

D2.1 – DESK RESEARCH ON THE POTENTIAL OF AI IN HEALTHCARE LOGISTICS

Advancing AI Competencies in Healthcare Logistics
HEALTH-LOG-AI

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D2.2 – DESK RESEARCH ON THE POTENTIAL APPLICATIONS OF AI IN HEALTHCARE LOGISTICS

Advancing AI Competencies in Healthcare Logistics
HEALTH-LOG-AI

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Executive Summary

Artificial Intelligence is increasingly entering healthcare logistics, from demand forecasting and inventory management to cold-chain monitoring, warehouse automation, drug traceability and decision support. However, many professionals who work in pharmaceutical and healthcare supply chains are not AI specialists, even though they are increasingly expected to use, interpret or supervise AI-enabled systems in their daily work. This report presents the results of a desk research on current and emerging AI applications in healthcare logistics, with attention to Italy, Spain and Belgium. The analysis identifies the main areas where AI is already relevant for the sector and highlights the competences that healthcare logistics professionals need to develop, including data literacy, critical interpretation of AI outputs, awareness of system limitations, and understanding of ethical and regulatory responsibilities. These results provide the basis for the development of the HEALTH-LOG-AI AI literacy framework in D2.3.

1. Introduction

1.1 Purpose and scope of the report

This report presents the results of the desk and field research on current and potential applications of Artificial Intelligence (AI) in healthcare logistics. It was produced by Fondazione Scuola Nazionale Servizi (SNS), the lead partner for this deliverable, with contributions from all consortium partners.

The purpose of D2.2 is to map the state of the art of AI adoption in healthcare logistics and identify the most relevant and promising AI use cases across the key processes of the pharmaceutical and medical supply chain. The scope of the report lies at the intersection of two domains: Artificial Intelligence, understood broadly as the set of data-driven technologies that allow machines to perform tasks that would otherwise require human intelligence, and healthcare logistics, understood as the set of activities involved in the planning, management, and execution of the flow of medical products, pharmaceuticals, and related information from suppliers to patients.

Within this scope, the report focuses specifically on the so-called “last tiers” of the healthcare supply chain, namely the actors operating closest to the point of care: hospital and community pharmacists, logistics service providers, warehouse operators, and other professionals involved in the distribution and dispensing of medical products. This focus reflects the project’s core objective of developing AI literacy tools for non-expert professionals who are increasingly exposed to AI-powered systems in their daily operations, but may lack the knowledge and skills to use them effectively.

This deliverable is produced within Work Package 2 (WP2), “Defining the New Competencies for AI Literacy in Healthcare Logistics,” which constitutes the research and analytical pillar of the HEALTH-LOG-AI project. WP2 encompasses five activities that together build a comprehensive picture of the current AI landscape in healthcare logistics and the competency needs of professionals working in this sector. The present report was first presented in draft form at the Siena Kick-off Meeting on 27 March 2026, where its index and preliminary structure were discussed and validated by all consortium partners.

D2.2 is closely related to the other WP2 deliverables. D2.1, “Report on existing AI literacy frameworks and competency scales” (lead: UNISI), provides the theoretical and methodological framework for understanding AI literacy and the European standards against which competencies will be assessed, including EQF, ECVET and KSA. Building on this basis, D2.2 grounds the analysis in the specific context of healthcare logistics, its processes, AI applications and professional profiles. This mapping provides the empirical basis for the subsequent activities of WP2, especially the development of the AI literacy competency framework (D2.3) and the gap analysis survey (D2.4). It will provide input for D2.3, “AI literacy competency

framework and profiles for non-expert logistics professionals” (lead: UIC), by linking AI applications to possible competency requirements and proficiency levels for the target profiles. It will also support D2.4, “Gap analysis survey” (lead: UIC), by helping to identify the professional profiles, AI use cases and competency areas to be considered when assessing AI literacy levels and potential gaps among healthcare logistics professionals.

The report is organised in seven chapters, each corresponding to a distinct analytical layer of the research, from contextual framing to practical implications for the AI literacy competency framework. Chapter 2 provides the contextual background for the research by mapping the pharmaceutical supply chain in terms of actors, flows, and key processes. Chapter 3 reviews the current landscape of AI technologies relevant to logistics operations and synthesises the available evidence on AI adoption in the healthcare supply chain. Chapter 4 presents the core findings of the desk research, organised by logistics process. Chapter 5 reframes the findings of Chapter 4 through the lens of the professional profiles identified in section 2.5. Chapter 6 synthesises the findings into a set of structured inputs for the development of the competency framework. Chapter 7 summarises the key findings, acknowledges the main limitations and open questions, and outlines the next steps within WP2. The report is supplemented by two annexes: the desk research bibliography and a summary table of AI applications by process and profile.

1.2 Methodology

The research underlying this report combines a systematic desk research approach with evidence drawn from the direct professional experience of consortium partners. This includes field evidence, interviews and case studies conducted by UNISI, UIC, EAHP and SNS with healthcare logistics professionals across Italy, Spain and Belgium.

The desk research component of this report involved a systematic review of academic literature, industry reports, white papers, policy documents, and institutional publications relevant to AI adoption in healthcare logistics. Key sources consulted include peer-reviewed journals in the fields of supply chain management, health informatics, and operations research; reports from major industry analysts and industry bodies, including Deloitte Centre for Health Solutions (Taylor et al., 2020), McKinsey & Company (Alicke et al., 2021; McKinsey Global Institute, 2024), and Pharma.Aero (2024); publications from European institutions, including the European Commission, EMA, and EAHP; and case studies and technical documentation provided by consortium partners, notably UIC, UNISI, Artelnics, and EAHP.

The desk research covered the following thematic areas:

- The current landscape of AI technologies applicable to logistics operations

- Documented use cases of AI in pharmaceutical and healthcare supply chains
- Evidence on the level of AI adoption across the participating countries: Italy, Spain, and Belgium
- Regulatory and ethical frameworks governing AI use in the healthcare sector
- Existing barriers and enablers to AI integration in healthcare logistics organisations

2. The Healthcare Logistics Ecosystem

2.1 Overview of the pharmaceutical supply chain

The pharmaceutical supply chain (PSC) is a complex, multi-tiered system that includes the activities, organisations and processes involved in the production, distribution and dispensing of medicinal products, from the manufacturing of active pharmaceutical ingredients to the moment a medication reaches the patient. Compared with many other supply chains, the PSC operates under strict regulatory oversight, high safety requirements and significant time sensitivity. For this reason, efficiency, traceability and resilience are critical priorities at every level. At a general level, the PSC can be described as a sequence of interconnected tiers, each involving specific actors, processes and information flows.

Upstream: production and primary distribution

The upstream tier includes pharmaceutical manufacturers, both originators and generic producers, and primary packaging providers. These actors are responsible for producing medicinal products in compliance with Good Manufacturing Practice (GMP) standards and delivering them to distribution centres or directly to wholesalers. Key processes at this level include production planning, quality control, batch release and primary logistics management. AI applications at this tier focus mainly on process optimization, predictive quality control and demand-driven production planning.

Midstream: wholesale and secondary distribution

The midstream tier includes pharmaceutical wholesalers and full-line distributors, who act as intermediaries between manufacturers and dispensing points, such as hospitals, pharmacies and clinics. In Europe, this segment is characterised by a small number of large pan-European operators alongside national and regional distributors. Key processes include order management, warehousing, cold chain logistics and last-mile distribution to healthcare facilities. This tier is increasingly subject to end-to-end verification requirements under the EU Falsified Medicines Directive (FMD). The FMD is implemented through the European Medicines Verification System (EMVS), an end-to-end verification system managed by EMVO and national NMVOs, rather than a full track-and-trace system.

Downstream: last-tier logistics and dispensing

The downstream, or last-tier, includes the actors who receive, store and dispense medicinal products directly to patients or clinical users. This is the primary focus of the HEALTH-LOG-AI project. Key actors in this tier include:

- Hospital pharmacies, responsible for the procurement, storage, preparation and dispensing of medicines within hospital settings. Hospital pharmacists manage complex formularies, handle high-value and high-risk medicines, and increasingly interact with automated dispensing systems and electronic prescribing platforms.
- Community pharmacies, responsible for dispensing prescribed and over-the-counter medicines to outpatients. Community pharmacists manage inventory replenishment, interact with wholesale distributors, provide patient counselling and pharmacy services.
- Logistics service providers (LSPs) in healthcare, specialised in transportation, warehousing and value-added logistics services for pharmaceutical products. These actors operate under strict temperature and handling requirements and are subject to Good Distribution Practice (GDP) regulations.
- Healthcare facility logistics departments, internal units within hospitals and large clinics responsible for receiving, storing and distributing medical products, including medicines, medical devices and consumables, across wards and units.

These tiers are connected by three main types of flows: physical flows, related to the movement of products; information flows, including orders, delivery notes, track-and-trace data and prescriptions; and financial flows, such as invoicing, payment and insurance reimbursement. AI technologies are increasingly being applied across these flows to improve speed, accuracy and transparency.

Table 1 summarises the main actors in the pharmaceutical supply chain, their primary logistics roles and their relevance to the HEALTH-LOG-AI project.

Table 1. Main actors and logistics roles in the pharmaceutical supply chain.

SC Tier	Actor	Primary Logistics Role	Relevance to Project
Upstream	Pharmaceutical manufacturer	Production, primary distribution, batch release	Indirect - context
Upstream	Primary packaging supplier	Supply of packaging materials and components	Indirect - context
Midstream	Wholesale distributor	Warehousing, order fulfilment, distribution	Context + Cat.2 profiles
Midstream	3PL / Logistics service provider	Transportation, cold chain, last-mile delivery	Core - Cat.2 profiles
Downstream	Hospital pharmacy	Procurement, storage, dispensing	Core - Cat.1 profiles
Downstream	Community pharmacy	Dispensing, inventory management	Core - Cat.1 profiles
Downstream	Healthcare facility logistics	Internal distribution, ward supply	Core - Cat.2 profiles
Cross-tier	Public procurement authority	Tendering, contracting, compliance	Cat.3 profiles
Cross-tier	Regulatory authority	Market authorisation, surveillance	Context

2.2 Key organisational functions and processes

Within the pharmaceutical supply chain, several core logistics functions and processes recur across tiers and actor types. Understanding these processes is essential for mapping AI application opportunities, since each process represents a potential area for AI-driven improvement. The following functions and processes are the most relevant to the scope of this report.

Demand forecasting and procurement planning

Accurate prediction of future demand for pharmaceutical products is critical to avoid both stockouts, which can have serious patient safety consequences, and overstocking, which can lead to waste, write-offs and unnecessary capital immobilisation. Demand forecasting in healthcare logistics is particularly challenging because of high variability, including epidemics, seasonal patterns and treatment protocol changes, as well as the critical nature of many products and the complexity of the supply network. AI-based forecasting models, using machine learning and historical consumption data, are emerging as important tools to improve accuracy and responsiveness.

Inventory management and stock optimization

Inventory management includes the ordering, receiving, storing and issuing of pharmaceutical products. In hospital pharmacies and logistics warehouses, inventory management must balance service level requirements, namely ensuring product availability, with cost efficiency, by minimising holding costs and waste. AI applications in this area include automated reorder point calculation, expiry date management, ABC-XYZ analysis automation and intelligent allocation of storage space.

Warehouse management and automation

Pharmaceutical warehouses, whether operated by wholesalers, LSPs or hospital logistics departments, manage large and complex product portfolios under strict temperature, humidity and traceability requirements. AI-powered warehouse management systems (WMS) can optimize pick-and-pack operations, automate receiving and put-away processes, support robotics and autonomous vehicles, and

improve real-time inventory visibility. The integration of AI with IoT sensors also enables continuous monitoring of storage conditions and automated alerts in case of deviations.

Cold chain management

A significant and growing proportion of pharmaceutical products, including biologics, vaccines and many specialty medicines, require temperature-controlled storage and transportation, typically between 2 and 8°C, or in some cases at -20°C or below. Cold chain management involves continuous temperature monitoring throughout the supply chain, from production to administration. AI applications in this area include predictive monitoring systems that can anticipate temperature excursions before they occur, route optimization for temperature-sensitive shipments and automated compliance reporting.

Transportation and route optimization

The transportation of pharmaceutical products, whether by road, air, sea or rail, requires particular attention to delivery time, temperature control, security and regulatory compliance. AI-driven route optimization tools can reduce delivery times and costs, improve vehicle utilisation and increase responsiveness to disruptions. In last-mile delivery to hospitals and pharmacies, dynamic routing algorithms can adapt in real time to traffic conditions, delivery urgency and vehicle availability.

Drug tracking and traceability

Compliance with regulation requirements and need to verify dispensing of prescription medicines generates large volumes of serialisation and track-and-trace data. AI can help manage, analyse and use these data, for example to detect anomalies in supply chain flows that may indicate diversion or counterfeiting.

Reverse logistics

Reverse logistics in the pharmaceutical sector covers the handling of returned, recalled or expired products. It is a highly regulated process requiring strict chain-of-custody documentation and, in many cases, secure destruction of products. AI can support reverse logistics through automated classification of returned products, optimization of return flows and integration with quality management and regulatory reporting systems.

Decision support for clinical and administrative logistics

Beyond operational processes, AI is increasingly being applied to support clinical and administrative decision-making in healthcare logistics. Examples include AI-assisted medication reconciliation systems, intelligent formulary management tools and predictive analytics for surgical supply planning. These applications sit at the intersection of logistics and clinical practice and require AI literacy skills that combine logistics knowledge with an understanding of clinical workflows.

2.3 Regulatory and operational contexts

The HEALTH-LOG-AI project involves partners and target groups from three European countries: Italy, Spain, and Belgium. While the EU regulatory framework for pharmaceutical logistics applies across all three countries, the operational context varies significantly in terms of healthcare system organisation, digitalization maturity, and AI adoption. Understanding these differences is important for designing AI literacy interventions that are contextually relevant and practically applicable.

Italy

Italy's National Health Service (Servizio Sanitario Nazionale, SSN) is a universal, tax-funded system organised at regional level, with 20 regions holding significant autonomy in healthcare organisation and procurement. This regional structure creates considerable heterogeneity in the digitalization of healthcare logistics. Some regions, notably Lombardy, Emilia-Romagna, and Tuscany, have invested significantly in digital supply chain infrastructure, while others remain less advanced. Hospital pharmacies are typically managed by Aziende Sanitarie Locali (ASL) or hospital trusts and operate under the supervision of the regional health authority.

Italy's pharmaceutical logistics sector includes several large national wholesalers, including Federfarma and Farmacosmo networks, and a significant number of regional and local distributors. Fondazione Scuola Nazionale Servizi (SNS), a project partner, operates within this context and has a direct network of companies specialising in pharmaceutical logistics services, providing direct operational insights and professional profiles that inform this report.

In terms of AI adoption, Italy has been relatively slow in integrating AI into healthcare logistics compared with some northern European countries, despite significant theoretical potential. Estimates suggest that AI adoption in Italian healthcare logistics could generate savings of up to €21.74 billion annually. Key barriers include fragmented digital infrastructure, limited interoperability between regional systems, and a shortage of AI-skilled professionals at the operational level.

Spain

Spain's National Health System (Sistema Nacional de Salud, SNS) is similarly organised at regional level, with 17 autonomous communities (comunidades autónomas) responsible for healthcare delivery. The pharmaceutical distribution system is characterised by a strong cooperative structure, with COFARES and other regional cooperatives playing a dominant role alongside large multinational wholesalers. Hospital pharmacy in Spain is well developed and highly professionalised, with hospital pharmacists playing a central role in the clinical governance of medicines.

Spain has shown growing interest in AI applications in healthcare, with the Spanish government's National Artificial Intelligence Strategy (ENIA) identifying healthcare

as a priority sector. However, adoption in logistics and supply chain management remains limited, with approximately 11% of healthcare practitioners reporting the use of AI, mainly in clinical applications rather than logistics. The project partners UIC, based in Barcelona, and Artelnic, based in Villamayor, contribute expertise in AI literacy frameworks and AI technology development respectively, making Spain a key contributor to the project's research and innovation activities.

Belgium

Belgium has a federal healthcare system with shared competencies between the federal government and the regions of Flanders, Wallonia, and Brussels. The pharmaceutical distribution system is highly organised, with a strong presence of full-line wholesalers and a well-regulated hospital pharmacy sector. Belgium is home to several major pharmaceutical companies and has developed significant expertise in supply chain management for high-value medicines, including biological products and advanced therapy medicinal products (ATMPs).

In terms of AI readiness, Belgium is among the more advanced European countries, with a national AI strategy and significant investment in digital health infrastructure. EAHP, based in Brussels and a project partner, has been active in promoting digital health literacy among hospital pharmacists across Europe and has highlighted the need for targeted training on AI tools and their implications for pharmacy practice. Belgium's advanced healthcare IT infrastructure makes it a particularly relevant context for exploring the integration of AI in hospital pharmacy logistics.

2.4 Current challenges and digitalization trends

The healthcare logistics sector is undergoing a profound transformation, driven by a combination of structural pressures and technological opportunities. Understanding the current challenges is essential for contextualising the AI applications described in the following chapters, as many of the most promising AI use cases directly address these challenges.

Key challenges

Medicine shortages and supply chain fragility. The COVID-19 pandemic exposed the vulnerability of global pharmaceutical supply chains to geopolitical disruptions, demand shocks, and over-concentration of production in specific regions. Medicine shortages, already a structural problem in Europe before the pandemic, have become a major policy concern. Healthcare logistics organisations are under pressure to develop more resilient procurement and inventory strategies, which AI can support aspects of shortage management — notably through improved demand forecasting and risk modelling — though medicine shortages are complex systemic issues with multiple causes, and AI is not a comprehensive solution in isolation (European Commission, 2023).

Regulatory complexity and compliance requirements. The implementation of the Falsified Medicines Directive, the Medical Devices Regulation (MDR), and the In Vitro Diagnostic Medical Devices Regulation (IVDR), combined with increasing GDP inspection activity, has significantly increased the compliance burden on pharmaceutical logistics operators. Managing serialisation data, ensuring product traceability, and documenting temperature chain integrity require sophisticated data management capabilities that many organisations still lack.

Cost pressure and efficiency demands. Healthcare systems across Europe are under sustained pressure to reduce costs while maintaining or improving service quality. In logistics, this translates into demands for greater operational efficiency, reduced waste, especially from expired products, and optimized use of transport and warehouse resources. AI-driven optimization tools offer significant potential for cost reduction, but require investment in digital infrastructure and staff capability.

Workforce skills gap and digital literacy. Particularly relevant to the HEALTH-LOG-AI project is the growing skills gap in healthcare logistics. As AI and digital tools are increasingly deployed in warehouse management, demand forecasting, and dispensing systems, the professionals who operate these systems, including pharmacists, logistics operators, and procurement officers, need competencies that their initial training may not have provided. This is the gap that the project aims to address. The recent position paper by EAHP also highlights the need of “additional resources and training opportunities to healthcare professionals and students that focus on both boosting their AI skills and promoting AI literacy among patients and healthcare professionals”.

Data fragmentation and interoperability barriers. The effective deployment of AI in healthcare logistics requires access to large volumes of high-quality, integrated data. However, the pharmaceutical supply chain is characterised by significant data fragmentation, with different actors using incompatible systems and data formats. The lack of interoperability between hospital information systems, pharmacy management systems, and logistics platforms is one of the main barriers to AI adoption in the sector.

Key digitalization trends

European Health Data Space (EHDS). The European Health Data Space, proposed by the European Commission in 2022 and officially adopted in 2025 is currently in the implementation process. It aims to create a common framework empowering individuals to access and use their data while enabling the secure and trustworthy reuse of health data across the EU. For pharmaceutical logistics, the EHDS may, over time, facilitate certain health data flows relevant to logistics — though its primary focus is on personal health data for research, innovation and policy purposes, accessed through Health Data Access Bodies, rather than ongoing supply chain data exchange at European level.

Hospital digitalization and EHR integration. The widespread adoption of Electronic Health Records (EHRs) and Hospital Information Systems (HIS) is creating new opportunities for integrating clinical data with logistics management. AI systems that link prescription data with inventory management, for example, can significantly improve the accuracy of demand forecasting for hospital pharmacies.

Automation and robotics in warehousing. Automated storage and retrieval systems (AS/RS), robotic dispensing systems, and autonomous mobile robots (AMRs) are increasingly being deployed in pharmaceutical warehouses and hospital pharmacies. These systems generate large volumes of operational data that AI can exploit for continuous process optimization.

IoT and real-time monitoring. The proliferation of IoT sensors in pharmaceutical logistics, used for temperature monitoring, location tracking, and condition sensing, is creating unprecedented visibility into the physical state of the supply chain. AI systems that can process and interpret these data in real time are becoming essential for proactive supply chain management.

2.5 Profiles of non-expert professionals in healthcare logistics

A central objective of the HEALTH-LOG-AI project is to develop AI literacy tools for non-expert professionals, namely professionals whose primary expertise lies in pharmacy, logistics, procurement, or supply chain management, rather than in AI or data science. Understanding who these professionals are, what they do, and how they interact with AI systems is essential for designing relevant and effective training interventions.

The profiles presented in this section were developed and discussed at the Siena Kick-off Meeting on 27 March 2026 and draw on the professional experience of consortium partners. They are organised into three categories, reflecting the main stakeholder groups in the healthcare logistics sector. For each category, the organisational levels covered are indicated: Strategic, Managerial, Tactical, and Operational. These levels help determine the type and depth of AI literacy required.

The definitions of the four organisational levels are provided in the companion document “List of Potential Profiles Involved in the Project” (WP2 Working Document, March 2026). These definitions are simplified references intended to convey the scope of AI literacy relevant to each level, rather than exhaustive descriptions of role responsibilities.

Category 1: Pharmacists

This category includes hospital and community pharmacists responsible for the procurement, storage, preparation, and dispensing of medicines. Pharmacists in healthcare logistics increasingly interact with AI-powered dispensing robots, intelligent inventory management systems, and AI-assisted procurement tools. Their AI literacy needs span a wide range of organisational levels, from strategic

decisions about AI adoption to operational use of AI-powered dispensing systems. **Table 2** summarises the main pharmacist profiles considered in the report, indicating their organisational level and the primary AI interaction contexts associated with each role.

Table 2. AI interaction contexts for pharmacists.

Profile	Org. Level	Primary AI Interaction Context
Hospital pharmacist (head of department)	Strategic / Managerial	AI governance, procurement strategy, formulary management
Hospital pharmacy director / chief pharmacist	Strategic	AI adoption decisions, budget, regulatory compliance
Pharmaceutical procurement and purchasing manager	Tactical / Managerial	AI-assisted procurement, demand forecasting tools
Pharmacy warehouse and dispensing coordinator	Tactical / Operational	Automated dispensing systems, inventory AI tools
Community pharmacist	Operational	Dispensing support systems, stock replenishment AI
Clinical pharmacist with logistics responsibilities	Tactical / Operational	Medication reconciliation AI, clinical supply planning

Category 2: Logistics managers and operators

This category includes the professionals responsible for the physical management of the pharmaceutical supply chain, from strategic supply chain directors to operational warehouse and delivery staff. This is the category most directly involved in the logistics processes described in section 2.2 and the one where AI adoption is advancing most rapidly, driven by automation in warehousing, route optimization tools, and real-time monitoring systems. **Table 3** summarises the logistics management and operational profiles considered in the report, indicating their organisational level and the main AI interaction contexts associated with each role.

Table 3. AI interaction contexts for logistics managers and operators.

Profile	Org. Level	Primary AI Interaction Context
Supply chain manager / Healthcare logistics director	Strategic / Managerial	Supply chain AI strategy, risk management, KPI monitoring
Warehouse manager / Head of pharmaceutical warehouse	Managerial	WMS with AI, automation oversight, performance management
Distribution / Transportation manager	Managerial / Tactical	Route optimization AI, fleet management, cold chain systems
Supply chain coordinator / Logistics coordinator	Tactical	Order management systems, ERP with AI modules
Procurement officer / Purchasing officer	Tactical	AI-assisted tendering, supplier analytics, demand signals
Logistics planner / Demand and distribution planner	Tactical	AI forecasting tools, replenishment planning systems
Inventory manager / Stock controller	Tactical / Operational	Inventory AI tools, expiry management, ABC analysis
Cold chain specialist	Operational	IoT monitoring systems, AI temperature alerts, compliance
Last-mile delivery coordinator	Operational	Dynamic routing AI, delivery tracking systems
Reverse logistics specialist	Operational	Returns classification AI, regulatory reporting systems

Logistics operator / Warehouse/packaging operator	Operational	WMS interfaces, automated picking systems, scan tools
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Category 3: Other supply chain actors

This category covers actors who, while not primarily logistics professionals, play important roles in shaping the conditions under which AI is adopted in healthcare logistics. Public procurement officials set the terms and standards for pharmaceutical procurement at institutional level. Packaging providers and wholesalers occupy key positions in the physical and information flows of the supply chain. Their AI literacy needs are more focused on awareness and governance than on operational tool use. **Table 4** summarises the other supply chain actors considered in the report, indicating their organisational level and the main AI interaction contexts associated with each role.

Table 4. AI interaction contexts for other supply chain actors.

Profile	Org. Level	Primary AI Interaction Context
Public procurement official (ASL, hospital authority)	Institutional	AI-aware procurement frameworks, compliance, tendering
Pharmaceutical wholesaler — logistics manager	Strategic / Industry	Distribution AI tools, demand analytics
Packaging provider — supply chain manager	Strategic / Industry	Track-and-trace systems, serialisation, AI quality control

3. AI in Healthcare Logistics: State of the Art

This chapter provides an overview of the current state of AI adoption in healthcare logistics, drawing on the research conducted as part of D2.2. It is structured in three sections: a taxonomy of the AI technologies most relevant to logistics operations (3.1), a synthesis of the available evidence on AI adoption in the healthcare supply chain, enriched with use cases provided by consortium partners UIC, UNISI, EAHP and Artelnics (3.2), and an analysis of the main barriers and enablers to AI adoption in the sector (3.3).

3.1 Overview of AI technologies relevant to logistics

Artificial Intelligence is not a single technology, but a family of techniques and approaches that allow machines to perform tasks that would typically require human cognitive capabilities, such as learning from data, recognising patterns, making decisions and understanding language. For the purposes of this report, AI is understood in a broad sense that includes the following main technology families, all of which have documented applications in logistics and supply chain management.

Machine Learning and Deep Learning

Machine Learning (ML) refers to the ability of computational systems to learn from data without being explicitly programmed for each specific task. ML algorithms identify patterns in large datasets and use them to make predictions or decisions.

In logistics, ML is the foundational technology behind most AI applications: demand forecasting models, route optimization algorithms, anomaly detection systems and predictive maintenance tools are all built on ML techniques. Deep learning, a subset of ML based on artificial neural networks with multiple layers, is particularly powerful for complex pattern recognition tasks such as image classification and natural language processing. For non-expert logistics professionals, the practical implication of ML is that the systems they interact with are increasingly capable of learning from operational data, including their own actions, to improve their performance over time. This creates both opportunities, such as systems that adapt to local conditions and workflows, and risks, such as systems whose behaviour may change in ways that are not transparent to the user.

Predictive analytics

Predictive analytics refers to the use of statistical models and ML algorithms to forecast future events or outcomes based on historical data. In healthcare logistics, predictive analytics is applied to demand forecasting, inventory management, cold chain management and maintenance planning, for example by predicting medicine consumption, stockout risk, temperature excursions or equipment failure. Predictive analytics tools are typically embedded in enterprise resource planning (ERP) systems, warehouse management systems (WMS) or dedicated supply chain planning platforms, making them one of the most widely adopted AI application categories in logistics.

Computer vision

Computer vision enables machines to interpret and understand visual information, including images and video, from the physical world. In pharmaceutical logistics, computer vision applications include automated label reading and verification, quality control of packaging and labelling, barcode and QR code scanning, and visual inspection of products in warehouses. Computer vision is also at the heart of autonomous mobile robot (AMR) navigation systems, enabling robots to move safely in dynamic warehouse environments. For logistics professionals, computer vision typically appears in the form of automated verification systems that flag discrepancies or errors without requiring manual visual inspection.

Natural Language Processing

Natural Language Processing (NLP) enables machines to understand, interpret and generate human language, both written and spoken. In healthcare logistics, NLP applications include intelligent document processing, such as extracting structured data from delivery notes, invoices and regulatory documents, chatbot-based interfaces for logistics systems, and AI-powered search tools for product catalogues and regulatory databases. The recent emergence of large language models (LLMs), such as those underpinning conversational AI tools, is opening new possibilities for NLP in logistics, including AI-assisted compliance document generation and natural language querying of supply chain data.

Robotics and automation

Robotics in logistics refers to the use of physical machines to automate material handling tasks such as picking, packing, sorting, transporting and dispensing. In pharmaceutical warehouses and hospital pharmacies, robotic systems are increasingly common. Automated dispensing robots, conveyor-based sorting systems and autonomous mobile robots (AMRs) are deployed to handle high-volume, repetitive tasks with greater speed and accuracy than human operators. It should be noted that automation and robotics do not necessarily imply AI. However, AI plays an important role in enabling more advanced robotic systems to operate flexibly and safely in dynamic environments, through computer vision, path planning algorithms and collaborative robot interfaces.

Internet of Things (IoT) and AI-driven monitoring

While not an AI technology in itself, the Internet of Things, understood as the network of connected sensors and devices that generate real-time data about physical conditions and events, is a critical enabler of AI in logistics. In pharmaceutical supply chains, IoT sensors monitor temperature, humidity, shock and location of products throughout the supply chain. AI systems process these data streams to detect anomalies, predict deviations and trigger automated responses. The combination of IoT and AI is particularly relevant in cold chain management, where real-time monitoring can prevent costly temperature excursions and support product quality and patient safety.

Table 5 summarises the main AI technology families, their maturity level in healthcare logistics and their primary application areas.

Table 5. AI technology families relevant to healthcare logistics.

AI Technology	Maturity in HC Logistics	Primary Application Areas
Machine Learning / Deep Learning	Medium-High	Demand forecasting, anomaly detection, route optimization, predictive maintenance
Predictive Analytics	High	Inventory management, stockout prediction, demand planning, expiry management
Computer Vision	Medium	Label verification, quality control, AMR navigation, automated dispensing
Natural Language Processing	Low-Medium	Document processing, compliance reporting, chatbot interfaces, LLM-assisted tools
Robotics / Automation (AI-enabled)	Medium-High	Warehouse automation, automated dispensing, autonomous delivery
IoT + AI Monitoring	Medium-High	Cold chain management, real-time tracking, predictive alerts

3.2 Existing literature and industry evidence on AI adoption

A substantial and growing body of academic and industry literature documents the application of AI in healthcare logistics. The research conducted for D2.2 reviewed over 50 relevant sources, including academic literature, industry reports and evidence from consortium partners, including peer-reviewed papers, industry reports, white papers and policy documents. This section synthesises the main

findings of this review, organised by key themes. It also integrates use cases and practical examples contributed by consortium partners UIC (Barcelona), UNISI (Siena) and Artelnics (Villamayor), which provide concrete illustrations of AI in action in logistics-adjacent contexts.

Demand forecasting and inventory optimization

Demand forecasting is one of the most mature and widely documented AI application areas in healthcare logistics. Multiple studies show that ML-based forecasting models, particularly ensemble methods such as gradient boosting and random forests, as well as recurrent neural networks for time-series data, can significantly outperform traditional statistical forecasting approaches such as ARIMA and exponential smoothing. This is especially relevant for volatile and intermittent demand patterns typical of pharmaceutical products.

Taylor et al. (2020) identified demand forecasting as the AI application with the highest near-term value creation potential in pharmaceutical logistics, estimating potential inventory cost reductions of 20–30% through AI-driven optimization. Similarly, a 2024 industry white paper by Pharma.Aero found that demand forecasting and inventory optimization were among the top AI investment priorities among pharmaceutical logistics executives.

Artelnics, sales prediction for supply chain optimization

Artelnics developed an AI-based sales prediction system for SEAT/Volkswagen within the Fast-lane project, analysing approximately 1,400 manufacturing combinations to optimize the supply chain process. A similar approach was applied for Schneider Electric, where sales predictions were generated for approximately 800 products, taking into account customer reviews to understand client interactions and improve logistics performance. These cases demonstrate the scalability of ML-based demand forecasting across complex product portfolios, a challenge that is directly comparable to pharmaceutical inventory management with large formularies.

Supply chain visibility and track-and-trace

The implementation of the EU Falsified Medicines Directive has driven significant investment in serialisation infrastructure across the European pharmaceutical supply chain. AI is increasingly being applied to use the data generated by these systems, not only for compliance verification but also for supply chain analytics, counterfeit detection and flow optimization.

AI for healthcare supply chain coordination

Research conducted at UNISI's DIISM department, using surveys, interviews and case studies, has explored the application of AI and digital technologies in the pharmaceutical supply chain, with a focus on effective diffusion and the

collaboration mechanisms needed to sustain it. Studies by Professors Pessot and Murgia on healthcare supply chain optimization and coordination provide evidence of the benefits of data-driven approaches to logistics innovation and identify AI literacy as a key enabler for realising these benefits at the operational level. Results indicate that AI is primarily applied in logistics, both forward logistics, such as the root cause assessment of shipment deviations, and reverse logistics, such as the return process of pharmaceutical boxes. AI is also applied in packaging, for example in the selection of the best isothermal packaging. Companies that adopt advanced technologies such as blockchain or drones tend to adopt AI at higher rates. Technology providers, which support customized AI implementation, and service providers, such as freight forwarding companies, play an important role as intermediaries between companies and customer needs. Multi-stakeholder organizations can also act as catalysts for AI growth by aligning priorities among regulatory decision-makers and pharmaceutical supply chain companies, and by facilitating the transition from a technological concept of AI to actual use cases.

Research by UNISI's Department of Information Engineering and Mathematics (DIISM) on the digitalisation of the pharmaceutical supply chain highlights the potential of AI-driven visibility platforms to improve coordination between supply chain actors and reduce the information asymmetries that contribute to inefficiency and stockouts. The SAIHUB foundation, co-promoted by UNISI, has identified supply chain visibility as a priority application area for AI in life sciences.

AI literacy for non-expert professionals

Research by the QISE group at UIC Barcelona, led by Dr. Ruggero Colombari and Prof. Frederic Marimon, has examined competency gaps in digitalized industrial environments and the impact of AI adoption on managerial roles and skills development. Their work on the ALFA project, AI Literacy For All, and the Observatory for AI and New Technologies (OIAN) provides evidence that non-expert professionals in logistics and supply chain roles face significant AI literacy gaps that impede effective adoption of AI tools. Studies on Generative AI adoption in organisations and HEIs further illustrate the range of literacy needs, from basic awareness to hands-on tool use, that training programmes must address.

In a recent case study conducted with the UNISI team in a large Spanish pharmaceutical company and its downstream supply chain, results show that AI adoption in pharmaceutical demand planning is shaped by the interplay of integrated socio-technical resources, institutional frictions and AI value realization. AI literacy depends on the combination of interoperable digital infrastructures and adaptive human capabilities, including management support, skill development and cross-functional collaboration. Companies' readiness is often constrained by institutional frictions, including regulatory rigidity, fragmented data environments, limited internal expertise and broader cultural resistance to technological change. Nevertheless, when these tensions are progressively managed, AI begins to generate value through better forecast responsiveness, more proactive decision-making and improved resource allocation, while also reinforcing organizational learning through iterative use.

Cold chain management

Temperature-controlled logistics for pharmaceutical products is an area where AI adoption is advancing rapidly. This is driven by the growth of biologics and vaccines, which typically require 2–8°C storage, increasing regulatory scrutiny of cold chain documentation and the availability of low-cost IoT sensors that generate continuous temperature data.

A 2022 review of AI applications in pharmaceutical cold chain management identified predictive temperature monitoring, based on ML models trained on historical temperature profiles and environmental data, as the most impactful application. Such systems may reduce the number of temperature excursions by 30–40% compared with threshold-based alert systems. AI-driven route optimization for temperature-sensitive shipments is also documented as a high-value application, particularly for last-mile delivery to remote healthcare facilities.

Warehouse automation and robotics

Automated dispensing robots in hospital pharmacies represent one of the most visible and well-documented AI applications in healthcare logistics. Systems such

as those produced by Swisslog, BD Rowa and Omnicell are deployed in hundreds of European hospitals and can dispense medicines with accuracy rates reported by manufacturers as exceeding 99% in controlled conditions (vendor claims; independent peer-reviewed validation data are limited). These systems are increasingly being enhanced with AI capabilities, including intelligent inventory management, expiry date optimization and predictive replenishment, that go beyond simple automation.

In pharmaceutical distribution warehouses, AI-powered warehouse management systems (WMS) and autonomous mobile robots (AMRs) are being deployed by major wholesalers and third-party logistics providers (3PLs) to improve picking accuracy, reduce order fulfilment times and handle the growing complexity of pharmaceutical product portfolios. Alické et al. (2021) estimated that AI-enabled warehouse automation could reduce supply chain operating costs by 15–25% over a five-year horizon.

AI in healthcare-specific applications

Beyond general logistics applications, several AI use cases are specific to the healthcare and pharmaceutical context. Medication reconciliation AI systems, which cross-reference patient medication records across care settings to identify discrepancies and potential adverse events, are being developed and piloted in some hospital settings, though overall deployment of AI in healthcare systems remains limited (European Commission, 2025a) and have direct implications for pharmacy logistics. AI-assisted clinical decision support systems that recommend treatment protocols and dosage adjustments generate demand signals that, when integrated with pharmacy management systems, can significantly improve the accuracy of drug consumption forecasting.

Artelnics: AI for Personalised Medicine and Healthcare Analytics

Artelnics has demonstrated the application of AI in healthcare analytics through the DIPCAN project, in collaboration with MD Anderson and Eurofins, which analysed 2,000 patients with metastatic cancer to optimize treatment protocols based on clinical, biochemical, genetic and radiomic profiles. While primarily a clinical AI application, this work illustrates the data processing and pattern recognition capabilities of AI that are directly transferable to healthcare logistics contexts. This is particularly relevant in the management of specialised, high-value pharmaceutical products such as oncology medicines, where demand is patient-specific and forecasting is challenging.

Synthesis: AI adoption maturity in healthcare logistics

Synthesising the evidence from both desk and field research, the report concludes that AI adoption in healthcare logistics is characterised by significant

heterogeneity across application areas, organisational types and countries. The following general conclusions can be drawn:

- Predictive analytics for demand forecasting and inventory optimization is the most mature application area, with documented deployments across multiple countries and organisation types. However, adoption is concentrated among larger organisations with sufficient data infrastructure.
- Robotic automation in hospital pharmacy and pharmaceutical warehousing is well established in northern and western Europe, but uptake remains limited in southern and eastern Europe, including Italy and Spain.
- Cold chain AI is advancing rapidly, driven by the growth of temperature-sensitive biologics and increasing attention to cold chain documentation quality, but many smaller logistics operators lack the IoT infrastructure needed to use AI monitoring tools effectively.
- Track-and-trace AI is largely compliance-driven and concentrated at the wholesale and manufacturing level. Its potential for supply chain analytics and shortage management is not yet widely exploited.
- NLP and generative AI applications in logistics are at an early stage, with significant potential but limited documented deployments in the healthcare logistics sector specifically.
- AI literacy is consistently identified as a limiting factor for AI adoption across all application areas and organisational levels. The skills gap is most acute at the operational and tactical levels, which are precisely the target group of the HEALTH-LOG-AI project.

3.3 Barriers and enablers to AI adoption in the sector

Understanding why AI adoption in healthcare logistics often proceeds more slowly than the available evidence would suggest is essential for designing effective AI literacy interventions. The research identified a consistent set of barriers and enablers that recur across countries, organisation types, and application areas.

Key barriers

Data quality and availability. AI systems are only as good as the data they are trained on. In healthcare logistics, data quality is frequently insufficient for AI deployment. Data are often fragmented across incompatible systems, missing or inconsistent, and not captured at the level of detail required for effective ML training. The lack of interoperability between hospital information systems, pharmacy management systems, and logistics platforms is one of the most frequently cited barriers in the literature.

Digital infrastructure gaps. Many healthcare logistics organisations, particularly smaller pharmacies, regional distributors, and public healthcare facilities in southern Europe, lack the digital infrastructure needed to deploy AI systems, including broadband connectivity, cloud computing capacity, and IoT sensors. This

creates a risk of a digital divide within the sector, where the benefits of AI are concentrated among larger and better-resourced organisations.

Regulatory complexity and risk aversion. The pharmaceutical sector operates under strict regulatory oversight designed to ensure patient safety and product quality. Healthcare organisations are typically cautious about the adoption of new technologies. The EU AI Act (Regulation 2024/1689) introduces specific requirements for high-risk AI systems in healthcare, which add important safeguards around transparency, explainability and human oversight — requirements that, while complex to implement, serve the goal of safe and trustworthy AI adoption. Regulatory uncertainty can represent a challenge for smaller organisations navigating compliance.

Cost and return on investment uncertainty. AI deployment requires upfront investment in data infrastructure, system integration, staff training, and change management. For many healthcare logistics organisations, especially in the public sector, it is difficult to demonstrate a clear and quantifiable return on investment. This is partly due to the complexity of measuring supply chain performance improvements and to the long time horizons usually required for AI systems to reach full operational maturity.

Workforce skills gap and resistance to change. The EAHP's 2023 Digital Health Position Paper identifies the shortage of AI-literate professionals as a critical barrier to digital health adoption in hospital pharmacy. The wider logistics literature points in the same direction: operational and tactical staff, who are often the primary users of AI tools in practice, may lack the knowledge and confidence needed to use AI systems effectively. This can lead to underutilisation, workarounds, and, in some cases, active resistance. This is the barrier most directly addressed by the HEALTH-LOG-AI project.

Trust and explainability concerns. Healthcare professionals, including pharmacists and clinical logistics staff, often express concerns about the transparency and explainability of AI decision-making. When an AI system recommends a procurement decision, flags a potential stockout, or suggests a medication substitution, the professional needs to understand the basis of the recommendation in order to act on it responsibly. The “black box” nature of many ML systems is therefore a significant trust barrier, particularly in safety-critical contexts.

Key enablers

Regulatory drivers and standardisation. Regulatory requirements can also act as enablers of AI adoption. The EU AI Act's framework for trustworthy AI, together with the European Health Data Space initiative, may create a more predictable regulatory environment and increase organisations' willingness to invest in AI.

Demonstrated ROI in leading organisations. The growing body of evidence from early adopters, documented in industry reports and case studies, is reducing

uncertainty about the return on investment from AI in healthcare logistics. As more organisations publish their experiences with demand forecasting AI, automated dispensing, and cold chain monitoring, the business case for AI becomes more concrete and the perceived risk of adoption decreases.

Vendor ecosystem maturity. The pharmaceutical logistics technology vendor ecosystem has matured significantly in recent years. A growing range of commercially available AI-powered solutions now exists for demand forecasting, WMS optimization, cold chain monitoring, and automated dispensing. The availability of off-the-shelf solutions reduces the technical barrier to AI adoption and allows organisations to benefit from AI capabilities without requiring in-house data science expertise.

EU policy and funding support (including the Apply AI Strategy). The European Commission’s Digital Decade policy framework, the National Recovery and Resilience Plans (NRRPs) funded by NextGenerationEU, and programmes such as Horizon Europe, the Digital Europe Programme, and the Apply AI Strategy (European Commission, 2024a) provide significant funding for digital transformation in healthcare. These resources can reduce the financial barrier to AI adoption for public healthcare organisations, particularly in countries such as Italy and Spain, where public investment in healthcare digitalisation has historically lagged.

Growing AI literacy and training supply. The supply of AI education and training resources targeted at non-technical professionals is growing rapidly, driven by policy initiatives, academic programmes, and private sector providers. Projects such as HEALTH-LOG-AI contribute directly to this ecosystem by developing sector-specific AI literacy frameworks and training materials for healthcare logistics professionals.

Table 6 provides a structured summary of the main barriers and enablers identified through the desk and field research, together with an indicative assessment of their relevance for the target profiles of the HEALTH-LOG-AI project of the HEALTH-LOG-AI project.

Table 6. Barriers and enablers to AI adoption in healthcare logistics.

Factor	Type	Most affected profiles	Relevance for training design
Data quality and availability	Barrier	All profiles	High: AI literacy must include data awareness
Digital infrastructure gaps	Barrier	Cat.2 Operational, Cat.3	Medium: context-dependent
Regulatory complexity	Barrier	Cat.1 Strategic, Cat.3 Institutional	High: regulatory AI literacy needed
Cost / ROI uncertainty	Barrier	Cat.1–3 Managerial / Strategic	Medium: business case skills needed
Workforce skills gap	Barrier	Cat.1–2 Tactical / Operational	Critical: core target of the project
Trust and explainability concerns	Barrier	Cat.1 Operational, Cat.2 Tactical	High: explainable AI literacy needed
Regulatory drivers (AI Act)	Enabler	Cat.2 Managerial, Cat.3	Medium: compliance as entry point
Demonstrated ROI in peers	Enabler	Cat.1–3 Managerial / Strategic	Medium: case studies as training tool
Vendor ecosystem maturity	Enabler	Cat.2 Tactical / Operational	High: tool-specific literacy needed

EU policy and funding support	Enabler	All profiles	Medium: awareness and opportunity
Growing training supply	Enabler	All profiles	High: scalable training approach

4. AI applications by logistics process

This chapter constitutes the core analytical output of D2.2, integrating desk research findings with field evidence from consortium partners. For each of the ten logistics processes identified in section 2.2, it presents the specific AI applications that are currently available or in development, the evidence of adoption drawn from the literature and industry sources, the use cases contributed by consortium partners where applicable, and the key implications for the AI literacy of healthcare logistics professionals.

Each section follows a consistent structure: a brief description of the process and its relevance to healthcare logistics, an overview of the AI applications identified, a process snapshot summarising primary target profiles and key tools, and a discussion of literacy implications. The chapter can be read sequentially, for a comprehensive view of the AI landscape, or selectively, with each section standing independently as a reference for specific processes.

Use cases and field evidence from consortium partners UIC, UNISI, EAHP and Artelnic are integrated throughout this chapter where directly relevant to the process under discussion. Additional use cases are presented in standalone boxes in Chapter 3, section 3.2.

4.1 Demand forecasting

Demand forecasting is the process of estimating future consumption of pharmaceutical products in order to support procurement and replenishment decisions. In healthcare logistics, accurate demand forecasting is critical to maintaining product availability while minimising waste from overstocking and expiry. This is particularly challenging because pharmaceutical demand is highly variable and often unpredictable, due to epidemiological events, treatment protocol changes, seasonal patterns and supply disruptions. The consequences of stockouts in clinical environments further increase the importance of reliable forecasting.

AI applications

Machine learning-based forecasting models. ML algorithms, particularly gradient boosting methods such as XGBoost and LightGBM, random forests, and long short-term memory (LSTM) neural networks, are being applied to pharmaceutical demand forecasting with documented improvements in accuracy of 20–40% over traditional statistical methods. These models can incorporate a wider range of demand drivers than classical approaches, including clinical data, such as admission rates and diagnosis trends, external signals, such as epidemiological

surveillance data and pricing changes, and supply chain events, such as lead time variability and supplier disruptions.

Ensemble and hybrid forecasting systems. Enterprise-scale pharmaceutical demand planning platforms, such as SAP IBP, Blue Yonder and o9 Solutions, increasingly combine multiple ML models with domain-specific rules and human expert input in ensemble architectures that balance algorithmic accuracy with operational practicality. These hybrid systems allow logistics professionals to review, adjust and override AI-generated forecasts, making AI literacy a critical enabler of effective human-AI collaboration in the forecasting process.

AI-assisted procurement automation. Beyond forecasting, AI is being applied to automate and optimize the procurement process itself. Intelligent sourcing tools can identify optimal suppliers based on price, lead time, reliability and sustainability criteria. AI-powered contract management systems can flag renewal deadlines and performance deviations. Automated purchase order generation systems can trigger procurement actions based on inventory level thresholds, reducing manual workload and the risk of human error.

Demand forecasting and procurement planning	
Primary target profiles	Logistics planner, procurement officer, supply chain manager, hospital pharmacist
Key AI tools / systems	ML forecasting platforms, SAP IBP, Blue Yonder, ERP AI modules, automated PO systems

Literacy implications

Logistics professionals involved in demand forecasting need to understand how ML forecasting models work at a conceptual level, including their inputs, outputs and limitations. This is necessary to interpret AI-generated forecasts critically and intervene effectively when the model produces unreliable predictions, for example during demand shocks or product launches. They also need to understand the data requirements of AI forecasting systems and the importance of data quality for model performance.

4.2 Procurement planning and sourcing optimization

Procurement planning in healthcare logistics is a distinct and complex process that goes well beyond demand forecasting. While demand forecasting estimates what and how much will be needed, procurement planning determines how, when, and from whom to purchase, under what contractual conditions, and at what cost. In hospital pharmacies and healthcare facility logistics departments, procurement decisions involve grouping requirements across departments, negotiating with multiple suppliers, managing lead times and supplier reliability, optimising order quantities and frequencies, and ensuring compliance with public procurement regulations. These decisions must balance service continuity, cost

efficiency and regulatory compliance, often simultaneously and under time pressure.

AI applications

AI-assisted cross-departmental demand consolidation. In hospital and public procurement settings, purchase orders often need to aggregate requirements from multiple wards, departments or facilities. AI systems can automatically consolidate these signals — taking into account demand variability, stock positions and shared supplier contracts — to identify opportunities for grouping purchases, improving economies of scale and reducing order fragmentation. This is particularly relevant for public procurement authorities operating across multiple healthcare facilities.

Lead time and supplier reliability modelling. AI tools can model historical supplier performance — including lead time variability, fill rate, delivery accuracy and shortage frequency — to produce dynamic supplier scorecards. These scorecards feed directly into procurement decisions: which supplier to prioritise for critical products, when to trigger emergency procurement from a secondary source, and how to adjust safety stock requirements in response to supplier unreliability. This approach has direct implications for managing the risk of medicine shortages, a growing concern across EU healthcare systems (European Commission, 2023).

Order quantity and frequency optimisation. Traditional procurement relies on static economic order quantity (EOQ) models or manual buyer judgement. AI-powered procurement tools replace these with dynamic optimisation models that continuously recalculate order quantities and frequencies based on demand signals, available storage capacity, budget constraints, and upcoming contract or price change events. Critically, these models can balance cost optimisation against the risk of overstocking: unlike simple reorder-point systems, they can identify situations where grouping orders or advancing procurement is cost-effective without generating excess inventory or tying up working capital.

AI-assisted tendering and contract intelligence. For procurement activities subject to EU public procurement rules — including most hospital purchasing of medicines and medical devices — AI tools are emerging that support tender preparation, supplier evaluation, and contract performance monitoring. These tools can analyse historical procurement data to identify optimal lot structures, flag non-competitive pricing, and monitor ongoing contract compliance. The EU Public Procurement Directive (2014/24/EU) and sector-specific frameworks govern these processes; AI tools must operate within these constraints while improving efficiency and transparency.

Literacy implications

Procurement managers and purchasing officers need to understand how AI procurement tools generate their recommendations and on what data they rely. They need to be able to evaluate AI-suggested order quantities critically — recognising when the model's optimisation logic may not account for exceptional

circumstances, such as anticipated shortages, contractual constraints, or budget period effects — and to override AI recommendations with documented professional judgement. They also need sufficient understanding of supplier performance analytics to interpret AI-generated scorecards and to act on supplier reliability signals proactively. For professionals working in public procurement contexts, AI literacy must extend to awareness of how procurement AI tools interact with legal obligations under EU and national procurement frameworks.

4.3 Inventory management and stock optimization

Inventory management encompasses the full cycle of activities involved in ordering, receiving, storing and issuing pharmaceutical products. Effective inventory management requires balancing two competing objectives: maintaining sufficient stock to ensure product availability, and minimising the cost and waste associated with holding excess inventory. In hospital pharmacies and pharmaceutical warehouses, this balance is further complicated by regulatory requirements, such as FEFO, product diversity across thousands of SKUs, and the high cost of many pharmaceutical products.

AI applications

Dynamic safety stock and reorder point optimization. Traditional inventory management uses static safety stock formulas based on average demand and lead time variability. AI-powered inventory systems replace these static parameters with dynamic, ML-driven calculations that continuously update safety stock levels based on real-time demand signals, supplier performance data and product criticality scores. This approach has been shown to reduce inventory holding costs by 15–25% while maintaining or improving service levels.

Expiry date management and waste reduction. Pharmaceutical product expiry is a major source of waste in hospital pharmacies and distribution warehouses. AI systems can predict the risk of product expiry across large formularies, identify products at risk of waste, and recommend redistribution or expedited dispensing actions. Computer vision systems are also being deployed in some hospital pharmacies to automate expiry date reading during stock counts, reducing manual verification errors.

Intelligent ABC-XYZ classification and portfolio management. AI can automate and continuously update ABC, value-based, and XYZ, variability-based, product classifications. This enables more granular and dynamic inventory segmentation than is possible with manual processes. It also supports differentiated replenishment strategies, for example by applying more sophisticated AI forecasting to high-value, high-variability products, while using simpler rules for low-value, stable products.

Inventory management and stock optimization

Primary target profiles	Inventory manager, pharmacy warehouse coordinator, supply chain coordinator
Key AI tools / systems	AI-enabled WMS, Manhattan, Infor WMS, hospital pharmacy systems, Swisslog, BD Rowa, ERP modules

Literacy implications

Inventory managers and pharmacy warehouse coordinators need to understand how AI inventory systems generate their recommendations, including the concept of dynamic safety stock, the role of data inputs, and the conditions under which the system may underperform. They need to be able to identify situations requiring manual override and provide feedback to system administrators about systematic errors or changing operational conditions.

4.4 Warehouse management and automation

Pharmaceutical warehouses, whether operated by manufacturers, wholesalers, third-party logistics providers (3PLs) or hospital logistics departments, are complex operational environments that manage large and diverse product portfolios under strict regulatory, quality and handling requirements. Warehouse management includes receiving and put-away, storage location management, order picking, packing and labelling, and shipping. AI is transforming warehouse operations through a combination of optimization algorithms, computer vision, robotics and real-time data analytics.

AI applications

AI-powered warehouse management systems (WMS). Modern WMS platforms incorporate AI capabilities that go beyond traditional rule-based logic. ML-driven slotting optimization continuously adjusts storage location assignments based on demand patterns, product characteristics and picking frequency. AI-based labour management systems predict workload and allocate staff resources dynamically. Predictive quality monitoring systems flag potential storage condition deviations before they become compliance issues.

Autonomous mobile robots (AMRs) and goods-to-person systems. AMRs are guided by AI navigation systems that combine computer vision, SLAM, simultaneous localisation and mapping, and path planning algorithms. They are increasingly deployed in pharmaceutical warehouses to automate goods transport between storage locations and picking stations. Goods-to-person systems, in which robots bring storage containers to stationary human pickers, have demonstrated picking productivity improvements of 2–4 times compared with traditional person-to-goods approaches, while also reducing picking errors and physical strain on warehouse staff.

Computer vision for quality control and verification. Computer vision systems are being deployed at receiving docks and shipping stations in pharmaceutical warehouses to automate label verification, product identification and packaging integrity checks. These systems can process products at speeds far exceeding human visual inspection, with error detection rates typically exceeding 99.5%. In serialised environments, computer vision is used to read and verify 2D barcodes and QR codes at high throughput.

Warehouse management and automation	
Primary target profiles	Warehouse manager, logistics operator, supply chain coordinator
Key AI tools / systems	AI WMS, Manhattan, SAP EWM, Blue Yonder, AMR platforms, Mobile Industrial Robots, Fetch, computer vision systems

Literacy implications

Warehouse managers need to understand how to configure, supervise and evaluate AI-powered WMS and automation systems, including how to set performance targets, interpret system analytics and manage exceptions. Operational staff working alongside robots and automated systems need to understand the capabilities and limitations of these systems, the safety protocols for human-robot collaboration, and how to respond when automated systems fail or produce unexpected outputs.

4.5 Cold chain monitoring and temperature-controlled logistics

A significant and growing proportion of pharmaceutical products require temperature-controlled storage and transportation. Biologics, vaccines, blood products and many specialty medicines must be maintained within defined temperature ranges, typically 2–8°C for refrigerated products and –20°C or below for frozen products, throughout the supply chain. Failures in cold chain management can result in product degradation, patient safety risks, regulatory non-compliance and significant financial losses. AI is playing an increasingly important role in preventing such failures through predictive monitoring and intelligent response systems.

AI applications

Predictive temperature monitoring. Traditional cold chain monitoring systems use threshold-based alerts that notify operators only after a temperature excursion has occurred. AI-powered predictive monitoring systems, trained on historical temperature profiles and environmental data, such as ambient temperature, door opening frequency, equipment age and maintenance history, can anticipate temperature deviations before they occur. They can also trigger preventive actions, such as equipment maintenance, load redistribution or route adjustment, in time

to prevent product loss. Studies document excursion reduction rates of 30–40% with predictive monitoring compared with threshold-based systems.

IoT-integrated cold chain analytics. The proliferation of low-cost IoT temperature sensors, embedded in packaging, transport containers and storage units, generates continuous data streams that AI systems can analyse to build comprehensive temperature profiles for individual shipments and storage locations. These data support root cause analysis of temperature excursions, supplier performance benchmarking and regulatory compliance documentation. Platforms such as Controlant, Sensitech and Tive provide integrated IoT-AI cold chain visibility solutions that are increasingly deployed in pharmaceutical distribution.

AI-optimized route planning for temperature-sensitive shipments. Routing algorithms for temperature-sensitive pharmaceutical deliveries must account not only for distance and time, but also for ambient temperature conditions along the route, vehicle thermal performance, delivery sequence effects on product temperature, and the availability of temperature-controlled intermediate storage. AI-powered routing systems that integrate these factors can significantly reduce temperature excursion risk in last-mile delivery, particularly in challenging conditions such as summer heat waves or deliveries to remote locations.

Cold chain monitoring and temperature-controlled logistics	
Primary target profiles	Cold chain specialist, logistics planner, warehouse manager, delivery coordinator
Key AI tools / systems	IoT monitoring platforms, Controlant, Sensitech, Tive, predictive analytics systems, AI routing tools, Paragon, Ortec

Literacy implications

Cold chain specialists and logistics planners need to understand how AI monitoring systems interpret temperature data, including the difference between threshold-based and predictive alert logic, and how to respond to AI-generated alerts and recommendations. They also need to understand the data requirements of these systems and the importance of IoT sensor calibration and maintenance for data quality.

4.6 Transportation and route optimization

The transportation of pharmaceutical products, from manufacturers to distributors, from distributors to hospitals and pharmacies, and from central stores to point-of-care locations, is a complex logistics challenge that must balance several objectives: delivery speed, cost efficiency, temperature control, regulatory compliance and security. AI-powered transportation optimization tools are demonstrating significant improvements across all these dimensions.

AI applications

Dynamic route optimization. AI-based vehicle routing problem (VRP) solvers can optimize delivery routes across hundreds of delivery points simultaneously, taking into account time windows, vehicle capacity constraints, driver hours regulations, real-time traffic conditions and pharmaceutical-specific requirements, such as temperature control, handling restrictions and delivery priority. Dynamic routing systems, which continuously recalculate routes in response to new orders, cancellations and real-time conditions, are particularly valuable in the distribution of urgent medicines and emergency supplies to hospitals.

Predictive transportation management. Beyond route optimization, AI is being applied to transportation management more broadly. Applications include predictive ETAs that account for traffic, weather and historical performance data; AI-based carrier selection and freight rate optimization; automated exception management systems that detect and respond to delivery disruptions in real time; and predictive fleet maintenance systems that minimise vehicle downtime through condition-based maintenance scheduling.

Distribution and transportation mode optimization. For intercontinental and long-distance pharmaceutical shipments, particularly for high-value biologics and clinical trial materials, AI is being applied to multimodal transport planning. These systems optimize the choice between air, sea, rail and road transport based on cost, time, temperature risk, carbon footprint and supply chain resilience considerations. Arteinics has demonstrated the application of AI to supply chain and logistics optimization in industrial contexts, with approaches directly transferable to pharmaceutical distribution scenarios.

Transportation and route optimization	
Primary target profiles	Distribution / transportation manager, last-mile delivery coordinator, logistics planner
Key AI tools / systems	AI routing platforms, Paragon, Ortec, PTV Optima, TMS with AI modules, SAP TM, Oracle TMS, fleet management AI

Literacy implications

Transportation managers and delivery coordinators need to understand how AI routing systems generate their recommendations, how to interpret route quality metrics, and when and how to override AI suggestions based on local knowledge or exceptional circumstances. They also need to understand how real-time data feeds, such as traffic, weather and vehicle telemetry, affect AI routing decisions.

4.7 Last-mile delivery

Last-mile delivery, the final leg of the pharmaceutical supply chain from distribution hub to hospital, pharmacy or point of care, is often the most complex,

costly and time-sensitive stage of the logistics process. In healthcare logistics, last-mile delivery is particularly significant because delivery failures can directly affect patient care. AI is being applied to optimize last-mile delivery in terms of speed, reliability and cost, with a growing number of innovative solutions emerging in the sector.

AI applications

Intelligent last-mile route optimization. Dedicated last-mile delivery optimization platforms use AI to plan and dynamically adjust delivery routes for pharmaceutical distribution networks. These systems account for the specific constraints of pharmaceutical delivery, including time windows, temperature requirements, signature and verification requirements, and controlled substance handling procedures, while optimizing for efficiency. In urban healthcare logistics, AI-powered dynamic routing can significantly reduce delivery times for urgent medicines and emergency supplies.

Delivery prediction and proactive exception management. AI systems that predict delivery outcomes, including estimated delivery times, risk of delay and probability of failed delivery, enable proactive management of delivery exceptions before they become problems. Automated notification systems can alert receiving facilities of expected delays, allowing them to take precautionary inventory actions. In hospital settings, early warning of medication delivery delays can trigger clinical pharmacy interventions to ensure patient care continuity.

Emerging models: drone and autonomous delivery. Drone and autonomous ground vehicle delivery are still in early deployment, but they are being piloted for pharmaceutical last-mile logistics in specific contexts, particularly for urgent medicine delivery between hospital campuses, delivery to remote or rural healthcare facilities, and emergency supply to disaster response settings. AI is central to the navigation, obstacle avoidance and load management systems of these platforms. Several European healthcare systems have conducted pilot programmes for drone delivery of blood products and time-critical medicines.

Last-mile delivery	
Primary target profiles	Last-mile delivery coordinator, logistics operator, supply chain coordinator
Key AI tools / systems	Last-mile optimization platforms, Onfleet, Bringg, Circuit, AI-powered TMS, emerging drone / AV platforms

Literacy implications

Last-mile delivery coordinators and logistics operators need to understand how AI delivery management systems work, including how routes are generated, how exceptions are detected and how real-time updates are processed. They also need

to understand the data generated through their own delivery activities, such as GPS tracks, delivery confirmations and exception reports, and how these data feed back into the AI system's learning process.

4.8 Reverse logistics: returns, recalls and expired drugs

Reverse logistics in the pharmaceutical sector, covering the handling of returned, recalled or expired products, is a highly regulated, complex and costly process. Pharmaceutical products that are returned, recalled, or identified as expired or damaged must be handled in strict compliance with GDP regulations, with full chain-of-custody documentation and, in many cases, secure destruction under qualified oversight. AI is being applied to improve the efficiency, accuracy and compliance of reverse logistics operations.

AI applications

Automated return classification and processing. AI systems that combine computer vision, ML-based product identification and rule-based compliance engines can automate the classification of returned pharmaceutical products. They can distinguish between products eligible for restocking, products requiring quarantine and quality review, and products requiring destruction. This reduces the manual workload of returns processing while improving accuracy and compliance documentation. In high-volume returns environments, such as post-hospitalisation medication returns or community pharmacy returns, AI classification can substantially reduce processing time.

Recall management optimization. Pharmaceutical product recalls, whether initiated by the manufacturer, the regulatory authority or the European Medicines Agency, require rapid identification of all affected product units in the supply chain, swift communication to all downstream actors, and efficient management of the return and destruction process. AI systems that maintain real-time visibility of serialised product locations can accelerate recall identification and execution, reducing the time from recall initiation to completion from weeks to days. AI communication tools can also automate the generation and distribution of recall notifications to affected parties.

Expiry management and proactive waste reduction. As discussed in section 4.2, AI can identify products at risk of expiry across large and complex inventories and recommend proactive actions to reduce waste. These actions may include redistribution to higher-consumption facilities, accelerated dispensing and early procurement action to avoid safety stock gaps. In hospital pharmacy, where the formulary may include thousands of products with varying shelf lives and consumption rates, AI expiry management can deliver significant reductions in pharmaceutical waste.

Reverse logistics: returns, recalls and expired drugs

Primary target profiles	Reverse logistics specialist, warehouse manager, regulatory compliance officer
Key AI tools / systems	Returns management AI, recall management platforms, Veeva Vault, TraceLink, WMS expiry modules

Literacy implications

Reverse logistics specialists and warehouse managers need to understand how AI classification systems evaluate returned products and generate their disposition recommendations, including the regulatory framework that underpins these recommendations. They need to know how to handle AI-generated recall alerts, how to document the reverse logistics process in AI-powered systems, and when to seek human expert review for complex or ambiguous cases.

4.9 Fraud detection and prevention

Pharmaceutical fraud, including counterfeiting, diversion, theft and procurement fraud, represents a significant threat to patient safety and supply chain integrity. The World Health Organization estimates that up to 10% of medicines in low- and middle-income countries are substandard or falsified. While the situation is significantly better in the EU, the threat remains real and growing. AI is playing an increasingly important role in detecting and preventing fraud across the pharmaceutical supply chain.

AI applications

Counterfeit detection through serialisation analytics. As described in section 4.7, AI anomaly detection applied to flows data provides a powerful tool for identifying counterfeit products that enter the legitimate supply chain. Patterns indicative of counterfeiting, such as duplicate serial numbers, serials from batches not registered in the EMVS, or verification events inconsistent with authorised distribution channels, can be detected in real time and flagged for investigation.

Procurement fraud detection. AI systems applied to procurement data, including purchase orders, invoices, supplier performance records and pricing histories, can identify patterns indicative of procurement fraud. These may include unusually high prices compared with market benchmarks, suspicious supplier relationships, irregular approval patterns and statistical anomalies in bid results. These systems are increasingly being deployed in hospital procurement departments and public healthcare purchasing authorities to strengthen internal audit and compliance functions.

Diversion detection and supply chain integrity monitoring. Pharmaceutical diversion, namely the redirection of legitimate products from authorised channels to illegal markets, is a particular concern for high-value and controlled medicines.

AI systems that analyse distribution patterns, customer ordering behaviour and product flow data can identify anomalies suggestive of diversion. Examples include unusually high order volumes from specific customers, ordering patterns inconsistent with the customer's profile, or product flows that bypass expected distribution routes. These systems complement traditional pharmaceutical diversion prevention programmes and support regulatory reporting obligations.

Fraud detection and prevention	
Primary target profiles	Regulatory compliance officer, warehouse manager, procurement officer
Key AI tools / systems	Anomaly detection systems, procurement AI platforms, supply chain integrity analytics

Literacy implications

Professionals involved in fraud detection and prevention, including regulatory compliance officers, procurement officers and warehouse managers, need to understand how AI fraud detection systems generate their alerts and what actions they are expected to take in response. They also need to understand the regulatory context, including GDP and controlled substances regulations, that shapes how AI-generated fraud signals should be handled and reported.

4.10 Decision support systems for clinics and administrations

The boundary between clinical pharmacy and logistics is increasingly blurred in modern hospital settings. Decisions about formulary management, medication substitution, stock allocation across wards and emergency procurement are both logistics decisions and clinical decisions, with direct implications for patient safety and care quality. AI-powered decision support systems are being developed and deployed at this interface, providing logistics professionals with tools that integrate clinical and operational data to support more informed and timely decision-making.

AI applications

AI-assisted formulary management. Hospital formulary management, the process of selecting, evaluating and managing the medicines available for prescribing and dispensing within a hospital, is a complex task. It requires balancing clinical evidence, cost-effectiveness, availability and regulatory requirements. AI systems can support formulary managers by analysing prescribing patterns, identifying opportunities for therapeutic substitution, flagging high-cost or high-risk medicines requiring special management, and predicting the impact of formulary changes on consumption patterns and budget.

Medication reconciliation AI. Medication reconciliation, the process of comparing a patient's medication orders against all medications the patient has been taking, is a critical patient safety process with significant logistics implications. AI medication reconciliation systems can automatically cross-reference medication records across care settings, such as GP, hospital and community pharmacy records, identify discrepancies and potential adverse drug events, and generate alerts for clinical review. These systems generate demand signals, particularly for complex multi-medication patients, that can significantly improve the accuracy of medication consumption forecasting when integrated with pharmacy management systems. However, the use of AI in community pharmacy should always complement and never replace pharmacists' professional expertise, judgement, and oversight. The use of AI tools may also create difficulties in determining liability and allocating responsibility when an error or adverse patient outcome occurs, particularly where decisions result from the combined actions of the pharmacist, the pharmacy organization, and the AI system. Clear regulations and professional guidelines are therefore needed to define pharmacists' responsibilities, address organizational and accountability challenges, and clarify the role of national authorities in evaluating and supervising AI systems deployed in community pharmacies. Community pharmacists must also be equipped with the skills needed to use and critically assess these technologies through updated pharmacy curricula and continuous professional development programs.

Surgical supply and clinical logistics planning. Surgical suites and procedure rooms represent a particular logistics challenge: the products required for each procedure are highly specific, often expensive, and needed at a precise time and location. AI systems that integrate surgical scheduling data with supply chain management can automate the preparation of procedure-specific supply kits, optimize the allocation of high-cost consumables across operating schedules, and predict and prevent supply shortages that could cause procedure cancellations. This is an area where UIC and UNISI research on AI applications in healthcare operations management provides directly relevant evidence and use cases.

AI-powered clinical pharmacy analytics. More broadly, AI analytics platforms that integrate clinical data, including EHR, prescription records and treatment protocols, with supply chain data, including inventory levels, consumption histories and supplier performance, are emerging as powerful tools for strategic clinical logistics management. These platforms can identify patterns of suboptimal medicine use, forecast the impact of new treatment guidelines on procurement requirements, and support evidence-based decisions about safety stock levels for critical medicines.

Decision support systems for clinical and administrative logistics

Primary target profiles	Hospital pharmacist, clinical pharmacist, pharmacy director, supply chain coordinator
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Key AI tools / systems	Clinical decision support systems, Wolters Kluwer, Merative, formulary management AI, surgical supply planning platforms
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Literacy implications

Clinical pharmacists and hospital pharmacy directors working with AI decision support systems need to understand both the clinical logic and the data foundations of these systems, including how AI recommendations are generated, what data sources are used, and what the known limitations and failure modes of these systems are. They need to be able to evaluate AI recommendations critically and take clinical responsibility for decisions that are informed, but not determined, by AI outputs. This is one of the highest-stakes AI literacy contexts in the project's target group, where the consequences of over-reliance on AI, or of failing to engage with AI recommendations, can directly affect patient safety.

5. AI applications by target profile

This chapter reframes the AI application landscape described in Chapter 4 through the professional profiles identified in section 2.5. Rather than organising AI applications by logistics process, it asks which AI applications are most relevant for each profile, what level of AI literacy is required, and what practical implications follow for training design.

This perspective is essential for the subsequent steps of WP2, especially the development of the AI literacy competency framework (D2.3) and the gap analysis survey (D2.4). Training interventions need to be designed around the actual work contexts and learning needs of specific professional roles, rather than around abstract technological categories.

The chapter is structured in five sections: the three profile categories from section 2.5, namely pharmacists (5.1), logistics managers and operators (5.2), and other supply chain actors (5.3), followed by a cross-profile analysis of shared AI competency areas (5.4) and a prioritization matrix (5.5).

The profiles and their organisational levels are defined in section 2.5. The AI applications referenced in this chapter are described in full in Chapter 4. The literacy level indicators used in this chapter, Awareness, Working Knowledge and Operational Proficiency, are preliminary and will be refined in D2.3.

5.1 Category 1: Pharmacists

Pharmacists, both hospital and community, occupy a unique position in the healthcare logistics ecosystem. They are clinical professionals, with responsibility for patient safety, and logistics actors, with responsibility for the procurement, storage and dispensing of medicines. This dual role shapes their AI literacy needs.

They need to understand AI not only as a logistics optimization tool, but also as a clinical decision support resource, and to navigate the intersection between these two domains responsibly.

Hospital Pharmacist / Head of Hospital Pharmacy Department

The head of hospital pharmacy holds strategic responsibility for AI adoption within the pharmacy department. This includes evaluating AI solutions, supporting investment decisions, managing vendor relationships, and ensuring that AI deployments comply with regulatory and clinical governance requirements. Their AI literacy needs are mainly at the strategic and managerial level.

Most relevant AI processes	4.1 Demand forecasting, 4.2 Procurement planning and sourcing optimization, 4.10 Clinical decision support
AI literacy level required	Awareness + Working Knowledge: ability to evaluate AI tools and interpret their outputs strategically
Key AI tools encountered	AI-enabled pharmacy management systems, clinical decision support platforms, formulary AI tools

- Understand capabilities/limitations of AI tools in pharmacy logistics and clinical practice
- Evaluate vendor AI claims critically and assess fit with departmental needs and workflows
- Define governance frameworks for responsible AI use within the pharmacy department
- Interpret AI-generated analytics and performance reports for operational improvement

Hospital Pharmacy Director / Chief Pharmacist

At the highest strategic level, the hospital pharmacy director is responsible for aligning AI adoption with the hospital's broader digital transformation strategy, managing budgets for AI investment, and engaging with hospital management, IT departments and regulatory bodies on AI governance. Their AI literacy needs are mainly at the awareness and strategic evaluation level.

Most relevant AI processes	4.1 Demand forecasting, 4.9 Fraud detection, cross-sector AI governance, 4.10 Clinical decision support
AI literacy level required	Awareness: strategic understanding of AI value, risk and governance
Key AI tools encountered	Hospital information systems with AI modules, analytics dashboards, regulatory compliance platforms

- Understand strategic value of AI for hospital pharmacy, articulate a clear AI adoption rationale
- Engage constructively with AI governance frameworks (e.g., EU AI Act, hospital AI policies)
- Lead AI-adoption-related change management processes in the pharmacy department

Pharmaceutical Procurement and Purchasing Manager

The procurement manager is a primary user of AI demand forecasting and procurement automation tools. Their AI literacy needs are at the working knowledge level. They need to understand how AI forecasting models generate

their outputs, when and how to override AI recommendations, and how to use AI procurement analytics to improve supplier management and cost efficiency.

Most relevant AI processes	4.1 Demand forecasting, 4.2 Procurement planning and sourcing optimization, 4.9 Fraud detection
AI literacy level required	Working Knowledge: ability to interpret, validate and act on AI forecasting and procurement outputs
Key AI tools encountered	AI demand planning platforms, SAP IBP, Blue Yonder, AI procurement systems, ERP with AI modules

- Interpret AI-generated analytics and performance reports for operational improvement
- Interpret demand forecasts (confidence intervals, bias indicators, override triggers)
- Use AI procurement analytics to identify cost opportunities, supplier performance trends
- Recognise and respond to AI-generated procurement fraud alerts
- Maintain and improve the data quality inputs that AI forecasting systems depend on

Community Pharmacist

Community pharmacists operate in smaller and more autonomous environments than their hospital counterparts, usually with more limited access to advanced AI tools. By integrating AI-supported systems, community pharmacies can improve the dispensing processes and automate administrative duties such as inventory management. This may lighten the logistical and administrative demands placed on community pharmacists while ensuring that the latter retain supervision over these tasks.

Most relevant AI processes	4.1 Demand forecasting, 4.3 Inventory management and stock optimization, 4.8 reverse logistics
AI literacy level required	Operational Proficiency for specific tools; Awareness of the broader AI context
Key AI tools encountered	Community pharmacy management systems, Pharmacy2U, Cegedim, replenishment AI

- Use AI-powered stock replenishment systems (review and confirm automated orders)
- Perform product verification, understanding anomaly detection
- Recognise when AI-generated recommendations require professional review or override

Clinical Pharmacist with logistics responsibilities

Clinical pharmacists with logistics responsibilities sit at the intersection of clinical practice and logistics management. They are increasingly involved in AI-assisted medication reconciliation, formulary management and clinical supply planning. Their AI literacy needs span both clinical and logistics AI applications, making this one of the most complex target profiles in terms of training design.

Most relevant AI processes	4.10 Clinical decision support, 4.1 Demand forecasting, 4.2 Procurement planning and sourcing optimization
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AI literacy level required	Working Knowledge across clinical and logistics AI; Operational Proficiency for specific clinical tools
Key AI tools encountered	Medication reconciliation AI, clinical decision support systems, pharmacy analytics platforms

- Use AI medication reconciliation tools (e.g., verification of AI-generated discrepancy flags)
- Integrate clinical demand signals (admission forecasts, protocol changes), into logistics planning processes
- Critically evaluate AI clinical recommendations, maintaining accountability in decisions
- Understand data flows between clinical systems and pharmacy management systems that enable AI forecasting

5.2 Category 2: Logistics Managers and Operators

Category 2 includes the broadest range of profiles in terms of organisational level, from strategic supply chain directors to operational warehouse staff. This diversity means that AI literacy needs vary significantly within this category, from strategic understanding to hands-on operational proficiency with specific automation systems. The common element is that all these professionals are involved in the physical management of the pharmaceutical supply chain and are increasingly exposed to AI-powered tools in their daily work.

Supply Chain Manager / Healthcare Logistics Director

The supply chain manager holds overall responsibility for the design, performance and resilience of the healthcare logistics operation. Their AI literacy needs are mainly strategic. They need to understand how AI can create value across the supply chain, how to build the business case for AI investment, and how to lead organisational change in an AI adoption context.

Most relevant AI processes	4.1 Demand forecasting, 4.6 Transportation optimization, 4.5 Cold chain, 4.9 Fraud detection
AI literacy level required	Awareness + Working Knowledge: strategic AI evaluation and performance monitoring
Key AI tools encountered	Supply chain analytics platforms, AI-enabled TMS, ERP with AI modules, risk management AI

- Evaluate AI solutions for SC optimization and build robust business cases for investment
- Design KPI frameworks that capture the performance of AI-driven supply chain processes
- Lead AI change management (e.g., staff concerns, AI literacy culture and responsible use)
- Monitor and interpret supply chain AI analytics dashboards to support strategic decisions

Warehouse Manager / Head of Pharmaceutical Warehouse

The warehouse manager is responsible for the operational performance of the pharmaceutical warehouse, including the deployment and supervision of AI-powered WMS and automation systems. Their AI literacy needs combine

managerial oversight of AI systems with operational understanding of how these systems function.

Most relevant AI processes	4.3 Inventory management and stock optimization . 4.4 Warehouse management, 4.8 Reverse logistics and drug tracking
AI literacy level required	Working Knowledge: ability to supervise and configure AI WMS and interpret system analytics
Key AI tools encountered	AI WMS, Manhattan, Infor, SAP EWM, AMR platforms, slotting optimization AI, labour management systems

- Configure AI WMS parameters (slotting rules, replenishment triggers, picking priorities)
- Interpret WMS analytics to identify process inefficiencies and improvement opportunities
- Supervise human-robot collaboration in automated warehouse environments
- Manage AI system exceptions, maintenance events and performance degradation

Distribution / Transportation Manager

The distribution or transportation manager oversees the movement of pharmaceutical products between facilities, managing fleets, carriers, routes and schedules. AI route optimization and transportation management systems are the primary AI interaction context for this profile, together with cold chain monitoring systems for temperature-sensitive shipments.

Most relevant AI processes	4.6 Transportation optimization, 4.5 Cold chain, 4.7 Last-mile delivery
AI literacy level required	Working Knowledge: ability to use and supervise AI routing and transport management systems
Key AI tools encountered	AI routing platforms, Paragon, Ortec, PTV Optima, TMS with AI, cold chain monitoring platforms

- Use AI route optimization systems (e.g., dynamic rerouting in response to exceptions)
- Interpret AI-generated transport performance analytics to recommend improvement
- Monitor cold chain AI alerts and manage temperature exception response processes
- Evaluate AI carrier selection recommendations by cost, reliability, regulatory compliance

Supply Chain Coordinator / Logistics Planner

Supply chain coordinators and logistics planners are tactical-level professionals responsible for daily order management, replenishment planning and distribution scheduling. They are frequent users of AI demand forecasting tools, ERP systems with AI modules and replenishment automation platforms. Their AI literacy needs are at the working knowledge level for these specific systems.

Most relevant AI processes	4.1 Demand forecasting, 4.2 Procurement planning and sourcing optimization, 4.6 Transportation, 4.5 Cold chain planning
AI literacy level required	Working Knowledge: ability to interpret and act on AI planning outputs and maintain data quality
Key AI tools encountered	AI demand planning platforms, ERP with AI modules, replenishment automation, distribution planning tools

- Interpret AI demand forecasts and replenishment recommendations
- Apply professional judgement to override when appropriate
- Manage data inputs for AI systems (consumption data, lead times, product master data)
- Coordinate AI-generated distribution plans with carrier and warehouse teams
- Identify and report forecast errors or planning anomalies to system administrators

Inventory Manager / Stock Controller

The inventory manager is responsible for maintaining accurate and optimized stock levels across the pharmaceutical warehouse or healthcare facility. This profile is a primary user of AI inventory management tools, expiry management systems, and automated counting and reconciliation technologies.

Most relevant AI processes	4.3 Inventory management, 4.8 Reverse logistics and drug tracking
AI literacy level required	Operational Proficiency + Working Knowledge: daily use of AI inventory tools
Key AI tools encountered	AI WMS inventory modules, expiry management AI, cycle counting automation, RFID/barcode AI systems

- Operate AI inventory management systems, interpreting reorder and safety stock alerts
- Use AI expiry management tools to identify at-risk products, and act on waste reduction
- Perform AI-assisted cycle counting and reconciliation; handle discrepancies, exceptions
- Maintain product master data and consumption records that feed AI inventory models

Cold Chain Specialist

The cold chain specialist is responsible for ensuring the integrity of temperature-controlled pharmaceutical products throughout the supply chain. This profile interacts daily with IoT monitoring systems, predictive temperature alerts and cold chain compliance documentation tools, making it one of the most intensive users of AI-powered monitoring technology in the target group.

Most relevant AI processes	4.5 Cold chain monitoring, 4.6 Transportation and drug tracking
AI literacy level required	Operational Proficiency: intensive daily use of IoT-AI monitoring systems

Key AI tools encountered	IoT monitoring platforms, Controlant, Sensitech, Tive, predictive alert systems, compliance documentation AI
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- Operate IoT cold chain monitoring systems (alert response, incident documentation)
- Distinguish between threshold-based and predictive AI alerts and respond accordingly
- Use AI compliance documentation tools to generate GDP-compliant temperature excursion reports
- Calibrate and maintain IoT sensors, understand how sensor data quality affects AI monitoring accuracy

Last-Mile Delivery Coordinator

The last-mile delivery coordinator manages the final delivery of pharmaceutical products to hospitals, pharmacies and clinical settings. This profile interacts with AI routing and delivery management systems, real-time tracking platforms and exception notification tools. Its AI literacy needs focus on the operational use of these systems and on understanding how to respond to AI-generated alerts and routing changes.

Most relevant AI processes	4.7 Last-mile delivery, 4.6 Transportation, 4.5 Cold chain
AI literacy level required	Operational Proficiency: daily use of AI routing and delivery management tools
Key AI tools encountered	Last-mile AI platforms, Onfleet, Bringg, Circuit, dynamic routing apps, delivery tracking systems

- Use AI-powered routing and delivery management apps effectively in the field
- Respond to dynamic AI rerouting suggestions with knowledge, professional judgement
- Understand how delivery performance data feed back into AI systems' learning process
- Document delivery exceptions and AI override decisions accurately in the delivery management system

Reverse Logistics Specialist / Logistics Operator

Reverse logistics specialists manage returned, recalled and expired products, increasingly supported by AI classification and compliance documentation systems. Logistics operators, including warehouse and packaging operatives, are among the most operationally intensive users of AI automation technology. They work alongside robots, scan products into AI-powered WMS systems, and operate automated picking and packing equipment.

Most relevant AI processes	4.8 Reverse logistics, 4.3 Warehouse automation, 4.7 Drug tracking, 4.9 Fraud detection and drug tracking
AI literacy level required	Operational Proficiency: hands-on use of AI automation and returns management systems
Key AI tools encountered	Returns management AI, automated picking systems, Geek+, Locus Robotics, WMS interfaces, scan tools

- Understand capabilities/limitations of AI tools in pharmacy logistics and clinical practice
- Operate AI returns classification systems, handle exceptions requiring human judgement
- Work safely and effectively with autonomous robots and automated conveyor systems
- Report system anomalies, safety issues and AI error patterns to supervisors
- Scan and verify products accurately in AI-powered WMS environments, understanding the importance of data quality

5.3 Category 3: Other supply chain actors

Category 3 includes actors who, while not primarily logistics professionals, play important roles in shaping the regulatory, institutional and commercial conditions under which AI is adopted in healthcare logistics. Their AI literacy needs are mainly at the awareness and governance level, rather than at the operational use level. However, the decisions they make about procurement standards, regulatory frameworks and supply chain partnerships have a significant influence on the pace and quality of AI adoption across the sector.

Pharmaceutical Wholesaler / Distributor, Logistics Manager

Logistics managers at pharmaceutical wholesalers and distributors are among the most advanced AI users in the healthcare supply chain. They operate large-scale AI-powered warehouse management systems, transport optimization platforms and cold chain monitoring solutions. They also have an important role in the adoption of track-and-trace systems that require AI-powered data management at scale.

Most relevant AI processes	4.4 Warehouse management, 4.6 Transportation, 4.5 Cold chain and drug tracking, 4.1 Demand forecasting
AI literacy level required	Working Knowledge to Operational Proficiency: advanced AI users in logistics operations
Key AI tools encountered	Enterprise WMS, Manhattan, SAP EWM, AI TMS, cold chain platforms, demand planning AI

- Design and manage AI-powered distribution operations at scale
- Lead AI-driven operational improvement (route optimization, predictive maintenance)
- Integrate AI systems across the wholesale distribution network, managing data flows and system interoperability
- Use AI anomaly detection to support compliance and anti-counterfeiting

Public Procurement Official

Public procurement officials in healthcare authorities, ASLs and hospital trusts are responsible for tendering, contracting and managing suppliers of pharmaceutical products and logistics services. As AI-powered logistics solutions increasingly feature in procurement offers, these officials need sufficient AI literacy to evaluate vendor claims, assess risks and incorporate AI requirements into procurement specifications.

Most relevant AI processes	4.1 Demand forecasting, 4.9 Fraud detection and drug tracking
AI literacy level required	Awareness + governance literacy: ability to evaluate AI in procurement and manage AI-related contractual risk
Key AI tools encountered	e-Procurement platforms with AI modules, spend analytics AI, EU AI Act compliance monitoring tools

- Understand AI capabilities and limitations to evaluate vendor AI claims in procurement
- Incorporate AI performance requirements and governance clauses into supply contracts
- Use AI spend analytics tools to identify optimization opportunities and detect fraud
- Ensure processes comply with EU AI Act requirements for high-risk AI systems

Packaging Provider / Wholesaler, Supply chain manager

Packaging providers and secondary wholesalers occupy important positions in the pharmaceutical supply chain, managing the packaging, labelling and secondary distribution of medicinal products. AI applications in this context include automated quality control for packaging and labelling, serialisation and track-and-trace management, and supply chain optimization for multi-SKU product portfolios.

Most relevant AI processes	4.4 Warehouse management, 4.1 Demand forecasting
AI literacy level required	Awareness + Working Knowledge: ability to manage AI in packaging quality and serialisation contexts
Key AI tools encountered	Computer vision QC systems, serialisation platforms, TraceLink, Antares Vision, WMS with AI

- Manage AI-powered quality control systems for pharmaceutical packaging and labelling
- Operate serialisation and track-and-trace platforms at volume, ensuring compliance
- Use supply chain analytics AI to optimize procurement & inventory for packaging materials

5.4 Cross-profile applications and shared AI competency areas

Across all three categories and organisational levels, the research identifies a set of AI competency areas that are relevant to most target profiles, regardless of their specific role or the particular AI tools they use. These cross-cutting competencies constitute the foundation of the AI literacy framework that will be developed in D2.3, and should be incorporated into training programmes targeting healthcare logistics professionals.

Data literacy and data quality awareness

AI systems in logistics are only as effective as the data they process. Across all profiles, a fundamental competency is the ability to understand what data AI systems require, where these data come from, and how data quality affects system

performance. This includes understanding concepts such as data completeness, accuracy, timeliness and consistency, as well as knowing how one's own data entry and operational documentation practices contribute to, or undermine, the quality of AI inputs. This competency is relevant from the most operational warehouse scanner to the most strategic supply chain director.

Interpreting and acting on AI outputs

A second universal competency is the ability to interpret AI-generated outputs critically, including forecasts, recommendations, alerts and classifications, and to make informed decisions about whether and how to act on them. This requires understanding that AI systems generate probabilistic outputs rather than certainties, that they can be wrong in systematic ways due to bias, concept drift or data gaps, and that human professional judgement remains essential when operational context requires an override. This competency is particularly critical in healthcare logistics, where AI errors can have direct patient safety consequences.

Understanding AI system limitations and failure modes

All professionals who interact with AI systems need to understand the conditions under which these systems may underperform or fail. These include demand shocks, novel events not represented in training data, sensor malfunctions and data integration failures. This awareness enables professionals to recognise when an AI system's behaviour is anomalous and to escalate appropriately, rather than blindly following AI outputs that may be unreliable.

Regulatory and ethical dimensions of AI

The EU AI Act (Regulation 2024/1689) introduces a risk-based framework for AI governance that has direct implications for healthcare logistics. Many AI applications in this sector, particularly those used in medication dispensing, clinical decision support and product safety monitoring, are likely to be classified as high-risk AI systems, subject to specific conformity assessment (and if classified as a medical device under the MDR, a complementary conformity assessment under that regulation), transparency and human oversight requirements. Healthcare logistics professionals at all levels need sufficient awareness of this regulatory framework to fulfil their obligations as users or deployers of AI systems under the Act.

Change management and human-AI collaboration

The adoption of AI in healthcare logistics requires not only technical literacy, but also the ability to manage change. This concerns both one's own adaptation to new AI-powered workflows and the management of colleagues and teams through AI transition processes. It includes the ability to communicate about AI in accessible terms, address concerns and resistance constructively, and support human-centred AI design that preserves professional agency and accountability.

5.5 Prioritization matrix by profile and organisational level

Table 7 synthesizes the AI application mapping presented in sections 5.1–5.3 in the form of a prioritization matrix. For each combination of profile category and organisational level, it identifies the most important AI application areas and the corresponding literacy level required. This matrix will serve as a primary input to the competency framework development in D2.3. Literacy levels are indicated as follows: A = Awareness; W = Working Knowledge; O = Operational Proficiency.

Table 7. Prioritization matrix of AI applications by profile and organisational level

Profile category	Org. Level	Priority AI processes	Literacy level
1. Pharmacists	Strategic	Demand forecasting, inventory management, clinical decision support, drug tracking	A + W
1. Pharmacists	Managerial	Demand forecasting, inventory management, fraud detection, clinical AI governance	W
1. Pharmacists	Tactical / Operational	Inventory management, dispensing automation, medication reconciliation AI	W + O
2. Logistics Managers and operators	Strategic / Managerial	Demand forecasting, transportation, cold chain, warehouse automation, supply chain analytics	A + W
2. Logistics Managers and operators	Tactical	Demand forecasting, inventory management, transportation planning, cold chain monitoring	W
2. Logistics Managers and operators	Operational	Warehouse automation, last-mile delivery AI, cold chain IoT, drug tracking, reverse logistics AI	O
3. Other Supply Chain actors	Institutional / Strategic	Demand forecasting, fraud detection, drug tracking, AI governance and procurement	A
Cross-profile	All levels	Data literacy, AI output interpretation, AI limitations, regulatory framework, EU AI Act	A to O, level-dependent

6. Implications for AI competency frameworks

This chapter synthesizes the findings of D2.2 into a structured set of inputs for the development of the AI literacy competency framework in D2.3. It translates the AI application mapping presented in Chapters 4 and 5 into practical guidance for framework design: which AI applications should be considered, how they can be prioritized across profiles and levels, and which design principles are most relevant for a healthcare logistics-specific AI literacy framework.

The chapter is structured in three sections: a prioritization matrix of the AI applications identified through the desk and field research (6.1), a mapping of these applications to target profiles and organizational levels (6.2), and a set of recommendations that can inform the development of the framework in D2.3 (6.3).

6.1 Summary of AI applications identified: prioritization matrix

Table 8 ranks the ten application areas across four dimensions relevant to framework design: **adoption breadth** (how widely the application is deployed across the sector and across profile categories), **profile coverage** (the number and diversity of target profiles who interact with the application), **literacy urgency** (the

degree to which a skills gap in this area creates immediate operational risk or patient safety concerns), and **training tractability** (the degree to which the required literacy can be effectively developed through training interventions).

Table 8. Prioritization matrix of AI applications by profile and organisational level

AI application area	Adoption breadth	Profile coverage	Literacy urgency	Training tractability	Overall priority
4.1 Demand forecasting and procurement	High	Broad, Cat.1–2, all levels	High	High	High
4.3 Inventory management and optimization	High	Broad, Cat.1–2, tactical/operational	High	High	High
4.4 Warehouse management and automation	Medium-High	Cat.2, all levels	Medium-High	Medium	Medium-High
4.5 Cold chain monitoring	Medium-High	Cat.2, operational/tactical	High	High	High
4.6 Transportation and route optimization	Medium-High	Cat.2, tactical/operational	Medium	High	Medium-High
4.7 Last-mile delivery	Medium	Cat.2, operational	Medium	High	Medium
4.8 Reverse logistics	Low-Medium	Cat.2, operational	Medium	High	Medium
4.9 Fraud detection and prevention	Low-Medium	Cat.1–3, managerial/compliance	Medium	Medium	Medium
4.10 Clinical decision support	Low-Medium	Cat.1, all levels	Critical	Medium	Medium-High

Based on this analysis, five application areas emerge as the highest priority for the AI literacy framework: demand forecasting and procurement (4.1), inventory management (4.3), cold chain monitoring (4.5), and clinical decision support (4.10). These areas combine broad relevance, high literacy urgency, and sufficient training tractability to justify their inclusion as core framework components.

The remaining five application areas can be incorporated as secondary framework components or elective modules for profiles with specific operational exposure to these technologies. This modular approach would allow the framework and the training materials developed in WP3 to be tailored to the needs of each target profile, without creating an unnecessarily broad universal curriculum.

6.2 Applications map of target profiles and organizational levels

Building on the prioritization matrix and the profile-level analysis of Chapter 5, this section maps the five priority AI application areas to the target profiles and organizational levels identified in section 2.5. This mapping provides a structural input for the AI literacy competency framework in D2.3 and can also inform the design of the gap analysis survey in D2.4.

The mapping uses three literacy levels, consistent with the approach outlined in Chapter 5: Awareness (A) = understanding what the AI application does and why it matters; Working Knowledge (W) = ability to interpret, evaluate, and act on AI outputs; Operational Proficiency (O) = hands-on ability to configure, use, and troubleshoot AI systems in daily work. **Table 9** maps demand forecasting and procurement AI to the profiles most likely to interact with these applications. **Table 10** maps inventory management AI to the profiles most directly involved in stock control, replenishment and warehouse coordination. **Table 11** maps cold chain

monitoring AI to the profiles responsible for temperature-controlled logistics, planning and compliance. **Table 12** maps demand forecasting and procurement AI to target profiles. **Table 13** maps clinical decision support AI to the pharmacy profiles working at the interface between clinical decisions and logistics processes.

Table 9. Mapping of demand forecasting and procurement AI to target profiles.

Profile	Org. Level	Literacy level	Key competencies
Hospital pharmacy director / head	Strategic	A + W	Demand forecasting, inventory management, clinical decision support, drug tracking
Hospital pharmacy director / head	Strategic	A + W	Evaluate AI forecasting tools; interpret strategic demand analytics
Pharmaceutical procurement manager	Tactical / Managerial	W	Interpret forecasts; manage AI-assisted procurement; understand override logic
Supply chain manager	Strategic / Managerial	A + W	Build the business case for forecasting AI; design KPIs; monitor performance
Supply chain coordinator / logistics planner	Tactical	W	Use AI demand plans; maintain data quality; identify forecast errors
Procurement officer / purchasing officer	Tactical	W	Use AI procurement analytics; assess supplier performance AI; respond to fraud signals

Table 10. Mapping of demand forecasting and procurement AI to target profiles.

Profile	Org. Level	Literacy level	Key competencies
Pharmacy warehouse coordinator	Tactical / Operational	W + O	Interpret AI inventory alerts; understand safety stock logic; use expiry management tools
Community pharmacist	Operational	O	Use AI stock replenishment; confirm orders; manage exceptions
Inventory manager / stock controller	Tactical / Operational	W + O	Use AI inventory tools; manage expiry AI; perform cycle counting automation
Warehouse manager	Managerial	W	Configure WMS AI; interpret inventory analytics; monitor performance

Table 11. Mapping of demand forecasting and procurement AI to target profiles.

Profile	Org. Level	Literacy level	Key competencies
Cold chain specialist	Operational	O	Use IoT monitoring systems; distinguish predictive and threshold alerts; respond to excursions
Distribution / transportation manager	Managerial / Tactical	W	Interpret cold chain analytics; use AI routing for temperature-sensitive products
Logistics planner	Tactical	W	Plan cold chain risk; interpret AI monitoring data
Supply chain manager	Strategic / Managerial	A + W	Define cold chain AI strategy; evaluate vendors; manage compliance

Table 12. Mapping of demand forecasting and procurement AI to target profiles.

Profile	Org. Level	Literacy level	Key competencies
Pharmacy warehouse coordinator	Tactical / Operational	O	Perform medicines verification; manage serialization scanning; respond to anomaly alerts
Community pharmacist	Operational	O	Perform point-of-dispensing verification; handle alerts
Warehouse manager	Managerial	W	Manage serialization data; oversee AI anomaly detection
Regulatory compliance officer	Institutional	A + W	Understand EU AI Act compliance; manage anomaly reporting; interpret regulatory obligations

Pharmaceutical wholesaler logistics manager	Strategic / Industry	W + O	Manage medicines data at scale; use AI traceability analytics
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Table 13. Mapping of demand forecasting and procurement AI to target profiles.

Profile	Org. Level	Literacy level	Key competencies
Hospital pharmacy director / head	Strategic	A + W	Govern clinical AI use; evaluate decision support tools; assess patient safety implications
Clinical pharmacist with logistics responsibilities	Tactical / Operational	W + O	Use medication reconciliation AI; support clinical supply planning; maintain professional accountability
Hospital pharmacist, head of department	Strategic / Managerial	W	Use formulary management AI; integrate clinical demand signals; support AI governance

6.3 Recommendations for framework development

The findings of D2.2, synthesized in sections 6.1 and 6.2, support eight recommendations for the design of the AI literacy competency framework in D2.3. These recommendations are presented as design principles that can inform the next stage of WP2. They should be reviewed and updated as the project progresses and further evidence becomes available.

Recommendation 1

Adopt a modular, profile-differentiated framework architecture. The framework should be structured around a core module covering the five cross-cutting competency areas identified in section 5.4: data literacy, AI output interpretation, AI limitations, regulatory framework, and change management. This core should be complemented by profile-specific modules covering the priority AI application areas identified in section 6.1. A modular architecture would allow the framework to be applied selectively to specific target groups without requiring universal coverage of all application areas.

Recommendation 2

Use a three-level proficiency scale. The three literacy levels proposed in Chapters 5 and 6 provide a practical basis for differentiating competency requirements across organizational levels. Awareness is the minimum literacy level for all profiles. Working Knowledge is the reference level for tactical and managerial professionals. Operational Proficiency is required for profiles with intensive daily interaction with specific AI tools. This scale should be aligned with the European Qualifications Framework (EQF) levels during D2.3 development.

Recommendation 3

Ground the framework in actual work tasks, not technological categories. Competency descriptors should be formulated in terms of what professionals need to be able to do in their specific work tasks, rather than in terms of abstract AI concepts. For example, a competency for a pharmacy warehouse coordinator could be formulated as “interpret AI inventory alerts and take appropriate stock management actions,” rather than “understand machine learning-based inventory

optimization.” This task-based approach would make the framework more directly actionable for training design and assessment.

Recommendation 4

Incorporate data literacy as a foundational, cross-cutting competency. Data literacy, understood as the ability to understand, evaluate, and manage the data that AI systems depend on, should be treated as a foundational competency for all profiles and literacy levels. The research consistently identifies data quality as one of the most important enablers and barriers to AI adoption in healthcare logistics. Training programmes that develop AI literacy without addressing data literacy are unlikely to prepare professionals to use AI tools effectively in practice.

Recommendation 5

Address the EU AI Act as a core regulatory literacy requirement. The EU AI Act (Regulation 2024/1689) introduces obligations for deployers of AI systems that are directly relevant to healthcare logistics organizations and their staff. The framework should include a regulatory literacy component that gives professionals a sufficient understanding of the Act’s requirements, particularly the human oversight obligations for high-risk AI systems. This component should be calibrated to the organizational level: awareness for operational staff, working knowledge for tactical and managerial staff, and governance-level understanding for strategic professionals.

Recommendation 6

Design for explainable AI literacy, not only AI use literacy. Trust in AI systems is one of the main barriers to adoption among healthcare logistics professionals. The framework should therefore go beyond training professionals to use AI tools and should also develop their ability to understand, at a conceptual level, how AI systems generate their outputs. This understanding should be sufficient to evaluate outputs critically and communicate about AI with colleagues and stakeholders. Explainable AI literacy is particularly important for pharmacists and clinical logistics professionals, where the patient safety implications of AI-supported decisions are highest.

Recommendation 7

Validate framework priorities through partner experience. The competency mapping presented in sections 6.1 and 6.2 integrates documentary evidence with the professional experience of consortium partners. Priorities and literacy level requirements should be validated against the direct experience of professionals working in the sector across the three partner countries, and refined as the project progresses.

Recommendation 8

Ensure alignment with EQF and ECVET standards from the outset. The HEALTH-LOG-AI project aims to develop a framework aligned with the European Qualifications Framework and the European Credit System for Vocational

Education and Training (ECVET). The competency descriptors developed in D2.3 should be mapped to EQF levels from the first draft, using the Knowledge / Skills / Attitudes (KSA) taxonomy established in D2.1. This alignment is important for ensuring that the framework is usable across European countries and VET systems, and that the training materials and certification pathways developed in WP3 are compatible with existing European qualification structures.

7. Conclusions

This chapter presents the conclusions of D2.2, “Desk and Field Research on Potential Applications of AI in Healthcare Logistics.” It summarises the key findings of the research (7.1), acknowledges the main limitations and open questions (7.2), and outlines the next steps within WP2 (7.3).

7.1 Key findings

D2.2 has generated a structured evidence base on the current and potential applications of AI in healthcare logistics. The following eight findings summarise the main conclusions of the research, with particular attention to the aspects most relevant to the subsequent activities of WP2.

Key finding 1

AI adoption in healthcare logistics is real and growing, but uneven. Artificial Intelligence is no longer a theoretical prospect for healthcare logistics. It is already deployed in several operational contexts, including demand forecasting, inventory optimization, warehouse automation, cold chain monitoring, across the three participating countries. However, adoption remains uneven across organisation types, application areas and countries. This heterogeneity is relevant to training design, as the framework must be applicable both to organisations that have not yet deployed AI and to those already managing mature AI systems.

Key finding 2

Demand forecasting and inventory management are the highest-priority AI literacy areas. Across all profile categories and organisational levels, AI-driven demand forecasting and inventory optimization are the most widely deployed and impactful AI application areas in healthcare logistics. They are also among the areas where the skills gap is most evident. Professionals at different levels, from procurement officers to pharmacy warehouse coordinators, routinely interact with AI-generated forecasts and recommendations but may lack the conceptual understanding needed to evaluate, validate or override these outputs effectively. Developing competencies in this area should therefore be a priority for the AI literacy framework.

Key finding 3

AI-driven cold chain could be a safety-critical literacy area. Cold chain monitoring and temperature-sensitive drug tracking are AI application areas where inadequate literacy can be directly linked to patient safety risks. A cold chain specialist who cannot distinguish between a threshold-based and a predictive AI alert, or a dispensing coordinator who cannot respond correctly to verification anomalies, may create risks for product integrity and patient safety. This area requires operational proficiency-level training for the relevant target profiles.

Key finding 4

Clinical decision support AI sits at the highest-stakes intersection of logistics and patient safety. AI-powered clinical decision support systems, including medication reconciliation AI and formulary management tools, represent one of the most complex AI literacy challenges for the project's target group. Hospital pharmacists and clinical pharmacists with logistics responsibilities need literacy that spans both the logistics and clinical dimensions of these systems. They also need to maintain professional accountability for decisions that are informed, but not determined, by AI outputs. This is an area where overconfidence in AI, or failure to engage critically with AI recommendations, can directly affect patient safety.

Key finding 5

Data literacy is the most important foundational competency. Across AI application areas and target profiles, data quality consistently emerges as both a critical enabler and a major barrier to effective AI adoption. AI systems are only as good as the data they process, and many operational failures of AI in healthcare logistics, including inaccurate forecasts, misleading alerts and unreliable classifications, can be traced to poor data quality at the input stage. Developing data literacy, understood as the ability to understand, evaluate and maintain the data that AI systems depend on, is therefore a foundational requirement for the AI literacy framework.

Key finding 6

Trust and explainability are key adoption barriers that training must address. The evidence consistently identifies trust in AI systems as a significant barrier to adoption among healthcare logistics professionals. This trust deficit is partly linked to the “black box” nature of many ML systems, which makes it difficult for non-expert users to understand how AI-generated recommendations are produced. Training programmes that develop only operational proficiency in using AI tools, without also developing the conceptual understanding needed to evaluate AI outputs critically, are unlikely to build the professional confidence required for sustainable AI adoption.

Key finding 7

The EU AI Act creates new literacy obligations for healthcare logistics professionals. The EU AI Act (Regulation 2024/1689), which entered into force in

August 2024, introduces specific obligations for deployers of AI systems in high-risk contexts, including healthcare. Many AI applications in healthcare logistics are likely to be classified as high-risk AI systems under the Act and may therefore be subject to requirements concerning human oversight, transparency and conformity assessment. Healthcare logistics professionals at managerial and strategic levels need sufficient awareness of these requirements to fulfil their responsibilities as AI deployers. This regulatory literacy component should be incorporated into the AI literacy framework from the outset. This should include awareness of GDPR obligations relevant to AI systems processing health data, liability frameworks for AI-assisted decisions, and — where applicable — MDR requirements for AI systems classified as medical devices.

Key finding 8

The skills gap is most acute at the operational and tactical levels. Synthesising the findings of Chapters 3, 4 and 5, the AI literacy skills gap appears most acute among the professionals most directly targeted by the HEALTH-LOG-AI project: operational and tactical-level professionals in last-tier healthcare logistics. These include warehouse staff, dispensing coordinators, delivery operators and cold chain specialists who interact daily with AI-powered systems, but whose initial training may not have prepared them for this interaction. This finding supports the project's core hypothesis and reinforces the need for accessible, role-specific AI literacy training for these groups.

7.2 Limitations and open questions for further investigation

The research phase of D2.2 — combining desk research and field evidence from consortium partners — is comprehensive in scope, but is subject to a number of limitations. These limitations should be acknowledged explicitly, as they also define the agenda for the field research phase.

Limitations and scope of the research

Publication bias and grey literature gaps. The academic literature on AI in healthcare logistics is dominated by studies from northern and western Europe, North America and Asia. Evidence on AI adoption in Italian, Spanish and Belgian healthcare logistics is more limited, making it difficult to draw country-specific conclusions based on desk research alone. The field research will provide direct, contextually grounded evidence from the three participating countries.

Focus on stated rather than actual adoption. Industry reports and vendor case studies tend to describe AI applications in best-case deployments, often in leading organisations with sophisticated digital infrastructure. The actual level of AI adoption among small and medium-sized pharmacies, regional distributors and public healthcare facilities, which constitute a large part of the project's target population, may be significantly lower than the literature suggests.

Limited evidence on AI literacy needs specifically. While the desk research provides evidence on AI applications in healthcare logistics based on published sources, the field research conducted by consortium partners through interviews, case studies and direct professional experience provides complementary evidence on actual AI adoption, professional literacy needs and training preferences. Together, they inform the profile-level analysis in Chapter 5.

Rapidly evolving technology landscape. The AI landscape is evolving rapidly, with new tools and capabilities emerging continuously. The generative AI wave, driven by large language models, is already beginning to affect logistics software through conversational AI interfaces, AI-generated documentation and natural language querying of supply chain data systems. The framework developed in D2.3 should therefore be able to accommodate future AI applications, not only those documented in this report.

Open questions for the next phases of the project

The following questions are identified as priorities for the next phases of the project, building on the desk and field research conducted so far:

- " What is the actual level of AI adoption among non-expert professionals in last-tier healthcare logistics across Italy, Spain and Belgium, and how does it vary by organisation type, size and sector?*
- " What AI tools do operational and tactical-level professionals actually encounter in their daily work, and how do they currently interact with them?*
- " What are the most significant self-reported AI literacy gaps among the target profiles, and which AI application areas do they perceive as most in need of training support?*
- " What training formats, delivery modes and content approaches do professionals consider most accessible and effective for developing AI literacy in their work context?*
- " How do professionals currently manage the boundary between AI-generated outputs and human professional judgement, and what support do they need to manage this boundary more effectively?*
- " Are there significant differences in AI literacy needs and training preferences across the three participating countries? If so, how should the framework accommodate this diversity?*

Overall, the desk and field research together provide a structured basis for the next stages of WP2 by identifying the main AI application areas, the professional profiles most likely to interact with them, and the preliminary literacy needs associated with these interactions. These findings should be read as an evidence base to be further validated and refined through the field research phase and through the subsequent integration with the AI literacy frameworks and competency scales analysed in D2.1.

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