Supply Chain Improvement

Monitor and improve the efficiency of production processes

The Challenge

AutoTech Motors, a leader in automotive manufacturing, seeks to revolutionize its supply chain operations because it faces integration and inventory management issues. The company aims to employ Industry 4.0 technologies to enable vertical and horizontal integration among supply chain partners, enhancing collaboration and synchronizing the ecosystem. AutoTech also aims to develop advanced demand forecasting systems to address inventory challenges. Another industry goal is to ensure supply chain transparency and traceability, offering real-time material and component tracking to enable proactive decision-making and rapid disruption responses. Finally, AutoTech Motors wants to cater to individual customer requirements while maintaining operational efficiency and reducing lead times.

Industry Sector:
Automotive Manufacturing Industry

Challenge classification:
Supply Chain Improvement; Vertical Integration; Horizontal Integration; On-Demand Custom Manufacturing; Warehouse and Inventory Management; Material Flow Control; Supply Chain Transparency; Demand Forecasting.

Time for Project Completion:
30 months

Main Requirements

- Enable vertical and horizontal integration among suppliers, manufacturers, and distributors;
- Implement demand forecasting models to improve production planning and inventory management;
- Develop a transparent supply chain system to track and trace materials and components;
- Facilitate on-demand custom manufacturing to meet customer requirements.

Other Requirements

N/A

Key Performance Indicators

N/A

Other information

Are there any existing systems or technologies being utilized for supply chain management, inventory control, or demand forecasting?
We currently use an enterprise resource planning (ERP) system to manage production orders and inventory control. However, there is a need for more advanced supply chain management tools and demand forecasting.

What is the status of the network infrastructure in the facility?
Our network infrastructure is well-established and provides comprehensive coverage across facilities.

Which communication protocols or systems need to be integrated into the supply chain?
Yes, the industry has approximately 20 legacy machines without digital controllers.

Are there any specific communication protocols currently in use on the shop floor?
These devices, such as sensors and tracking devices, utilize wireless technologies, such as Wi-Fi, Bluetooth, or cellular networks. We prioritize communication protocols such as Wi-Fi, Bluetooth, MQTT, CoAP or cellular networks for efficient and lightweight data transmission. We also want to integrate communication protocols, such as radio frequency identification (RFID) for product identification and IoT sensors for real-time tracking, into the supply chain.

Are there specific requirements or limitations concerning connectivity that must comply with industry standards or regulations?
Compliance with industry standards and regulations is a top priority for us. Connectivity solutions must align with the relevant standards.

Research Phase

Taking into account the challenge description, its requirements and its information, elaborate at least 5 questions that can lead your research for a solution.

Research questions:

1. How can Industry 4.0 technologies be effectively integrated into the existing ERP system to achieve seamless vertical and horizontal integration among suppliers, manufacturers, and distributors in the automotive supply chain?
2. What advanced demand forecasting models and algorithms are most suitable for the companys' production planning and inventory management needs, considering the complexities of the automotive manufacturing industry?
3. How can a transparent supply chain system be developed and implemented to effectively track and trace materials and components in real-time, ensuring supply chain transparency, traceability, and rapid disruption response?
4. What communication protocols and IoT technologies should be prioritized for integrating legacy machines and modern sensors into the supply chain to ensure efficient and lightweight data transmission, product identification, and real-time tracking?
5. How can on-demand custom manufacturing processes be established to meet individual customer requirements while optimizing operational efficiency, reducing lead times, and minimizing disruptions in the automotive production flow?

Given the questions and the main requirements of the challenge previously listed:

- *identify possible technologies using the Planet4 Taxonomy Explorer;*
- *identify and analyze the sources (papers, articles, etc.) of those technologies that best suit the challenge;*

Technologies identified in the taxonomy:

Sensors (hardware), Cellular communication, LTE/GSM/4G/5G, Short-range wireless, Wi-Fi, WLAN (wireless local area network),

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Sources of those technologies that best suit the challenge:

1. https://www.digiteum.com/iot-supply-chain/
2. https://www.libelium.com/iot-solutions/smart-industry/
3. https://www.sciencedirect.com/science/article/pii/S2351978920319338
4. https://iopscience.iop.org/article/10.1088/1755-1315/252/5/052001
5. https://zerynth.com/customers/case-studies/blockchain-enabled-iot-shipment-tracking-system/
6. https://ieeexplore.ieee.org/document/9453558

7. https://www.sciencedirect.com/science/article/pii/S1877050920305251
8. https://www.mdpi.com/2076-3417/11/15/6787
9. https://aws.amazon.com/it/blogs/apn/supply-chain-tracking-and-traceability-with-iot-enabled-blockchain-on-aws/
10. https://zerynth.com/products/4zeroagent/
11. https://learn.microsoft.com/en-us/azure/architecture/solution-ideas/articles/supply-chain-track-and-trace

In light of the discoveries made:

- *report the answers for the questions above;*
- *compare 2-3 of the more common solutions identified in the sources (how would they change the approach to the solution? What are the possible benefits/issues in such a use of these technologies?);*
- *draw initial conclusions on which path you want to take in proposing a solution.*

Answers:

1. By implementing IoT sensors (hardware) across the supply chain, using short-range wireless technologies (Wi-Fi, WLAN) for connectivity, and enabling communication through MQTT protocol. Cloud data storage and computing can aggregate and process data, ensuring real-time integration. Cellular communication (4G/5G) enhances remote connectivity and data transmission.
2. Utilizing Support Vector Regression (SVR) and Random Forest algorithms for demand forecasting. Historical data from sensors can be collected through cellular communication and Wi-Fi networks, feeding the predictive models hosted on cloud data storage.
3. By integrating IoT sensors with blockchain technology for secure and immutable data recording. Then visualizing the supply chain events and data using data visualization tools and platforms, providing transparency and traceability to respond rapidly to disruptions.
4. Integrate short-range wireless technologies (Wi-Fi) and MQTT for communication between legacy machines and modern IoT sensors. Employ cellular communication (4G/5G) for real-time data transmission from sensors to the cloud. Implement RFID technology for product identification. Utilize IoT sensors for real-time tracking of materials and components.
5. Using cellular communication (4G/5G) for instant communication of custom design specifications. Integrate data from customer orders and design specifications into the cloud for processing. Use data visualization tools to monitor and manage custom manufacturing requests and production workflows.

Comparison:

The choice of the most suitable technology stack was guided by a thorough knowledge of the literature. Given the requirements expressed by the company, several solutions were studied. However, to take into account all phases of implementation, from retrofitting existing equipment to implementing and deploying machine learning algorithms, it would be advantageous to consider a single vendor. In this way, it would be possible to avoid possible integration problems that might arise. Three possible solutions are the AWS (Amazon Web Service) [9], Azure [11], and Zerynth [5] environments. Although they all allow the software integration phase, only Zerynth also provides the physical device that can modernize legacy systems. Therefore, to enable flawless implementation of all requirements, we opted for the Zerynth environment.

Conclusions:

In response to the challenges faced by AutoTech Motors, a comprehensive approach can be implemented. Leveraging a combination of IoT sensors for data collection, cellular communication (4G/5G) for real-time data transmission, and short-range wireless technologies (Wi-Fi) for facility communication, the integration of Industry 4.0 technologies becomes achievable. MQTT ensures lightweight and efficient data exchange.
As highlighted in the literature [8], demand forecasting is improved through machine learning algorithms like Support Vector Regression (SVR) and Random Forest, bolstered by cloud data storage and computing. Supply chain transparency and traceability are achieved by integrating blockchain with cellular communication, MQTT, and IoT sensors. Visualization tools provide real-time insights.
Legacy machines are integrated with modern sensors using short-range wireless technologies and MQTT, while cellular communication ensures efficient data transmission. Lastly, for on-demand custom manufacturing, cellular communication and cloud integration facilitate instant communication and data processing. This combined approach addresses AutoTech Motors' goals, enabling an agile and efficient automotive supply chain.

Proposed Solution

Making use of the technologies identified after the analysis of the sources, describe a possible solution to the challenge. Also, do not forget the constraints (time, number of devices to produce/connect, etc.): the solution must be applicable to the real context of the company that commissioned the challenge.

Solution Summary

Brief description of the solution (1-2 paragraph + 1 image)

The proposed solution addresses AutoTech Motors' automotive manufacturing challenges through advanced technologies. IoT sensors strategically placed across machinery, storage, and vehicles enable informed decisions, including modern sensors like the Zerynth 4ZeroBox for legacy systems. Short-range wireless tech (Wi-Fi) ensures intra-facility communication, while cellular (4G/5G) allows seamless integration across partners. MQTT facilitates lightweight data exchange. Transparency and traceability are achieved through IoT sensors linked to Ethereum Smart Contracts via the 4ZeroBox and Zerynth Device Manager. Demand forecasting integrates machine learning algorithms, sensor and ERP data, automating production planning via Zerynth AI Agents. On-demand custom manufacturing leverages cellular communication and cloud processing, aided by visualization tools for efficient workflow management.

Solution Description

Describe the solution and its details

In response to the multifaceted challenges confronted by the company within the automotive manufacturing sector, the solution proposal converges a range of cutting-edge technologies. By embracing these technologies we aim to remodel its supply chain operations while resolving integration and inventory management hurdles.

Firstly, the implementation of IoT sensors stands as a pivotal step. These sensors will be strategically placed across machinery, inventory storage facilities, and transportation vehicles. By gathering real-time data, these sensors will form the bedrock of informed decision-making. To address the challenge of legacy machines, modern sensors are introduced depending on the machines. In this way a wide range of data can be gathered, such as vibration, energy, pressure, temperature, flow (in case of fluids or gas) and humidity. This can be achieved through the use of the Zerynth 4ZeroBox.

To enable efficient communication within the supply chain ecosystem, a multifaceted approach is proposed. Intra-facility communication is facilitated through short-range wireless technologies, such as Wi-Fi, ensuring seamless interaction among elements within a confined area. For broader communication spanning different locations and partners, cellular communication (4G/5G) emerges as a crucial tool. This widespread connectivity allows information to flow uninhibitedly, supporting vertical and horizontal integration between suppliers, manufacturers, and distributors. Within facilities, lightweight data exchange is facilitated by MQTT, enabling swift communication.

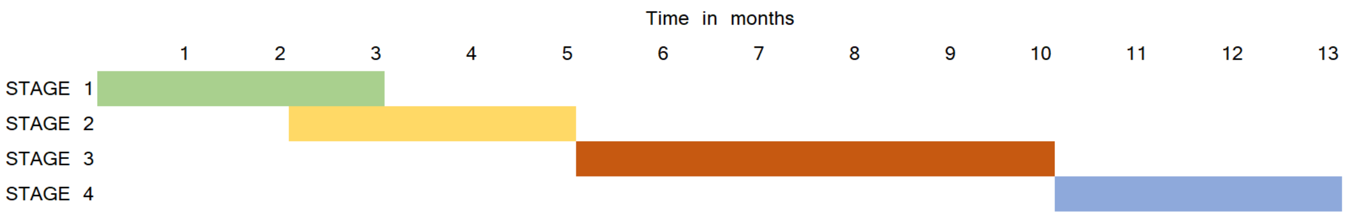
A cornerstone of this solution is the drive for transparency and traceability throughout the supply chain. Thanks to the 4ZeroBox it is possible to gather sensor data, generate, sign and transactions to Ethereum Smart Contract. In tandem, the Zerynth Device Manager orchestrates a comprehensive suite of functionalities, including shipment tracking, historical sensor reading visualization, and the provision of a platform for customers to execute final shipping payments. IoT sensors, working in tandem with blockchain technology, ensure secure and transparent record-keeping of supply chain events.

Regarding demand forecasting and planning, machine learning algorithms like Support Vector Regression and Random Forest come to the forefront. Leveraging historical data and external factors captured both from sensors and ERP data, these algorithms refine demand predictions. Such predictions are then integrated into the cloud-based platform enabling an automated response in production planning and inventory management, bolstering overall operational efficiency.

Lastly, for on-demand custom manufacturing, cellular communication serves as the conduit for instantaneous communication of custom design specifications. These specifications, integrated into the cloud-based platform, undergo real-time processing. Visualization tools provide a clear overview of the custom manufacturing workflow, aiding in optimal operational management.

Implementation Plan

Describe the solution implementation plan considering among other things: gantt chart with milestones, high-level cost analysis, possible difficulties (at least 3 major issues or difficulties) and additional opportunities (at least 2 extra benefits).



Stage 1 - Pilot Deployment Phase (3 months):

- Month 1-2: Install IoT sensors across selected machinery and facilities. Implement MQTT for lightweight data exchange. Integrate Zerynth 4ZeroBox for legacy machines.
- Month 2-3: Configure short-range wireless (Wi-Fi) and cellular (4G/5G) communication networks.

Stage 2 - Blockchain Integration and Transparency Enhancement (3 months):

- Month 3-4: Implement Zerynth Device Manager for data aggregation and interaction with Smart Contracts.
- Month 4-5: Test sensor data transmission and blockchain integration.

Stage 3 - Demand Forecasting and Cloud Integration (5 months):

- Month 6-7: Establish data pipelines to feed sensor and ERP data into the cloud platform.
- Month 7-8: Develop and integrate machine learning algorithms for demand forecasting.
- Month 9-10: Develop automated production planning and inventory management processes.

Stage 4 - Custom Manufacturing and Visualization Tools (3 months):

- Month 11-12: Develop cloud-based processing for real-time custom manufacturing requests.
- Month 12-13: Integrate visualization tools for workflow management and oversight.

High-Level Cost Analysis:

Equipment retrofitting	10,000-15,000 €
Sensors (highly depends on type of equipment)	600 - 3,000 €
IoT gateways	8,000 €
IoT expert labor	3,300 - 5,000 €
AI expert/data scientist labor	10,000 - 50,000 €
Computer scientists/IT specialist labor	20,000 - 40,000 €
TOTAL	**51,900 - 121,000 €**

Possible Difficulties:

- Integration Complexity: Ensuring seamless integration of diverse technologies (IoT sensors, cellular networks, blockchain, cloud platforms) across the supply chain may require extensive configuration and compatibility testing.
- Legacy System Adaptation: Retrofitting legacy machinery with modern sensors can encounter challenges due to varying interfaces, compatibility, and sensor accuracy.

- Data Security and Privacy: Blockchain integration necessitates robust data security measures to safeguard sensitive supply chain data, including encryption, access controls, and GDPR compliance.

Additional Opportunities:

- Operational Optimization: Accurate demand forecasting and real-time tracking enable streamlined production, reducing overstocking, minimizing lead times, and optimizing resource allocation.
- Customer Engagement: The Zerynth Device Manager's visualization capabilities can extend to customer interfaces, allowing them to monitor their orders, interact with the supply chain process, and make informed decisions.