O3OZONE

Graph Networks in Smart Manufacturing

Transforming Maintenance, Supply Chains & Processes

From Siloed Systems to Interconnected Insights

Complex, Interconnected Operations

Modern manufacturing operations are highly complex & interconnected, from machines on the shop floor to global supply chains.

Limitations of Siloed Data

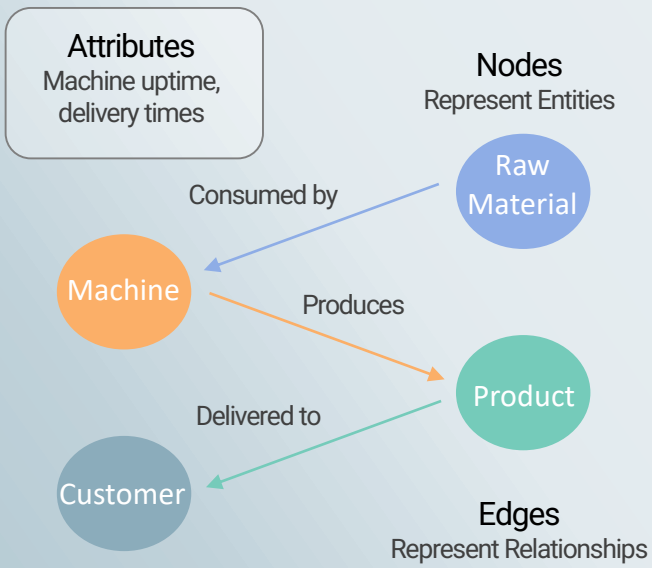
Traditional linear or siloed data systems (separate ERP, MES, supply chain databases) fail to capture cross-domain linkages. Critical interdependencies remain hidden in disconnected data, creating blind spots & inefficiencies.

GRAPH NETWORK

Graph-Based Modeling of Relationship

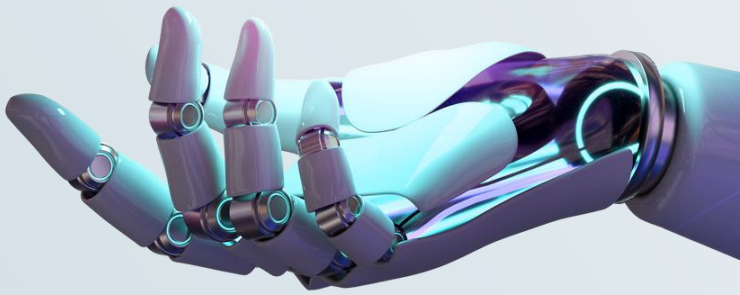
A **graph network** refers to a mathematical structure (a graph) used to represent relationships between objects. These objects are represented as **nodes** (or vertices), & their connections are represented as **edges** (or links).

Graph Network



Graph network models rely on three key components:

- **Nodes:** These represent entities in your manufacturing system, such as machines, process steps, sensors or inventory items.
- **Edges:** These are the relationships or interactions between nodes, like the material flow between machines / suppliers or communication between IoT sensors.
- **Attributes:** Nodes & edges can carry data, such as machine temperature, machine uptime, material costs, or delivery times, which enrich the model's insights.



Why Graph Networks Are Different

Traditional Models Miss Relationship

Traditional tools like tables, spreadsheets, & relational databases are designed to store data independently.

Machine Failures
Cannot model how a fault in Machine A might disrupt downstream machines B & C

Supplier Delays
Don't capture ripple effects across multiple product lines when one supplier is late

Process Sequencing
Fail to reflect how production stages rely on each other for timing, quality, & throughput

Graph Networks Embrace Interconnectivity

Unlike traditional models, graph networks are designed to reflect how things are connected.

Relationship-First Design
Every machine, sensor, material, or supplier is a node ; every connection is a relationship (edge)

Causal Understanding
Enables systems to learn how one change impacts others ; ideal for root cause analysis

Dynamic Simulation
Easily simulate scenarios like a machine breakdown or supplier disruption to assess impact

Contextual Prediction
Predict outcomes not just from one data point, but based on surrounding dependencies

Benefits of Graph Networks in Manufacturing

Graph networks help manufacturers move from isolated data to connected intelligence.

Predictive Maintenance
Detect early failure patterns by analyzing connected sensor & equipment behavior ; reducing downtime & repair costs

Process & Bottleneck Optimization
Visualize dependencies across stages to eliminate inefficiencies, rebalance loads, & maximize throughput

Root Cause & Impact Analysis
Trace defects, delays, or supply chain issues to their origin across interconnected systems — not just symptoms

Unified Data Model
Integrate ERP, MES, IoT, & supplier data into one graph for real-time visibility & cross-functional collaboration

Graph Intelligence Architecture: Turning Data into Decisions

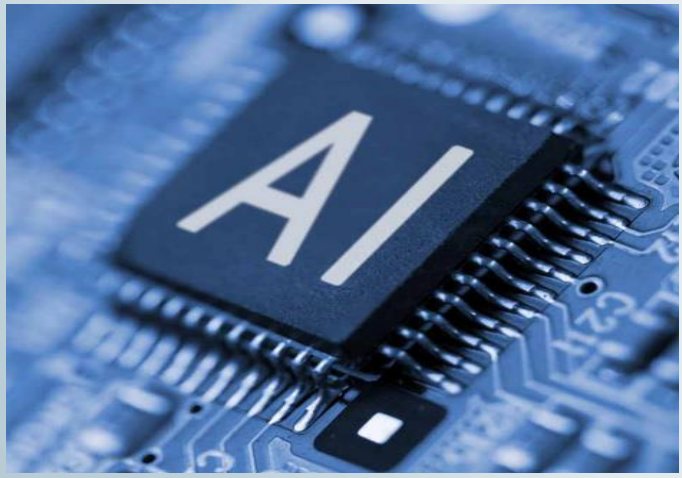
Data Ingestion & Graph Construction

Mapping SQL Tables to Python Graph Objects : Manufacturing data stored in SQL is converted into graph-ready Python objects

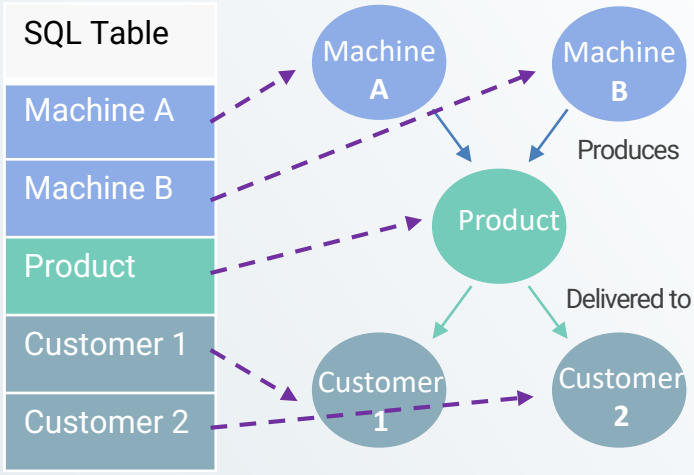
- Tables *such as Machines, Process Steps, and Suppliers* become **nodes.**
- Relationships become **edges** *such as feeds into, uses, delivers to.*

Graph Network Processing

- **Contextualization:** Enrich nodes and edges with relevant **attributes** *(e.g., machine uptime, supplier reliability)* to provide context for analysis.
- **Clustering:** Apply graph clustering techniques to grouped into meaningful clusters *(e.g., production cells, supplier types).*
- **Graph Layer Implementation:** Incorporate specialized layers within the GNN architecture to capture hierarchical and relational patterns, enhancing the model's predictive capabilities.



Relational-to-Graph Mapping



From Knowledge Graph to Mathematical Model

Targeted subgraphs are used to feed domain-specific predictive functions, such as :

f(machine, shift, product) = estimated-material-required or g(component, supplier, season) = delivery-risk-score. These functions enable forecasting of raw material usage, predictive maintenance, downtime impact simulation, and production planning optimization.

Integration with LLMs

Once the graph is processed, it serves as the basis for generating natural language prompts that allow LLMs to interact with users. E.g. a prompt like *"The capper depends on the filler. Both are slowing down this shift. What's the root cause?"*

Based on real-time graph insights, it may respond with recommendations such as *"Machine A is affecting Machine B due to overpressure. Recommend inspecting the air pressure regulator."*

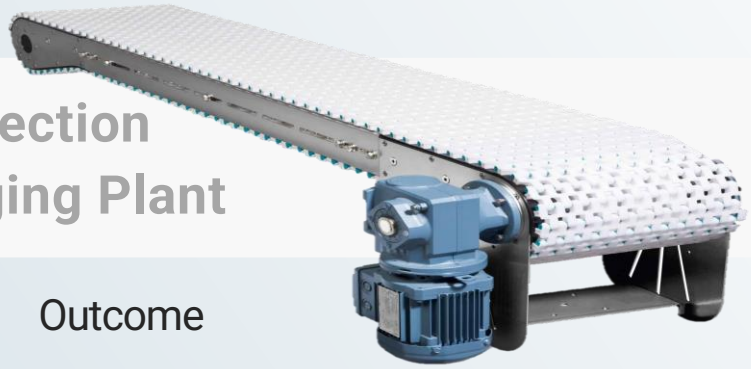
Predictive Maintenance with Graph Networks

Traditional Maintenance Challenges

- Time-based schedules often lead to over-maintenance or surprise failures
- Lack of context: sensors monitor equipment individually without understanding how they interact
- Root causes remain hidden in linear data ; only symptoms are treated

Graph-Powered Maintenance

Graph networks connect machines, components, & sensors based on real-world dependencies. Using GNNs, manufacturers can detect how failures propagate across assets & enable predictive maintenance based on system-wide risk, not just individual asset age.



Graph-Based Anomaly Detection Prevents Downtime in Packaging Plant

Industry : Packaging (Folding Cartons)

Problem :

Recurring equipment failures caused line stoppages & high maintenance costs. Traditional time-based maintenance overlooked how faults spread across connected machines.

Approach :

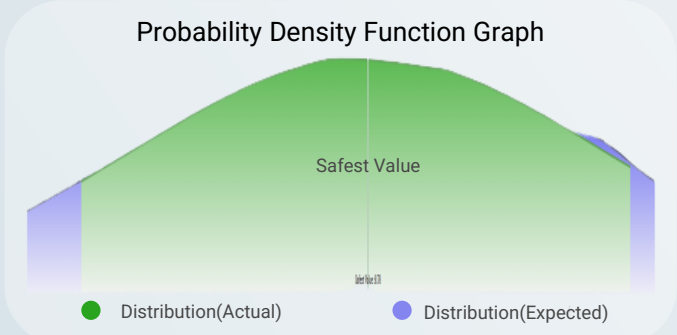
Using O3OZONE's Graph Neural Network, the system detected how pressure anomalies in one node (a motor) propagated to downstream assets like conveyors & sealers. O3OZONE recommended maintenance prioritization based on impact paths.

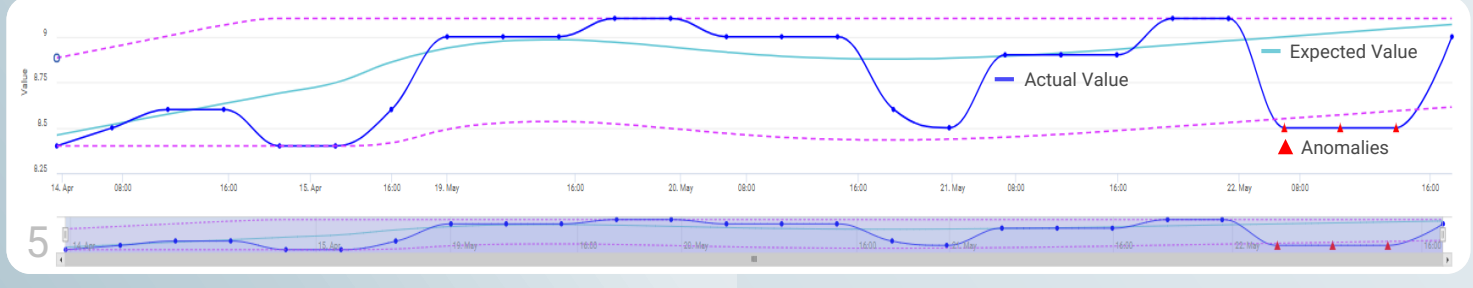
Outcome

37% Reduction in Unplanned Downtime

25% Decrease in Maintenance Labor Hours

SAR **750,000** saved in **6** months





Process Optimization with Graph Networks

Challenges in Process Optimization

- Production bottlenecks are hard to trace with linear tools
- Value stream maps don't reflect real-time flow or dependencies
- Manual diagnostics miss interactions between machines, shifts, & buffers
- Delay propagation across steps is rarely visible

Graph-Based Optimization

By simulating the full production flow, the graph helps detect blockers, identify cycle mismatches, & reveal hidden dependencies. The resulting insights can then feed into mathematical models to predict line performance under different loading conditions & improve scheduling decisions.

Eliminating Bottlenecks in Production Using Graphs

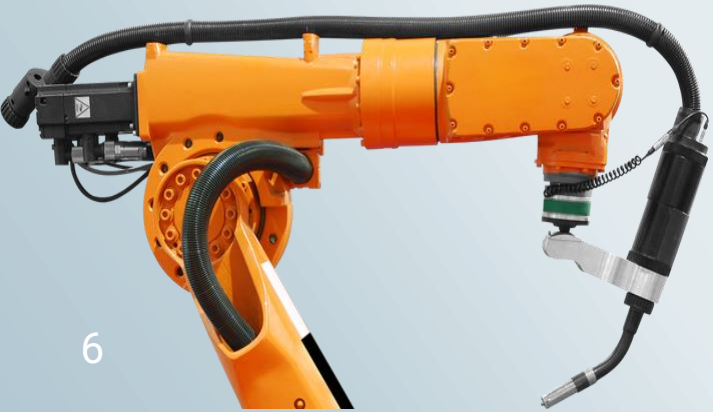
Industry : Food & Beverages Plant

Problem :

The filling & capping machines often desynchronized, causing line stalls. Traditional tools failed to identify the misalignment.

Approach :

The plant modeled each station as a node, including buffers & shift handovers. Graph clustering was used to segment core bottling processes. Insights from the graph were passed to a function to simulate line balance.



Outcome

Throughput Increase

12% increase in line throughput

Changeover Reduction

25% reduction in changeover delays

Real Time Decision Making

Graph dashboards now support real-time decision-making across shifts

Supply Chain Optimization with Graph Networks

Gaps in Current Supply Chain

- Limited visibility across multi-tier suppliers
- Static supply chain design can't respond to disruption
- Impact of supplier failure hard to trace across products
- Over-reliance on manual audits & reactive planning

Dynamic Supply Chain Using Graphs

Supply chains can be modeled as live graphs, linking suppliers, components, routes & lead times. This enables manufacturers to simulate the ripple effects of delays/shortages, identify high-risk nodes such as single-source suppliers or critical materials, & dynamically optimize fulfillment, sourcing & logistics in response to real-time disruptions.

Graph-Based Risk Visibility for PET Packaging Supply Chain

Industry : Plastic Bottles & Packaging

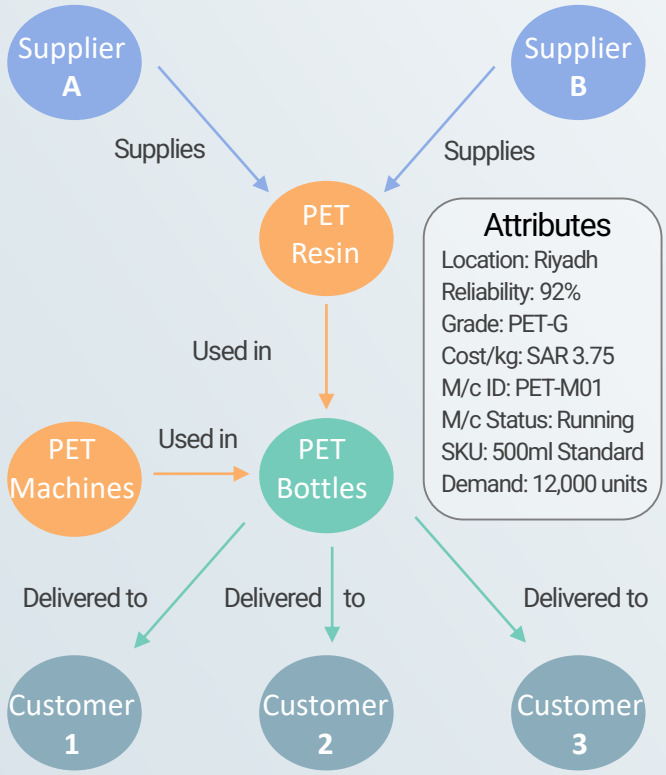
Problem :

A key supplier of PET resin faced repeated customs clearance delays, causing disruptions in raw material availability. Traditional ERP systems failed to forecast impact across product lines.

Approach :

The company mapped its supply network as a graph, linking suppliers, ingredients, routes, & production dependencies. O3OZONE's Graph analytics identified critical nodes & exposed supply chain vulnerabilities. Alternate sourcing routes & supplier substitutions were simulated.

Supply Chain Dependency Graph Network



Prevented production disruption across **3 high-dem & SKUs**

18% reduction in expedited freight costs

Supply planning now guided by a **graph-powered risk simulation tool**

End-to-End Traceability Across Your Factory; Powered by O3OZONE

O3OZONE seamlessly integrates with your ERP system, enabling real-time data capture, analysis, & traceability across your entire manufacturing process. Built on globally recognized GS1 standards, it allows batch tracking at any stage, providing instant insights on machine, production, supplier details, & other critical data.

With advanced analytics, intelligent reporting tools, & AI-driven insights, O3OZONE transforms raw data into actionable intelligence. Manufacturers can detect trends, identify inefficiencies, prevent costly issues, & optimize performance in real-time.

By streamlining operations, enhancing regulatory compliance, & supporting predictive maintenance, O3OZONE empowers industries to drive efficiency, quality improvement, & sustainable growth.

Meet Regulatory Compliance

Many industries have strict traceability requirements & regulation, especially food & beverages, pharmaceuticals, & automotive. O3OZONE makes audits easier by collecting, processing, & analyzing traceability data & producing reports.

Improve Quality Control

Identify & address quality issues early for improved consistency. Integrating O3OZONE with your ERP for full traceability helps reduce waste & meet customer quality expectations.

Optimize Supply Chains

Reduce costs by optimizing your supply chain. Track products & components back to their origin to identify bottlenecks & inefficiencies. This leads to better inventory management, reduced lead times, & improved resource allocation.