D2.1: ECOSYSTEM DEFINITION AND REQUIREMERTS

ANNEX 7: CLUSTER 3A DEFINITION AND REQUIREMENTS

This annex covers Cluster 3 - AgriTech Transformation and Sustainability Initiative (ATSI), exploring how COP-PILOT supports the integration of IoT, robotics, and edge processing across the agricultural value chain to improve productivity, sustainability, and nutritional quality in leafy vegetable production. It demonstrates how advanced technologies including UAVs, smart supply chain management, and multi-cloud data orchestration can help the European agricultural sector meet growing environmental, market, and consumer demands.

D2.1: Ecosystem definition and requirements

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Abstract	The COP-PILOT platform is an open collaborative system for managing services across IoT, edge and core computing environments. COP-PILOT is built to enable secure and intelligent operations that connect diverse sectors. This document brings together an ecosystem of technical blueprints and services models across 5 main domains to support the development of these infrastructures. With a focus on seamless cross domain integration, it lays the foundation for private edge deployments and digital ecosystems across Europe. This deliverable sets the direction for building a platform that drives smarter, more secure, and collaborative digital transformations across multiple industries.
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* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

DATA: Data sets, microdata, etc.

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

SECURITY: Deliverables related to security issues

OTHER: Software, technical diagram, algorithms, models, etc.

CLUSER 3A INTRODUCTION

Agriculture in Europe is at a pivotal juncture, facing the dual challenge of increasing production to meet growing demand while adhering to stringent environmental sustainability norms. The European Green Deal and the new Common Agricultural Policy mandate a transformative approach to agricultural practices, emphasising towards reduced carbon footprint, biodiversity preservation and sustainable resource use. At the same time, there is a rising consumer demand for agricultural products that are not only nutritionally superior but also produced in an environmentally sustainable manner. However, traditional agricultural methods often fall short in efficiently meeting these modern standards, leading to gaps in productivity, sustainability and meeting consumer expectations. Additionally, there is an emerging concern about antinutrients in crops, which can impact nutritional quality and consumer health. This scenario calls for a transformative approach that harmonises productivity, sustainability and nutritional quality in agriculture.

The AgriTech Transformation and Sustainability Initiative (ATSI) Pilot, addresses all these challenges and focuses on fostering interoperability and seamless data sharing across the agricultural value chain, supporting sustainable production of leafy vegetables to meet market and health demands, and propelling the European agricultural sector towards economic growth and competitiveness. ATSI presents a multidisciplinary collaboration involving key partners from technology, academia and industry, and enhances the integration of edge processing, IoT and robotics to boost farming operations.

ATSI specifically targets the leafy vegetables sector, leveraging a suite of advanced technologies for real-time crop monitoring, pest management, and targeted interventions. This includes deploying IoT sensor networks and utilising drones (UAVs) and Agrirobots (UGVs) for environmental and crop health monitoring. A significant component of ATSI is the enhancement of Just-In-Time (JIT) logistics and smart supply chain management, utilising advanced tracking, routing optimization and blockchain to ensure the timely and efficient transport of products. Additionally, ATSI emphasises the importance of data management through the development of a multi-cloud orchestration platform and data lake, facilitating seamless integration and analytics across diverse agricultural data sources.

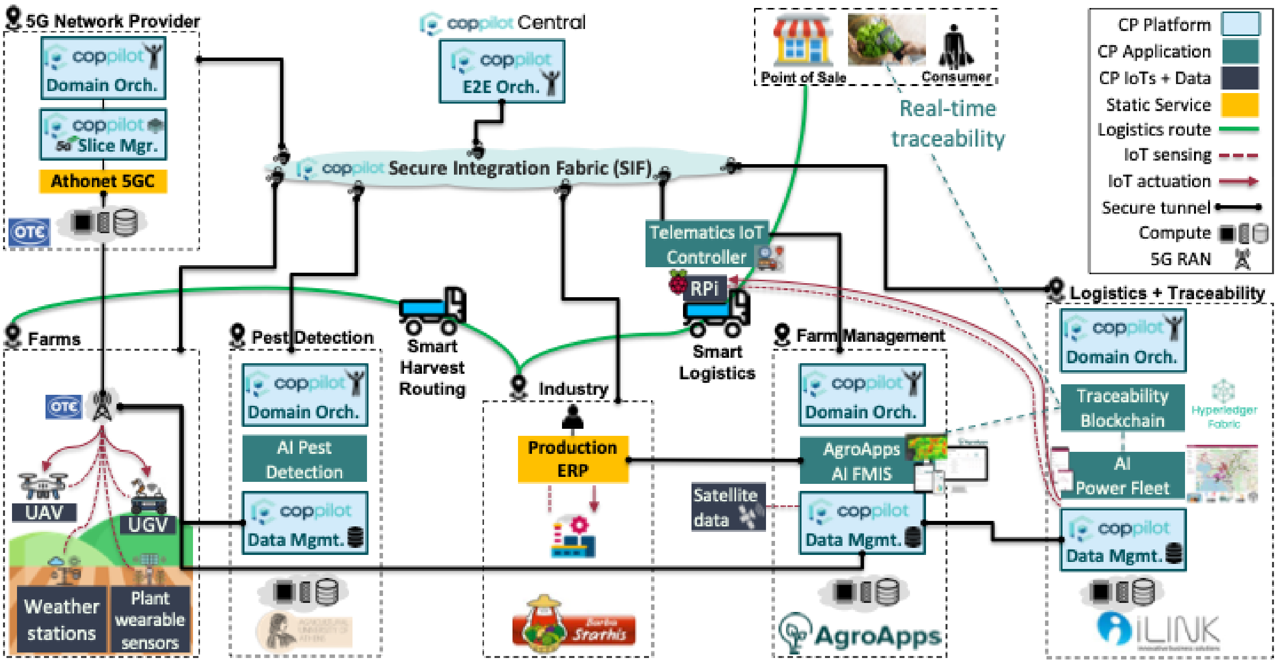

Figure 7.1 Cluster 3A Deployment Diagram

Partners and roles

AgroApps: Provider of AgroApps 360, a farm management information system (FMIS), digital services and analytics platform.

AUA: Provider of Autonomous Ground Robots (UGV) for precision spraying.

TOR: Provider of plant wearable IoT sensors to monitor antinutrient content in leaves.

ILINK: Provider of blockchain infrastructure and telemetry for secure, traceable transport of agricultural goods.

BAR: Provider of pilot farms, weather stations and UAVs (drones).

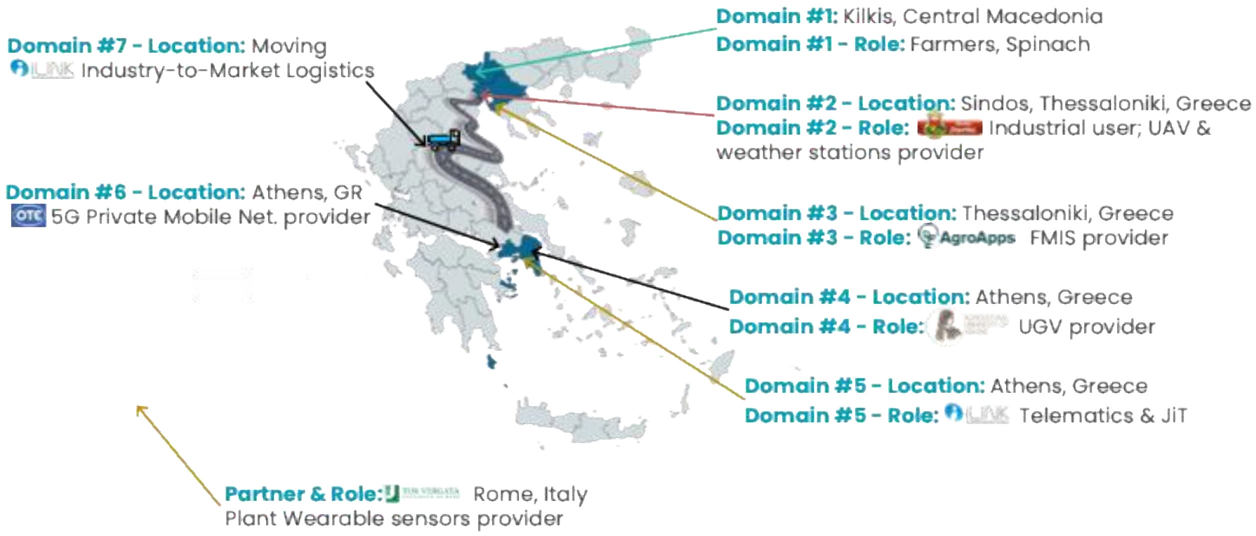

Figure 7.2 Cluster 3A Partners roles & domains

Objectives and ambition

Spinach production in Europe, while substantial at 775,475 tons in 2021, confronts several challenges exacerbated by climate change. These include unpredictable weather patterns affecting irrigation and crop yield, with potential reductions of up to 50%. A significant concern in spinach cultivation is the presence of antinutrients in leaves, which can impact the nutritional quality of the crop. Traditional methods for detecting weeds, pests and diseases often result in delayed interventions, contributing to crop losses. Inefficiencies in irrigation scheduling, applying proper fertilisation, and defining optimal harvest times further increase the levels of antinutrients (oxalate) and lead to reduced productivity. Additionally, the lack of a robust traceability system in the supply chain, leads to substantial losses and limited consumer information.

Cluster 3A and ATSI aims to:

- Align agricultural practices with the European Green Deal and the new CAP, focusing on reduced carbon footprints, biodiversity preservation and sustainable resource usage in spinach cultivation.
- Implement a transformative approach that harmonizes productivity, sustainability and nutritional quality in vegetables cultivation.
- Foster interoperability and seamless data sharing, and streamline integration of IoT, edge computing and robotics in open-air farming to enhance vegetable crop health monitoring, weeds, pest and disease management and optimize input use.
- Transform farm to fork logistics through advanced real-time monitoring and secure, blockchain-enabled tracking.

The aggregation and analysis of data gleaned from the ATSI's initiatives will yield invaluable insights for farmers, policymakers and researchers alike, facilitating data-driven decision-making, the formulation of sustainable agricultural policies and the spur of innovation within the agricultural sector. Furthermore, the project anticipates delivering substantial community and ecosystem benefits by preserving biodiversity, enhancing soil health and minimizing chemical runoff, thereby fostering healthier ecosystems, improving water quality and bolstering resilience to climate change for the benefit of communities and natural habitats across Europe.

Testbed description

Barba Stathis' (BAR) is the testbed provider for Cluster 3A. BAR is an agri-food company with a large group of people (more than 700 employees) who are devoted to the same mission: to produce the safest and most nutritious vegetables. Both in Greece and abroad, BAR operates in the sale of frozen vegetables and dough, as well as fresh salads, under the brand names, Barba Stathis and Chryssi Zymi. BAR seeks to bring to the market innovative products of unrivalled quality and maximum safety standards. At present, BAR owns five factories to produce vegetables and dough, with more than 11,000 points of sale. BAR also operates abroad, with exports to 5 continents and 22 countries.

BAR places much value on the relationship of trust and collaboration with Greek farmers. To achieve this, BAR promotes "Contract Farming", a collaborative program with hundreds of Greek farmers who share the same values, ideals and high standards as the company. Applying an Integrated Crop Management system, the company carries out quality controls on the cultivated vegetables at every stage, from production to harvest. By examining the soil conditions and microclimate of each region, BAR selects areas with the best climate and the most fertile fields, to sow the seed varieties most suitable to each location.

At the same time, BAR innovates and invests in precision agriculture utilizing cutting-edge technologies (sensors, weather stations, UAVs etc.). Specifically, UAVs are being used to map in-field variability and detect crop health problems.

Business Impact for Barba Stathis through Participation in COP-PILOT is summarized in the following:

- Enhanced Farming Efficiency:
    - Enable timely and precise interventions in the field, improving crop protection strategies while minimizing reliance on chemical inputs. This leads to safer working conditions for farmers and more efficient farming operations.
- Sustainable Leafy Vegetable Production:
    - Promote environmentally responsible practices by reducing pesticide use through targeted, data-driven applications, lowering the environmental footprint and supporting the company's sustainability goals.
- Alignment with Market and Health Expectations:
    - Deliver higher yields with fewer anti-nutritional compounds and reduced chemical residues, ensuring products meet evolving consumer and regulatory health standards.
- Economic Growth & Cost Optimization:

  - Lower input and production costs while supporting optimal contract pricing strategies, resulting in improved profit margins and greater overall business growth.
- Competitive Advantage in the Market:
  - Drive down the cost of the final product, enhancing price competitiveness and reinforcing the brand’s position in both domestic and international markets.
- Strengthened Traceability and Data Integrity:
  - Improve transparency and traceability across the entire supply chain, ensuring product safety, compliance, and trustworthiness from farm to fork.
- Efficient and Sustainable Logistics:
  - Optimize transport routes and delivery schedules to reduce logistics costs, shorten time-to-market, maintain freshness and quality and significantly cut down CO_2 emissions.

The Cluster 3A - ATSI testbed is located in Central Macedonia, Greece, on BAR’s contractual leafy-vegetable production fields. As a testbed provider, BAR will select two plots of land in the Kilkis region, in Macedonia where spinach will be cultivated on behalf of the company. The size of the selected plots is approximately one hectare with a soil composition of Sandy Clay Loam.

Data from established weather stations will be used to obtain information regarding air temperature and humidity, soil temperature and moisture, rainfall, solar radiation and wind speed. BAR will also utilize a UAV. The model of the UAV that will be used in Cluster 3A is a DJI Matrice350 RTK and the selected camera is micasense red edge. A variety of vegetation indices and spectra will be acquired above the selected plots, to assess vegetation health and detect weeds.

ANNEX 7.A: UC 3A.1 - INTEGRATED PRECISION AGRICULTURE AND CROP MONITORING

Description

Short Description

This use case focuses on enabling real-time crop and environmental monitoring through the integration of IoT sensors, plant-wearable devices, UAVs, and UGVs (ground robotic platforms). Its main purpose is the early and efficient detection and management of weeds in spinach cultivation, as well as to quantify anti-nutrient levels in leaves, allowing for precise and timely interventions that improve resource efficiency, crop health, nutrition and yield outcomes. A significant component of ATSI is the enhancement of Just-In-Time (JIT) logistics and smart supply chain management, utilising advanced tracking, routing optimization, and blockchain to ensure the timely and efficient transport of products.

Complete Description

Use Case #3A.1 addresses the growing need for precision in the production of leafy vegetables - crops that are both sensitive to environmental conditions and highly perishable along the supply chain. The use case introduces an integrated monitoring system that combines in-field IoT infrastructure, aerial (drone) surveillance, and advanced analytics to deliver a continuous, real-time view of crop and field status. Through this system, farmers are empowered to early detect weed patches within the land parcel and suboptimal crop health conditions that may lead to antinutrient formation in leaves, enabling informed decision-making and timely, targeted interventions.

Recognizing the specific biological and growth cycle characteristics of leafy vegetables, the approach adapts to each stage of production. While wearable plant sensors are deployed only after plant emergence, other key components such as UAV surveillance, and satellite imaging operate from the earliest stages of the growing cycle. The combination of these technologies within a single, interoperable system ensures comprehensive crop monitoring, reduces input waste and enhances the ability to respond dynamically to in-field conditions, all while supporting broader goals of food quality, traceability and environmental stewardship.

The implementation of UC#3A.1 unfolds through a series of interconnected steps that reflect the crop's lifecycle, and the technological infrastructure deployed in the ATSI pilot. From sensor deployment to data-driven interventions, each stage plays a critical role in building an intelligent, responsive and efficient crop monitoring system. The following outlines the main processes and interactions involved in executing this use case.

Step 1: Sensor Deployment and Real-Time Data Acquisition

The process begins with the integration of weather station data coming from BAR's network of stations. The stations continuously measure and transmit data on critical environmental parameters.

Following plant emergence, plant-wearable sensors are applied to representative plants to collect physiological data, such as anti-nutrient concentration which are indirect plant stress indicators. This step enhances granularity in plant-level monitoring and provides insights into nutritional quality and crop health that are especially relevant for leafy vegetables. The pilot will aim to explore the relationship between soil properties, cultivation practices and anti-nutrient buildup in plant tissue to determine influencing factors and mitigation strategies. Two fields of spinach will be studied, representing different soil types and nutrient strategies: alkaline and neutral soil. This selection is based on the impact of pH on nutrient bioavailability and crops' stress responses. For instance, alkaline soils amplify oxalate concentration in spinach. The experimental design will allow to investigate the effects from nutrient deficiency, standard fertilization and excessive fertilization, intertwined with soil pH. Monitoring will involve frequent (10-day) plant tissue analysis, covering pre-harvest growth stages. Oxalates in spinach will be measured, creating concentration curves to gauge anti-nutrient changes during growth and ripening. Using the collected data, the wearable sensor's accuracy will be evaluated and predictive models for antinutrient levels will be developed. The purpose of the models is to provide reliable risk estimates of antinutrient accumulation in spinach and will be integrated into the FMIS.

Step 2: Aerial and Satellite-Based Monitoring

Drones (UAVs) are programmed to perform routine flyovers, capturing high-resolution multispectral images of the crop canopy. These aerial images are analysed to assess plant vigour, detect anomalies and early identify weed patches, among pest and disease outbreaks. While drone flights will be set at a regular routine, the activation of pest and disease alerts from the FMIS will trigger additional/emergency flights. These drones will capture high-resolution images over the parcels to identify potential threats like pests and disease.

Initially, the use of the drone aims to make quick recognitions and timely map weeds post-planting and pre-emergence. The captured images are sent to the cloud and from there to the FMIS. Once weed patches are identified and mapped, a response dictated by the FMIS is transmitted to unmanned ground vehicles (UGVs) for swift and targeted actions, like spraying. The drone will be deployed in spinach fields in Central Macedonia, Greece.

Simultaneously, satellite imagery, particularly from Copernicus Sentinel-2 missions, is used to assess crop development using vegetation indices like NDVI. Satellite data complement UAV observations by offering a macro view of field variability and long-term crop performance trends.

Step 3: Edge Processing and Data Fusion

All incoming data streams, from in-field sensors, plant wearables and UAVs are processed in real-time by on-site edge devices and cloud services. Joint utilisation and processing of data streams will allow the detection of anomalies, predict risks and identify emerging issues like pest outbreaks.

This edge-based analysis ensures rapid decision support even with intermittent internet connectivity. The resulting multidata system creates a rich, multilayered dataset that fuses micro-level (plant-specific) and macro-level (field-wide) insights, generating a comprehensive understanding of crop and environmental conditions.

Step 4: Decision Support and Targeted Interventions

The AgroApps 360 Farm Management Information System (FMIS) is a commercial product that runs models to predict soil moisture, crop growth, water consumption and final yield. The FMIS automatically acquires and processes Sentinel-2 imagery, applies zonal statistics and image filtering to produce vegetation indices, and finally feeds algorithms that calculate an array of qualitative and quantitative crop characteristics. Aerial images captured from UAVs can also be inserted into the system. The tool estimates the optimum time (day and hour) for spraying and generates precise alerts for potential pest and disease outbreaks by running agro-meteorological algorithms and harmonizing real-time data from IoT weather stations and high-resolution weather forecasting. AgroApps 360 employs a Crop Calendar, where every in-farm activity, ranging from seeding density and crop variety to applied fertilizers, crop protection operations, and irrigation events, is meticulously recorded throughout the growing season. The AgroApps 360 FMIS provides decisionmakers (farmers, agronomists, agri-food industry consultants) with actionable recommendations for targeted interventions, such as adjusting irrigation, deploying pest control agents, or modifying nutrient applications. These recommendations may be executed manually or passed on to autonomous field robots (see UC#3A.2) for fully automated interventions, ensuring that the right actions are taken at the right place and time, minimizing waste and maximizing impact.

Utilizing the robust infrastructure of AgroApps 360, the intention is to establish it as the foundational basis to create a multi-agent interoperable solution. This solution will introduce the seamless cooperation of two heterogeneous autonomous vehicles; a UAV and a UGV, through a centralized, intelligent control by the FMIS. This system also capitalizes on the AgroApps' sensor engine which is designed to merge diverse communication methods into a unified, efficient system for real-time monitoring and data integration. Utilizing cutting-edge technology, it ensures seamless connectivity and user-friendly operations for gathering, processing, and analysing real-time data from various sources and third parties, such as IoT devices, sensors, UAVs, UGVs.

Step 5: Integration with FMIS and Blockchain Traceability

All data collected and all actions taken in the field are logged in the AgroApps 360 FMIS for planning, tracking, and reporting purposes. A permission blockchain infrastructure (Hyperledger Fabric) is used to securely store critical records and ensure tamper-proof traceability of interventions, environmental conditions, and crop status across the production lifecycle.

This secure data backbone supports compliance with sustainability and food safety standards, while also enhancing transparency across the value chain—from field to retailer.

Expected Outcomes

- Continuous, real-time monitoring of crop and environmental conditions
- Early detection of threats and more accurate risk predictions
- Reduced input use and resource waste through targeted interventions
- Higher yields and improved product quality
- Enhanced transparency and traceability through secure data logging
- Stronger decision-making and planning supported by integrated analytics

Current Operational Landscape

In the current landscape, **farmers in the Barba Stathis network of contractual agreements carry out most cultivation practices manually or with minimal technological support.** They rely on general seasonal calendars, traditional knowledge, and basic machinery to manage the time and application dose of irrigation water, fertilizers, and crop protection products. Guidance from BAR's agronomists - consultants is provided as much as possible through **periodic field visits**, where they visually assess the crop condition and instruct the farmer on corrective measures. In some of the visits, drone flights are performed to monitor crop health; those are typically initiated and controlled by agronomists, and the data is not routinely accessible to the farmer.

Farmers or hired transporters are then responsible, when the crop season ends, for collecting and for **delivering harvested crops to the Barba Stathis facility**, often with minimum coordination or post-harvest monitoring. As a result, delays in harvesting or transportation can reduce product freshness and market value.

There is **little to no integration between farmers' activities and the broader supply chain,** and most data is either undocumented or stored in isolated notebooks, spreadsheets or siloed tools. Farmers receive limited feedback or predictive insights, reducing their ability to adjust practices proactively. This traditional, reactive model contributes to inefficiencies in crop performance, resource use and overall supply chain coordination.

To address the shortcomings of the current fragmented model, Cluster 3A technologies are deployed in synergy with BAR's agronomists to support farmers in their day-to-day activities. This cooperation enables notable improvements in localized decision-making, as farmers gain access to digital tools and advisory support that were previously unavailable or underutilized.

As part of the Cluster 3A technology rollout, farmers are introduced to plant-wearable sensors, which allow them to monitor key indicators, such as antinutrient levels. They also gain access to weather-based alerts and microclimate forecasting tools, helping them plan more effectively irrigation, fertilization and crop protection. AgroApps' digital agriculture services, satellite data processing and agronomic models allow farmers to engage with data dashboards, receive basic model-generated recommendations, and collaborate more closely with BAR's agronomic team.

Drone flights are still operated by BAR's agronomists, but now they are scheduled based on crop growth insights or risk of disease/pest infestations, and the drone data can now be integrated into AgroApps 360 FMIS. The autonomous UGVs are introduced to selected fields, programmed to perform specific spraying tasks, though their operation still requires human supervision and tasking planning. AgroApps 360 might serve now as a data visualization platform accessible to both agronomists and farmers, allowing for basic coordination around inputs and harvesting timelines.

Farmers would continue to **manage harvesting and post-harvest delivery logistics manually**, but with possible support from basic telemetry tools provided by BAR to monitor delivery status. While this setup would improve field-level operations and partially digitize advisory workflows, farmers would still operate within an environment where **data is only semi-integrated**, where **actions are only semi-automated**, and where **feedback remains delayed and fragmented**.

Farmers benefit, but **they are not fully empowered;** they still depend on agronomists for interpreting multi-source data, and they lack autonomous decision-support tools and seamless access to end-to-end supply chain insights.

Logistics operations will show marked improvement through the combined involvement of AgroApps and iLink. Thanks to AgroApps 360, **Barba Stathis agronomists gain near-daily visibility into the condition of each contractual farm**, enabling them to more accurately plan harvesting schedules based on real-time crop maturity, stress levels, and environmental conditions. This proactive monitoring significantly enhances harvest coordination between farmers and agronomists.

At the same time, **iLink deploys solutions to improve traceability throughout the transport chain**, enabling the **routing of harvested crops from land parcels to BAR's processing facility**, and from there to the **final point of sale**. Telemetry devices and geolocation services are applied to both **owned and outsourced vehicles**, offering greater visibility into delivery timing, vehicle status, and handling conditions.

However, despite these advances, logistics operations still **lack full automation and dynamic responsiveness.** Routing decisions are improved, but not yet continuously optimized based on real-time variables. While **traceability is introduced**, it remains **partially siloed** and does not yet achieve **full integration with upstream data and downstream retail systems**, limiting the potential for a seamless, end-to-end orchestration across the entire supply chain.

COP-PILOT Infused operational Landscape

With the deployment of **COP-PILOT infrastructures**, Cluster 3A transforms from a collection of advanced technologies into a **fully orchestrated, intelligent and secure agricultural ecosystem**. This infrastructure enables **end-to-end integration and real-time decision-making**, empowering all actors, and especially farmers, to operate within a unified digital environment that optimizes both production and logistics.

Farmers remain at the center of cultivation, but their role is redefined through continuous digital support. Equipped with **wearable plant sensors** and connected field devices, they receive **real-time alerts and recommendations** directly through the AgroApps 360 platform. These insights—ranging from irrigation scheduling to antinutrient levels and pest stress—are processed locally via edge AI and centrally orchestrated across all system components. Farmers no longer rely solely on periodic agronomist visits; instead, they have **ongoing, actionable insights** to inform daily practices and optimize inputs.

Barba Stathis agronomists are now fully integrated into the digital loop. Through near-daily data streams coming from the field, UAV missions are scheduled automatically based on observed crop behavior, not calendar routines. UAV and satellite data is fused with on-ground sensor inputs in **AgroApps 360**, where machine learning models assess risks and identify areas requiring intervention. **AUA's autonomous UGVs** are then dispatched precisely where needed, carrying out **precision spraying or scouting actions** based on data-driven priorities, reducing both chemical inputs and operational overhead.

iLink's infrastructure provides full traceability and logistics orchestration from **the harvest-to-industry** and **industry-to-retail** legs (UC3A.4) of the value chain. Every harvest is automatically registered, geotagged, and tracked from the parcel to the Barba Stathis facility using **telemetry and blockchain-based logging**. Transport operations—across both owned and outsourced fleets—are dynamically routed using real-time telemetry, weather, and demand data. This allows for **smart Just-in-Time (JIT) delivery**, minimizing spoilage, maintaining product freshness, and reducing fuel consumption.

All data is stored, processed, and shared via a **secure multi-cloud infrastructure**, fully aligned with **GDPR and data sovereignty requirements**, and made accessible to authorized users via interoperable APIs and COP-PILOT's unified orchestration layer. **Blockchain technology ensures end-to-end traceability**, supporting both internal quality assurance and external certification requirements, while offering transparent reporting to consumers, retailers, and authorities.

The **true power of COP-PILOT** lies not only in connecting individual technologies, but in enabling **automated, trusted coordination** across all actors—from farmer to field robot, from transporter to point-of-sale. The result is a living ecosystem that is **adaptive, resilient, and scalable**, capable of reducing losses, increasing efficiency, and demonstrating measurable sustainability impact. Cluster 3A, under COP-PILOT, becomes a **blueprint for next-generation digital agriculture**—where every decision is smarter, every action is timely, and every stakeholder is empowered by trusted data.

Main actors and roles

Table 7.1 Main actors and roles

Actor name	Actor type	Actor Description and Role
Farmers	Field Operators	Farmers perform daily cultivation tasks such as irrigation, fertilization, and field inspection. Their actions are now guided by near real-time insights delivered through the AgroApps 360 platform, which processes data from wearable sensors, satellite sensors and UAVs to provide early alerts and crop health assessments.
Barba Stathis	Agronomists & Plant Managers	Barba Stathis and its agronomists oversee field performance and coordinate interventions across their contractual farms. They plan UAV flights, guide farmers consultations and determine harvesting timelines based on continuous data from TOR's plant sensors, UAV imagery, Satellite data and weather data aggregated and transformed into action-based information through AgroApps 360.
TOR Vergata	Plant Wearable Sensors Technology Provider	TOR develops and provides wearable plant sensors to be installed on pilot fields. These sensors collect continuous data on plant stress, and antinutrient levels. The analysis of the collected data within AgroApps 360 will feed the decision making of farmers and the planning of cultivation plan of BAR agronomists.
AgroApps	FMIS and digital services provider	AgroApps will deploy the AgroApps 360 FMIS, collecting and integrating data from IoT sensors, UAVs, Satellite data and weather data. It generates predictive analytics and visual dashboards that support the daily cultivation decisions (spatial and temporal) of farmers and Barba Stathis agronomists.
UBITECH	Infrastructure Provider	UBITECH ensures real-time transmission of monitoring data from the field to the FMIS. It supports edge-based preprocessing of sensor data and guarantees network availability, enabling timely decision-making throughout UC#3A.1.
Consumers/ retailers etc	Indirect Stakeholders	Consumers and retailers benefit from better crop quality and safety, as a result of the more precise and data-informed cultivation practices enabled by continuous monitoring and targeted interventions.

Ambition, Motivation and Objectives

The ambition of UC#3A.1 is to radically transform how leafy vegetable production is monitored and managed, particularly within the context of contractual farming ecosystems such as those operated by Barba Stathis in Central Macedonia. Traditional approaches rely heavily on manual field scouting, limited data capture, and loosely coupled tools, leading to suboptimal decision-making, input inefficiencies, and quality inconsistencies. The use case is motivated by the need to deliver real-time, precise, and traceable crop insights, bridging the gap between ground-truth monitoring, aerial surveillance, and digital farm management systems.

The motivation behind UC#3A.1 is rooted in both the agronomic and market-driven urgency to improve crop quality, reduce chemical residues, and align with evolving sustainability and consumer standards. There is also a strategic opportunity to improve workforce efficiency and reduce costs through smart automation and coordination across the value chain.

To overcome these structural limitations, Cluster 3A and UC#3A.1 leverages the COP-PILOT orchestration platform to deliver a seamless, modular and interoperable monitoring system that integrates:

- IoT sensor networks and wearable plant sensors from TOR,
- UAV-based surveillance provided by Barba Stathis,
- UAV-UGV orchestration via AI from AUA, (UC3A.2)
- multi-cloud data management,
- FMIS decision support powered by AgroApps,
- and blockchain-secured traceability and logistics coordination by iLink (UC3A.4)

This full-pledged integration is enabled and orchestrated through COP-PILOT’s edge-native architecture, which allows for distributed intelligence, secure interoperability, and dynamic service orchestration across heterogeneous agricultural infrastructures.

UC#3A.1 aligns with the core project objectives of COP-PILOT:

- Enable interoperable edge service orchestration across critical sectors (here: agriculture and agri-logistics),
- Facilitate AI-based decision-making at the edge using fused in-situ and aerial data,
- Support cross-actor collaboration via secure, traceable data and service transactions,
- Deliver measurable environmental, societal and economic benefits through technology-driven agri-transformation.

Challenges addressed

UC#3A.1 addresses a set of persistent and cross-cutting challenges that affect both the sustainability and productivity of leafy vegetable production in Europe, particularly in contractual farming systems. The primary technical challenge is the fragmentation of monitoring tools and data streams. Farmers, agronomists, and processors often rely on disconnected devices, siloed data sources, and manual processes that delay action and increase uncertainty. Traditional scouting methods offer limited spatial coverage and poor responsiveness to fast-evolving threats such as pest outbreaks, plant stress, or climatic anomalies.

A second key challenge is the lack of real-time, predictive decision support. Even where monitoring devices are deployed, they rarely form part of a fully integrated, intelligence-driven ecosystem. Agronomic decisions are made reactively, based on intuition or lagging indicators, leading to inefficient use of resources such as pesticides, water, and fuel. This contributes to high production costs, environmental degradation, and inconsistent product quality.

Moreover, the traceability and accountability gap in the pre-harvest stage presents a regulatory and market barrier. Retailers and consumers increasingly demand verifiable, data-backed assurance of crop health, safety, and sustainability, yet most producers lack the tools to provide such transparency from seed to shelf.

By leveraging the COP-PILOT orchestration platform, UC#3A.1 tackles these challenges head-on. It delivers an interoperable, modular, and secure monitoring infrastructure that combines sensor data, UAV imagery, and satellite inputs into a single decision-support system. It also facilitates automated response workflows, traceability through blockchain, and analytics at the edge—offering a blueprint for how digital agriculture can overcome fragmentation, inefficiency, and compliance risk.

Expected outcomes

UC#3A.1 is expected to demonstrate tangible benefits across multiple dimensions—agronomic, environmental, economic, and societal. The core outcome is the deployment of a fully orchestrated, multi-source crop monitoring system, capable of delivering real-time crop condition insights at scale across contract farming plots. This will enable both farmers and agronomists to make earlier, smarter, and more targeted decisions.

Agronomically, the outcome is a measurable improvement in crop health and resource use efficiency, enabled by precision interventions and predictive alerts. The integrated system will allow for 30–40% reduction in pesticide usage, optimized irrigation, and better management of antinutrient accumulation. These will lead to higher crop quality and yield stability. Environmentally, UC#3A.1 contributes to lower carbon and chemical footprints, reducing diesel usage through fewer field visits, limiting chemical runoff, and ensuring smart logistics coordination. Societally, farmers are empowered with digital tools that enhance autonomy and reduce labor burden, while consumers benefit from safer, traceable produce. From a business perspective, the key outcome of UC#3A1 is a replicable and scalable model for crop monitoring orchestration that can be extended to other crops, regions, and production systems. At the same time It validates and demonstrates the COP-PILOT architecture as a reliable backbone for multi-actor collaboration, service integration, and secure data flow in agriculture.

Key pain points

UC#3A.1 is deployed around the resolution of several persistent **pain points** that currently inhibit innovation and efficiency in the agricultural value chain:

Delayed and manual field assessments: Field conditions are typically assessed through infrequent agronomist visits, leading to missed windows for optimal intervention and reactive decision-making.

Data fragmentation and lack of interoperability: UAV imagery, weather data, soil metrics, and plant stress readings are rarely integrated into a single platform, forcing users to work across multiple tools that don’t communicate.

Limited edge intelligence and local processing: Data is often sent to centralized systems with processing delays, instead of being analyzed close to the source for immediate action.

Unpredictable input usage and cost variability: Without precise monitoring, resource application (pesticides, fertilizers, water) is generalized and often excessive, inflating costs and environmental impact.

No pre-harvest traceability layer: While post-harvest traceability is advancing, field-level actions before harvest (e.g., spraying, stress events, nutrient levels) are not logged or auditable, creating transparency gaps for processors and retailers.

Farmer disengagement with digital tools: Digital solutions often exclude the farmer or are too complex for regular use, reinforcing dependency on external advisors and weakening adoption.

UC#3A.1, enabled by COP-PILOT architecture and components, directly targets these pain points by offering an orchestrated system where data is unified, processed at the edge, and used to support both **autonomous actions and human decisions** in a timely, traceable, and user-friendly way.

UC Diagrams

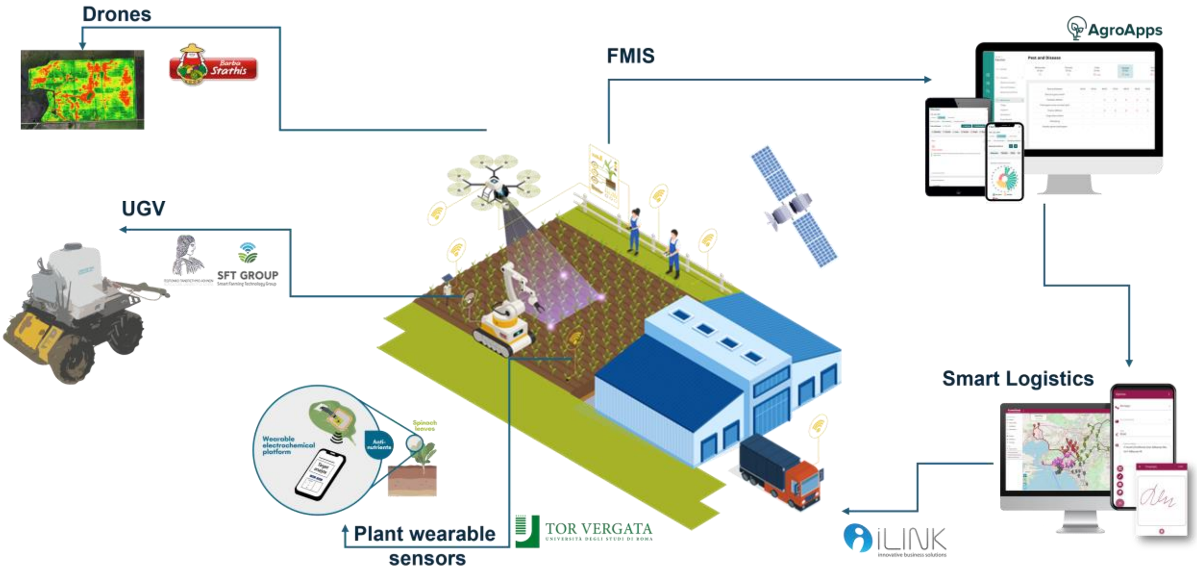

Figure 7.3 Cluster 3A high level Diagram

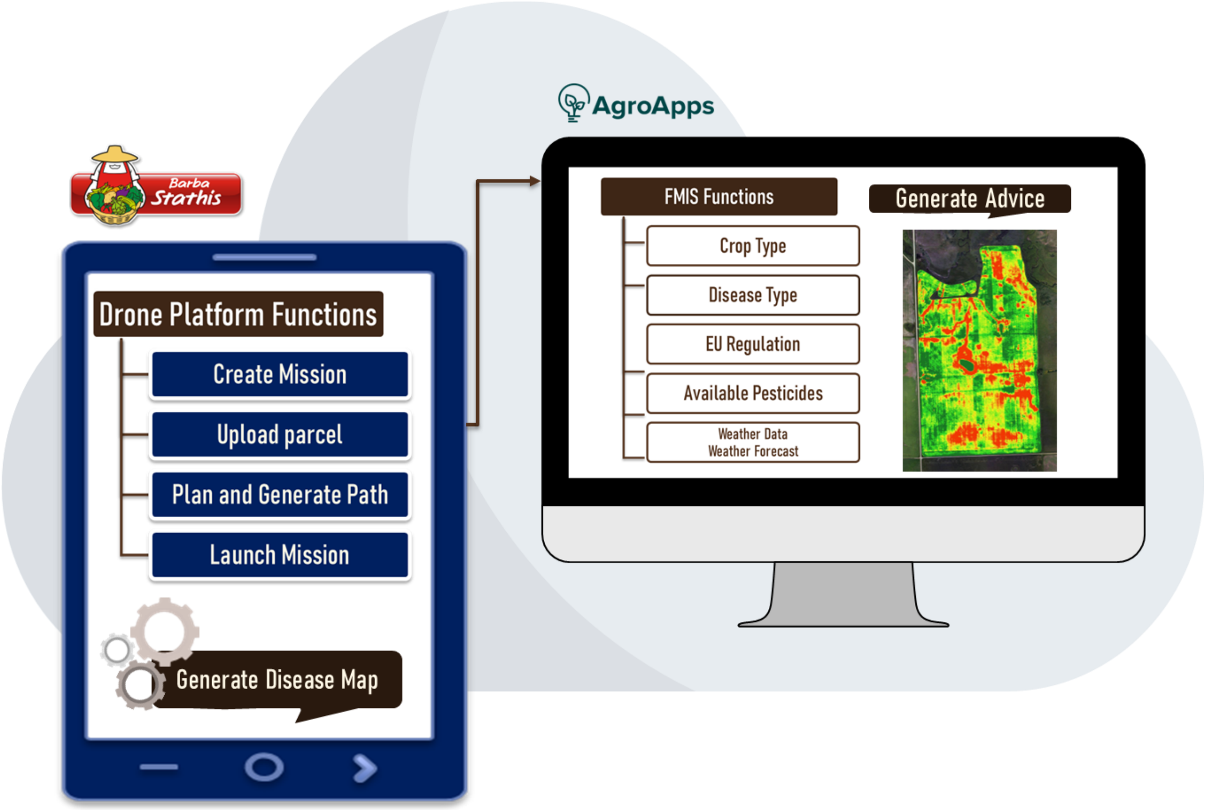

Figure 7.4 Cluster 3A, UC3A.1 Diagram (a)

Figure 7.5 Cluster 3A, UC3A.1 Diagram (b)

UC3A.1 UML Diagram

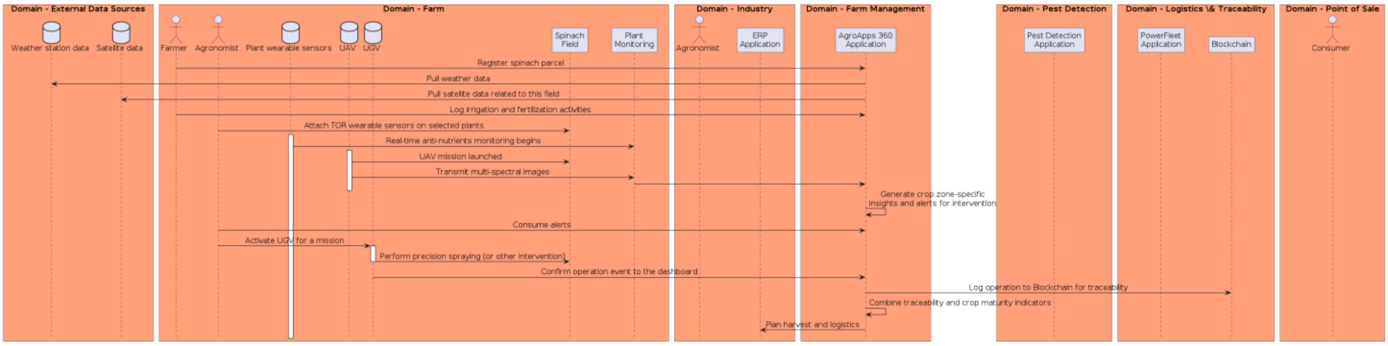

Figure 7.6 UC3A.1 UML diagram

Scenarios description

Table 7.2 Cluster 3A Scenarios description

Step No.	Step Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Reference to Scenario number
Step 1	Sowing is completed and monitoring cycle begins	Register field and initiate monitoring	Farmer registers the spinach parcel in AgroApps 360. Weather station and satellite data collection is activated for real-time tracking.	CREATE	Farmer / Barba Stathis	AgroApps	Field metadata, crop type, weather data	Scenario 1
Step 2	Crop emerges and cultivation begins	Log early-stage practices	Farmer logs irrigation and fertilization activities, which are stored in AgroApps to track inputs and support future analytics.	CHANGE	Farmer	AgroApps	Irrigation logs, fertilization doses, timestamps	Scenario 1
Step 3	Plants reach sensor deployment maturity	Deploy plant wearables	TOR and Barba Stathis agronomists attach wearable sensors on selected plants to start real-time antinutrients monitoring.	EXECUTE	TOR / Agronomist (Barba Stathis)	AgroApps	Sensor ID, crop ID, geo-tagged position, deployment timestamp	Scenario 1
Step 4	Sensor signals crop stress or anomaly	Trigger UAV mission	Based on data thresholds or planned schedule, a UAV mission is launched to capture multispectral imagery of the spinach plots.	EXECUTE	Agronomist (Barba Stathis)	UAV system	UAV flight plan, target zones	Scenario 1
Step 5	UAV flight completed	Analyze crop imagery	UAV captures and transmits multispectral imagery to AgroApps where a number of vegetation indices are computed and mapped against crop zones.	CREATE	UAV system	AgroApps	Multispectral image set, vegetation indices, anomaly maps	Scenario 1

Step 6	Data from all sources is synchronized	Generate recommendations	AgroApps integrates weather, wearable sensor, and UAV data to generate crop zone-specific insights and alerts for intervention.	REPORT	AgroApps	Farmer / Agronomist	Crop health maps, treatment recommendations, alert priority	Scenario 1
Step 7	Intervention is planned	Execute targeted action	Farmer or UGV (AUA) performs precision spraying or other intervention on affected areas. Application map returns to AgroApps.	EXECUTE	Farmer / Agronomist / UGV	AgroApps / iLink	Spraying plan, area treated, input logs	Scenario 1
Step 8	Intervention completed	Update traceability records	AgroApps logs the intervention event and passes the updated field action history to iLink’s blockchain system for traceability.	CHANGE	AgroApps / Farmer	iLink	Input usage, intervention type, timestamp, location ID	Scenario 1
Step 9	Crop nears harvest	Notify processor on readiness	AgroApps compiles traceability and crop maturity indicators and informs Barba Stathis to plan harvest and logistics.	REPORT	AgroApps	Barba Stathis	Readiness status, harvest window, final traceability report	Scenario 1

Requirements

Functional requirements

Table 7.3 UC#3A.1 functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
FR1	If a new crop cycle begins	Must	Register + Crop Field in AgroApps 360 + {Include parcel ID, location, crop variety, and planned timeline}
…	If the crop cycle start is confirmed	Must	Retrieve + Satellite Imagery (e.g. Copernicus) + {Initial image must cover full AOI}
FRx	If a new spinach crop cycle is registered	Must	Collect + Weather & Soil Data + {Ambient conditions, soil moisture, and rainfall measured daily pre- and post-planting}
	If wearable sensors are installed on the crop	Must	Stream + Plant Stress and Anti-nutrient Signals + {Data sampled & stored securely }
	When UAV completes a scheduled flight	Must	Process + Aerial Imagery + {Generate vegetation indices and spatial maps}
	Once satellite, UAV, and wearable data are all available	Must	Fuse + Multi-source Observations + {Derive AI-based recommendations, highlight intervention zones and urgency level}
	After any targeted intervention	Must	Record + Action Logs in AgroApps 360 and Blockchain + {Log treatment type, location, timestamp, and operator identity}

Non-functional requirements

Table 7.4 UC#3A.1 non-functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
NFR1	If sensor or image data is generated	Must	Ensure + Data Availability + {Accessible via COP-PILOT interface with <10 sec response time during peak monitoring}
NFR2	When multi-source data is fused	Must	Guarantee + Data Consistency + {No conflicting values across time-aligned EO, UAV, and wearable sources}
NFR3	During transmission of plant sensor or UAV data	Must	Secure + Data in Transit + {TLS/SSL encryption for all MQTT and HTTP(S) transmissions}

NFR4	When farmers access the AgroApps dashboard	Must	Maintain + System Usability + {Interfaces must load in <3 sec and be usable on desktop/tablet in the field}
NFR5	For traceability records stored on blockchain	Must	Assure + Data Integrity + {Immutability of intervention logs and traceability history throughout supply chain}
NFR6	For all actors contributing data	Must	Enforce + Role-Based Access Control + {Only authorized actors can view or manipulate specific datasets (e.g., Barba Stathis, iLink)}
NFR7	When UAVs or UGVs operate autonomously	Could	Provide + Operational Redundancy + {Fail-safe protocols to ensure continuity of operation in case of sensor dropout or GPS loss}

Business requirements

UC3.1 responds to the evolving demands of sustainable agriculture, resilient food systems, and data-driven market operations. Its deployment is framed by clearly defined business requirements across three dimensions: **sustainability**, **societal value**, and **market/business performance**. Each category includes a set of real-world needs—ranging from reducing environmental footprint to empowering farmers and enhancing product traceability—and is supported by measurable indicators. These requirements guide the design, validation, and long-term commercial legacy of the use case within the Cluster 3A while ensuring alignment with both EC policy priorities and AgriFood sector operational goals.

Sustainability business requirements

UC3.1 is designed to align closely with the sustainability priorities of both the European Green Deal and consumers and food sector demand for sustainable food production systems. The use case directly contributes to environmental objectives by reducing chemical input use, minimizing waste, and lowering the carbon footprint across leafy vegetable cultivation. Through the integration of wearable plant sensors, satellite data and UAV-based imaging, the system enables precise, data-driven interventions that replace traditional, calendar-based practices. Farmers and agronomists can detect early signs of crop stress or pest pressure and apply pesticides or fertilizers only where necessary, resulting in a projected 30% reduction in input use per hectare. This not only limits the environmental impact of agrochemicals but also reduces water consumption through more accurate irrigation decisions, with water use efficiency expected to improve by at least 15%. In addition, digital scouting supported by AgroApps 360 reduces the need for repeated field visits by agronomists, leading to fewer vehicle movements, optimized use of UAVs, and reduced diesel consumption by field machinery. These shifts contribute to a reduction in emissions, with a target of 20% lower operational carbon footprint over the production cycle. UC#3A.1 also avoids the deployment of redundant or siloed technologies by consolidating all monitoring activities into a single interoperable platform. This results in a leaner, more efficient infrastructure that not only reduces technical complexity but also supports long-term scalability. Overall, UC#3A.1 brings tangible and measurable improvements to environmental performance, positioning sustainability as a core value driver for all participating actors.

Table 7.5 UC#3A.1 sustainability requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SR1	Reduce chemical inputs when crop health monitoring enables early detection	Must	Apply treatments only to affected crop zones on the basis of near real-time sensor and UAV data	≥ 30% reduction in pesticide and fertilizer use per hectare
…	Improve water use efficiency under precision irrigation recommendations	Could.	Adjust irrigation based on plant sensor data, Weather data (nowcasting & forecasting) avoid overwatering or drought stress	≥ 15% improvement in water used per kg of crop yield
SRx	Reduce on-site visits through digital remote monitoring	Could	Replace frequent field inspections, improve timely UAV scouting lead to timely agronomists monitoring/ consultation.	≥ 20% reduction in fuel usage and GHG emissions from vehicle movement
	Eliminate redundancy in monitoring systems	Must	Use integrated platform + to replace fragmented tools + enable data interoperability + multisource digital services through one FMIS for all practices/ tasks.	Consolidation of systems; reduction in overlapping tool use; allow interoperable systems.
	Align farming operations with EU sustainability goals	Must	Monitor and document inputs and outputs + using digital traceability aligned with EU Green Deal principles.	Improved sustainability audit readiness; traceability logs linked to each parcel

Societal business requirements

UC#3A.1 addresses a critical set of societal business requirements, particularly in its ambition to empower farmers, enhance the quality of life for agronomic personnel, and ensure equitable and secure access to digital agricultural innovation. The use case lowers the barriers to entry for digital farming by integrating intuitive tools—such as wearable plant sensors and user-friendly interfaces in AgroApps 360—that are accessible even to non-digitally native farmers.

This accessibility is further reinforced by the close collaboration between Barba Stathis agronomists and contracted farmers, ensuring that technology adoption is guided and inclusive. Moreover, the solution is designed with scalability and affordability in mind, enabling broader rollout beyond large farms or early adopters. By reducing the need for constant in-field scouting and manual monitoring, UC#3A.1 contributes to **workforce efficiency**—agronomists can cover more ground virtually, and farmers are relieved from repetitive field inspections, allowing them to focus on strategic tasks. This improves not only operational workflows but also reduces physical labour demands and associated stress.

In terms of **data protection**, all personal and operational data collected through sensors and UAVs is managed under strict GDPR compliance, with access governed through permissioned structures in the COP-PILOT & AgroApps ecosystem.

UC#3A.1 also supports societal resilience by contributing to the production of higher-quality, safer food, with traceable inputs and minimized exposure to unnecessary chemicals. These improvements deliver value both to producers and to consumers, reinforcing the trustworthiness of digitally enhanced agricultural practices. The societal benefits of UC#3A.1 will be assessed through a combination of adoption rates among farmers, reductions in manual labor hours, improvements in service accessibility, and the number of stakeholders—especially smallholder farmers—benefiting from real-time decision support and traceable, environmentally friendly production.

Table 7.6 UC#3A.1 societal requirements

Req . ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SC1	Improve accessibility for all farmer profiles	Must	Design intuitive tools and dashboards that provide value usable by non-expert and non-digitally native farmers	% of farmers using system independently; onboarding success rate
…	Ensure affordability for small and medium-sized farms	Must	Deploy modular advisory and sensor tools that will be affordable for diverse farm sizes	% of smallholder users onboarded; cost per farm compared to baseline
	Increase workforce efficiency in field monitoring and advisory tasks	Could	Replace manual scouting with satellite and UAV-assisted monitoring resulting in increased field coverage per agronomist	≥ 40% reduction in field visit hours; # of farms monitored per agronomist
SCx	Enhance farmer quality of life through reduction in repetitive labour	*Must*	Automate crop health assessment workflows + and reduce time and physical burden of farmers scouting	Reduction in farmer field hours
	Guarantee secure and compliant handling of	Must	Manage all data flows through GDPR-compliant infrastructure, while	No data breaches; full GDPR compliance documented; audit logs maintained

	user and sensor data		enabling role-based data access and auditability.	

Market business requirements

Cluster 3A and UC#3A.1 are market-led and accordingly shaped by a clear set of market and business requirements aimed at maximizing the **economic viability, scalability, and competitiveness** of smart agriculture practices in leafy vegetable production. The primary goal is to translate real-time agronomic monitoring into **cost savings, improved product value, and stronger positioning in high-demand and sustainability-led markets**. Through the use of wearable sensors, UAV imaging, and FMIS-based analytics, the system enables **better crop management decisions**, reducing losses due to pest outbreaks, stress misdiagnosis, or mistimed interventions. This results in **higher consistency and reliability in yield and quality**, which directly impacts the bottom line for both farmers and the processor (Barba Stathis).

A key business requirement is **long-term cost effectiveness**. By optimizing input usage and reducing labour hours spent on manual monitoring and interventions, UC#3A.1 significantly reduces operational costs per production cycle. These cost efficiencies are compounded when scaled across multiple farms and seasons, especially when supported by predictive analytics that allow for proactive planning rather than reactive management. The **reduction of rejections at the processing facility**, through better harvesting decisions, also ensures less product and value is lost at critical control points, improving overall resource use efficiency.

Another important aspect is **reduced integration and onboarding costs**. UC#3A.1 builds on an existing FMIS backbone (AgroApps 360), which acts as a centralized hub for multi-source data collection and decision-making. This avoids the need for piecemeal solutions or expensive middleware, making the system **cost-efficient to adopt and expand**. The use of open APIs and standardized data flows reduces barriers to interoperability and supports smoother integration with downstream systems like logistics, traceability platforms, and retail supply chains.

From a commercial strategy perspective, UC#3A.1 enables **market differentiation and expansion**. The ability to verify and document sustainable production practices—such as reduced input use and traceability from field to shelf—creates opportunities for entering **premium or certified product segments** (e.g., traceable, environmentally friendly, or digitally monitored produce). This adds value to the product and can command higher margins or secure contracts with retailers that prioritize sustainable sourcing.

Lastly, the use case supports **increased profitability and ROI** for all actors involved. Farmers benefit from higher productivity per hectare, fewer wasted resources, and greater crop quality—improving both their income and resilience. Barba Stathis benefits from reduced supply chain variability, improved forecasting, and greater trust in the consistency and traceability of their supply. Altogether, these improvements support a more resilient and adaptive business model, capable of responding to evolving regulatory frameworks, consumer preferences, and climate conditions.

Key quantifiable measures of these business requirements include reductions in per-hectare production costs, decreases in post-harvest losses, increases in yield consistency and quality compliance, reduction in system onboarding time and cost, and market penetration into certified or value-added product categories. These indicators form the basis for evaluating the commercial and operational success of UC#3A.1 within the broader Cluster 3A strategy.

Table 7.7 UC#3A.1 market (business) requirements

Req . ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
BR1	If farms integrate COP-PILOT-enabled monitoring	Must	Reduce + Operational Costs + {Savings from early detection and precision input use}	≥15% reduction in chemical input costs
BR2	When UAVs and AI generate recommendations	Must	Improve + Decision-Making Speed + {Reduce time between anomaly detection and intervention}	≤24h from UAV flight to field action
BR3	If farmers adopt wearable sensors	Could	Increase + Value per Hectare + {Enable precision fertilization and improve quality/yield}	≥10% increase in average yield per ha
BR4	When traceability data is integrated with iLink	Must	Enhance + Market Confidence + {Provide digital proof of production conditions to buyers}	Verified traceability for 100% of product
BR5	If logistics optimization is triggered	Could	Lower +Quality Loss+ {Optimize harvesting and routing from farms to industry}	≥10% reduction in fuel use and delivery time

KPIs and KVIs

UC/vertical Specific

**KPI: Crop yield per hectare increased by 10–15% through timely interventions.
KVI: Advanced precision agriculture tools (UAVs + sensors) used in leafy vegetable sector to promote sector digitalization.**

The integration of UAV-based multispectral imaging, wearable plant sensors, and AI-enabled analytics in UC3A.1 ushers in a new era of digitalization for the leafy vegetable sector. This vertical-specific application demonstrates how high-frequency, multi-source data can shift farming practices from reactive to predictive, empowering farmers/producers and AgriFood industries like Barba Stathis, to optimize crop care and harvest planning. The deployment not only upscales field operations but also catalyses a broader transformation toward data-driven decision-making across the AgriFood value chain.

Sustainability

**KPI: Reduce pesticide use by 20%; Reduce water use by 15%.
KVI: Sensor-driven monitoring enables low-impact crop care practices and efficient irrigation.**

By continuously monitoring key environmental and physiological crop parameters, the system enables timely and localized interventions that reduce resource wastage. Real-time weather data, soil moisture trends, and plant stress signals feed into precision irrigation and spraying strategies that avoid overapplication. This sustainability-oriented use of data leads to measurable reductions in water, fertilizer, and pesticide usage, supporting environmental stewardship and compliance with EU Green Deal objectives.

Environmental

KPI: UAV and satellite-driven monitoring and decision-making reduces environmental exposure by reducing excess inputs.
KVI: Targeted interventions reduce chemical runoff and soil contamination by ≥25%.

UAV imagery and AI-driven analysis allows agronomists and farmers to identify specific crop zones requiring intervention, avoiding uniform and mass chemical applications. This precision approach directly reduces the volume of agrochemicals released into the environment, mitigating their negative impact on soil health and biodiversity. By minimizing leaching and runoff, the system contributes to cleaner water systems and aligns with EU environmental protection standards.

Societal

KPI: Increase digital tool accessibility for small farmers by 30%.
KVI: Lower onboarding costs by ≥40% using AgroApps platform and COP-PILOT infrustructure; enhance data-driven skills in rural workforce.

The AgroApps 360 offers an accessible, low-barrier interface that allows farmers, including those with minimal digital experience, to onboard and benefit from precision farming technologies. Supported by COP-PILOT architecture and components, and with minimal hardware requirements and pre-integrated services, training and deployment costs are reduced significantly. The platform promotes digital literacy and upskills the rural workforce, fostering a new generation of digitally capable farmers while bridging the technology gap in underserved regions.

Operational and Efficiency

KPI: Real-time decisions within 24h of anomaly detection

KPI: Reduce scouting workload by 50%.

KVI: 95% of UAV missions result in actionable alerts.

The coordinated use of plant wearables, satellite imagery, and UAVs ensures that field scouting is data-triggered and only initiated when anomalies are likely. This dramatically reduces unnecessary site visits while increasing the likelihood that each UAV mission leads to a targeted intervention. The result is higher efficiency in agronomic planning and a leaner, more responsive crop management system, reducing labor and maximizing field productivity.

Economic and business

KPI: Operational costs reduced by 15%; logistics waste reduced by 10%.
KVI: Blockchain-based traceability increases market value for spinach by enhancing transparency.

By logging every action from planting to post-intervention on a blockchain ledger, the platform ensures complete transparency and traceability. This enhances consumer trust and opens access to premium markets that demand verified sustainability credentials. Retailers and food processors benefit from greater supply chain visibility, and producers can command better prices by demonstrating compliance and quality assurance through immutable records.

Scalability and EU Sovereignty

KPI: Interoperability with >5 platforms via unified API.

KVI: COP-PILOT deployment strengthens EU-grown digital agriculture infrastructure; reinforces autonomy over data pipelines and logistics tech.

UC#3A.1 leverages EU partners expertise and develops components to build a sovereign and scalable digital agriculture stack. This ensures that sensitive agricultural data is managed within EU-compliant frameworks while avoiding dependency on foreign technologies. The modular nature of the platform allows it to scale easily across different crops, regions, and actors, serving as a replicable model for secure, interoperable agriculture transformation across Europe

Legal and Ethics Requirements

Involvement of Volunteers

No volunteers are involved in the execution of UC#3A.1. All activities are conducted on contractual farming plots operated under agreements between Barba Stathis and professional farmers. There is no requirement for additional consent beyond what is already defined in the contractual terms and pilot agreements. Transparency, accountability, and ethical safeguards are embedded via the project’s governance and data processing policies.

Data Related Activities

The use case involves the collection, processing, and analysis of various datasets including:

- Environmental data from weather stations (temperature, humidity, solar radiation, etc.)
- UAV multispectral imagery (NDVI, and vegetation indices, crop maps)
- Satellite data from Copernicus services
- Plant wearable sensor data (anti-nutrient levels, stress indicators)
- Operational logs and traceability information (spraying actions, input applications, etc.)

The purpose of data collection is to enable real-time crop monitoring and targeted intervention, supporting increased sustainability and operational efficiency. Data will be stored in the AgroApps 360 platform and accessed by authorized partners (e.g., Barba Stathis, iLink, AUA). Blockchain technology, provided by iLink is used to secure traceability data, ensuring integrity and tamper-resistance. All data processing complies with GDPR and relevant EU data regulations. Data will be retained only for the duration of the project and necessary post-project auditing, after which anonymization or deletion policies will apply. The Data Management Plan will provide further details.

AI Systems

The UC#3A.1 integrates AI for the following purposes:

- Crop health assessment using UAV and satellite imagery
- Predictive analytics using weather and sensor data to trigger intervention alerts

- Machine learning models (e.g., LSTM) for detecting stress patterns and forecasting disease onset

All AI systems operate at edge or cloud level and remain under full human oversight. The models do not make final decisions autonomously; they provide recommendations to agronomists or farmers who take action. The AI components do not fall under the high-risk category as defined by Annex III of the AI Act. Bias is controlled through inclusive training datasets and monitoring performance across diverse farm conditions. Transparency is ensured by keeping all algorithmic outputs explainable through dashboards and traceable logs.

Other

All field trials are conducted with full transparency and involvement of local stakeholders.

IPR

All developments, including AI models, data fusion algorithms, and traceability frameworks developed within UC#3A.1 will be assessed for protectability. Ownership will align with the contribution of technical partners (e.g., AgroApps, iLink, AUA), with shared licensing models considered where multi-party innovation exists. Foreground knowledge will be detailed and structured accordingly for exploitation as part of WP6 activities

Risk identification and assessment

Table 7.8 UC#3A.1 risk assessment

Risks	Likelihood (L / M / H)	Impact (L / M / H)	Mitigation
1. Delayed deployment of wearable sensors due to technical or field limitations	M	M	Ensure early-season testing and have backup sensors; schedule deployment windows during known crop growth stages
2. UAV flight disruption due to adverse weather conditions	H	M	Schedule alternate flight dates; use satellite imagery as fallback; integrate weather forecasts into UAV planning
3. Low signal coverage affecting real-time data transmission from field sensors	M	H	Deploy local gateways and buffer storage.
4. Data overload or incompatibility between UAV, wearable, and satellite systems	M	M	Harmonize data schemas via COP-PILOT APIs; test data fusion pipeline early in the season
5. Farmers underusing system due to low digital literacy or interface complexity	L	AH	Provide dedicated training and support from Barba Stathis agronomists;
6. Blockchain traceability fails to sync timely due to data congestion or operator delay	L	M	Automate record dispatch; define strict syncing windows after each intervention
7. AI recommendations are misinterpreted or ignored	M	M	Maintain human-in-the-loop control; provide clear alert labels and decision support explanations

8. GDPR or ethical breach through misconfigured data access	L	H	Utilise RBAC, anonymise datasets, and conduct regular access audits

ANNEX 7.B: UC 3A.2 - ADVANCED AGRIROBOTICS FOR AUTONOMOUS INTERVENTION

Description

Short Description

This use case focuses on employing autonomous UGVs equipped with AI for edge data processing, facilitating precision spraying and pest management. Its main purpose is to detect weeds, based on sensors and UAVs allowing precise and timely interventions, reducing reliance on chemical inputs and enhancing sustainability.

Complete Description

STEP 1: UAV Flights

The process begins with routine flights from UAVs, over the fields owned by Barba Stathis. The Drones capture images from multispectral cameras.

Following plant emergence, flights will be conducted in regular intervals to create maps of the fields. This step ensures field-level monitoring and provides insights into the development and position of the weeds, within the spinach cultivations.

STEP 2: Processing of UAV data

The UAV images will be used to create Otho-mosaics of the fields. These maps will then transfer to the cloud where an AI model will conduct object-based Image classification and will create maps of classes such as weeds, crops, and soil.

Then it will assess the cover percentage of weeds, within the field, to identify if actions are needed, based on a threshold.

STEP 3: Initiate UGV interventions

The UGV will be connected to the orchestrator, and it will be waiting for a command to act. The condition for initiating the UGV intervention will be the weed cover percentage, increasing above the pre-established threshold.

STEP 4: Assessment of infestations

The UGV (Unmanned Ground Vehicle) retrieves the recommendations and autonomously navigate through the field to reach the locations where specific actions, such as weed spraying, have been recommended. Upon arrival at each target area, it will perform a second assessment using its on-board cameras. The captured visual data will be processed locally, on edge, using machine learning algorithms to validate and refine the recommended intervention. As a final security measure, a human operator will inspect the situation to ensure the appropriate and safe execution.

STEP 5: Execution of weed spot spraying

After the human operator validates the final assessment, the UGV will navigate again through the field, and it will start targeted (spot) spraying of the weeds. After the end of the mission, it will send the results (weeds/ spraying information) to be stored in the FMIS.

Current Operational Landscape

In conventional spinach cultivation across Greece, weed control is primarily performed through chemical spraying, forming a standard practice among most farmers in the region. The process generally begins with the pre-emergence application of selective herbicides, sprayed before the spinach sprouts, to prevent early weed establishment while avoiding direct contact with the sensitive spinach leaves. In some cases, particularly where weeds persist beyond the initial phase, post-emergence spraying is carried out, with care taken to target undesired plant species without damaging the spinach crop.

Spraying is typically done using low-pressure sprayers to ensure uniform coverage over the soil surface and reduce the risk of herbicide drift or crop damage. The selection of herbicides is based on known or observed weed species, as well as the specific growth stage of the spinach, with farmers following general application rates, and timing rules. Based on that, decisions on when and how to spray rely heavily on visual inspection and personal judgment, with little to no use of advanced sensing or digital support systems.

This approach, while effective in many cases, leaves room for inefficiencies. Spraying may be misaligned with actual weed pressure, resulting in either under-treatment, which compromises crop yields, or over-application, which contributes to unnecessary input use and environmental stress. Without access to spatially resolved weed data or targeted treatment tools, farmers operate within a largely manual, experience-based paradigm of weed management.

In the absence of full COP-PILOT integration, weed control under the Cluster 3A model can still be enhanced through selective use of digital tools and automation support, particularly under the guidance of Barba Stathis agronomists. Farmers continue to manage spraying themselves, but now benefit from advisory services, based on collected data.

Weed monitoring becomes partially digitized, with UAV flights conducted periodically to gather multispectral imagery of fields. This imagery is processed to produce early indicators of weed presence and growth patterns. The results are made available in the FMIS dashboard, giving agronomists a higher-level view of weed pressure across contractual farms.

However, this data does not always reach the farmer in real-time, nor is it detailed enough to enable fully precise interventions. Farmers still make the final decision on when to spray and what products to use, typically selecting herbicides based on traditional practices and agronomist suggestions. While the system allows for more informed planning, actual execution remains largely manual and uniform across fields, with limited targeting or dosage optimization.

Overall, the system provides a moderate step forward with data and analytics being semi-automatically integrated in the process, but it falls short of delivering true precision or autonomy. Farmers still rely on fragmented insights, agronomists remain central to decision-making, and environmental or input-use benefits remain limited by execution constraints.

COP-PILOT Infused operational Landscape

With the deployment of the COP-PILOT architecture, weed control in spinach cultivation is transformed into a precision-driven, fully orchestrated process. The entire weed management workflow, from detection to treatment, is digitized, coordinated, and optimized across multiple technologies, reducing input use, improving efficacy, and enhancing sustainability.

After crop emergence, UAVs conduct routine surveillance flights, collecting multispectral and RGB imagery of fields. These images are stored in the FMIS, where cloud AI models identify weed infestations with high spatial accuracy. Detected weed patches are automatically logged and analyzed, with infestation thresholds applied to trigger the creation of intervention plans.

When weed pressure exceeds the pre-defined tolerance level, the FMIS, via the COP-PILOT orchestration layer, automatically generates a targeted spraying mission. This mission includes maps of weeds and the GPS-tagged coordinates of infested zones. The mission is wirelessly transmitted to autonomous UGVs operating in the area.

Upon receiving the mission, the UGVs activate their onboard sensors, combining LiDAR, GPS, and high-resolution imaging to validate the weed presence and assess the surrounding vegetation. They perform real-time classification of weed types and calculate optimized herbicide dosages on a patch-by-patch basis, using machine learning, computer vision and decision-support algorithms.

Before executing any operation, the UGVs transmit their localized assessments and treatment proposals back to human controllers, typically agronomists or technical supervisors, through the FMIS interface. Once reviewed and approved, the UGVs proceed with precise spot spraying, delivering only the required quantity of herbicide in each affected area, significantly reducing both chemical usage and exposure risk.

All spraying activity is automatically recorded and stored in the FMIS and linked blockchain systems, ensuring full traceability of inputs, decisions, and outcomes. This transparent record supports compliance, certification, and performance benchmarking, while also feeding into predictive models for future weed control cycles.

This new model empowers farmers and agronomists alike, shifting weed control from reactive labor to intelligent automation. The COP-PILOT ecosystem enables data-driven decisions, real-time responsiveness, and environmental responsibility all of which are characteristics of a next-generation agricultural practice that is scalable, measurable, and resilient.

Main actors and roles

Table 7.9 Main actors and roles

Actor name	Actor type	Actor Description and Role
Barba Stathis	Agronomists & UAV pilots	Barba Stathis and its agronomists oversee the agro-management of the Spinach cultivation. They plan and conduct UAV flights, creating maps of the fields. These maps will be used for training machine learning algorithms to detect patches of weeds withing the fields
AUA	UGV provider	Agricultural university of Athens and its researchers are using their UGV to conduct weed detection and spot spraying in agricultural fields. This is done through machine learning and optical sensors (cameras).
UBITECH	Infrastructure Provider	UBITECH is responsible for the FMIS. Through this, the data will be transmitted and shared between the different components such as the UAV and UGV. The platform

		supports preprocessing of data, that helps the decision-making throughout the use case.

Ambition, Motivation and Objectives

The ambition of UC#3A.2 is to improve weed management in leafy vegetable production through advanced precision spraying methods. Traditional weed control practices rely heavily on empirical approaches, limited data insights, and uniform chemical application, which neglects field variability and results in inefficient resource use, suboptimal decision-making, and inconsistent crop quality.

UC#3A.2 is designed to deliver accurate, real-time, and fully traceable weed spraying solutions, integrating cutting-edge technologies such as aerial surveillance, machine learning algorithms, computer vision systems, and robotics. These technologies enable precise identification and targeted treatment of weeds, minimizing environmental impact and enhancing crop health. This innovative approach addresses critical agronomic and market-driven challenges, aligning with evolving environmental sustainability standards, regulatory compliance requirements, and consumer expectations for reduced chemical usage and safer produce.

Additionally, UC#3A.2 provides substantial benefits through enhanced data collection and analytics, offering growers actionable insights for improved decision-making. This precision-based model facilitates proactive and informed management strategies, significantly reducing chemical residues and optimizing resource allocation. Furthermore, UC#3A.2 strategically targets improved workforce productivity, reduced operational costs, and enhanced automation and coordination throughout the entire weed management process, ultimately fostering a more sustainable, profitable, and efficient agricultural sector.

To success in its goal, UC#3A.2 uses the COP-PILOT orchestration platform to deliver a seamless, modular and interoperable processes that integrates:

- UAV-based field and crop monitoring,
- Real time edge and UAV-based weed and crop image segmentation,
- UAV-UGV orchestration via AI
- FMIS decision support and data exchange.

This integration is enabled and orchestrated through COP-PILOT’s edge-native architecture, which allows for distributed intelligence, secure interoperability, and dynamic service orchestration across heterogeneous agricultural infrastructures.

UC#3A.2 aligns with the same core project objectives of COP-PILOT 3A.1 UC such as:

- Interoperable edge service orchestration,
- AI-based decision-making at the edge,
- Using fused in-situ and aerial data,
- Support secure and traceable cross-actor collaboration,

- Deliver multilevel benefits through technology-driven agri-transformation.

Challenges addressed

UC#3A.2 addresses significant challenges impacting the sustainability and productivity of leafy vegetable management and production. A primary technical challenge is the fragmentation of monitoring tools and data streams. Farmers, agronomists, and processors often rely on empirical methods, outdated management practices, and manual processes, causing delayed action, increased uncertainty, excessive chemical use, and neglect of field variability. Traditional scouting methods further exacerbate these issues by limiting responsiveness to rapidly emerging threats, such as pest outbreaks.

A second critical challenge is the absence of real-time predictive decision support. Monitoring devices, even when deployed, rarely integrate into an intelligent, data-driven ecosystem. Consequently, agronomic decisions are often reactive, based on intuition or delayed indicators, leading to inefficient resource utilization, increased production costs, environmental degradation, and economic losses.

Moreover, a significant gap exists in traceability and accountability during the pre-harvest stage, posing regulatory and market risks. Retailers and consumers increasingly demand verifiable, data-supported assurances regarding crop health, safety, and sustainability. Yet, most producers lack the necessary tools to deliver transparency from seed to shelf.

Leveraging the COP-PILOT orchestration platform, UC#3A.2 effectively addresses these challenges by providing an interoperable, modular, and secure monitoring infrastructure that integrates UAV imagery and UGV operations through an advanced decision-support system. It also enables automated response workflows, blockchain-driven traceability, and edge analytics, thus establishing a robust framework for digital agriculture that mitigates fragmentation, enhances operational efficiency, and ensures regulatory compliance.

Expected outcomes

UC#3A.2 is anticipated to deliver substantial benefits across multiple dimensions. The primary outcome is the deployment of a fully orchestrated, multi-source automated weed control system capable of accurately detecting and precisely managing weeds across contract farming plots. This system empowers farmers and agronomists to make earlier, more informed, and targeted management decisions.

From an agronomic standpoint, UC#3A.2 significantly improves resource use efficiency through precision interventions and predictive alerts, enabling a 30–40% reduction in herbicides application and energy consumption by decreasing manual labor. This improvement leads directly to higher crop quality.

Environmentally, the solution contributes to reducing carbon footprints and chemical residues, minimizing diesel consumption due to fewer field visits, and significantly decreasing chemical runoff through precision spraying techniques.

Societally, the initiative empowers farmers with advanced digital tools, enhancing their autonomy, reducing labour intensity, and providing consumers with safer and fully traceable produce.

Commercially, UC#3A.2 establishes a replicable and scalable weed management model applicable to various crops and geographic regions. Additionally, it validates and demonstrates the effectiveness and reliability of the COP-PILOT architecture as a foundational infrastructure for multi-stakeholder collaboration, seamless service integration, and secure agricultural data management.

Key pain points

UC#3A.2 directly addresses persistent pain points hindering innovation and efficiency in agricultural value chains:

1. **Delayed and manual field assessments:** Current field evaluations rely on infrequent agronomist visits, causing delays in optimal intervention times and reactive rather than proactive decision-making.
2. **Uniform chemical application:** Traditional weed control involves indiscriminate spraying of entire fields to ensure weed management, resulting in low resource-use efficiency, increased chemical usage, higher costs, and negative environmental impacts.
3. **Lack of interoperability:** UAV imaging, UGV actions, and decision-support systems are seldom integrated within a unified platform, forcing stakeholders to manage multiple unconnected tools, creating inefficiencies and operational complexity.
4. **Limited edge intelligence and local processing:** Data is frequently sent to centralized systems for analysis, creating processing delays and hindering timely, localized decision-making.
5. **Environmental impact:** Generalized resource application (herbicides) without precise monitoring significantly contributes to environmental degradation and chemical runoff.

UC Diagrams

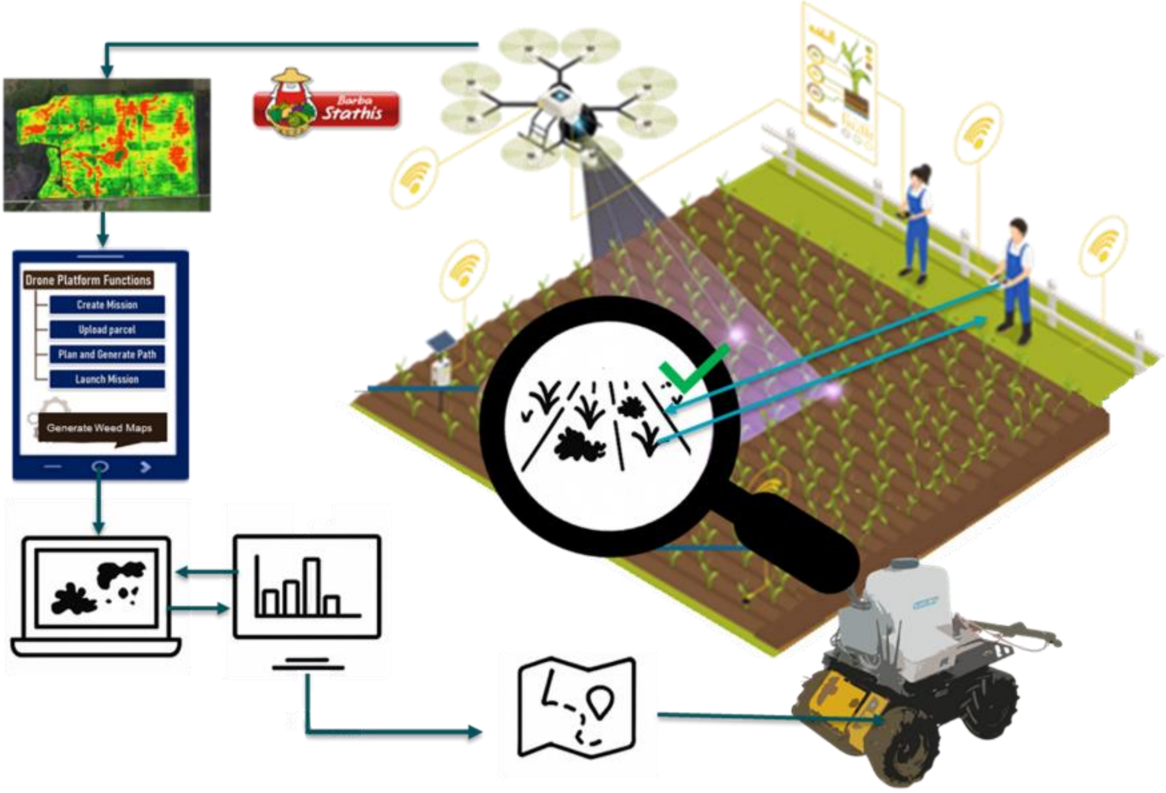

Figure 7.7 UC#3A.2 Diagram

UC3A.2 UML Diagram

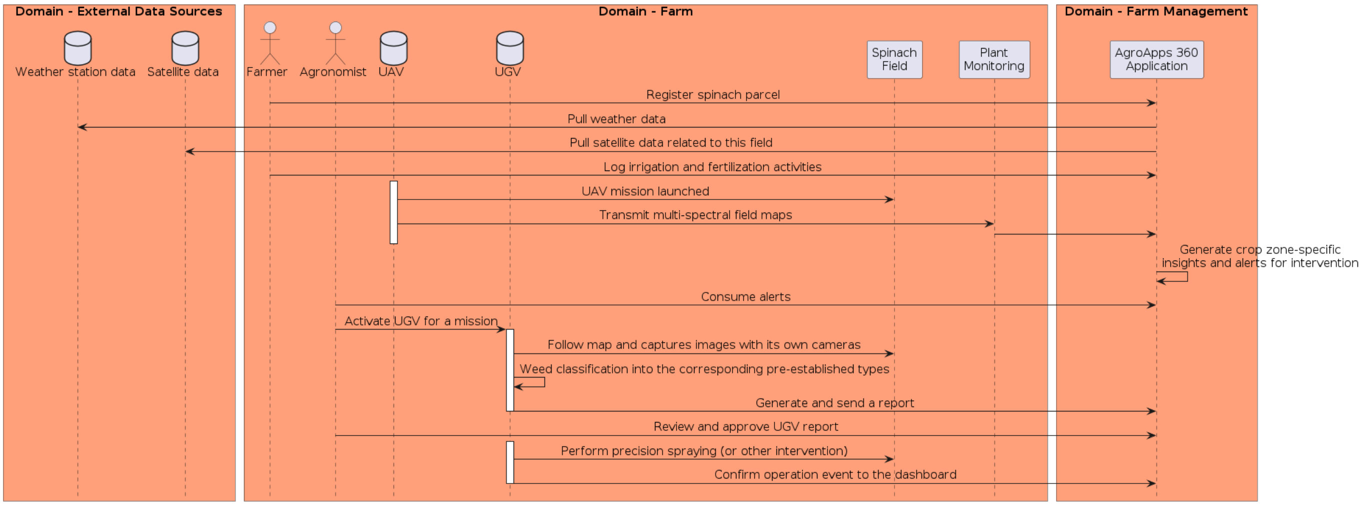

Figure 7.8 UC3A.2 UML diagram.

Scenarios description

Table 7.10 UC#3A.2 Scenarios description

Step No.	Step Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Reference to Scenario number
Step 1	Sowing is completed and monitoring cycle begins	Register field and initiate monitoring	Farmer registers the spinach parcel in AgroApps 360. Weather station and satellite data collection is activated for real-time tracking.	CREATE	Farmer / Barba Stathis		Field metadata, crop type, weather data	Scenario 1
Step 2	Crop emerges and cultivation begins	Log early-stage practices	Farmer logs irrigation and fertilization activities, which are stored in AgroApps to track inputs and support future analytics.	CHANGE	Farmer		Irrigation logs, fertilization doses, timestamps	Scenario 1
Step 3	UAV flights begin to estimate weed pressure	Initiate UAV mission	Barba Stathis agronomists will conduct UAV flights to create RGB/multispectral field maps.	EXECUTE	Agronomist (Barba Stathis)		UAV flight plan	Scenario 3A.2
Step 4	UAV-captured maps will be assesses to classify weed patches	Image weed-crop segmentation	Based on pre-trained machine learning algorithms the images will be processed to generate a map with 3 classes (crops, weeds, other)	EXECUTE	AUA		UAV maps (multispectral images)	Scenario 3A.2

Step 5	Spot spraying is being recommended	Generate UGV recommendations	Based on a threshold (percentage of weeds in the field) a suggestion will be created to initiate the UGV to take action (spray weeds) within the field	CREATE	UGV system		Weed maps, location/action recommendation	Scenario 3A.2
Step 6	UGV moves to assess the recommendations	UGV mission initiation	The UGV receives the signal to initiate the spraying mission. It travels to the general locations of weeds, spotted by the UAV flights and it captures images with its own cameras.	CREATE	UGV system		Weed maps, images	Scenario 3A.2
Step 7	Intervention is planned	Assess the weeds	The UGV processor will assess each image to classify the weeds into the corresponding pre-established types. Then it will generate and send a report.	CREATE	Agronomist		Weed assessment, images, locations	Scenario 3A.2
Step 8	Intervention starts	Get confirmation	After the agronomists confirm the assessment, they send a confirmation to the UGV to initiate the	CREATE	UGV		Assessment confirmation	Scenario 3A.2

			spraying process					
Step 9	Spraying execution	Starting intervention	The UGV moves in the field and it executes spot spraying in the areas where weeds are being confirmed. Afterwards it creates and sends a report of completion	EXECUTE	UGV		Assessment confirmation, locations	Scenario 3A.2

Requirements

Functional requirements

Table 7.11 UC#3A.2 functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
FR1	If a new crop cycle begins	Must	Register + Crop Field in FMIS + {Include parcel ID, location, crop variety, and planned timeline}
FR2	When UAV completes a scheduled flight	Must	Process + Aerial Imagery + {Generate vegetation indices and spatial maps}
FR3	When Action is required	Must	Derive AI-based recommendations, create classified maps
FR4	After any targeted intervention	Must	Record + Action Logs, Log treatment type, location, timestamp, operator identity, dose amount.

Non-functional requirements

Table 7.12 UC#3A.2 non-functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
NFR1	If UAV image data is generated	Must	Ensure data Availability via COP-PILOT interface at the end of the mission.
NFR2	When UAVs or UGVs operate autonomously	Could	Ensure continuity of operation in case of sensor dropout or GPS loss
NFR3	For all actors contributing data	Must	Ensure that only actors who need the data for an upcoming action can access only the data they need

Business requirements

Sustainability business requirements

UC#3A.2 must meet key sustainability requirements to support environmentally responsible agriculture. The system should enable measurable reductions in energy consumption by optimizing machinery use and limiting unnecessary field operations through predictive and targeted interventions. It must also minimize redundant technologies by integrating UAVs, UGVs, and analytics into a single interoperable platform, thereby reducing hardware duplication and associated waste. Precision spraying should drive a significant reduction in chemical runoff and herbicides usage—targeted at 30–40%—which contributes to lower soil and water contamination. Additionally, edge computing capabilities should replace centralized data processing, reducing demands associated with data transmission and remote server use.

Table 7.13 UC#3A.2 sustainability requirements

Req . ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SR1	Reduce chemical inputs	*Must*	spot weed spraying only to the weeds, based on the image classification	>30% reduction in herbicides
SR2	Replace visits for field scouting	Could	Frequent visits in the field will be replaced by UAV flights. This will lead to standardised and timely desicion making	≥ 15% reduction in fuel consumption
SR3	Reduce hardware duplication	Must	By using a unified, integrated platform to connect tools, the interoperability will be promoted.	Reduce hardware overlapping; improve dataflow

Societal business requirements

UC#3A.2 must ensure accessibility, inclusivity, and tangible societal benefits across the agricultural value chain. The system should be user-friendly and affordable, particularly for smallholders and contract farmers, lowering the barriers to digital adoption. Training and onboarding must be streamlined to support new users with limited technical backgrounds. Data protection and privacy are critical, requiring compliance with relevant data governance standards (such as FAIR) to safeguard sensitive information. The solution should also enhance workforce efficiency by automating repetitive tasks, thus reducing physical labor and improving overall quality of life for field workers.

Table 7.14 UC#3A.2 societal requirements

Req . ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SC1	Reduce human-based field scouting	Could	by flying a UAV and using AI to spot weeds and weed pressure will lead to reduced need for a farmer/agronomist	≥ 20% reduction in field visit hours

			to navigate within the field to assess the situation	
SC2	Ease of use	Must	The process of assessing the actions, suggested by the UGV image analysis should be easy and usable/understandable by non-experts.	The farmers (50%?) should be able to use the system without dedicated personnel
SC3	Secured data and data flow	*Must*	All data storage and data flows should follow the required EU regulations	Full GDPR compliance; follow FAIR standards

Market business requirements

To realize the goals of UC#3A.2, several key business requirements must be met. First, the system must support seamless integration of diverse hardware and data sources, including UAVs, UGVs, sensors, and imaging tools, through a common interoperable platform. This integration should enable real-time communication, automated workflows, and decision-making capabilities. Second, the platform must be scalable and modular to accommodate various crop types, plot sizes, and farming contexts, especially within contract farming arrangements. Third, robust data governance, security, and traceability mechanisms—such as blockchain—must be embedded to ensure transparency, regulatory compliance, and consumer trust. Additionally, local edge processing capabilities are required to reduce latency and support in-field intelligence. Lastly, the system should provide intuitive, role-specific interfaces for agronomists, farm operators, and supply chain stakeholders to ensure widespread usability and adoption.

Table 7.15 UC#3A.2 market(business) requirements

Req . ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
BR1	UAVs and ML weed detection	Compulsory	Improve decision making and weed detection accuracy.	<24h from detection to action
BR2	UGV weed classification	Good to have	It reduces the need for chemicals by calibrating the amount of herbicide, needed per weed patch	>15% reduction in chemical input
BR3	UGV spot spraying	Compulsory	It reduces the need for herbicide by doing spot spraying and not just homogeneously spray the whole field area	>15% reduction in chemicals
BR4	Actions are happening on edge	Compulsory	Reduces the need for network connection and enables transparency	Ensures that the data is traceable and that there is minimized latency in processing and enschange.

Co-funded by
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KPIs and KVIs

UC/vertical Specific

KPI: >30% herbicide use reduction per hectare, through precise interventions.
KVI: Advanced precision agriculture tools (UAVs, UGVs and ML) used in leafy vegetable sector to promote sector digitalization.

The integration of UAV-based imaging, Machine learning-based weed detection and UGV-enabled spot spraying in UC3A.2 leads to more precise and sustainable weed management practice, in leafy vegetables. This application demonstrates how the connection between UAVs and UGVs, with data being analyzed by ML can transform uniform chemical applications to precision based, empowering farmers/producers and AgriFood industries like Barba Stathis, to optimize their input application. The application of COP-PILOT improves the precision of operations and encourages data-driven decision making.

Sustainability

KPI: Reduce herbicide use by 30%;
KVI: Machine learning-based enables precise and efficient weed management.

By continuously monitoring the field, based on UAVs, the system enables timely and localized interventions that improves resource use. Observations of weed pressure and detecting the weed patches in the field, ensures faster and data-driven decision making. This sustainability-oriented use of data leads to measurable reductions in herbicide usage and improvement in resource use efficiency.

Environmental

KPI: UAV and UGV monitoring and ML-based decision-making reduces environmental exposure by reducing excess inputs.
KVI: Targeted interventions reduce chemical runoff and soil contamination by ≥25%.

UAV imagery and AI-based image analysis, combined with UGV-based spot spraying allows for precise weed spot spraying, avoiding uniform and mass chemical applications. This targeted method lowers the amount of herbicides entering the environment, helping to protect soil quality and biodiversity. By reducing runoff and leaching, it supports more sustainable weed control and complies with EU environmental regulations.

Societal

KPI: ≥ 70% reduction in manual spraying operations
KVI: ≥ 80% positive satisfaction rate from participating farmers

Supported by COP-PILOT architecture and components, manual weed spraying will be reduced contributing to the improved quality of life for the workers. The platform promotes the usage of digital tools, contributing to the reduction of the need for manual operations.

Operational and Efficiency

KPI: Real-time decisions with actions taking place within 24h from decision making. KPI: Reduce scouting workload by 50%.

The coordinated use of UAVs and UGVs ensures that field scouting is gradually replaced by vision, robotics and AI and only initiated when uncertainty exists in the AI-based classification. This dramatically reduces unnecessary site scouting while increasing the likelihood that UAVs and UGVs will capture most of the weed patches in the field. The result is higher efficiency in agronomic planning and a more precise weed management system, reducing labour.

Economic and business

KPI: Operational costs reduced by 15%;
KVI: Blockchain-based traceability increases market value for spinach by enhancing transparency.

By reducing the need for labour for field scouting and by changing uniform herbicide application to precision spot spraying the operational cost is being reduced drastically, compared to the traditional methods. Moreover, by logging every action on a blockchain ledger, the platform ensures complete transparency and traceability. This enhances consumer trust and opens access to premium markets that demand verified sustainability credentials.

Scalability and EU Sovereignty

KPI: ≥ 3 EU regions indicate interest by end of project.
KVI: 100% of UGV data processed and stored within EU jurisdiction

UC#3A.2 data processing will be done mainly on edge and throughout the acquisition and analysis, the sensitive agricultural data will be managed and stored within EU-compliant frameworks while avoiding dependency on foreign technologies. The ability to scale the processes to other regions and crops makes it easier to adapt the UC#3A.2 processes from other actors across Europe.

Legal and Ethics Requirements

Involvement of Volunteers

There will be no volunteers involved in the execution of UC#3A.2. The activities related to the use case will be conducted by Barba Stathis and farmers/professionals employed or contracted by Barba Stathis. The UGV will be employed by researchers of Agricultural University of Athens.

Data Related Activities

The datasets related to the Use Case are:

- UAV imagery (RGB, crop maps, weed segmentations)
- UGV imagery (video and frames captured by the UGV camera)
- Operational logs and traceability information (spraying actions, input applications, etc.)

The purpose of data collection is targeted weed spraying, supporting sustainability and operational efficiency. The data will be made available to the components through FMIS. Blockchain technology will ensure traceability and security. All data processing complies with the relevant EU data regulations. Data will be retained only for the duration of the project and necessary post-project auditing, after which anonymization or deletion policies will apply. The Data Management Plan will provide further details.

AI Systems

The UC#3A.2 uses AI for the following purposes:

- Machine learning models for weed pressure estimation from UAV images
- Machine learning models for weed type classification based on UGV images

All AI systems operate on edge or cloud level and remain under full human oversight. The models do not make final decisions autonomously; they provide recommendations to agronomists or farmers who take action. The AI components do not fall under the high-risk category as defined by Annex III of the AI Act. Bias is controlled through inclusive training datasets and monitoring performance across diverse farm conditions. Transparency is ensured by keeping all algorithmic outputs explainable through dashboards and traceable logs.

Other

All field trials are conducted with full transparency and involvement of local stakeholders.

Risk identification and assessment

Table 7.16 UC#3A.2 risk assessment

Risks	Likelihood (L / M / H)	Impact (L / M / H)	Mitigation
1. UAV flight disruption due to adverse weather conditions	H	M	Integrate weather forecasts into UAV planning; UGVs will have alternative action flags, based on previous flights
2. Data incompatibility between UAVs and UGVs	M	M	Test data pipeline early in the season
3. Farmers underusing system due to low digital literacy or interface complexity	L	L	Most of the processes will be conducted by dedicated personnel.
4. AI recommendations are not accurate	M	M	Maintain human-in-the-loop control

ANNEX 7.C: UC3A.3 - SECURE DATA MANAGEMENT AND INTEROPERABILITY

Description

Short Description

UC3A.3 addresses the need for secure and interoperable data sharing across multi-cloud infrastructures and diverse stakeholders in the agri-food sector. It targets persistent challenges in fragmented data ownership, unverifiable provenance, and regulatory compliance. The use case implements a federated data architecture enhanced with blockchain-based traceability, ensuring cryptographic data integrity and transparency across the value chain—from field data acquisition to logistics and retail. This aligns with EU food safety standards and digital trust frameworks. iLink leads the technical implementation using Hyperledger Fabric and secure telemetry pipelines that capture, sign, and transmit data on crop cultivation, transport, and storage. Real-time validation enables stakeholders to access tamper-proof information on freshness and origin. UC3A.3 demonstrates how federated governance and blockchain-backed telemetry can support trusted, automated, and regulation-aware agricultural systems.

Complete Description

UC3A.3 introduces a sophisticated Secure Multi-Cloud Data Federation and Blockchain Traceability Layer, constituting the foundational digital trust framework for orchestrating agricultural and logistics operations across Cluster 3A. The infrastructure, architected and implemented by iLink using Hyperledger Fabric, functions as a modular, permissioned distributed ledger system designed to meet the compliance, auditability, and interoperability requirements of a multi-stakeholder agri-tech ecosystem.

Principal Blockchain Capabilities Developed by iLink

- Immutable and Transparent Digital Ledger

  Hyperledger Fabric provides a shared, tamper-resistant ledger that ensures the integrity and traceability of recorded transactions. All authorized participants access the same trusted data, which fosters transparency and supports regulatory compliance. This is essential in agri-food logistics, where traceability and accountability are critical.

- Smart Contracts and Business Process Automation

  Fabric uses “chaincode” to encode and enforce business logic, enabling automation of functions such as compliance verification, product quality checks, and conditional payments. Chaincode can be written in general-purpose programming languages, lowering the technical barrier for developers. These smart contracts reduce manual processes and support reliable execution of inter-organizational agreements.

- Data Security and Integrity

  Transactions on the Fabric ledger are cryptographically signed and verifiable, ensuring they are both authentic and immutable once committed. This prevents fraud and guarantees that data remains consistent across the network. Fabric’s architecture enhances trust among stakeholders and supports long-term data resilience.

- Traceability and Provenance Tracking

  Fabric enables end-to-end visibility by recording every stage of a product's lifecycle — from farming and harvesting to storage and delivery. Provenance tracking includes information on production inputs, environmental conditions, and handling practices. This supports fast and precise recalls and strengthens consumer confidence in food quality.

- Controlled Access and Confidentiality

  The use of private channels and private data collections (PDCs) allows for role-based access and isolation of sensitive data. Only authorized parties can view confidential information such as pricing or GPS locations, while data integrity remains publicly verifiable when needed. This model supports selective transparency while preserving competitive privacy.

- Modular Architecture and Flexible Consensus

  Fabric's plug-and-play architecture supports interchangeable components such as ordering services, membership management, and consensus mechanisms (e.g., Raft). This flexibility allows networks to be tailored to specific performance, trust, and scalability requirements. It also simplifies upgrades and adaptations across diverse use cases.

- Integration with Existing Systems and Interoperability

  Hyperledger Fabric supports REST APIs and can integrate with external systems like ERP or WMS through custom interfaces. Although full cross-blockchain interoperability remains a challenge, emerging tools and standards (e.g., Hyperledger Cacti) are enabling future extensibility. Integration capabilities are vital for creating seamless agri-digital ecosystems.

This blockchain-enabled infrastructure aligns with the EU's strategic imperatives for food traceability, digital sovereignty, and interoperable agri-data ecosystems, offering a high-TRL reference architecture for regulatory-compliant, automated, and transparent smart farming systems.

Main actors and roles

Table 7.17 Main actors and roles

Actor name	Actor type	Actor Description and Role
iLINK	Use Case Owner	iLink is the main developer of the blockchain infrastructure and telemetry security layer via blockchain encryption. It ensures end-to-end data integrity, timestamping, and digital signature of events across the production and logistics chain. iLink integrates Hyperledger Fabric into the testbed and provides programmable APIs for data verification and traceability integration with COP-PILOT's orchestration services.
AgroApps	Data Collector & Blockchain Writer	AgroApps collects sensor data from all IoT and edge devices installed across the supply chain (e.g., field sensors, transport sensors, storage units). It aggregates and processes this data and writes validated telemetry

		events onto the blockchain to enable end-to-end traceability of agri-product batches.
Barba Stathis	Agronomists & Packaging Unit	Barba Stathis is responsible for managing lettuce batches. It oversees harvesting operations and performs product packaging. Each packaged batch is assigned a unique QR code linked to its traceability data on the blockchain, enabling full lifecycle visibility from farm to consumer.
Consumer	Final Consumer	Read Data via QR Code

Ambition, Motivation and Objectives

The growing complexity of the agri-food value chain, especially in sectors such as leafy vegetable production, creates an urgent need for more reliable and transparent data sharing mechanisms. Ensuring product quality, regulatory compliance, and timely deliveries requires full visibility over environmental conditions, operational events, and logistics parameters from the moment of harvest to the point of sale. However, the current ecosystem remains fragmented, with data often siloed across organizations and managed by systems that offer little or no interoperability. These limitations hinder collaboration, delay decision-making, and reduce confidence in the integrity of the supply chain.

At the same time, stakeholders face increasing pressure to demonstrate not only compliance with traceability regulations but also their ability to proactively manage quality and risk. Traditional approaches to traceability are inadequate in this context: manual logging, centralized repositories, and isolated databases are prone to error, manipulation, and information loss. What is needed is a system capable of securely capturing and verifying operational data in real time, while ensuring it can be used dynamically across organizational and technological boundaries.

This use case aims to deliver a fully decentralized, secure traceability infrastructure based on blockchain and IoT data. Agricultural events—such as harvesting, packaging, transportation, and storage—will be continuously monitored through embedded IoT and edge devices. Data will be immutably logged on a distributed ledger, where it is cryptographically signed and timestamped. This will enable supply chain actors to verify the authenticity, timing, and condition of each product batch without relying on centralized authorities or intermediaries. Beyond traceability, the system will support accountability, collaboration, and optimization.

A key ambition of the use case is to treat traceability not as a retrospective compliance tool, but as a proactive service that supports automation and intelligence. The integration with an orchestration platform allows for real-time responses to operational deviations. For instance, when a shipment is exposed to suboptimal conditions—such as a temperature excursion—this information is recorded on the ledger and can trigger actions such as alerts, dynamic rerouting, or SLA renegotiation. By embedding this functionality within a federated, cross-sector digital architecture, the use case sets the foundation for scalable and replicable data ecosystems that respect sovereignty, promote transparency, and reduce overhead.

The use case aligns with the project’s aim to support distributed service orchestration by integrating secure, real-time data into an environment that can monitor, manage, and adapt to changing operational conditions. It contributes to the broader objective of enabling trustworthy collaboration across domains by exposing verified product lifecycle data through standard, interoperable interfaces. It introduces a novel mechanism for transforming raw data (IoT) into actionable events, thereby supporting automated, policy-based orchestration without relying on human intervention. It serves as a reference for cross-sector integration, showing how logistics, agriculture, and data services can converge through a shared trust infrastructure. The orchestration platform provides the necessary logic to link events to decisions, allowing for traceability data to be more than passive documentation—turning it into a core component of the system's adaptive intelligence. It also ensures secure and coherent system-wide operation, enforcing access control, consistency, and compliance across a diverse set of actors and technical environments.

Challenges addressed

- **Deployment and Management Complexity**

Hyperledger Fabric requires configuring multiple interdependent components (e.g., peers, orderers, Certificate Authorities), which increases the technical and operational complexity of launching and managing a blockchain network.

- **Scalability and Performance Limitations**

As network size and data volume grow, throughput may degrade. The system's performance is highly dependent on proper configuration and chain code optimization, making real-world scalability a significant concern.

- **High Implementation and Maintenance Costs**

Deploying Fabric demands considerable investment in infrastructure, software development, integration, and skilled personnel. These requirements can pose barriers for small and medium enterprises or individual farmers.

Interoperability with Legacy and External Systems

Integrating Fabric with existing IT systems or other blockchain platforms remains technically challenging due to a lack of shared standards and system heterogeneity.

- **Shortage of Specialized Technical Expertise**

Successful implementation requires advanced knowledge in cryptography, distributed systems, and chain code development. The scarcity of skilled professionals is a significant adoption bottleneck.

- **Governance and Compliance Complexity**

Establishing shared governance rules—regarding data ownership, access rights, and regulatory compliance (e.g., GDPR)—is challenging, especially in multi-party networks with conflicting interests.

Despite the trust-enhancing nature of blockchain, real-world deployment is often hindered by the lack of pre-existing trust among stakeholders, which complicates the formation of cooperative consortia.

Expected outcomes

- **Improved Traceability and Transparency**

Blockchain allows near real-time tracking of products from farm to fork. Traceability is significantly enhanced, enabling instant identification of issues. For example, Walmart reduced tracking time from 7 days to 2.2 seconds.

- **Enhanced Food Safety and Quality Monitoring**

Sensor data (e.g., temperature, humidity) stored immutably on-chain allows stakeholders to validate that food safety conditions are met throughout logistics. This minimizes spoilage and consumer health risks.

- **Operational Efficiency through Automation**

Smart contracts automate business workflows such as compliance checks, inventory updates, and payments. This reduces human intervention, accelerates operations, and lowers transaction costs.

- **Increased Trust and Collaboration**

Fabric promotes transparency and data integrity among verified parties, strengthening trust even in competitive environments. This enables collaboration across fragmented agri-food supply chains.

- **Strengthened Digital Sovereignty and Compliance**

With private data channels and role-based access, Fabric supports GDPR-compliant implementations and ensures that organizations retain control over their sensitive data.

Key pain points

- **High Setup and Operational Complexity**

Deploying Hyperledger Fabric requires careful configuration of components like CAs, MSPs, peers, orderers, and channels. Its modular architecture increases administrative overhead, especially for teams with limited blockchain experience.

- **Performance Bottlenecks and Scalability Limits**

Fabric networks may encounter congestion, particularly during ordering or validation under load. Achieving high throughput requires advanced tuning, and real-world performance often falls short of lab conditions.

- **High Total Cost of Ownership (TCO)**

Implementing Fabric involves significant investment in hardware, power, development, maintenance, and skilled personnel. Additional spending may be needed for IoT or RFID devices to enable automated data capture.

- **Interoperability Challenges**

Fabric offers limited native compatibility with legacy systems or other blockchains. The absence of standardized data formats and protocols complicates integration across diverse platforms.

- **Weak Infrastructure in Rural Areas**

Lack of stable electricity and reliable internet connectivity in rural regions hinders deployment. This is particularly critical for real-time data validation and traceability scenarios.

- **Organizational Resistance to Change**

Stakeholders often resist shifting from familiar workflows to blockchain-based systems. Digital illiteracy and reluctance to trust automation further limit adoption.

- **Trust Deficit Among Stakeholders**

Despite blockchain's goal of fostering trust, initial distrust among potential participants remains a major non-technical barrier to adoption.

UC Diagrams

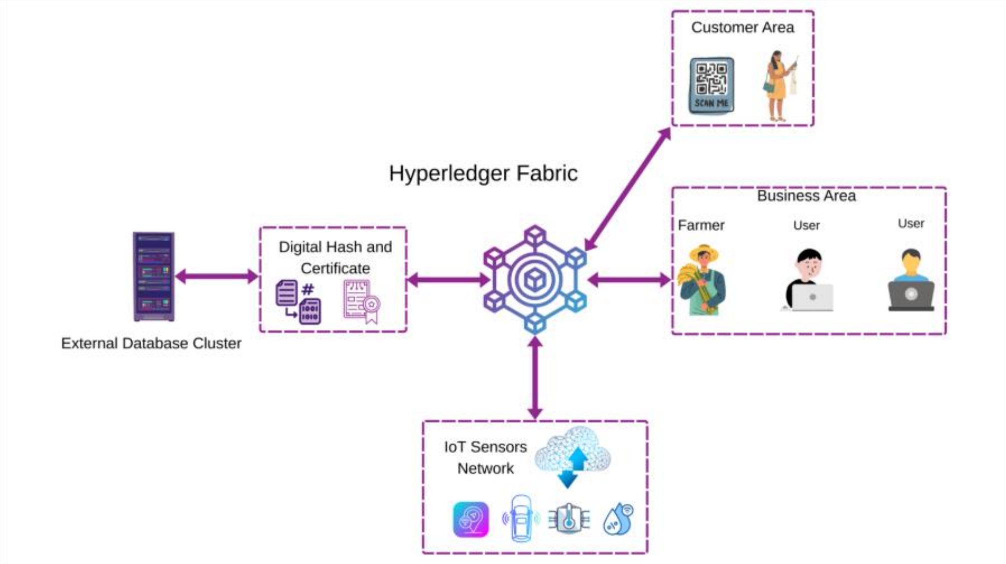

Figure 7.9 Hyperledger Fabric connections

UC3A.3 UML Diagram

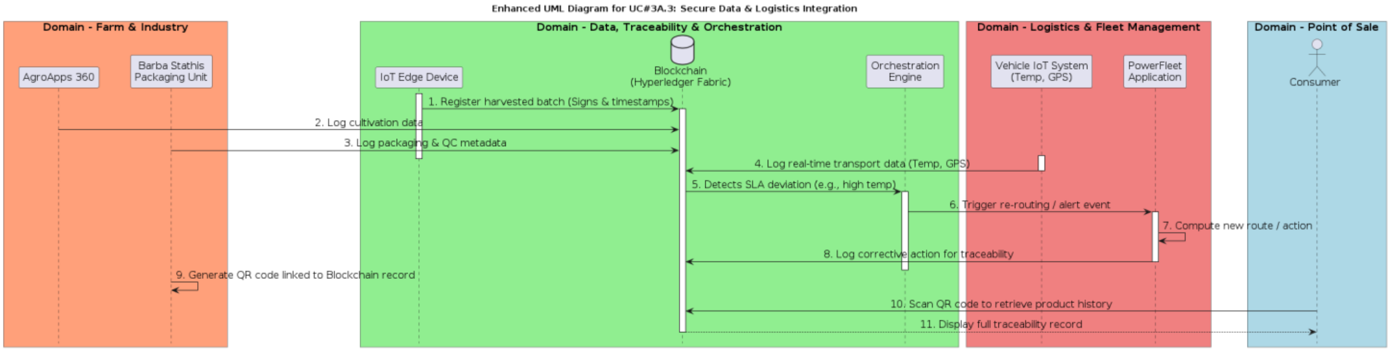

Figure 7.10 UC3A.3 UML diagram

Scenarios description

Table 7.18 UC#3A.3 Scenarios description

Scenario name:
Batch Traceability with SLA-triggered Orchestration
Step No.
1
Step Event
An IoT edge device register a newly harvested leafy vegetable batch. The system cryptographically signs and timestamps the event, which is recorded immutably on the blockchain ledger.
Name of process/activity
Register harvested batch
Description of process/activity
The edge device signs and timestamps the batch data, which is sent to the blockchain ledger.
Service
CREATE
Information producer (actor)
AgroApps – Barbastathis
Information receiver (actor)
Blockchain network (via edge device)
Information exchanged (IDs)
Batch identifier, harvest timestamp, product type, field location, producer ID
Reference to Scenario number
Step 1 of the UC3A.3 scenario
Step No.
2
Step Event
Completion of packaging and quality control process.
Name of process/activity
Log packaging and certification metadata.
Description of process/activity
Packaging staff scans the batch and uploads packaging details, temperature readings, and certifications. All data is verified and recorded immutably on the blockchain.
Service
EXECUTE
Information producer (actor)
Packaging unit
Information receiver (actor)
Blockchain network
Information exchanged (IDs)
Packaging timestamp, packaging center ID, certification ID, cooling status
Reference to Scenario number

Step 2 of the UC3A.3 scenario

Requirements

Functional requirements

Table 7.19 UC#3A.3 functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
FR1	The edge device	Must	Register each harvested batch as a unique blockchain entry with timestamp and producer ID
FR2	Blockchain System	Must	Log packaging and certification metadata immutably on the blockchain
FR3	The transport IoT sensors	Could	Transmit temperature, humidity, and GPS data during transportation
FR4	The orchestration engine	Could	Trigger SLA-based actions on PowerFleet (e.g., rerouting) when an SLA deviation event is detected
FR5	Blockchain System	Must	Provide a publicly query-able QR code linked to the product’s full lifecycle and blockchain proofs

Non-functional requirements

Table 7.20 UC#3A.3 non-functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
NFR1	The blockchain infrastructure	Must	Ensure data immutability and integrity
NFR2	The system	Must	Support data transmission from IoT sensors with low latency if it necessary.
NFR3	The orchestration engine	Must	React to SLA breaches detection
NFR4	The user interface	Could	Offer multilingual support and mobile accessibility for end-user traceability queries
NFR5	The data exchange layer	Must	Comply with GDPR and ensure access control via role-based permissions across all actors involved

Business requirements

The business requirements of UC3A.3 are structured around three interdependent dimensions: sustainability, societal value, and market viability. The aim is to ensure that the blockchain-based traceability framework delivers long-term operational and environmental value, while addressing user needs and unlocking new business potential within the agri-food domain. The identification and structuring of these requirements is based on stakeholder consultations, technical constraints, and scalability ambitions.

From a sustainability perspective, the use case targets significant improvement in environmental performance through the reduction of food waste and energy-intensive verification processes. The decentralized architecture of the blockchain solution eliminates the need for repeated auditing or physical document exchange, leading to savings in resources and emissions. In one scenario, certification data (e.g., organic status, harvest conditions) is immutably recorded on-chain at the time of packaging, avoiding redundant inspections downstream. These actions are measurable through indicators such as reduction in manual verification events and traceability resolution times.

In societal terms, the solution fosters transparency, fairness, and trust between producers, logistics actors, and end consumers. Farmers gain greater visibility and recognition for their production practices, while consumers can verify claims such as origin, environmental footprint, or pesticide usage via tamper-proof records. The system lowers barriers for small-scale producers to enter traceability programs, as participation does not require extensive digital expertise. For example, by simply scanning a batch code via a mobile interface, a farmer can trigger blockchain-based data entry with verified geolocation and timestamp metadata. Societal impact will be monitored through indicators such as number of participating smallholders and consumer engagement with traceability features.

From a market and business standpoint, the traceability infrastructure unlocks new opportunities for product differentiation, premium certification, and improved reputation management. Retailers and food processors gain the ability to provide provable product provenance, which supports both compliance (e.g., ESG reporting) and marketing. The business consultant supports the formulation of value propositions for participating stakeholders and ensures that the system is designed to enable scalable business models. In one scenario, a logistics operator integrates the traceability API into its own tracking app, allowing end-to-end chain-of-custody verification with minimal overhead.

Sustainability business requirements

The sustainability objectives of UC3A.3 are intrinsically linked to its use of blockchain infrastructure for enhancing traceability, transparency, and data accountability across agri-food value chains. The use case seeks to minimize environmental footprint by digitizing paper-based workflows, reducing redundant verification procedures, and optimizing the reuse of existing digital infrastructure (e.g., sensor networks, geotagging devices, and certification channels).

By adopting a decentralized, tamper-proof ledger, the system removes the need for physical audits or document transportation, thereby reducing emissions and energy consumption associated with traceability. In one scenario, a producer’s harvest and packaging records are entered via a lightweight edge device directly onto the blockchain, replacing the traditional multi-stage document handling and inspector visits. This reduces vehicle use, manual paperwork, and time-to-verification.

In alignment with circular economy principles, the system is built to repurpose existing IoT devices (e.g., GNSS modules used in logistics or agriculture) and avoids redundant installations. Moreover, the traceability logic is modular and scalable, designed to accommodate new batches, stakeholders, or certification schemes without reconfiguration of the underlying ledger.

Table 7.21 UC#3A.3 sustainability requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SR1	Energy usage during traceability transactions	Compulsory	Optimize blockchain consensus protocol	≥5% energy reduction per transaction (vs. traditional PoW baselines)

SR2	System scalability and modular traceability expansion	Good to have	Design ledger structure to support multiple stakeholders and product lines	Ability to onboard new producers/certifiers with <2 day setup time

Societal business requirements

UC3A.3 contributes to key societal objectives by promoting equitable access to traceability technologies, enhancing transparency across agri-food supply chains, and reinforcing data protection and ethical use. One of the main drivers of societal value in this use case is the empowerment of small-scale producers, particularly those in rural or digitally underserved regions. The system is designed to be accessible and usable by non-expert stakeholders, leveraging mobile and lightweight interfaces to facilitate seamless entry into blockchain-enabled traceability frameworks.

The system places strong emphasis on user-centricity and inclusive design. By lowering the technical entry barriers, it allows even resource-constrained users to participate in traceability networks. A scenario includes small producers registering their batches via smartphone-based tools that automatically timestamp and geolocate the data, requiring no blockchain expertise.

In addition, all data handling processes comply with GDPR and other regional data protection laws. Although the system stores no direct personal data, metadata could indirectly reference identifiable entities such as operators or delivery staff. As such, pseudonymization, role-based access controls, and audit trails are in place. Transparency is further enhanced through on-chain trace logs accessible to all relevant stakeholders, including consumers.

From a broader societal perspective, the ability to verify the environmental footprint, origin, and handling conditions of food products supports responsible consumption. It fosters consumer trust, encourages sustainable farming practices, and aligns with emerging expectations for ESG-compliant supply chains.

Table 7.22 UC#3A.3 societal requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SC1	User-friendliness of traceability data entry interfaces	Compulsory	Easy to use API	≥70% of new users able to onboard without external support
SC2	Transparency and accountability in food supply chain	Compulsory	Provide public trace reports per batch, available to consumers via QR-code scans.	Number of trace reports accessed by end-users
SC3	GDPR and data	Compulsory	Implement data minimization and	Full alignment with GDPR

	protection compliance for traceability metadata		pseudonymization policies	

Market business requirements

The market-oriented business requirements of UC3A.3 reflect the need for a traceability infrastructure that is not only technologically robust, but also economically viable and scalable across diverse agri-food networks. At the core of this use case lies the ability to reduce long-term operational costs associated with regulatory compliance, auditing, and documentation, while simultaneously increasing the commercial value of agri-products through verifiable provenance.

A primary market requirement is to ensure that the system offers low integration complexity and cost. To this end, the traceability infrastructure has been designed with standardized APIs and modular architecture, facilitating seamless onboarding for logistics operators, certification bodies, and cooperative platforms. A practical scenario involves a logistics partner integrating the blockchain traceability service using lightweight mobile endpoints, requiring no extensive infrastructure overhaul or IT reconfiguration. Time-to-integration and support overhead are expected to be minimal, encouraging adoption by both SMEs and large agri-processors.

From a sustainability and continuity standpoint, the blockchain backend is designed with fail-safe mechanisms and low operational overhead. The use of permissioned, energy-efficient blockchain protocols and edge-side data signing ensures that the solution remains cost-effective over time, without burdening participants with recurring licensing or hosting costs. In case of network outages, fallback procedures may allow batch certification to be temporarily cached and synchronized post-recovery, safeguarding business continuity and ensuring that data immutability is preserved even under constrained connectivity conditions.

Additionally, the traceability logic directly supports market expansion, particularly toward export markets and premium supply chains where verifiable ESG compliance and traceability are critical. The solution empowers producers and logistics operators to meet increasingly strict buyer and regulatory expectations regarding origin, quality assurance, and sustainability footprint. This, in turn, supports access to new revenue streams and competitive positioning.

Key measures include the tracking of onboarding time for new partners, total cost of ownership for traceability integration, and system availability under normal and degraded conditions.

The business consultant contributes by validating the economic models, assisting in defining pricing strategies, and ensuring that value propositions are aligned with market expectations and procurement logic.

Table 7.23 UC#3A.3 market(business) requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
BR1	Long-term cost-effectiveness of traceability mechanisms	Compulsory	Reduce certification and auditing costs {via blockchain-based automation and elimination of redundant inspections}	≥10% decrease in annual certification-related expenses

BR2	Expansion to new markets requiring certified provenance and ESG reporting	Good to have	Enable verifiable provenance for ESG-compliant supply chains {via tamper-proof batch history and product origin}	~≥10% increase in access to ESG-sensitive retailers and buyers
BR3	Maintenance and scalability cost of blockchain infrastructure	Good to have	Adopt low-energy, modular ledger structure {with minimal node requirements and edge-side data compression}	≥10% lower operating costs compared to traditional centralized traceability platforms

KPIs and KVIs

This use case focuses on the evaluation of blockchain performance and its business relevance in the agri-food value chain.

- KPIs include the transaction throughput (TPS), measuring how many transactions are processed per second, and the end-to-end transaction latency, which reflects the total time from submission to final commitment.
- Additional technical KPIs include endorsement latency, commit latency, and chain code execution time, which are essential for assessing platform responsiveness.
- KVIs focus on the ability to extract business insights from blockchain activity, such as timestamps for tracing processing delays, as well as logs and hashes that support trust and data integrity.

UC/vertical Specific

This use case evaluates real-time telemetry and AI-based routing for fresh produce delivery.

- KPIs include routing response time (target: <10 minutes), on-time delivery rate (target: >95%), number of reroutings (target: 0), and freshness deviations based on delivery temperature thresholds (target: <10%).
- KVIs emphasize transparency through consumer-accessible traceability (e.g., QR scans) and delivery efficiency as measured by internal logistics KPIs.

Sustainability

Contributes by minimizing energy consumption in blockchain operations, capturing node-level performance and comparing it with environmental benchmarks. These KPIs and KVIs support the broader objective of sustainable digital infrastructure.

Legal and Ethics Requirements

Legal and ethical compliance constitutes an ongoing commitment throughout the lifecycle of UC3A.3, particularly due to the project's focus on secure, interoperable traceability using blockchain infrastructure. Given the dynamic regulatory landscape in the EU—shaped by instruments such as the **GDPR**, **Data Governance Act**, and the **AI Act**—the legal and ethical frameworks adopted in this use case must remain adaptive and transparent. The present overview reflects the current understanding of legal and ethical dimensions and will be further elaborated as implementation progreses, and regulatory expectations evolve.

Involvement of Volunteers

The use case does not foresee the involvement of volunteers or human participants. All data and events are system-generated, sourced from logistics workflows, blockchain event logs, and edge devices deployed within operational environments. No personal or biometric data from individuals is expected to be collected, stored, or processed.

Data Related Activities

UC3A.3 centers on data integrity, immutability, and controlled access to supply chain information. Data managed in this use case includes:

- Batch identifiers, timestamps, GPS location data, operator ID hashes, packaging metadata, and transport event telemetry.
- All records are cryptographically hashed and stored in a permissioned blockchain ledger (e.g., Hyperledger Fabric).
- No direct personal data is stored, however, care is taken to ensure that metadata (e.g., operator activity) cannot be indirectly linked to individuals.

AI Systems

No AI system used.

ANNEX 7.D: UC3A.4 - SMART LOGISTICS AND SUPPLY CHAIN OPTIMIZATION

Description

Short Description

This use case addresses the need for intelligent, real-time management of logistics operations in the fresh produce sector, with a focus on perishable crops such as leafy vegetables. It introduces an AI-driven orchestration framework capable of dynamically adapting delivery routes and schedules based on telematics data gathered from refrigerated transport vehicles. Parameters such as temperature, humidity, and geolocation are continuously monitored and analysed using predictive models to estimate product freshness throughout the delivery lifecycle. The system integrates these insights into the service orchestration layer to enable automatic responses when predefined thresholds are violated. Through this approach, the use case ensures the efficient allocation of transport resources, reduces spoilage, and upholds service-level expectations across the agri-food supply chain.

Complete Description

Before the implementation of UC#3A.4, the logistics operations related to the transport of perishable agricultural goods—such as leafy vegetables—relied heavily on static planning methods and predefined distribution routes. Deliveries were managed using traditional scheduling systems, which lacked the capacity to adjust in real time to operational delays, temperature excursions, or unexpected freshness decay. Even though refrigerated vehicles were equipped with basic monitoring systems, the data collected from onboard sensors (e.g., temperature, location) was rarely used in a dynamic or proactive way. This disconnect between data collection and decision-making led to inefficiencies, such as late deliveries, unnecessary fuel consumption, underutilized vehicles, and in some cases, loss of product quality.

The coordination of the fleet was primarily manual, based on historic patterns and general assumptions regarding optimal delivery routes. In this context, no intelligent orchestration mechanism existed to manage resources based on real-time product condition or delivery constraints. There was also no central system to consolidate vehicle telemetry, delivery status, and routing information in a way that would enable just-in-time (JIT) logistics. The absence of route re-prioritization and lack of predictive decision-making limited the flexibility and responsiveness of the logistics network, especially in periods of high demand or environmental volatility.

With the integration of the COP-PILOT orchestration services and the deployment of PowerFleet—an advanced fleet management and route optimization system developed by iLink—the logistics operations in UC#3A.4 undergo a complete transformation. PowerFleet serves as the digital backbone of the use case, enabling intelligent, AI-assisted, just-in-time routing. It collects real-time telematics data from refrigerated vehicles (GNSS, temperature, cargo status) and uses advanced meta-heuristic algorithms (inspired by the Jsprit library) to continuously compute optimal delivery plans. The system adapts routing decisions dynamically, accounting for delays, vehicle capacity, freshness estimates, and service-level expectations.

The platform offers Routing as a Service (RaaS), exposing route optimization logic through APIs that connect with the COP-PILOT orchestration layer. When a deviation occurs—such as a predicted freshness drop below a critical threshold—the orchestrator can query PowerFleet to re-evaluate priorities and redistribute deliveries across the available fleet. The system's backend, developed in Java Object Oriented Programming Language and deployed in a Kubernetes containerized environment, supports full scalability and modularity. PowerFleet, though OpenAPI2.0 -Swagger API- also integrates with ERP and WMS systems for seamless coordination between order preparation, vehicle scheduling, and real-time delivery execution. Both drivers and logistics managers receive live notifications through web/mobile interfaces, ensuring synchronized action and complete transparency.

Main actors and roles

Table 7.24 Main actors and roles

Actor Name	Actor type	Actor description and role
iLINK	Use Case Owner	iLink plays a central role in the smart logistics layer of this use case. As the main technology provider, it is responsible for designing and deploying infrastructure that supports dynamic routing and real-time logistics optimization for transporting perishable agricultural goods. This includes integrating telematics components like GNSS tracking and environmental sensors into refrigerated vehicles. iLink also develops routing logic that reacts to live operational data. Delivery priorities and routes are adjusted based on freshness or service conditions. These services are provided through secure interfaces and are fully compatible with the COP-PILOT orchestration platform. iLink's role ensures that logistics decisions remain responsive, adaptive, and aligned with the perishable nature of the products.
AgroApps	Digital Agriculture Technology Provider	AgroApps supports the monitoring of crop and field conditions throughout the production phase. It plays a key role in enabling informed decision-making in the early stages of the logistics chain. AgroApps contributes to ensuring that product readiness is detected and communicated to the orchestration system on time.
Barba Stathis	Industrial Food Supply Chain Operator	Barba Stathis leads the processing and distribution phase of the value chain. It is responsible for transforming the raw product into a packaged item ready for delivery. The company ensures that the final logistics operations are aligned with quality, timing, and traceability objectives.

Ambition, Motivation and Objectives

The motivation behind this use case lies in the operational fragility and inefficiencies of conventional logistics systems managing perishable agricultural products. Leafy vegetables are particularly sensitive to time, temperature, and handling conditions, making their transport highly susceptible to product loss, quality degradation, and SLA violations. Existing routing and delivery mechanisms are typically static and reactive, offering limited flexibility in adapting to real-time telemetry or unforeseen disruptions during transportation. These shortcomings not only jeopardize product freshness and shelf-life but also increase operational costs and carbon emissions, undermining sustainability goals and customer trust.

In addition to the lack of adaptiveness, most logistics frameworks fail to incorporate freshness as a dynamic metric during transport. They operate under the assumption that products remain in optimal condition throughout the logistics chain, ignoring real-time environmental variations such as temperature excursions, humidity spikes, or delivery delays. This results in planning decisions that do not reflect the actual state of the cargo. There is thus a critical need for an orchestration-enabled logistics layer that can interpret telemetry signals, estimate freshness decay, and proactively reconfigure delivery routes and priorities based on context-aware, service-level-aware decision logic. This capability becomes even more impactful when implemented through a dedicated platform like PowerFleet, developed by iLink, which supports real-time vehicle monitoring and condition-aware re-routing, enabling true Just-in-Time (JIT) delivery performance.

The ambition of UC3A.4 is to create a dynamic, intelligence-driven logistics orchestration framework for perishable goods, capable of making real-time routing decisions informed by continuous telematics input. Through the integration of secure GNSS tracking, in-vehicle environmental sensing, and condition-aware routing logic, the use case aims to demonstrate how predictive logistics can move from theory into operational deployment. Rather than relying on fixed schedules and predefined responses, logistics operations are reimagined as fluid, adaptive systems that adjust in real time to uphold delivery integrity and product quality. PowerFleet's architecture is purpose-built to serve this ambition, acting as the logistics intelligence layer that delivers route optimization as a service, supports JIT coordination, and minimizes delays or quality losses through event-triggered adaptation.

Another key ambition is to validate how smart routing logic can be exposed as a reusable, programmable service that interoperates with other components of the COP-PILOT ecosystem. By deploying this functionality within a real industrial testbed, the use case seeks to establish a reference for just-in-time orchestration in logistics, where event-driven adaptation is not only possible but scalable. The system aspires to shift the paradigm from “route optimization” to “freshness-aware delivery orchestration,” creating measurable impact across sustainability, efficiency, and food security dimensions.

- The use case contributes to the overall project objectives by enabling the real-time orchestration of delivery services in accordance with freshness metrics and SLA constraints.
- It supports the project's ambition to demonstrate replicable, domain-agnostic orchestration patterns that can be extended across sectors such as food, health, and mobility.
- It introduces a novel use of secure telematics integration to drive event-based logistics decisions, contributing to innovation in real-time orchestration for perishable goods.
- It demonstrates how orchestration logic can integrate condition-aware parameters—such as freshness decay estimates—into actionable delivery decisions at the edge and cloud level.
- The COP-PILOT platform provides the orchestration foundation for automating decisions traditionally made manually, ensuring fast response to SLA breaches without operator intervention.
- The secure and modular orchestration layers (InfraOrch, ServOrch) allow for scalable deployment of the routing logic across heterogeneous infrastructure, while maintaining trust, policy enforcement, and data integrity

Challenges addressed

UC#3A.4 addresses a set of critical challenges that characterize traditional logistics systems operating in the agri-food sector. Chief among these is the inability of conventional routing frameworks to adapt dynamically to real-time data such as freshness levels, temperature deviations, or delivery delays. Static scheduling models often result in inefficient resource allocation, leading to overuse of vehicles, excessive fuel consumption, and poor responsiveness to unplanned disruptions.

Another key challenge lies in the fragmented nature of data systems across the supply chain. Environmental conditions, vehicle location, delivery timelines, and product condition data are typically siloed in isolated systems, preventing holistic visibility. Without a unifying orchestration layer, stakeholders lack the tools to optimize routes based on contextual factors or to re-prioritize deliveries in response to time-sensitive conditions. Furthermore, small-scale operators face barriers to entry in digitized logistics due to the lack of lightweight, affordable platforms that can interface with existing systems.

Expected outcomes

The integration of PowerFleet, combined with the COP-PILOT orchestration layer, is expected to deliver a demonstrable improvement in logistics efficiency, traceability, and operational resilience. By enabling Just-in-Time (JIT) routing decisions based on real-time sensor inputs and predictive freshness estimation, the system will reduce delivery times, minimize product loss, and enhance adherence to SLA parameters.

PowerFleet will also enable measurable reductions in vehicle kilometers traveled (VKT) and fuel consumption, through intelligent reallocation of delivery priorities and minimization of idle fleet capacity. Its ability to operate as Routing-as-a-Service (RaaS) ensures that both large-scale and smaller logistics providers can seamlessly integrate smart routing into their existing workflows. In turn, this supports scalability and market readiness, while promoting sustainability through emission reduction and better vehicle utilization.

Key pain points

Prior to the deployment of this use case, logistics coordination was hindered by a lack of integration between routing systems, environmental monitoring, and operational control. Decisions were reactive rather than proactive, resulting in frequent delays, suboptimal route choices, and limited capacity to address exceptions such as temperature breaches or blocked delivery windows.

Moreover, the absence of a system capable of dynamically orchestrating logistics processes led to high dependency on manual planning and little room for operational agility. Route revisions, when needed, had to be executed through direct human intervention, often without full visibility into fleet status or delivery urgency. This not only increased the cognitive load on planners and drivers but also exposed the system to avoidable inefficiencies and reputational risks. PowerFleet, by centralizing routing intelligence and exposing it to the orchestrator, directly alleviates these pain points through automation, contextual awareness, and real-time JIT decision-making.

UC Diagrams

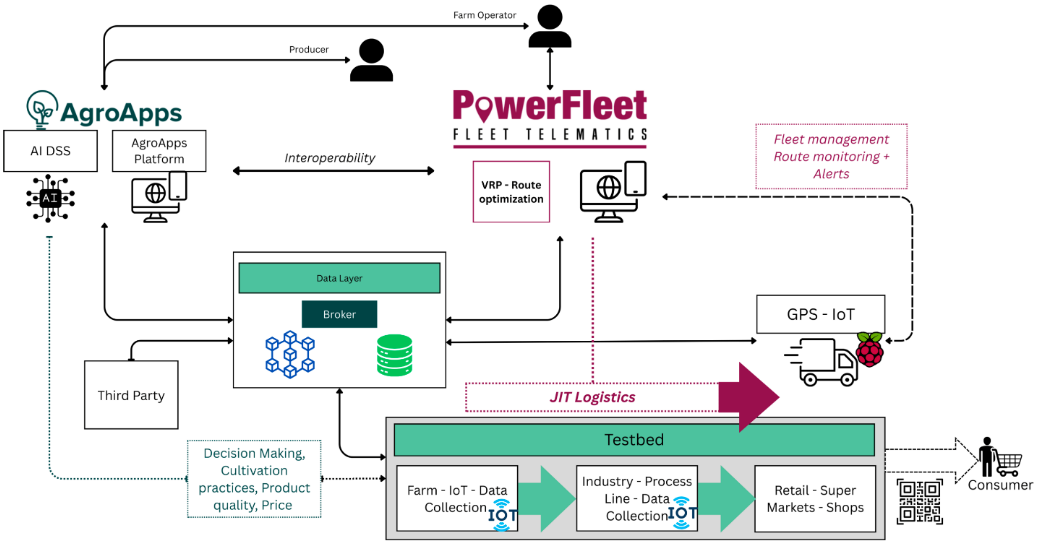

Figure 7.11 UC#3A.3 PowerFleet's architecture

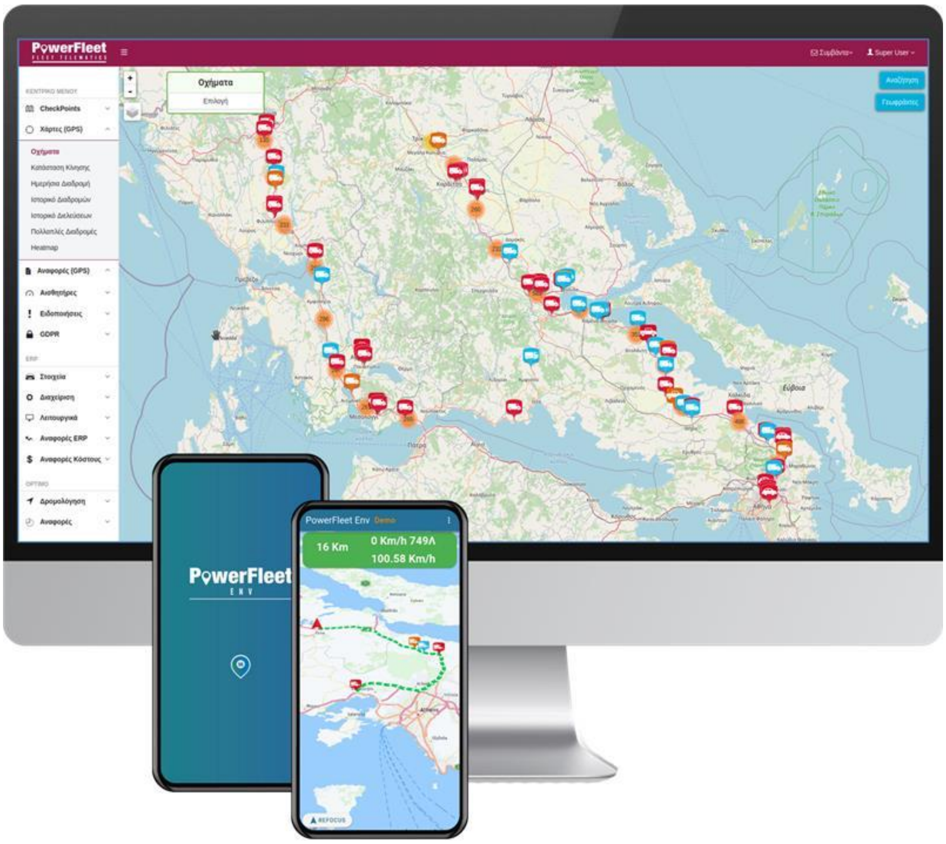

Figure 7.12 UC#3A.3 PowerFleet's visualisation

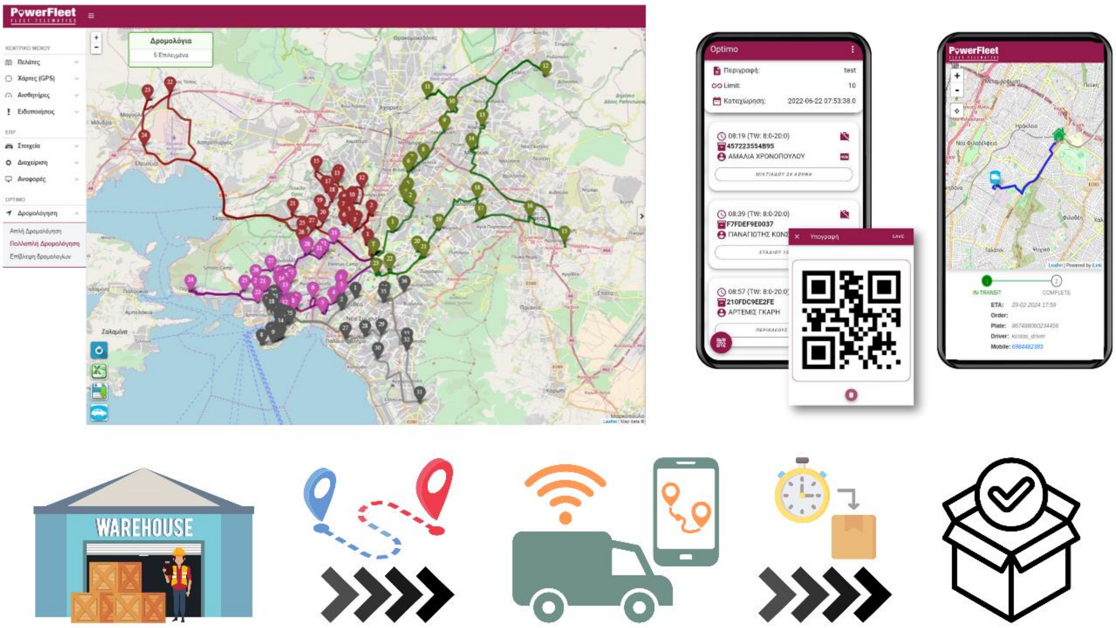

Figure 7.13 PowerFleet’s Routing-as-a-Service (RaaS) demostration

UC3A.4 UML Diagram

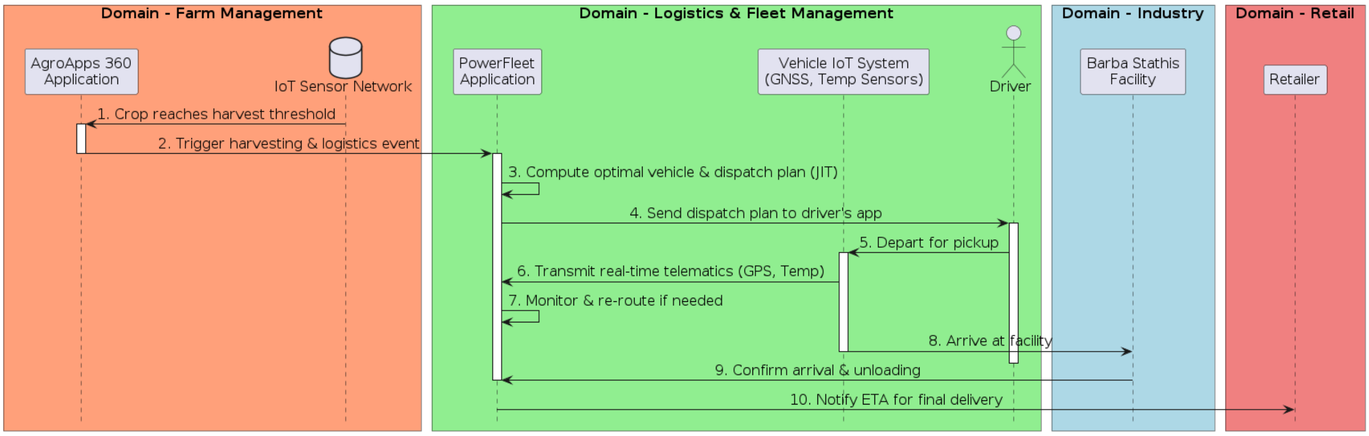

Figure 7.14 UC3A.4 UML diagram

Scenarios description

Table 7.25 UC#3A.4 Scenarios description

Scenario name:
Smart Logistics and Supply Chain Optimization
Step No.
1
Step Event
Lettuce batch reaches predefined growth and environmental threshold
Name of process/activity
Trigger harvesting and logistics orchestration
Description of process/activity
IoT sensors monitor crop status. When thresholds are met, AgroApps system emits an event to PowerFleet.
Service
CREATE
Information producer (actor)
IoT sensor network / AgroApps
Information receiver (actor)
Blockchain ledger + PowerFleet
Information exchanged (IDs)
Crop ID, location, time of readiness, environmental conditions, batch ID
Step No.
2
Step Event
Harvest readiness event received by PowerFleet

Name of process/activity
Compute optimal vehicle and dispatch plan (JIT logistics)
Description of process/activity
Upon receiving the harvest event, PowerFleet dynamically selects the appropriate vehicle and route using GNSS data, vehicle availability, and freshness optimization.
Service
GET + EXECUTE
Information producer (actor)
PowerFleet
Information receiver (actor)
Vehicle management unit + driver mobile app
Information exchanged (IDs)
Assigned vehicle ID, route coordinates, ETA, product type, temperature constraints
Step No.
3
Step Event
Vehicle departs farm with harvested lettuce batch
Name of process/activity
Monitor real-time delivery and update freshness data
Description of process/activity
During transport, IoT sensors collect and transmit data about temperature, humidity, shock/vibration, and geolocation. Blockchain and PowerFleet log the data continuously.
Service
REPORT + UPDATE

Information producer (actor)
Vehicle IoT system (sensors, GNSS unit)
Information receiver (actor)
PowerFleet + Blockchain ledger
Information exchanged (IDs)
Cargo temperature, GPS location, vibration level, time, batch ID
Step No.
4
Step Event
Vehicle arrives at processing facility with lettuce batch
Name of process/activity
Quality control, processing, packaging and QR tagging
Description of process/activity
Upon arrival, the lettuce batch is unloaded, inspected, processed, and packaged. A unique QR code is generated and linked to the blockchain data of each packaged unit.
Service
CREATE
Information producer (actor)
Factory quality control system / packaging system
Information receiver (actor)
Blockchain ledger / Consumer traceability service
Information exchanged (IDs)
Product ID, QR code, packaging timestamp, processing status, freshness certificate

Step No.
5
Step Event
Packaged units with QR codes are ready for distribution
Name of process/activity
Recalculate delivery routes and dispatch products to retailers
Description of process/activity
PowerFleet receives a packaging completion event and triggers the orchestration of outbound deliveries to retail stores. Routes are optimized based on freshness, distance, and SLAs.
Service
GET + EXECUTE
Information producer (actor)
PowerFleet
Information receiver (actor)
Vehicle fleet system / delivery drivers / retailers
Information exchanged (IDs)
Route ID, vehicle ID, delivery priority, QR-linked product batch, ETA
Step No.
6
Step Event
Products arrive at retail and become accessible to consumers
Name of process/activity
Enable end-user transparency through blockchain-based traceability
Description of process/activity

At the retail location, consumers can scan the QR codes on the packaged products and retrieve a full traceability record, including farm origin, processing, and delivery data.
Service
EXECUTE
Information producer (actor)
Blockchain explorer / QR code scanning interface
Information receiver (actor)
End-consumer / Retail interface
Information exchanged (IDs)
Product ID, timestamped events, batch history, freshness logs
Reference to Scenario number
UC3A.4 – Scenario 1

Requirements

Functional requirements

Table 7.26 UC#3A.4 functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
FR1	PowerFleet platform	Must	Trigger route optimization and vehicle dispatch
FR2	Blockchain infrastructure	Must	Store harvesting, transport, and packaging metadata
FR3	IoT sensor network (in field and vehicles)	Must	Collect and transmit real-time telemetry
FR4	QR code traceability interface	Must	Allow consumers to access product journey data
FR5	COP-PILOT orchestration layer	Must	Integrate with PowerFleet

Non-functional requirements

Table 7.27 UC#3A.4 non-functional requirements

Req. ID	Subject (+ Condition)	Commitment	Action + Object + {Constraint and/or Value}
NFR1	PowerFleet platform	Must	Respond to routing queries
NFR2	Blockchain smart contract	Must	Execute harvest trigger
NFR3	IoT data processing pipeline	Must	Ensure end-to-end delivery of sensor data
NFR4	QR code access at retail	Could	Maintain availability of traceability service {with >99% uptime}
NFR5	System integration (PowerFleet <-> COP)	Must	Support secure authentication and encrypted API communication {following ISO/IEC 27001 and GDPR compliance}

Business requirements

The business requirements of UC3A.4 are structured around three core pillars—sustainability, societal value, and market applicability—reflecting both the strategic orientation of the project and the real-world expectations of end-users. These requirements are derived from a combination of domain-specific challenges, stakeholder feedback, and the intended service architecture. Each category includes measurable targets and is illustrated through scenarios implemented in the pilot activities.

In terms of sustainability, the use case prioritizes the reduction of food waste and logistics-related emissions. Routing decisions must actively incorporate telematics data, such as temperature and estimated freshness, to minimize unnecessary transportation and reduce energy consumption in refrigerated units. For instance, in a scenario where two delivery routes are available, the orchestrator should choose the route that preserves product freshness while minimizing emissions, considering traffic and delivery windows. These decisions will be evaluated through KPIs such as CO_2 emissions per delivery unit and percentage reduction in spoiled goods.

Societal requirements center on improving the availability of fresh produce and ensuring equitable access to high-quality food, particularly in underserved areas. In one of the defined scenarios, deliveries to smaller or rural retail points are reprioritized based on real-time degradation risk, ensuring product freshness upon arrival. This contributes not only to public health but also to strengthening local food systems. In addition, the system must uphold data ethics, transparency, and interpretability, especially for human operators who supervise decision outputs. These aspects will be measured through delivery reliability scores and adherence to data governance standards.

From a market and business perspective, the orchestration of smart logistics must yield cost-efficiency, service differentiation, and operational resilience. The system is expected to reduce delivery delays, optimize route planning, and offer predictive insights that can be monetized or embedded into broader logistics services. One scenario includes the dynamic reassignment of delivery slots when freshness drops below acceptable thresholds—allowing suppliers to avoid penalties and maintain service contracts. Business value will be assessed through performance metrics such as cost per delivery, fleet utilization rate, and integration readiness for logistics operators.

Across all three categories, the business consultant contributes by validating the alignment of these requirements with industry needs, proposing scenarios that demonstrate commercial viability, and advising on value proposition consolidation for potential exploitation beyond the pilot.

Sustainability business requirements

The UC3A.4 use case incorporates sustainability as a foundational design principle, targeting measurable reductions in energy use, resource consumption, and environmental impact. By deploying dynamic, condition-aware routing based on real-time telematics, the system avoids inefficient transport loops and ensures that deliveries are optimized not only for speed but also for energy efficiency. Vehicle telemetry is used to regulate refrigerated storage use dynamically, minimizing excessive energy draw. This results in decreased fuel consumption and lower carbon emissions per delivery cycle.

The system has been designed with scalability and modularity in mind, allowing future logistics actors or new geographies to join without additional architectural overhead. Its orchestration model is adaptable to larger fleets or alternative vehicle types, including electric vehicles powered by renewable energy sources. Moreover, UC3A.4 explicitly avoids technological redundancy by integrating existing IoT and tracking infrastructure rather than replicating systems. This contributes to a circular economy logic where asset reuse and system-level efficiency are key values.

One of the scenarios foresees the use of predictive freshness analytics to pre-emptively reroute deliveries, reducing spoilage and unnecessary transport effort. Another scenario includes dynamic scheduling based on energy consumption thresholds, where low-energy routes are prioritized during peak emission periods. These features directly support the project’s sustainability vision by embedding environmental intelligence into operational logistics.

- Quantifiable indicators include:
    - Reduction in average fuel consumption per delivery route (target: >15%)
    - Reduction in product spoilage rate due to condition-aware routing (target: >10%)
    - Deployment readiness for renewable-energy-powered fleets (assessed via infrastructure compatibility reports)

Table 7.28 UC#3A.4 sustainability requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SR1	Energy consumption during refrigerated transport	*Good to have*	Energy usage of cooling units in transport fleet	≥10% reduction in average fuel consumption per route
SR2	Food spoilage due to delivery delays or inefficient routing	*Compulsory*	Spoilage losses during a month distribution	≥10% reduction in rejected or degraded products a month
SR3	Number of active delivery vehicles per shift	*Compulsory*	Active vehicle count for daily deliveries	≥10% reduction in usable active vehicle
SR4	Fuel consumption from delivery path length	*Compulsory*	Route distance for each shipment	≥10% reduction in average route length → direct diesel fuel savings

Societal business requirements

The societal impact of UC3A.4 extends beyond logistics optimization into the domain of equitable access, data ethics, and workforce well-being. In agricultural supply chains, especially those involving perishable products, small-scale operators and rural distribution points are often underserved by existing platforms. The use case aims to democratize access to advanced orchestration technologies by ensuring that the system is intuitive, low-barrier, and adaptable to non-expert users. This includes the provision of lightweight mobile interfaces for farmers and logistics personnel, allowing them to participate in orchestrated delivery systems without the need for technical expertise. Ease of onboarding and inclusive design principles are central business requirements in this category.

Another critical societal dimension is the system's commitment to data privacy and regulatory compliance. The orchestration logic and telematic exchange must be fully aligned with GDPR and related regional data protection frameworks. However, it is important to highlight that the UC does not focus on processing personal or behavioral data. Instead, it centers on the vehicle, the delivery process, and real-time routing conditions. Data streams originate primarily from in-vehicle systems, including GPS modules and environmental sensors, and are processed to optimize logistical performance, not to track or profile individuals. In this context, the role of the business consultant is to validate that privacy is not treated as an afterthought but embedded from the design phase through to deployment and user interaction, with appropriate safeguards tailored to the specific nature of operational data.

In terms of workforce dynamics, the use case promotes improved working conditions for drivers and logistics planners by reducing cognitive and physical workload. Through automated, AI-supported scheduling and routing, personnel can avoid repetitive manual planning and reduce time spent on inefficient or duplicated deliveries. Furthermore, by minimizing unnecessary transport, the system supports both environmental and personal well-being, limiting operator fatigue and exposure to road stress.

- The use case ensures GDPR-compliant data handling and auditing mechanisms that meet enterprise-level standards, while focusing primarily on operational telemetry rather than personal data.
- It enhances user accessibility for non-expert actors through simplified digital entry points and role-specific interaction layers.
- It improves workforce satisfaction and operational safety by automating repetitive scheduling and minimizing redundant movement.

Table 7.29 UC#3A.4 societal requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
SC1	Accessibility for new users in rural logistics operations	*Compulsory*	Simplify the onboarding process for farmers and logistic operators using intuitive mobile interfaces	Percentage of users completing onboarding without support, will increase the app usage
SC2	Data protection and GDPR compliance across all stakeholders	*Compulsory*	Implement encrypted communication and data handling mechanisms in compliance with GDPR	Number of data breaches reported; successful GDPR audits
SC3	Workforce efficiency through better scheduling and route transparency	*Good to have*	Enable AI-driven scheduling to reduce manual planning for logistics operators	Time saved per scheduling task; operator satisfaction survey results

Market business requirements

The UC3A.4 addresses multiple market-oriented requirements that aim to support long-term operational viability and economic impact, particularly in the domain of smart agri-logistics. As the orchestration layer enables intelligent routing and dynamic fleet coordination, it directly contributes to reducing the operational costs associated with fuel, labor hours, and delivery inefficiencies. This positions the solution as a key enabler of cost-effective, Just-in-Time (JIT) logistics for perishable goods, supporting both large-scale and regional supply chains where timing and freshness are critical.

Furthermore, the architecture is designed to support modular integration of new services, APIs, and hardware with minimal disruption. This reduces the cost and time-to-market for future expansions or adaptations and improves the return on investment for stakeholders who adopt the solution. By enabling gradual adoption, the system lowers the barrier for SMEs and third-party logistics providers to join the orchestration framework, promoting inclusivity and scalability. The JIT nature of PowerFleet ensures that even newly integrated components immediately participate in time-sensitive, condition-aware delivery optimization.

The solution also introduces built-in recovery and failover mechanisms, ensuring business continuity during device faults or connectivity loss. This is particularly relevant for perishable goods transport, where service degradation could lead to measurable financial losses. By maintaining routing logic close to real-time conditions, the JIT orchestration functionality ensures that critical deliveries can be reallocated or reprioritized dynamically. In this context, the business consultant contributes to validating the cost models and assessing the monetization potential of orchestration services.

- The orchestration-enabled smart routing results in a measurable reduction of delivery costs per unit transported, while increasing the reliability of JIT deliveries under varying logistical constraints.
- By offering standardized and lightweight integration options, the system enables logistics actors to quickly onboard new devices and services, reducing the integration cost and supporting market expansion beyond the testbed
- Failure recovery is embedded into the orchestration flow through fallback routes, pre-configured redundancy, and alert systems that allow proactive mitigation of service degradation

Table 7.30 UC#3A.4 market(business) requirements

Req. ID	Subject (+Condition)	Commitment	Action + Object + {Constraint and/or Value}	Quantifiable measures for assessment
BR1	Cost effectiveness of orchestrated logistics operations	*Compulsory*	Reduce unit delivery costs {via dynamic routing and optimized vehicle usage}	≥10% reduction in cost per delivery compared to baseline
BR2	Integration of new services, devices, or APIs	*Compulsory*	Enable seamless integration {with minimal configuration and standardized orchestration interfaces}	≤2 day average integration time per component
BR3	Time-to-market for onboarding	*Good to have*	Streamline onboarding process {through	≥10% decrease in average onboarding time

	new logistics actors		modular architecture and reusable connectors}	
BR4	Operational resilience and failover response	*Compulsory*	Maintain service continuity {through fallback logic, alerting and redundancy mechanisms}	≥80% of delivery processes unaffected by service interruptions

Legal and Ethics Requirements

Legal and ethics compliance is a central dimension of UC3A.4, which involves the deployment of dynamic, AI-assisted routing mechanisms and the processing of real-time telemetry data from logistics infrastructure. As emphasized in the Competitiveness Compass, the growing regulatory relevance of edge computing and smart logistics calls for continuous ethical and legal monitoring throughout the lifecycle of the use case. The current section provides an initial high-level mapping of the legal and ethical landscape, which will be periodically updated as the project evolves and relevant EU regulations mature (including GDPR, AI Act, Data Act, and the Cyber Resilience Act).

Involvement of Volunteers

The UC does not foresee the involvement of volunteers, vulnerable populations, or any human participants for testing or data collection. The system is designed to interact exclusively with commercial logistics assets (e.g., refrigerated trucks), devices (e.g., GNSS sensors), and platforms, all operated by trained personnel of the participating partners.

Data Related Activities

Data processing lies at the core of UC3A.4 and includes the collection and orchestration of telemetry data such as:

- GNSS coordinates, temperature and humidity logs, vehicle identifiers, delivery status events, and routing metadata.

Key legal and ethical safeguards include:

- All data will be processed in compliance with the GDPR, with data minimization and purpose limitation principles explicitly applied.
- Personal data is not expected; however, pseudonymization mechanisms are in place where operator IDs or vehicle identifiers could be traced back to individuals.
- Edge processing reduces unnecessary data transmission and helps comply with the Data Act by localizing processing as close to the source as possible.
- A comprehensive Data Management Plan (DMP) will be prepared under WP1 – Task 1.2 (D1.2), defining lifecycle practices, access policies, data retention, and anonymization techniques.

All stakeholders interacting with data will follow security protocols including OAuth2-based access control, end-to-end encryption, and periodic data integrity audits.

Other

Food traceability and safety regulations: The routing system must comply with food transport standards (e.g., Regulation (EC) No 852/2004) regarding temperature control, delivery documentation, and cold-chain continuity.

Cybersecurity: The use of edge devices and mobile logistics units introduces risks addressed through cyber-resilient architecture, secure firmware, and device authentication mechanisms, in alignment with the Cyber Resilience Act.

Ethical oversight: The use case will be periodically reviewed by the consortium's Legal and Ethics Board (ARTHUR partner) to evaluate adherence to privacy, transparency, and fairness principles.

IPR

The smart routing algorithms developed by iLink and integrated into the orchestration framework will follow a clear IPR framework, ensuring openness where possible and commercial licensing when appropriate.

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