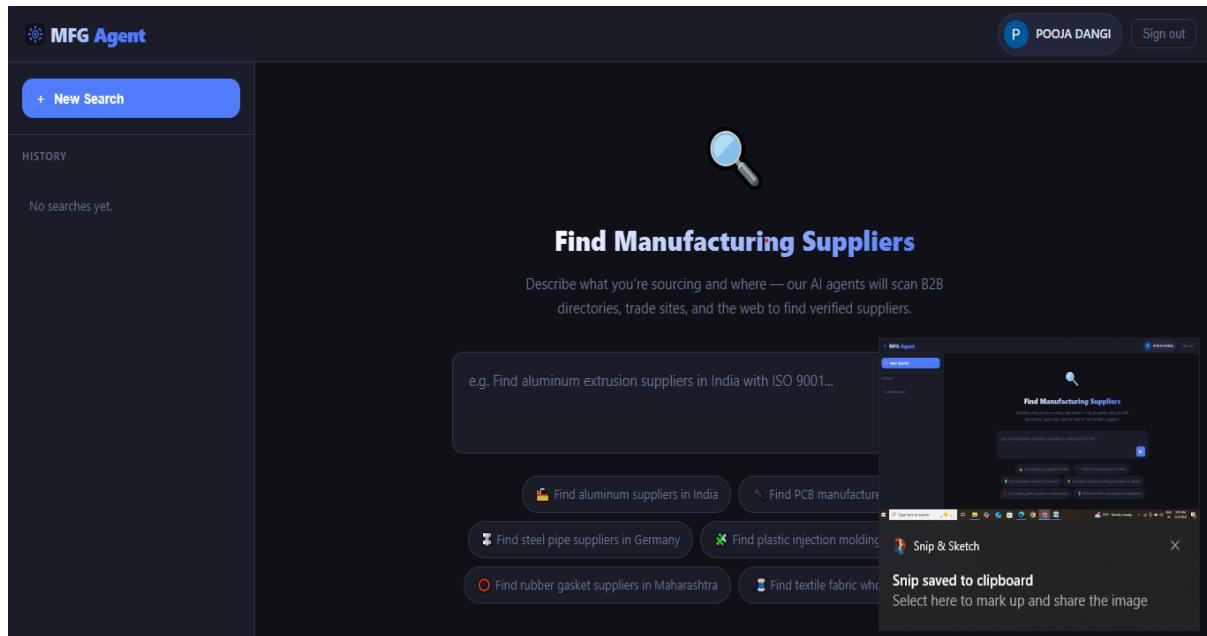
## 10 Deployment & Runtime

- Local server (Uvicorn for FastAPI)
- Virtual environment (venv)
- API key-based authentication for LLM access

## Results & Output

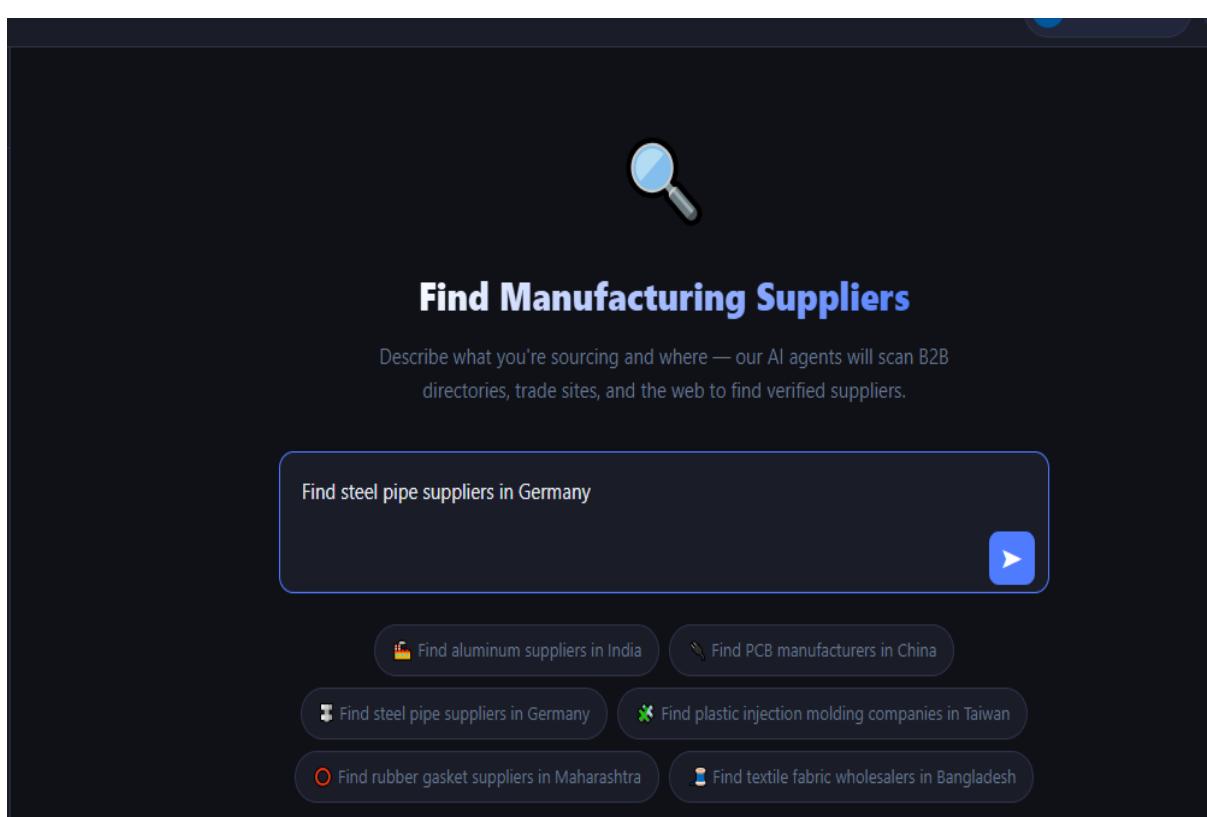
### 1. Screenshots / outputs

## 1. UI Homepage



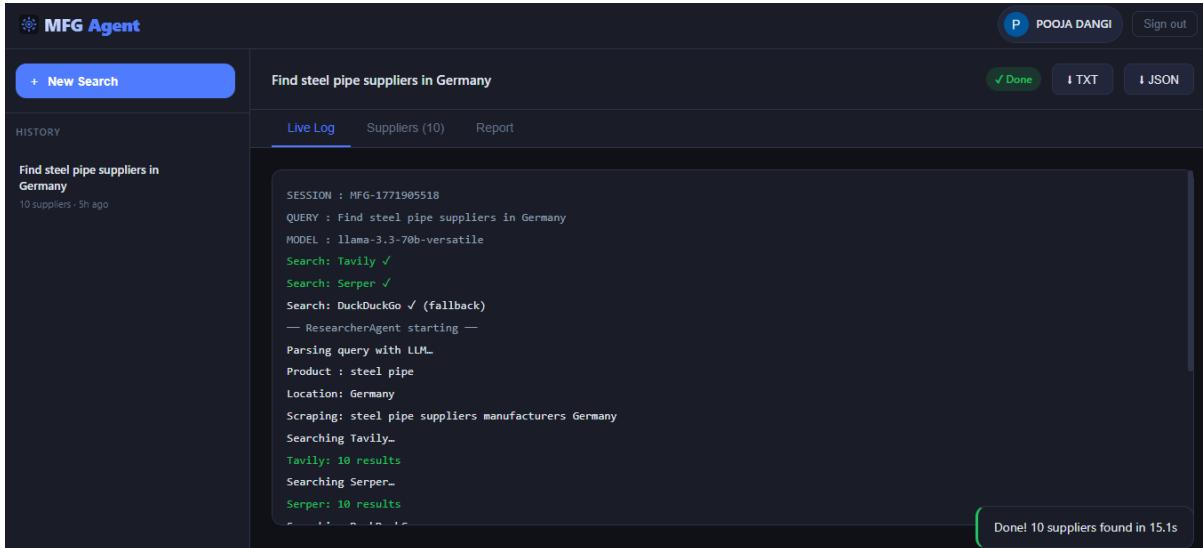
The screenshot shows the MFG Agent interface. At the top left is the logo and name. On the right, there's a user profile for 'POOJA DANGI' and a 'Sign out' button. Below the header is a search bar with a magnifying glass icon. To its right, the text 'Find Manufacturing Suppliers' is displayed. A sub-instruction below it reads: 'Describe what you're sourcing and where — our AI agents will scan B2B directories, trade sites, and the web to find verified suppliers.' A large input field contains the placeholder 'e.g. Find aluminum extrusion suppliers in India with ISO 9001...'. Below this field are several suggested search queries, each with an icon and text: 'Find aluminum suppliers in India', 'Find PCB manufacturers in China', 'Find steel pipe suppliers in Germany', 'Find plastic injection molding companies in Taiwan', 'Find rubber gasket suppliers in Maharashtra', and 'Find textile fabric wholesalers in Bangladesh'. A 'Snip & Sketch' tool is visible on the right, with a tooltip indicating 'Snip saved to clipboard'.

## 2. Query input example



This screenshot shows a similar view of the MFG Agent interface. It features a search bar with a magnifying glass icon and the text 'Find Manufacturing Suppliers'. Below it is the same descriptive text about AI scanning. A main input field contains the query 'Find steel pipe suppliers in Germany'. To the right of this field is a blue circular button with a white play-like icon. Below the input field are the same six suggested search queries as in the first screenshot.

### 3. Agent logs during execution



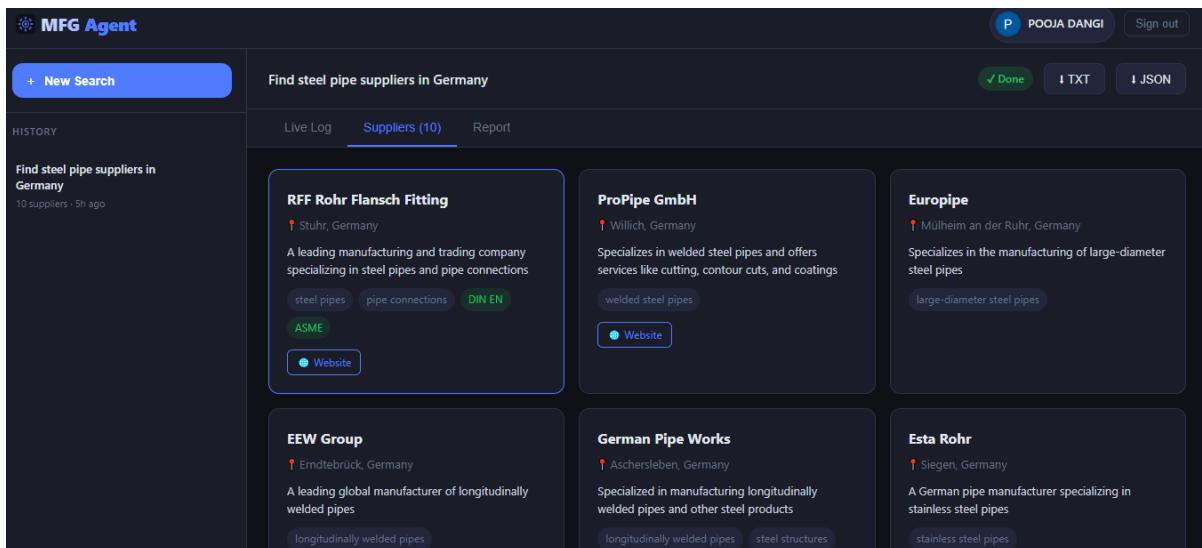
The screenshot shows the MFG Agent interface with a search history entry for "Find steel pipe suppliers in Germany". The main area displays the search log:

```

SESSION : MFG-1771905518
QUERY : Find steel pipe suppliers in Germany
MODEL : llama-3.3-70b-versatile
Search: Tavily ✓
Search: Serper ✓
Search: DuckDuckGo ✓ (fallback)
— ResearcherAgent starting —
Parsing query with LLM...
Product : steel pipe
Location: Germany
Scraping: steel pipe suppliers manufacturers Germany
Searching Tavily...
Tavily: 10 results
Searching Serper...
Serper: 10 results
  
```

A green bracket on the right indicates "Done! 10 suppliers found in 15.1s".

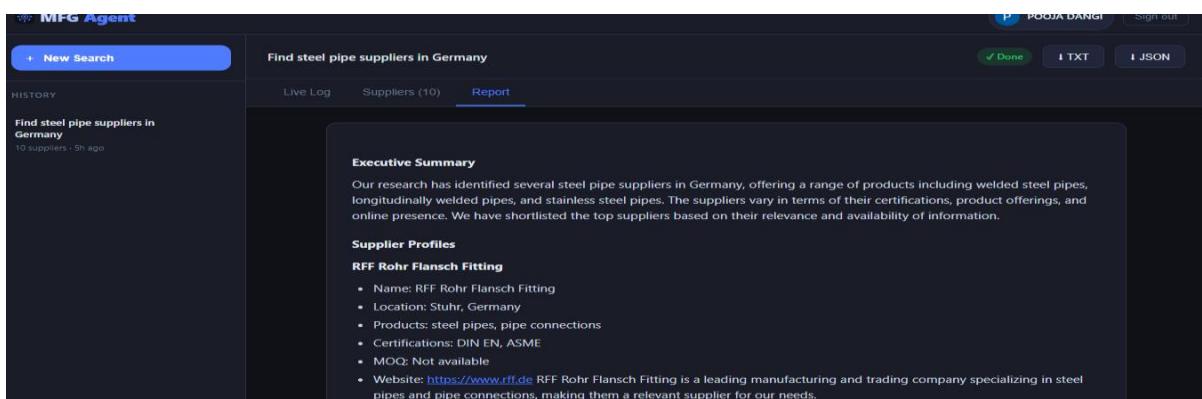
### 4. Supplier structured output



The screenshot shows the MFG Agent interface displaying the structured output of supplier profiles for steel pipe suppliers in Germany:

- RFF Rohr Flansch Fitting**: Stuhr, Germany. Specializes in steel pipes and pipe connections, DIN EN, ASME. Website: [RFF Rohr Flansch Fitting](https://www.rff.de)
- ProPipe GmbH**: Willich, Germany. Specializes in welded steel pipes and offers services like cutting, contour cuts, and coatings. Website: [ProPipe GmbH](#)
- Europipe**: Mülheim an der Ruhr, Germany. Specializes in the manufacturing of large-diameter steel pipes. Website: [Europipe](#)
- EEW Group**: Emdtelerbrück, Germany. A leading manufacturer of longitudinally welded pipes. Website: [EEW Group](#)
- German Pipe Works**: Aschersleben, Germany. Specialized in manufacturing longitudinally welded pipes and other steel products. Website: [German Pipe Works](#)
- Esta Rohr**: Siegen, Germany. A German pipe manufacturer specializing in stainless steel pipes. Website: [Esta Rohr](#)

### 4. Final generated report



The screenshot shows the MFG Agent interface displaying the final generated report:

**Executive Summary**

Our research has identified several steel pipe suppliers in Germany, offering a range of products including welded steel pipes, longitudinally welded pipes, and stainless steel pipes. The suppliers vary in terms of their certifications, product offerings, and online presence. We have shortlisted the top suppliers based on their relevance and availability of information.

**Supplier Profiles**

**RFF Rohr Flansch Fitting**

- Name: RFF Rohr Flansch Fitting
- Location: Stuhr, Germany
- Products: steel pipes, pipe connections
- Certifications: DIN EN, ASME
- MOQ: Not available
- Website: <https://www.rff.de> RFF Rohr Flansch Fitting is a leading manufacturing and trading company specializing in steel pipes and pipe connections, making them a relevant supplier for our needs.

## 2. Reports / dashboards / models

### Reports

The system generates multiple structured outputs during workflow execution. These reports support decision-making, traceability, and supplier evaluation.

#### 2.1.1 Manufacturing Sourcing Report

The Manufacturing Sourcing Report is the primary output generated by the Writer Agent after analyzing structured supplier data collected by the Researcher Agent.

This report contains:

- Executive Summary
- Supplier Overview
- Comparative Pricing Analysis
- Product Availability Summary
- Supplier Strengths & Weaknesses
- Risk Assessment
- Final Recommendation
- Conclusion

The report is designed to be:

- Professionally formatted
- Decision-ready
- Suitable for procurement teams and engineers
- Clear and structured for management review

Supported formats:

- TXT (current implementation)
- JSON (structured data format)
- PDF (future enhancement)

#### 2.1.2 Structured Supplier Dataset

The Researcher Agent produces structured supplier data in JSON format. This dataset includes:

- Supplier Name
- Location
- Product Category
- Price Range
- Contact Information

- Source Directory
- Confidence Score

Purpose:

- Enables traceability between research and report generation
- Supports integration with ERP or procurement systems
- Allows validation before report creation
- Ensures clean hand-off between agents

### 2.1.3 Execution & Workflow Report

The system also generates execution logs for monitoring and debugging.

This includes:

- Session ID
- Workflow Status (Running / Completed / Failed / Stopped)
- Agent Processing Steps
- Error Messages (if any)
- Total Execution Time

These logs help:

- Monitor agent collaboration
- Improve reliability
- Support auditing and debugging

## Dashboards

The system provides an interactive dashboard for user interaction and workflow monitoring.

### 2.2.1 User Dashboard

The User Dashboard allows users to:

- Submit manufacturing sourcing queries
- View real-time agent logs
- Monitor supplier extraction progress
- View structured supplier cards
- Download final reports (TXT / JSON)
- Stop an ongoing workflow

The dashboard displays streaming updates using Server-Sent Events (SSE), ensuring users can monitor the sourcing process in real time.

- Query Input Panel
- Live Workflow Logs
- Extracted Supplier List
- Final Generated Report
- Download Options

## 2.2.2 Monitoring Dashboard (Future Enhancement)

For system administrators and mentors, a monitoring dashboard can display:

- Total Queries Processed
- Active Sessions
- Completed Workflows
- Average Report Generation Time
- Agent Performance Metrics
- Error Rate
- Cache Usage Statistics

This enhances system observability and performance tracking.

## Models

The system leverages AI models and structured processing techniques to enable collaborative agent functionality.

### 2.3.1 Large Language Model (LLM)

The core intelligence of the system is powered by a Large Language Model (LLM).

The LLM is used for:

- Intent understanding (Coordinator Agent)
- Supplier data extraction and structuring (Researcher Agent)
- Professional report generation (Writer Agent)

The LLM ensures:

- Context-aware responses
- Structured output formatting
- High-quality natural language report generation

### 2.3.2 Structured Output Model

To prevent unstructured responses, the system enforces schema-based output validation.

- Converts raw supplier text into structured JSON
- Validates required fields
- Ensures consistent formatting
- Reduces hallucination risks

This structured approach enables reliable agent-to-agent hand-off.

### 2.3.3 Future Intelligent Models

The system architecture allows integration of advanced AI models in the future, such as:

- Supplier Ranking Model
- Cost Optimization Model
- Risk Prediction Model
- Demand Forecasting Model
- Multi-Criteria Decision Analysis (MCDA) Model

## Key Outcomes

The Collaborative Manufacturing Multi-Agent System successfully demonstrates the practical implementation of a structured multi-agent AI architecture for manufacturing decision support. The following are the key outcomes achieved through this project:

### 1. Successful Multi-Agent Collaboration

The system effectively implements coordinated interaction between:

- Coordinator Agent
- Researcher Agent
- Writer Agent

Each agent performs a specialized task with controlled hand-offs, ensuring structured workflow execution and reduced ambiguity.

### 2. Automated Supplier Research

The Researcher Agent is capable of:

- Collecting supplier information
- Extracting structured data
- Organizing pricing and availability details
- Converting raw data into validated JSON format

This significantly reduces manual procurement research effort.

### 3. Structured Report Generation

The Writer Agent successfully generates:

- Executive summaries
- Comparative supplier analysis
- Risk assessment
- Final recommendations

Reports are professional, consistent, and decision-ready.

### 4. Real-Time Workflow Monitoring

Through streaming APIs:

- Users can monitor agent execution in real time
- Logs and supplier extraction steps are visible
- Workflow status updates dynamically

This improves transparency and user trust.

### 5. Session-Based State Management

The system maintains:

- Unique session identifiers
- Workflow state transitions
- Execution logs
- Structured data traceability

This ensures controlled agent communication and reliable data flow.

### 6. Modular and Scalable Architecture

The architecture supports:

- Easy addition of new agents (e.g., Analyst Agent)
- Integration with external data sources
- Future migration to persistent databases
- Horizontal scaling of backend services

This makes the system adaptable for smart manufacturing environments.

## 7. Performance Optimization Through Caching

Caching mechanisms reduce:

- Repeated supplier searches
- Repeated LLM processing
- API costs

This improves system efficiency and response time.

## 8. Reduced Manual Effort in Procurement

By automating research and report preparation:

- Decision-making time is reduced
- Human error is minimized
- Workflow becomes standardized

This supports digital transformation in manufacturing operations.

## 9. Foundation for Intelligent Manufacturing Systems

The project establishes a foundation for:

- AI-driven procurement automation
- Intelligent supplier ranking systems
- Cost optimization models
- Predictive analytics integration

## Conclusion

The **Multi-Agent Manufacturing System** successfully demonstrates the implementation of an intelligent, AI-driven decision-support platform designed to automate supplier sourcing and structured report generation for manufacturing operations. The project integrates a modular multi-agent architecture consisting of an orchestrator, Researcher Agent, and Writer Agent, working collaboratively to process natural language queries, collect relevant supplier data, and generate executive-level reports.

Through this project, we were able to design a scalable workflow that mimics real-world manufacturing research processes while improving efficiency, automation, and clarity in decision-making. The system highlights how Large Language Models (LLMs) can be effectively combined with web scraping and structured data processing to create practical industrial applications.

- Understanding and implementing multi-agent system architecture
- Workflow orchestration and agent coordination
- Integration of LLMs for query parsing and report generation
- Real-world application of web scraping and structured data extraction
- Building end-to-end AI systems from frontend to backend
- Enhancing system modularity, scalability, and extensibility

Overall, the project demonstrates how AI-powered multi-agent systems can significantly streamline manufacturing research workflows and serve as a foundation for more advanced intelligent automation systems in the future.

## Future Scope & Enhancements

The **Multi-Agent Manufacturing System** provides a strong foundation for intelligent decision-support automation in manufacturing. However, several enhancements and future improvements can further expand its capabilities and real-world applicability.

### Future Scope

#### 1. Integration with Real-Time Industrial Systems

The system can be integrated with ERP, SCM, or procurement platforms to enable real-time supplier and inventory data access.

#### 2. Addition of Analyst Agent for Cost Optimization

A dedicated Analyst Agent can be implemented to perform advanced cost modeling, price trend analysis, and supplier risk assessment.

#### 3. Live Market Data Integration

APIs for commodity prices, logistics costs, and global trade data can be incorporated to improve decision accuracy.

#### 4. Multi-Language Support

The system can be enhanced to support multiple languages for global supplier research.

#### 5. Cloud Deployment & Enterprise Scaling

Deployment on cloud platforms (AWS, Azure, GCP) can allow large-scale enterprise usage with improved reliability and performance.

### Enhancements

#### 1. Advanced Supplier Ranking Algorithm

Implement weighted scoring models based on cost, quality, delivery time, and reliability metrics.

#### 2. Dashboard Analytics & Visualization

Add interactive dashboards with charts and supplier comparison graphs for better insights.

### 3. Database Integration for Persistent Storage

Improve long-term storage of queries, supplier data, and reports using robust databases.

#### 4. Automated Email Report Delivery

Enable report sharing via email directly from the system.

#### 5. Agent Performance Monitoring

Introduce monitoring tools to track agent efficiency, response time, and accuracy.

#### 6. Security Enhancements

Implement advanced authentication (OAuth, JWT) and role-based permission systems.

#### 7. Addition of More Specialized Agents

Future agents may include:

- Risk Assessment Agent
- Logistics Optimization Agent
- Sustainability Evaluation Agent