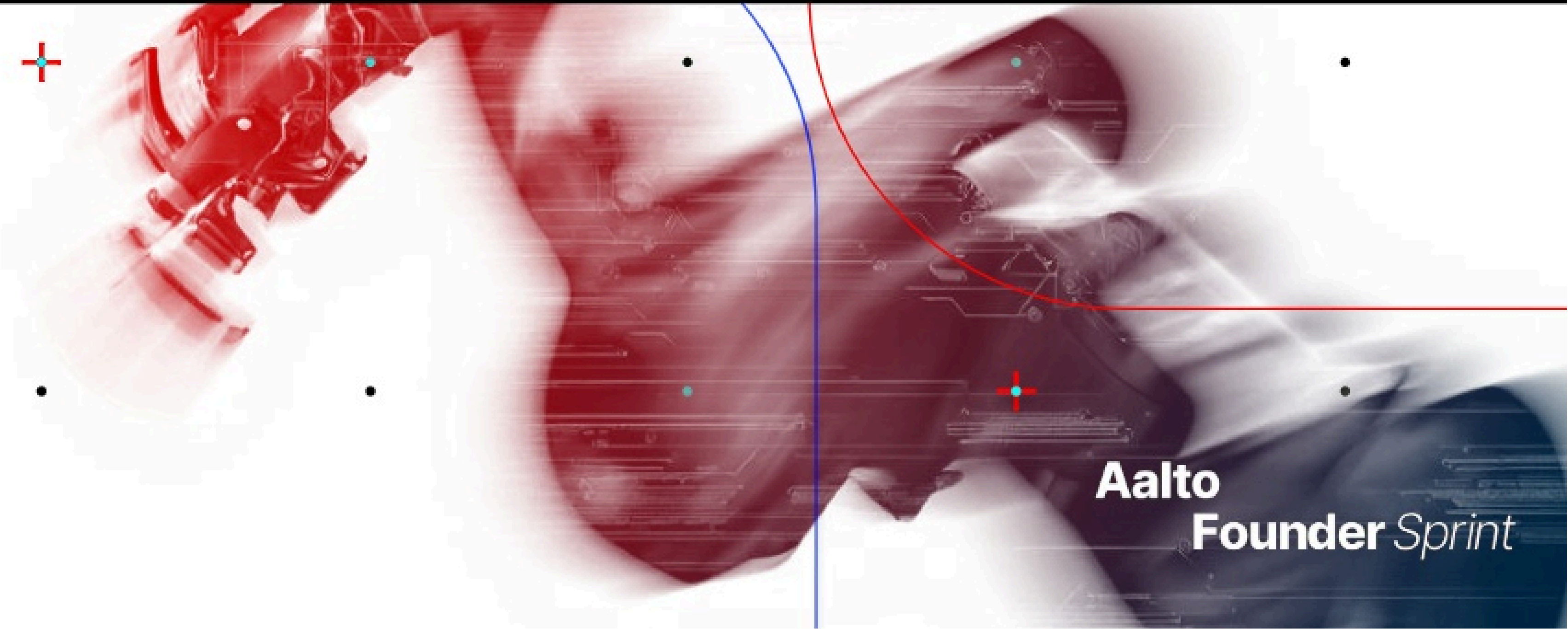
Automation to autonomy in

ROBOTICS

TREND RESEARCH



Aalto Founder *Sprint*

Aalto
Founder Sprint

We are thirteen university students who applied for Aalto Founder School. We have the ambition and desire to do something big in our lives, but we do not know exactly what. By writing this report, we are able to dig deeper into our own ideas and gain a better understanding of what is missing in the world and why. This report is our attempt to figure out what will happen in the years ahead and where we will be in that future.

Before we started interviewing and writing, we began by choosing the industries and themes we wanted to explore. It was a long process, as we wanted to choose the right ones and not anger anybody. At the same time, we wondered how many different topics we should have. After the long start, we divided ourselves into three teams and jumped right in. In total, we did over 80 interviews and visited a waste plant and an elderly care home to get a better grasp of these industries. When it was time to put pen to paper, it got chaotic for the whole group. However, as you can see, we managed.

Quite naively, we thought this would be easy. It was not. But the problems and challenges we experienced are the reason why we joined this program. There were moments when we were tired. We did not want to do an interview and just wanted to go to sleep, but having a great team helped us push through it. One person in our team sent 50 emails on a Sunday just to be able to get enough interviews. As of writing this, the design team is working on a Sunday night to finish their work. These are just a few of the many sacrifices our team has made.

Despite all the challenges we faced, there is no doubt that we will be reminiscing about them. We have learned so much together: having to decide on what topics to include in the report, determining who takes responsibility, and overall learning to deal with each other. Working hard on an idea and having it cut from the paper is not fun, but it teaches you not to take things personally. There are, once again, way too many examples that could be written here.

We are grateful for the organizers of Founder School for giving us this opportunity. The Sprint has not only created a very tight team but also provided an incredible experience for learning and self-development.

Finally, we want to thank all the people who agreed to be interviewed. You welcomed our curiosity with generosity. We couldn't have done this without you.

Table of Contents

Waste Management

Elderly Care

Construction

Abbreviations

ADL
Activities of daily living

AEC
Architecture, Engineering, and Construction

B2C
Business-to-Consumer

BIM
Building Information Modeling

BREEAM
Building Research Establishment Environmental Assessment Method

CAD
Computer-Aided Design

CapEx
Capital Expenditure

CAGR
Compound Annual Growth Rate

CES
Consumer Electronics Show

CSRD
Corporate Sustainability Reporting Directive

CPR
Construction Products Regulation

CNN
Convolutional Neural Network

ECG
Electrocardiogram

EHR
Electronic Health Record

EHDS
European Health Data Space

ESEF
European Single Electronic Format

ERI
Economic Research Institute

EUDAMED
European Database on Medical Devices

ESRS
European Sustainability Reporting Standards

FF/FL
Floor Flatness/Floor Levelness

GNSS-RTK
Global Navigation Satellite System – Real-Time Kinematic

HaH
Hospital-at-Home

HDPE
High-Density Polyethylene

HVAC
Heating, Ventilation, and Air Conditioning

ICT
Information and Communication Technology

LCO
Lithium Cobalt Oxide

LFP
Lithium Iron Phosphate

LIB
Lithium-Ion Battery

LIBS
Laser-Induced Breakdown Spectroscopy

Lidar
Light Detection and Ranging

LG
LG Corporation

M&A
Mergers and Acquisitions

MDR
Medical Device Regulation

Abbreviations

NCA
Nickel Cobalt Aluminium

NFRD
Non-Financial Reporting Directive

NMC
Nickel Manganese Cobalt

PET
Polyethylene Terephthalate

PLC
Programmable Logic Controller

PP
Polypropylene

PPE
Personal Protective Equipment

RaaS
Robotics-as-a-Service

ROI
Return on Investment

ROS
Robot Operating System

RPM
Remote Patient Monitoring

SAM
Serviceable Available Market

SLAM
Simultaneous Localization and Mapping

SME
Small and Medium-sized Enterprise

SOM
Serviceable Obtainable Market

SSOT
Single Source of Truth

TAM
Total Addressable Market

TEN-T
Trans-European Transport Network

UAV
Unmanned Aerial Vehicle

UWB
Ultra-Wideband

VC
Venture Capital

XRF
X-ray Fluorescence

YOLO
You Only Look Once

Introduction

Robotics is entering a new phase of technological and commercial maturity, moving beyond task automation toward higher levels of autonomy. This report explores this shift through three distinct sectors: elderly care, waste management, and construction. Each presents different challenges and opportunities. While elderly care requires safe operation within complex and intimate human contexts, waste management is shaped by extreme material variability in harsh industrial environments. Construction, in turn, demands strength and precision in open, unstructured settings.

Our selection reflects our team's diverse backgrounds and a deliberate effort to understand how robotics evolves across different real-world contexts. Rather than focusing on highly publicized demonstrations, we concentrate on practical applications in established industries where economic value can be clearly measured.

These sectors are operationally distinct, but they share one important feature: they are large, essential industries today and are expected to remain so in the decades ahead. Technological change in these fields therefore carries meaningful economic and societal impact.

This report examines robotics through three distinct sectors: **elderly care, waste management, and construction**. Each presents different challenges and opportunities. Elderly care demands empathy, adaptability, and safety in intimate human interactions. Waste management requires handling infinite material variety in harsh industrial conditions. Construction needs strength, precision, and operation in unstructured outdoor environments.

"AI is transforming every industry, and companies that can scale AI in the physical world will define the next era of human progress" (VML, 2026)

↗ What is a Robot

Any automatically operated machine that replaces human effort, though it may not resemble human beings in appearance or perform functions in a human-like manner (Encyclopædia Britannica, n.d.)

↗ Automation vs Autonomy

Automation involves executing pre-defined rules. If there are changes in workload, system architecture, or release schedules, humans must manually update or rewrite those rules to adapt (Bentley, 2025).

Autonomy enables systems to learn from context, adapt to new situations, and act independently. Instead of specifying step-by-step instructions, engineers define the desired outcome, allowing the system to determine how to achieve it (Bentley, 2025).

Robotics: A Modern Picture

What's Possible Today

Industrial Manufacturing Applications

Industrial robots successfully automate specific, well-defined manufacturing processes with high precision and consistency. Training requirements have dramatically reduced from two weeks in the 1980s to approximately two hours today. In waste management, vision-based sorting robots are commercially operational with out-of-the-box classifiers achieving approximately 90% accuracy. Data collection capabilities enable operators to track throughput and optimize processes in real-time.

Service Robotics and AI Systems

Consumer products like vacuum robots and floor cleaning robots function reliably in structured home environments, with entry-level products available for approximately €100. Object recognition and classification work adequately for trained categories in controlled conditions. Visual-language-action models can process image and text inputs to generate robotic actions in laboratory settings.

Humanoid Robots

Modern humanoids demonstrate impressive physical capabilities including backflips, running, and acrobatic movements. Hardware costs have plummeted to approximately €2,000 for basic platforms, while open-source robotic arms enable widespread experimentation at €200-300 price points.

"The world is built for humans who have two hands. That's why a humanoid robot kind of makes sense because it is similar to the human body." (Expert at International Alliance of Robotics Association)

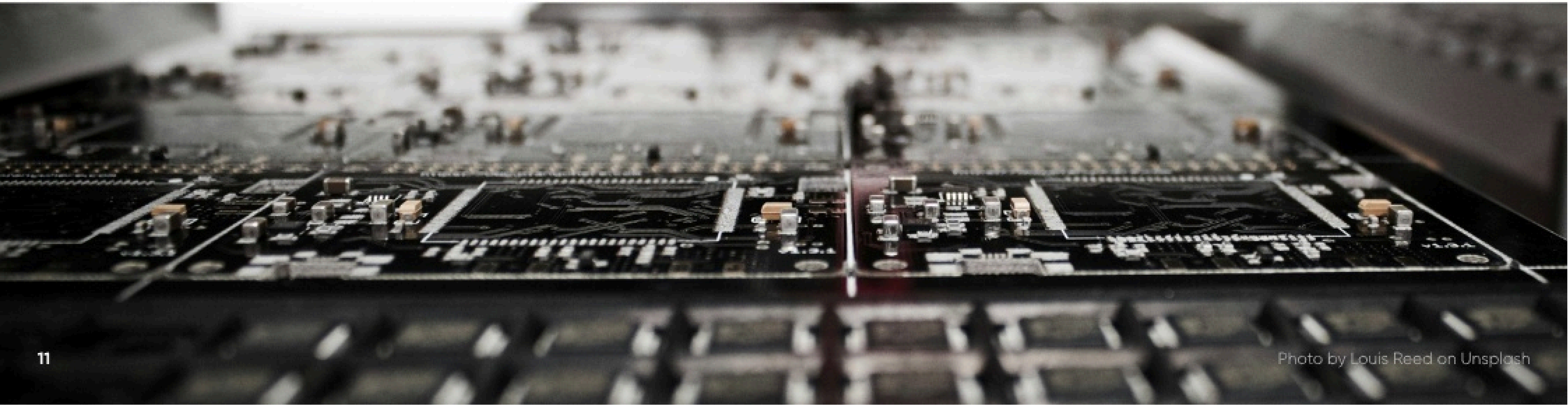


Photo by Louis Reed on Unsplash

Robotics: A Modern Picture

What's Possible in 5-10 Years

Enhanced Industrial Automation

Reconfigurable production lines with mobile robots will enable small-batch production. Voice and gesture control can become more reliable for industrial use, allowing natural communication with robots. Data-driven optimization will transform manufacturing, with robots providing unprecedented process visibility and real-time quality control based on market conditions.

Collaborative Robotics

Collaborative robots will function as tools supporting human workers, enabling them to triple production by automating simple tasks. Specialized robots for inspection and monitoring will proliferate, while domain-specific deployments will expand in hazardous environments like deep mining and automated warehouses.

Service Applications

Robots may follow the smartphone platform model, where users 'train' them for task-specific applications. Service robots will find applications in special therapeutic contexts, and as guides in museums and airports.

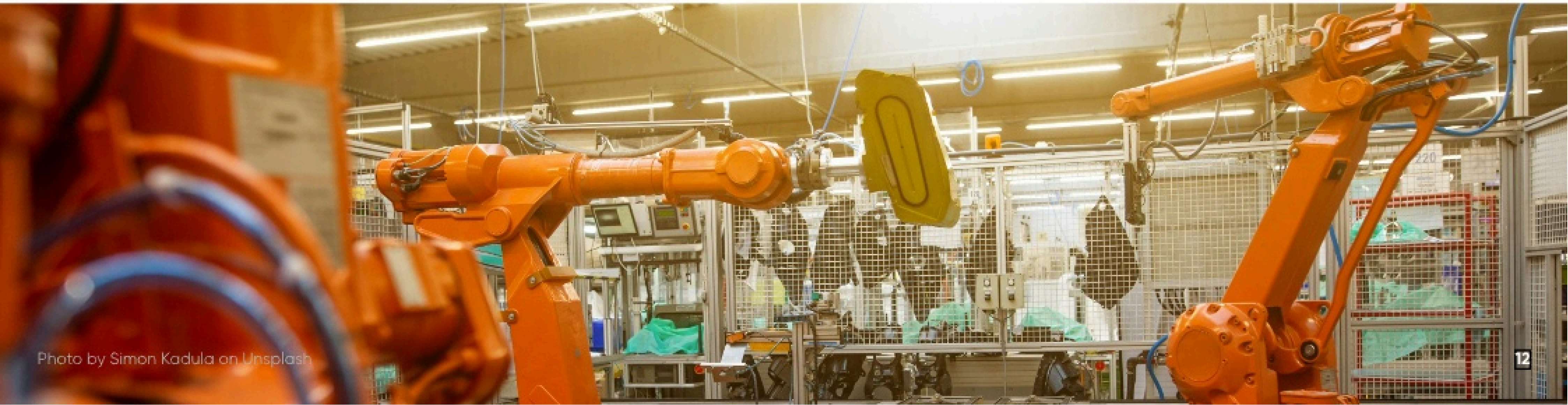


Photo by Simon Kadula on Unsplash

Robotics: A Modern Picture

What is not Possible in 5-10 Years

General Purpose Robots

Universal robots capable of performing diverse household tasks will not emerge. Robots lack the contextual reasoning to understand why tasks should be performed or how context changes execution.

"There will not be universal robots in 20 years." (Head of Robotics research group).

Dexterity and Adaptation Barriers

Hand-finger dexterity will remain a critical bottleneck. Multi-material object handling at industrial speeds will remain impossible. Environmental sensitivity will persist: each new installation will require extensive retraining. Home environments where objects appear unpredictably will defeat robotic systems designed for structured settings.

Safety and Economic Constraints

Full autonomy conflicts with safety standards requiring human oversight for critical decisions. Human workers costing €30,000-40,000 annually remain more economical than €300,000 robot investments for general-purpose tasks.

Photo by Built Robotics on Unsplash

Summary

Waste Management

Environmental imperative. The rapid electrification of transportation is creating an unprecedented EoL battery waste stream that will surge between 2030 and 2035, posing significant contamination risks if proper recycling infrastructure is not established.

Technological advancement. AI-powered robotics are transforming waste management, enabling precise material identification and recovery of valuable materials that traditional melting processes would destroy.

Economic consolidation. Major industry mergers have created well-capitalized operators that can invest in capital-intensive recycling infrastructure and advanced technologies.

Regulatory pressure. Stricter waste management mandates and sustainability reporting requirements make advanced recycling systems essential for compliance.

Spectra. It is an industrial sorting system that simplifies the lithium-ion battery recycling process. The system automates the identification and separation of battery cells without opening them up.

Elderly care

Aging population. The share of people over 60 is projected to nearly double globally by 2050. This creates higher demand for long-term care, home monitoring, and chronic disease management, putting pressure on hospitals and care systems.

Shortage of caregivers. Many countries face a structural shortage of nurses and caregivers due to retirements, high turnover, and declining job attractiveness. AI and robotics are being adopted to handle repetitive and administrative tasks.

Regulatory hurdles. EU rules like the MDR and AI Act classify medical AI and robotics as high-risk. Compliance requires strict safety, human oversight, and data governance, slowing product deployment and innovation.

Social robots. Robots like Paro and Lovot are used to reduce loneliness and support cognitive health. LLMs enable natural conversation, helping seniors reminisce and engage without replacing human care.

Exoskeletons. Wearable exoskeletons are becoming lighter, safer, and cheaper. They prevent falls, support mobility, and maintain independence. Subscription-based models (RaaS) make them accessible and reusable as needs change.

Construction

Aging workforce. The average age of the construction workforce is ~50 years. Alongside the older workforce, a lack of skilled labor will place a huge pressure on the construction industry, especially as a significant part of the workforce nears retirement in the upcoming decade.

Technology adoption. The industry struggles to adapt to technological innovation due to tight, industry wide margins alongside increasing project costs.

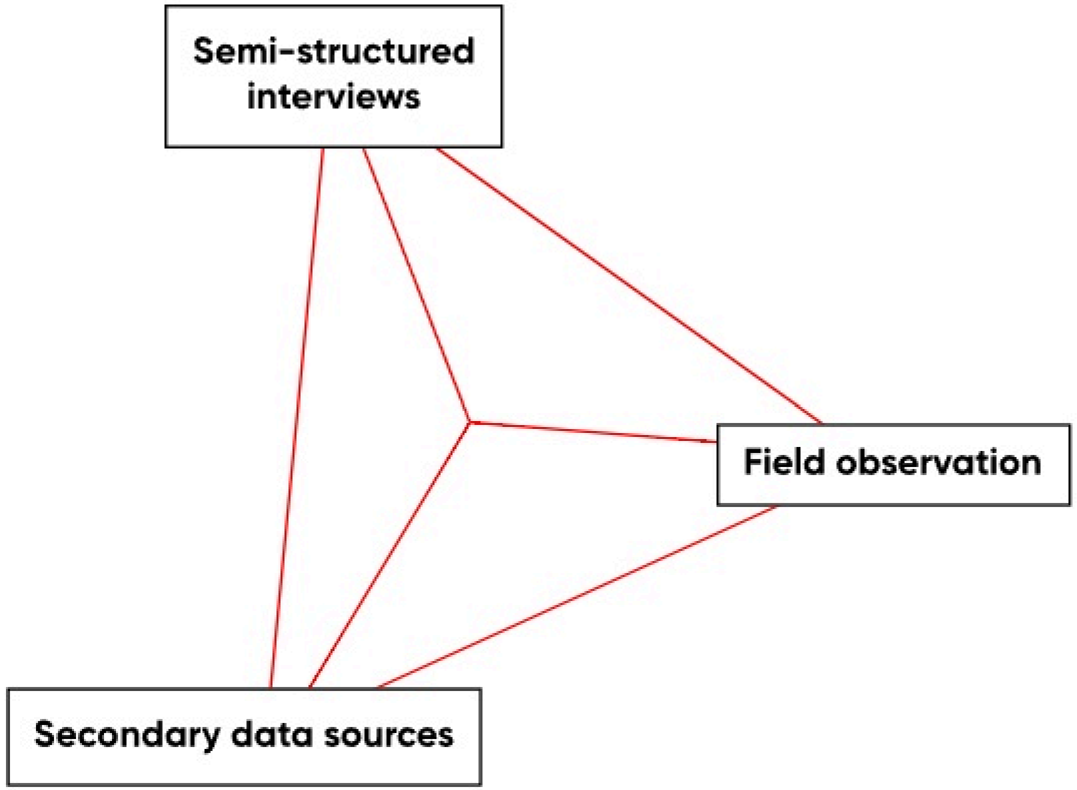
Lack of trust. Stakeholders of construction projects do not trust each other, creating a bottleneck to increased industry productivity, because it forms data silos and disintegrated workflows.

Outdated legislation. Construction SMEs consider slow-moving regulations as their biggest obstacle, while over half the construction companies in the EU view regulations as a hurdle for investment. Regulators also face challenges in project certification due to the combination of outdated regulations with increases in construction project complexity.

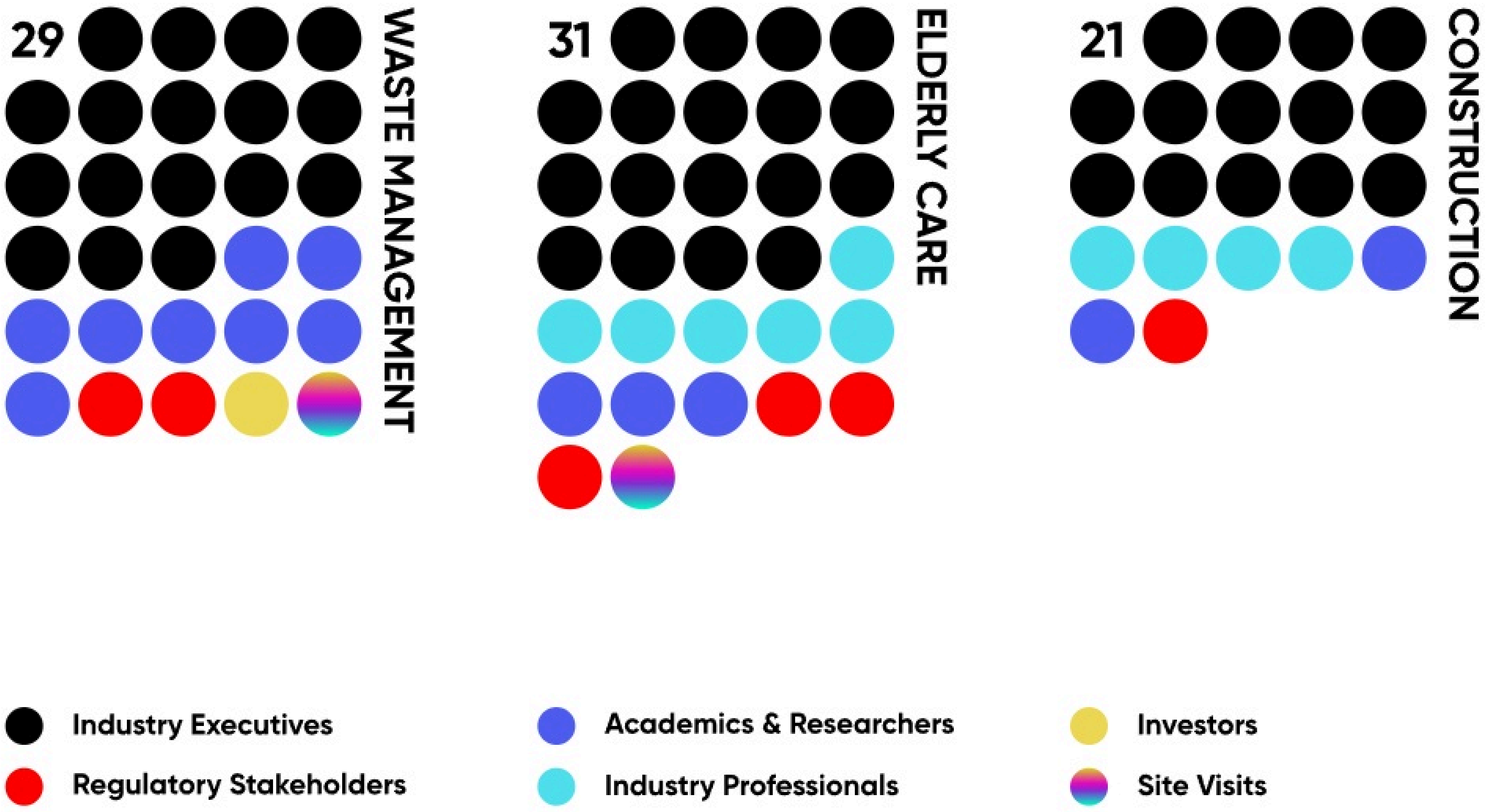
Exoskeletons. Wearable exoskeletons are becoming lighter, safer, and cheaper. They prevent falls, support mobility, and maintain independence. Subscription-based models (RaaS) make them accessible and reusable as needs change.

↗ Methodology

We adopted a **mixed-methods** research approach, combining qualitative and quantitative methods to build a comprehensive understanding of the selected industries. Findings were extensively validated through **triangulation.**



↗ 80+ Interviews Conducted



TRENDS

↗ Waste Management

Photo by Nathan Cima on Unsplash

Waste Management
Technology Trends

- AI-powered Robotics
- Molecular Recycling
- Direct Recycling

AI-Powered Robotics

AI robotics are revolutionizing waste sorting through advanced machine learning, enhancing efficiency and sustainability despite high capital barriers.

Artificial intelligence has fundamentally transformed waste management over the past decade, evolving robotics from simple automated sorting mechanisms into sophisticated systems capable of learning, adapting, and making complex decisions. While early robotic systems relied on basic frameworks like the Robot Operating System (ROS) and programmable logic controllers (PLCs) to coordinate mechanical sorting processes (Wardhana et al., 2023; Quigley et al., 2009), today's waste management facilities increasingly deploy AI-powered robots that can visually identify materials, distinguish between contaminated and recyclable items, and continuously improve their performance through machine learning algorithms.

Facts

Advanced visual recognition capabilities. Modern waste sorting robots utilize convolutional neural networks (CNNs) and object detection systems like YOLO (You Only Look Once) to identify and classify waste materials with increasing accuracy rates (Krizhevsky et al., 2012; Redmon et al., 2016). Companies like AMP Robotics and ZenRobotics have deployed AI-powered sorting systems in facilities across North America and Europe, processing thousands of tons of recyclables daily (ZenRobotics, 2025; AMP, 2024).

Granular material differentiation. Semantic segmentation models enable robots to analyze waste at pixel level, distinguishing between subtle material variations such as different plastic polymer types (PET, HDPE, PP) or identifying food contamination on packaging (Chen et al., 2017).

Self-improving systems. Reinforcement learning algorithms allow waste sorting robots to optimize their operations over time based on environmental feedback, adjusting picking speeds, grip pressure, and sorting decisions to maximize efficiency and minimize errors (Sutton & Barto, 2018).

Drivers

Surge in venture capital and corporate investment. The waste management AI and robotics sector has experienced explosive investment growth, with companies like AMP Robotics raising over $176 million in funding by 2023 and achieving unicorn status with a valuation exceeding $1 billion (Crunchbase, n.d.).

Regulatory demands and circular economy goals. Governments worldwide are implementing stricter recycling targets and extended producer responsibility legislation, requiring higher recovery rates and material purity.

Challenges

High capital investment. Implementing AI-powered robotic systems requires substantial upfront investment, often ranging from $500,000 to several million dollars per installation. It can be challenging to estimate the pay-back period and return-on-investment for waste facilities as the industry has long cycles for renovation planning (Former CEO at waste robotics company, personal communication, January 26, 2026).

Data dependency and algorithmic bias. AI models require extensive training datasets representing diverse waste streams, and performance can degrade when encountering unfamiliar packaging designs or regional waste variations (Postdoctoral researcher in Machine Learning, personal communication, 28 January, 2026).

Impact

Continuous operational efficiency and performance consistency. AI-powered robotic systems operate around the clock without fatigue, maintaining consistent sorting accuracy and throughput rates 24/7. This uninterrupted performance ensures predictable output quality and enables facilities to meet contracted recycling targets reliably, though effectiveness depends on proper system calibration and maintenance protocols (Expert at International Alliance of Robotics Association, personal communication, January 27, 2026).

Data-driven accountability and sustainability reporting. Unlike human sorters, AI-powered robots generate comprehensive real-time data on waste composition, contamination rates, and material recovery by source. This granular data proves invaluable for Corporate Sustainability Reporting Directive (CSRD) compliance, allowing companies to track their waste generation patterns and verify sustainability claims with auditable evidence (Former CEO at waste robotics company, personal communication, January 26, 2026).

Molecular Recycling

Molecular recycling transforms non-recyclable plastic waste into virgin-quality materials through chemical breakdown, bridging the gap between current recycling limitations and strict global circularity mandates.

Molecular recycling, also known as chemical or advanced recycling, represents a paradigm shift in how the waste management industry processes plastic waste that has traditionally been destined for landfills or incineration. Unlike mechanical recycling, which breaks down plastics into pellets through physical processes, molecular recycling uses chemical processes, including pyrolysis, gasification, and solvolysis, to break plastic polymers down to their molecular building blocks. This technology enables the conversion of mixed, contaminated, or previously non-recyclable plastics into virgin-quality raw materials that can be used to create new plastics, fuels, or chemical feedstocks, effectively creating a circular economy for materials that would otherwise contribute to environmental pollution.

The complete transition from mechanical and traditional chemical recycling to molecular recycling is, however, still underway with varying opinions on the timing (Senior Vice President at a publicly listed circular economy company, personal communication, 28 January, 2026).

Facts

Recycling Market Value. The global chemical recycling market was valued at approximately $14.8 Billion 2023 and is projected to reach $26.9 billion by 2030, driven by massive infrastructure investments and a shift towards a more circular plastic economy (Grand View Research, 2024).

Petrochemical Participation. Major petrochemical companies have committed billions to building molecular recycling facilities. ExxonMobil announced plans to process 500,000 metric tons (approximately 1 billion pounds) of plastic waste annually by year-end 2026 through its Exxtend technology (ExxonMobil, 2022)

Drivers

Mandate Recycled Content: The EU will require 30% recycled content in plastic bottles by 2030, which cannot be achieved through mechanical recycling alone (European Commission, 2019).

Reducing Plastic Pollution While Preserving Quality: Brands face regulatory demand to include recycled contents in their products, but recycled plastic may not meet food-grade and medical-grade requirements for consumer products (Ellen MacArthur Foundation, 2023).

Challenges

High Deployment Cost: The chemical recycling operating costs range from $300 to $1,000 per ton compared to $50 to $200 per ton for mechanical recycling, making molecular recycling dependent on favorable policy support, carbon credits, or premium pricing from committed brand partners (Oliver Wyman, 2024)

Environmental Concerns: Depending on the specific type of chemical recycling, the yields can be lower and the energy used can be more intensive than mechanical recycling and energy recovery (Uekert et al., 2023).

Impact

If successfully deployed at industrial scale, molecular recycling is expected to expand circular economy by enabling the recycling of multi-layer packaging, colored plastics, and contaminated waste streams that represent a significant portion of plastic waste currently excluded from traditional recycling systems. Notably, approximately 40% of the 100 million tons of multilayer thermoplastics produced globally each year becomes manufacturing waste that cannot be recycled through conventional methods and typically ends up in landfills or incinerators (University of Wisconsin-Madison, 2024).

Direct Recycling

Direct recycling advances battery recovery by preserving and repairing cathode structures instead of dissolving them, significantly reducing energy use and waste while requiring high-purity material streams

The lithium-ion battery (LIB) recycling industry is undergoing a fundamental transformation, moving away from traditional pyrometallurgical approaches toward more sophisticated hydrometallurgical processes and emerging direct recycling methods. Direct recycling represents a paradigm shift that aims to preserve cathode materials rather than dissolving them entirely, separating cathode powders, removing contaminants, restoring lithium content, and repairing crystal structures through controlled heat treatment (Harper et al., 2019). While currently limited to homogeneous streams like production scrap, this approach promises to save energy and preserve the embedded value of cathode manufacturing. Positioning it as a potentially game-changing solution for sustainable battery waste management (Postdoctoral researcher in Hydrometallurgy and Corrosion, personal communication, 28 January, 2026).

Facts

Transition to Hydrometallurgical Flowsheets: The chemical recycling industry is shifting from simple pyrometallurgical methods to sophisticated hydrometallurgical or hybrid flowsheets, enabling better material recovery of critical metals including lithium (Zeng et al., 2014).

Non-Destructive Techniques: Advanced non-destructive characterization techniques such as X-ray fluorescence (XRF), laser-induced breakdown spectroscopy (LIBS), and X-ray CT are being deployed on moving conveyors. These technologies identify cathode chemistry and internal battery conditions in real-time (Velázquez-Martínez et al., 2019).

AI and Digital Twins: AI-supported control systems and digital twins are being explored to optimize reagent and energy use. This maintains product quality, replacing traditional fixed-recipe approaches with adaptive, model-based control (Xu et al., 2020).

Driver

Growth of EVs: The explosive growth of electric vehicles and stricter environmental regulations worldwide are creating massive volumes of used batteries that need sustainable processing solutions, pushing the industry to develop smarter, more efficient recycling methods (Fan et al., 2020).

Widening Partnerships: Battery recyclers are increasingly partnering with manufacturing plants and even building facilities next door to battery factories, creating closer collaboration that encourages standardized processes and shared information systems (Zhang et al., 2018).

Challenges

Precision and Purity: Direct recycling requires incredibly precise conditions and purity levels to produce materials good enough for new batteries, making it extremely sensitive to contamination and difficult to use when different battery types get mixed together (Harper et al., 2019).

Difficult to Remove Parts: Taking apart old battery packs remains largely a manual job because manufacturers have designed thousands of different configurations optimized for performance and cost rather than easy disassembly, with glued components and complex fasteners that resist robotic handling (Harper et al., 2019).

Impact

The shift from rigid, pre-programmed processes to smart, self-adjusting systems reduces chemical waste and energy consumption while improving how much valuable material can be recovered from old batteries (Fan et al., 2020).

Modern sensor-based sorting technology enables recyclers to identify and separate different materials in real-time, transforming battery recycling from a one-size-fits-all bulk operation into a precision process tailored to each battery chemistry (Velázquez-Martínez et al., 2019).

Waste Management
Economic Trends

- Market Consolidation
- US: From Scrap Exporter to Importer

Market Consolidation

Global consolidation is replacing fragmented local markets with large-scale operators better equipped to fund the high-tech infrastructure and complex regulatory compliance required today.

The waste management industry has historically operated as a highly fragmented ecosystem. In the European Union alone, more than 44,000 enterprises operate in waste collection, treatment, disposal, and materials recovery (Eurostat, n.d.). The United States mirrors this fragmentation, with approximately 20,000 companies focused on waste collection (IBISWorld, n.d.) and an additional 5,000 specializing in waste treatment and disposal (Dun & Bradstreet, n.d.).

The last decade, however, witnessed a dramatic shift towards consolidation of the waste industry through both horizontal and vertical expansion. According to Statista, the global waste management market is projected to reach approximately $1.52 trillion in 2026, growing at a CAGR of roughly 5.5% through 2034, (Mordor Intelligence, 2026).

Facts

Waste Management acquired Advanced Disposal Services for $ 4.6 billion known as "the most significant consolidation in the waste industry in over a decade" (Rosengren, 2020). The deal added approximately 3 million residential, commercial, and industrial customers across 16 states, significantly expanding Waste Management's geographic footprint in the US.

Veolia acquired Suez for €13 billion, considered "the largest M&A in the global environmental sector" (Veolia China, 2021). This merger combined two French waste and water management giants that had been rivals since the 19th century, with Veolia arguing that together they could better compete against emerging global challengers, particularly from China (CNBC, 2021).

Drivers

Increasingly complex regulatory requirements favor well-capitalized operators: Environmental regulations governing waste handling, emissions, recycling standards, and landfill operations have become substantially more stringent and technically demanding. While smaller companies struggle to adapt, larger companies possess the financial strength to adapt to this demanding regulatory landscape (Expert at NG Nordic, personal communication, February 4, 2026).

Capital-intensive technology investments create competitive advantages for larger players: The adoption of automated sorting systems, advanced treatment technologies, emissions control equipment, and data management platforms requires substantial upfront investment. Larger companies can amortize these costs across broader operations and secure favorable financing terms, while smaller operators face difficulty justifying or funding such expenditures.

Challenges

Reduced competition may increase pricing power and limit innovation: As the number of independent operators decreases, customers in many regions face fewer alternatives. This reduced competitive pressure could lead to higher prices, less flexible service arrangements, and potentially slower innovation as dominant players face less pressure to differentiate their offerings. To tackle this, an example, Waste Management was made to divest 15 landfills, 37 transfer stations, 29 hauling facilities, and over 200 collection routes across 10 states to GFL Environmental (Rosengren, 2020).

Impact

Accelerated technology adoption and standardization across the industry: Consolidated operators can implement advanced technologies more rapidly across their expanded footprints, potentially improving overall industry efficiency, recycling rates, and environmental performance through standardized best practices and centralized expertise.

Transformation of employment and business opportunities: Small business owners and entrepreneurs who previously operated independent waste companies are increasingly becoming employees of larger corporations or exiting the industry entirely. This fundamentally changes the economic structure of communities where waste management provided local business opportunities and employment.

US: From Scrap Exporter to Importer

Driven by national security and global trade shifts, the U.S. is pivoting toward a domestic-first model by investing in recycling infrastructure to transform scrap metal from a major export into a strategic internal resource for manufacturing.

For decades, the U.S. has shipped millions of tons of scrap steel, aluminum, and copper overseas, particularly to China and other Asian markets. However, recent regulatory frameworks, infrastructure investments, and escalating international tensions signal a transition toward domestic recycling capacity, positioning the nation to potentially become a net importer of certain scrap metal categories (Expert at NG Nordic, personal communication, 26 January, 2026).

Facts

Importing Scrap Metal: The U.S. exported approximately 17 million metric tons of scrap metal in 2022, valued at over $10 billion, with ferrous scrap representing the largest category (American Iron and Steel Institute, 2023).

Infrastructure Investment and Jobs Act 2021: The Infrastructure Investment and Jobs Act of 2021 allocated $275 million specifically for recycling infrastructure grants, aimed at modernizing facilities and expanding domestic processing capabilities (Environmental Protection Agency, 2022).

Drivers

China's National Sword Policy (2018): dramatically restricted scrap imports, forcing the U.S. to reconsider its export-dependent model. Before the policy, China imported an estimated 45 million tons of scrap metal, waste paper, and plastic worth over $18 billion in 2016, but the policy banned 24 categories of solid waste and reduced contamination thresholds from 5-10% to 0.5%, fundamentally disrupting traditional trade flows (Brooks et al., 2018; Lowy Institute, 2020).

Resource Security: Strategic resource security concerns have intensified amid U.S.-China tensions, with policymakers viewing scrap metal, particularly aluminum and metals containing rare earth elements, as critical feedstock for defense manufacturing and infrastructure. The Department of Defense has invested in domestic scrap upcycling capabilities, with officials stating that "U.S. dependency on foreign sources for specialty metals presents a significant risk to national security" (U.S. Department of War, 2023)

Impact

Economic and employment benefits include significant job creation in recycling and manufacturing sectors, with the industry directly supporting almost 600,000 jobs while processing 137 million metric tons of materials annually (Recycled Materials Association, 2024)

Photo by Esra Nurdoğan

↗ Waste Management

↗ Society & Environmental Trends

- → From Migration to Automation
- → The EV Battery Paradox
- → Rising Microplastic Pollution

From Migration to Automation

Western Europe's waste sector is shifting from a reliance on cross-border migrant labor to robotic automation as pandemic-induced shortages and rising safety costs drive investment in high-tech sorting infrastructure.

For decades, waste management in Western Europe relied on an abundant supply of inexpensive labor from neighboring countries with lower wage levels. Polish, Romanian, and other Eastern European workers formed the backbone of collection and sorting operations across the Netherlands, Germany, and Scandinavia, making manual waste processing economically viable. However, the COVID-19 pandemic fundamentally disrupted this model. What was once a labor-intensive industry sustained by cross-border wage differentials is now embracing robotic solutions, marking a significant shift in how developed economies manage their waste streams.

Facts

Robotic adoption is accelerating rapidly across Europe. The European AI waste sorting robots market is projected to grow from $25.8 million in 2025 to $58.7 million by 2035, representing a compound annual growth rate of 8.6% (Future Market Insights, 2025). Europe remains the global leader in this niche holding 37.3% of total waste sorting robots market share, driven by advanced regulatory and waste management landscape (Market Data Forecast, 2024).

Eastern European workers constitute a substantial portion of the workforce in Western Europe. In the Netherlands specifically, Poland leads temporary worker numbers with approximately 82,500 people, followed by Romania, Ukraine, and Bulgaria, which together filled approximately 66,000 temporary jobs in 2024 (NL Times, 2026).

Drivers

Labor shortages and health concerns during COVID-19. Many workers from other EU Member States returned home in the first months of the pandemic, particularly to Eastern Europe. Worker shortages were subsequently reported across many European countries including Germany, France, Italy, the Netherlands, and Scandinavia (Andriescu, 2020).

Rising safety standards and worker protections have increased operational costs. Waste management workers were identified as particularly vulnerable during COVID-19 due to exposure to potentially infectious materials, with research showing SARS-CoV-2 can survive on cardboard for up to 24 hours and up to two to three days on plastic and stainless steel (van Doremalen et al., 2020). This prompted enhanced safety protocols, increased PPE requirements, and altered collection policies that made manual operations more expensive (Former CEO at waste robotics company, personal communication, January 26, 2026).

Challenges

High upfront capital investment remains a barrier to widespread adoption. While operational costs may decrease over time, the initial investment in robotic sorting systems represents a significant financial hurdle, particularly for smaller waste management facilities and municipalities with limited budgets (Expert at International Alliance of Robotics Association, personal communication, January 27, 2026).

Integration with existing infrastructure and workflows requires substantial operational restructuring. Facilities designed around manual sorting processes must be retrofitted or redesigned to accommodate robotic systems, creating disruption during transition periods and requiring workforce retraining (Former CEO at waste robotics company, personal communication, 26 January, 2026).

Impact

Transformation in occupational expertise. As automation increases, the industry will likely require more technical roles in robotics maintenance, programming, and supervision, while the current workforce will upskill themselves to utilize newly added robotic tools. Compared to operating an industrial robot 20 years ago, one can quickly learn how to work with modern robots with two-hour training due to friendlier user interface (Expert at International Alliance of Robotics Association, personal communication, 27 January, 2026).

The EV Battery Paradox

Navigating challenges in circular economy infrastructure and global sustainability

The rapid electrification of transportation over the past decade has positioned EVs as a cornerstone of climate mitigation strategies worldwide. However, this transition brings an unprecedented challenge: millions of lithium-ion battery packs will reach their end of life between 2030 and 2035, creating a waste stream that, if mismanaged, poses significant environmental and public health risks.

Facts

EV Manufacturing Growth: Global electric vehicle production has expanded exponentially, with cumulative sales surpassing 40 million units by the end of 2023. China leads manufacturing with over 60% of global production, followed by Europe and North America, with major manufacturers including Tesla, BYD, Volkswagen Group, and General Motors ramping up production capacity to meet net-zero targets (International Energy Agency, 2024).

Projected End-of-Life Battery Volume: Industry forecasts indicate that approximately 1.5 million metric tons of lithium-ion batteries will reach end of life globally by 2030. This volume is expected to surge to 20 million metric tons annually by 2040 as the initial wave of electric vehicles reaches retirement en masse, (International Renewable Energy Agency, 2024). Making a robust circular economy framework vital to manage this influx.

Environmental Contamination Risk: Improperly disposed EV batteries release heavy metals (cobalt, nickel, manganese) and lithium compounds into ecosystems. Studies show that battery electrolyte leachate can contaminate groundwater with fluoride concentrations exceeding safe drinking water limits by 5-10 times. While cobalt and nickel also bioaccumulate in the soil organisms. Bioaccumulate is the accumulation of any material in the biosphere. Entering food chains and posing neurological and carcinogenic risks to human and animal populations (Maritz et al., 2025).

Drivers

Regulatory Pressure: The European Union's Battery Regulation (2023) mandates minimum recovery rates of 90% for cobalt, copper, and nickel, and 50% for lithium by 2027, rising to 95% and 80% respectively by 2030. Similar extended producer responsibility frameworks are emerging in California, China, and South Korea, legally obligating manufacturers to finance collection and recycling systems (European Commission, 2023).

Economic Value Recovery: A single EV battery pack contains $1,000-$2,500 worth of recoverable materials at current commodity prices. With virgin lithium costs volatile and supply chains geopolitically concentrated in China, Australia, and Chile, recycled battery materials offer cost stability and supply security, driving investment in circular economic infrastructure (Hanna et al., 2025).

Challenges

Pre-Recycling Risk Assessment: Batteries from normally aged vehicles pose minimal risk, while those from crashed vehicles may have internal damage or an unstable chemical state that can trigger thermal runaway. Without detailed provenance data on usage history and vehicle accidents, recyclers cannot assess safety levels (Postdoctoral researcher in Hydrometallurgy and Corrosion, personal communication, 28 January, 2026).

Systematic Disassembly Complexity: Unlike consumer electronics with relatively uniform battery configurations, EV battery architectures are hierarchical and manufacturer-specific: individual lithium-ion cells, often 50-100 per module, are grouped into groups of modules. These bigger groups are typically 10-30 per vehicle, which together form battery packs weighing 300-600 kg. Each layer of modules requires manual or robotic disassembly under controlled conditions to prevent short-circuits.

During disassembly cables, cooling systems, and battery management electronics must be safely removed before chemical processing of lithium-ion cells can begin. Current recycling infrastructure lacks standardized automated disassembly protocols capable of handling these diverse battery packs at scale (Zorn et al., 2022).

Infrastructure Gaps: Despite policy ambitions, the (European Court of Auditors, 2026) reports that EU member states' recycling efforts remain in their infancy with the 2030 goal of sourcing 25% of strategic materials from recycled content appearing out of reach as only 15% of required battery collection and processing capacity are in place.

Impact

Operational Transformation: Waste management operators must invest in sensor-driven diagnostic systems, automated disassembly robots, and chemical processing expertise. These capabilities are traditionally outside of waste management operators core competencies, but will be necessary to meet regulatory compliance and capture material value (Postdoctoral researcher in Hydrometallurgy and Corrosion, personal communication, 28 January, 2026).

Environmental Risk Mitigation: Establishing effective battery recycling networks can reduce primary mining impacts by 30-50%. Additionally lowering EV lifecycle carbon emissions by 15-20% when powered by renewable energy, directly determining whether EVs deliver net climate benefits (Hanna et al., 2025).

Photo by Kindel Media

Rising Microplastic Pollution

As the EU moves toward landmark 2026 reporting requirements for microplastic emissions, the waste management sector faces a growing paradox: while regulatory mandates push for increased recycled plastic content, new research reveals that recycled synthetics can shed up to 55% more microplastic fibers than virgin materials.

The proliferation of plastic in consumer goods has created an environmental crisis that extends far beyond visible pollution. As plastic products break down through weathering, mechanical stress, and everyday use, they fragment into microplastics, particles smaller than 5mm that now permeate every ecosystem on Earth. These tiny particles have been detected in human blood, lungs, and placentas, raising serious concerns about their health implications (Leslie et al., 2022).

For the waste management industry, microplastics represent a particularly complex challenge: they are too small to be captured by conventional filtration systems, yet their accumulation in soil, water, and air poses significant risks to both environmental integrity and public health (Leslie et al., 2022).

Facts

Record Plastic Production: Global plastic production reached 400.3 million metric tons in 2022, with an estimated 14 million tons of microplastics accumulating on ocean floors alone (OECD, 2022). The invisible majority is that 99% of microplastics in the ocean sinks, while only 1% floats on the surface.

Microplastics in Garments: A single synthetic garment can release approximately 700,000 microplastic fibers per wash cycle, which wastewater treatment plants cannot fully capture (Napper & Thompson, 2016).

Drivers

Regulatory Mandates Recycled Plastic Adoption: The European Council will require up to 65% recycled content in single-use plastic bottles by 2040 and vehicle manufacturers to incorporate 15% recycled plastic within six years and 25% within ten years of upcoming 2026 legislation (European Commission, 2025).

Increased Consumer Awareness: Media coverage and scientific research has created public demand for microplastic reduction strategies, though economic behavior reveals that eco-friendly choices remain contingent on convenience and cost-neutrality rather than environmental values alone.

Challenges

Material Heterogeneity and Quality Inconsistency: Plastics vary significantly in composition, viscosity, and contamination levels across different waste streams and countries with differing sorting standards. Even clean polyethylene batches contain viscosity variations that cause production failures in manufacturing processes (CEO at a Finnish circular service company, personal communication, 29 January, 2026; Ragaert et al., 2017).

Economic Unviability: Recycled plastic costs exceed virgin plastic prices due to energy-intensive processing, costly infrastructure, additional labor, and complex logistics. When oil prices decline, the price gap widens further, while Chinese manufacturers flooding European markets with low-cost virgin materials have driven traditional recycling companies to bankruptcy despite regulatory pressure favoring recycled content (CEO at a Finnish circular service company, personal communication, 29 January, 2026).

Impact

Human Health Risks: Microplastics carry toxic additives and absorb environmental pollutants, potentially disrupting endocrine systems and causing inflammatory responses, with recycled plastics sometimes containing harmful substances accumulated from mixed waste streams (Cox et al., 2019).

Microplastic Generation: EU regulations make recycled plastic use mandatory regardless of economic considerations, forcing industries to absorb higher costs and quality uncertainties. Management systems must simultaneously invest in advanced technologies to improve recycled material quality and reduce microplastic generation throughout the recycling process (CEO at a Finnish circular service company, personal communication, 29 January, 2026).

Waste Management

Regulatory & Policy Trends

- The Global Shift Away from Landfilling
- Sustainability Reporting and CSRD

The Global Shift Away from Landfilling

Global waste management is shifting from landfilling to resource recovery, driven by strict climate directives and resource security, though infrastructure gaps and enforcement remain significant hurdles.

The traditional reliance on landfills as the primary solution for waste disposal is rapidly diminishing across the globe. From the European Union's ambitious circular economy directives to Asia's stringent waste diversion policies, countries are implementing comprehensive regulatory frameworks that prioritize waste prevention, recycling, and recovery over landfilling. Waste is now reimagined as a resource rather than a burden, with legislative measures increasingly mandating higher recycling rates, extended producer responsibility, and outright landfill bans for specific waste streams.

Facts

European Union's Landfill Directive: Member states are required to reduce municipal waste sent to landfill to 10% or less by 2035, representing a dramatic reduction from historical disposal patterns(European Commission, 2018).

Food Waste Landfill Ban in South Korea: The Korean government implemented a volume-based waste fee system and strict food waste landfill ban in 2005, resulting in food waste recycling rates exceeding 95% by 2019 (Lee et al., 2024; Tamasiga et al., 2022)

Drivers

Climate Change Mitigation: Landfills generate methane, a greenhouse gas 28 times more potent than carbon dioxide. As governments seek to meet Paris Agreement commitments, the ban on landfill is one of the strategic waste sector reforms (U.S. Environmental Protection Agency, 2024)

Waste as Valuable Raw Materials: Resource security concerns are pushing policymakers to view waste as valuable secondary raw materials, particularly as global supply chains face disruptions and nations seek to reduce dependence on virgin resource extraction (Expert at NG Nordic, personal communication, 26 January, 2026).

Challenges

Infrastructure Gaps: Many regions lack the facilities needed for alternative waste processing, requiring substantial capital investment in recycling plants, composting facilities, and anaerobic digestion systems that can take years to develop (World Bank, 2022).

Chasing Regulations: Enforcement and compliance difficulties emerge when regulations outpace public awareness or economic readiness, particularly in developing economies where informal waste sectors dominate and monitoring capacity remains limited (UN Environment Programme, 2021).

Impact

New opportunities for market disruption. As countries successfully reduce their landfill content, landfill operators pivot to recycling and resource recovery services. Meanwhile, existing waste management facilities have the confidence to invest in new technology that enhances waste treatment and recovery (Former CEO at waste robotics company, personal communication, January 26, 2026).

Sustainability Reporting and CSRD

The EU's Corporate Sustainability Reporting Directive (CSRD) transforms waste from a back-end utility into an audit-ready compliance metric, mandating standardized digital disclosures on resource circularity and material recovery.

Sustainability reporting has evolved from voluntary corporate communications to mandatory regulatory requirements, fundamentally reshaping how organizations disclose their ESG performance. The European Union's Corporate Sustainability Reporting Directive (CSRD), which came into force in January 2023, represents a paradigmatic shift in corporate transparency and accountability.

This directive expands the scope of mandatory sustainability reporting to approximately 50,000 companies operating in the EU (European Commission, 2023). The CSRD introduces standardized European Sustainability Reporting Standards (ESRS), establishes mandatory third-party assurance requirements, and requires companies to report both how sustainability issues affect their business and how their operations impact society and the environment (Abhayawansa et al., 2024).

Facts

Digital and Machine-Readable Reporting: The CSRD mandates comprehensive digital reporting using a machine-readable format through the European Single Electronic Format (ESEF) (Aureli et al., 2023).

Mandatory External Assurance: The CSRD requires mandatory external assurance of sustainability information, initially at a limited assurance level starting from the first year of reporting in 2025, with the European Commission mandated to adopt reasonable assurance standards by October 1, 2028, following a feasibility assessment (Deloitte, 2024).

Drivers

Climate Neutrality and Green Deal Alignment: The CSRD forms part of the EU's wider sustainable finance package supporting the European Green Deal, designed to mobilize and redirect capital flows toward sustainable investments and achieve climate neutrality by 2050, with an intermediate target of reducing greenhouse gas emissions by 55% by 2030 compared to 1990 levels (White & Case, 2024).

Quantifiable ESG Data: Investor demand for reliable, comparable ESG data to inform capital allocation decisions has intensified, with stakeholders increasingly integrating sustainability considerations into risk assessments and investment strategies (Abhayawansa et al., 2024).

Challenges

Data Collection Complexity: Organizations face substantial implementation challenges with the complexity of collecting, managing, and reporting data across diverse sustainability metrics spanning climate, biodiversity, human rights, and governance dimensions (Zampone et al., 2024).

Capacity Constraints: The shortage of qualified sustainability professionals and auditors capable of providing assurance services creates capacity constraints across the market (Abhayawansa et al., 2024).

Impact

Global Influence and Brussels Effect: The directive's extraterritorial reach influences global reporting practices, as non-EU companies with significant European operations must comply, creating a "Brussels effect" that extends European sustainability standards worldwide (NordESG, 2023).

Expectation for Precise Waste Data: For waste management companies, clients now demand for precise, verifiable measurement data on waste processing outcomes, including exact recycling rates and material recovery percentages. While sorting precision continues advancing through AI-driven autonomous learning, current technology can only provide bulk estimation, lacking the ability to quantify material flows and compositions in real-time (CEO at a Finnish circular service company, personal communication, 29 January, 2026).

EXPLORATION

↗ Waste Management

Photo by Nathan Cima

Waste Management
Exploration

- Misplaced Batteries as a Critical Hazard in Waste Management
- Manual Battery Sorting is Costly, Inefficient, and Unsafe

Misplaced Batteries as a Critical Hazard in Waste Management

- **1,200 fires annually** occur in UK sorting facilities alone.
- **€181 million in damages** inflicted yearly by battery-related fires.
- **70% year-over-year surge** in fire incidents as the problem escalates.

Misplaced Batteries as a Critical Hazard in Waste Management

Batteries infiltrate all types of waste streams because they are so ubiquitous and embedded in countless everyday devices. Consumers frequently discard them carelessly, mixing them with regular household trash instead of bringing them to dedicated recycling points (Gill & Stephens, 2022). Additionally, even partially used batteries are often thrown away rather than being reused or stored for proper recycling. Outside the home, defective, leftover, or end-of-life batteries from manufacturing processes also flood the waste stream. Together, discarded batteries from homes, offices, and industrial settings contaminate both general waste and more specialized streams, like e-waste.

When these batteries reach the sorting system, where everything is crushed, compressed, or grabbed by claws, they ignite fires regularly, shutting down operations and threatening to burn down entire facilities. According to the CEO of a circular service company, their facility suffers tens of fires each year (Personal communication, January 29, 2026). Another manager at a recycling plant confirms that they battle fires every week due to batteries lurking in already sorted waste (Personal communication, January 30, 2026).

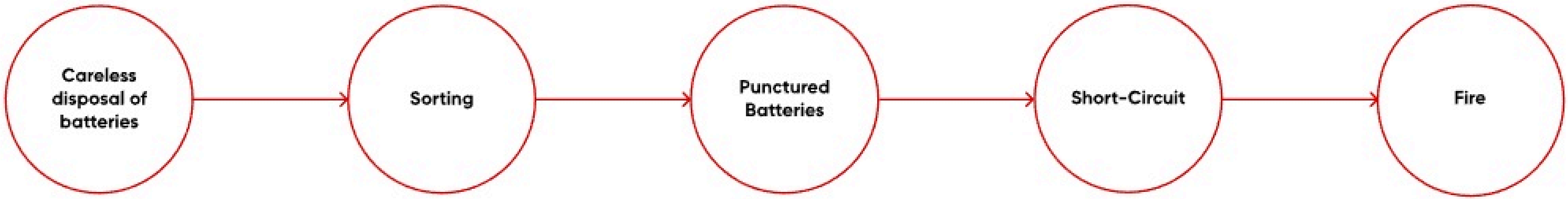
The financial and operational toll is staggering: in the UK alone, fires caused by batteries result in over €181 million in damages annually, with 1,200 incidents in 2023 representing a 71% increase from the previous year (Jowett, 2021), while the US experiences over 5,000 battery-related fires at recycling plants annually, with individual incidents costing up to €42 million in catastrophic cases (Heffernan, 2024).

Several technological solutions have emerged to address the battery detection and removal challenge in waste management facilities, yet large-scale implementation remains limited.

The EU-funded GRINNER project developed an autonomous system for detecting and extracting batteries from electronic waste, but its highly specialized design limits applicability beyond controlled e-waste streams (GrinnerProject, 2022). Similarly, Wesort.ai offers a system capable of identifying and removing batteries, though it struggles with the dense, compacted waste blocks commonly found in real-world operations (Wesort, 2023).

STEINERT has developed a more comprehensive solution using X-ray, color detection, 3D scanning, and induction sensors to identify batteries in mixed waste streams with high precision (Steinert, 2026). However, its prohibitive cost restricts adoption primarily to large-scale industrial facilities, leaving smaller recyclers without viable options.

Despite these technological advances, high costs and technical complexity prevent widespread deployment, leaving most facilities exposed to ongoing battery-related fire risks and operational disruptions.



Manual Battery Sorting is Costly, Inefficient, and Unsafe

- Mixing different battery types makes metal recovery **complex and expensive**.
- Most batteries are disassembled by hand, making the **process slow, dangerous, and costly**.

Manual Battery Sorting is Costly, Inefficient, and Unsafe

Despite growing interest and technological development, lithium ion battery recycling remains difficult due to the heterogeneity of the input material. For example, cobalt-rich lithium cobalt oxide (LCO) was used in older electronics, while nickel–manganese–cobalt (NMC) and nickel–cobalt–aluminium (NCA) chemistries are common among current EVs, and lithium iron phosphate (LFP) gaining popularity in newer EVs and stationary systems, among others (Fan et al., 2020; Zeng et al., 2014). Each chemistry has a different metal content and behaves differently in recycling. This means that the more metals there are in the mix, the more steps are required to recover them.

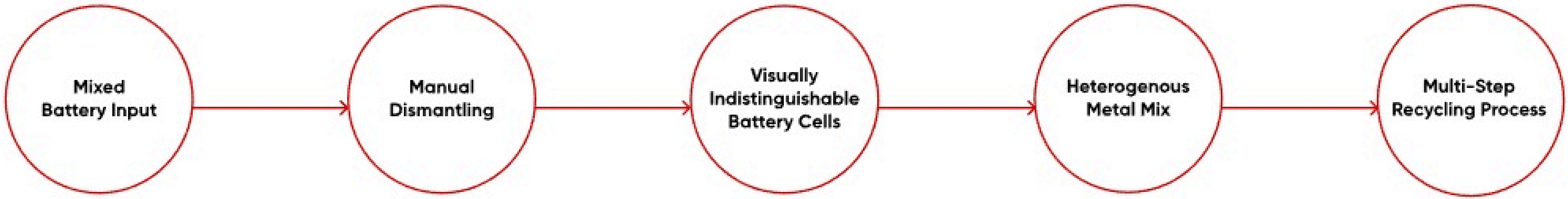
For recyclers, mixed input streams are problematic. In a flux of NMC batteries, even a small share of LCO cells can introduce impurities, further complicating the metal separation and downgrading output quality below battery-grade standards (Fan et al., 2020; Harper et al., 2019).

On top of chemical diversity, there is mechanical diversity. EV packs and consumer devices have not been designed for easy dismantling; hence, disassembly of packs and modules is still mostly done by hand. This manual work is slow, costly, risky, and unsafe. Any mishandling of damaged packs can lead to fires or explosions.

The economics of battery recycling remain challenging precisely because of these compounding difficulties. Recyclers face substantial costs for specialized logistics and hazardous material storage, extensive manual disassembly operations, and multi-stage chemical processing to separate mixed chemistries.

Moreover, profitability highly depends on metal prices and the incoming chemistry mix, factors outside recyclers' control. The investment risk is severe: plants require massive capital expenditure, yet face profound uncertainty and difficulties, often resulting in delayed projects or underutilized capacity (Gaines, 2014; IEA, 2023). In some cases, primary metal production actually consumes less energy per kilogram than complex recycling workflows for contaminated streams (Gaines, 2014).

In short, the two biggest bottlenecks in today's operations: labor-heavy disassembly and the amount of stages needed for the recycling process. Both problems are rooted in inefficient sorting at the front end. One solution to the problem would be to build an autonomous robot for dismantling the battery packs, but due to advancement of the needed technology and high development costs, we chose not to pursue this option within our timeframe.



IDEATION

↗ Waste Management

Photo by Nathan Cima

SPECTRA

Spectra is an **industrial sorting system that automates the identification and separation of mixed lithium-ion battery cells** by chemistry, format, and condition without opening them. By converting heterogeneous battery inflow into consistent feedstock, the system improves material purity, raises downstream yield, and reduces fire incidents caused by damaged cells.

Beyond physical separation, Spectra produces a traceability layer for quality control and compliance reporting, creating auditable records that support regulatory requirements including the European Union Battery Regulation's battery passport and recycled-content targets (European Parliament & Council of the European Union, 2023).

SPECTRA

Technology

Combines XRF (X-Ray Fluorescence), computer vision, and multivariate analysis (statistical methods analyzing multiple variables simultaneously).

Infers cell construction and chemistry without opening cells.

Detects anomalies indicating damage or elevated fire risk.

Proven Scientific Foundation

XRF, LIBS, and related spectroscopic methods can distinguish cathode chemistries and element ratios in lithium-ion batteries without opening cells (Velázquez-Martinez et al., 2019).

These techniques have not been deployed at industrial scale.

Real-Time AI Classification

AI classifiers fuse sensor signals in real time

Routes each cell into the correct output bin.

Enables plants to create tightly defined recycling streams and isolate damaged cells for safe handling.

Industrial Process

Integrates at front end of existing recycling lines

Provides chemistry-specific routing that hydrometallurgical and direct-recycling flowsheets increasingly need (Fan et al., 2020; Xu et al., 2020)

Installation & Integration

Professional setup and integration with existing lines.

Software License

Annual subscription for AI updates, traceability platform.

Capital Equipment Sale

One-time purchase of Spectra system.

Service & Maintenance

Annual serice contracts for callibration, parts and support

Market Size & Growth

Global LIB recycling market is projected to increase from \$16.23B (2024) to \$56.87B (2032) at ~17% CAGR, driven by EV adoption, gigafactory scrap, and new regulations (MarketsandMarkets, 2024; IEA, 2023; Fan et al., 2020).

Sorting and pre-treatment represents 5–15% of total recycling costs but has a disproportionate impact on labor, safety, uptime, and downstream yields.

Geographic Distribution

China currently dominates with 60–70% of global capacity, but EU and North America are the fastest-growing regions due to Battery Regulation and Inflation Reduction Act incentives (European Parliament & Council, 2023; IEA, 2023).

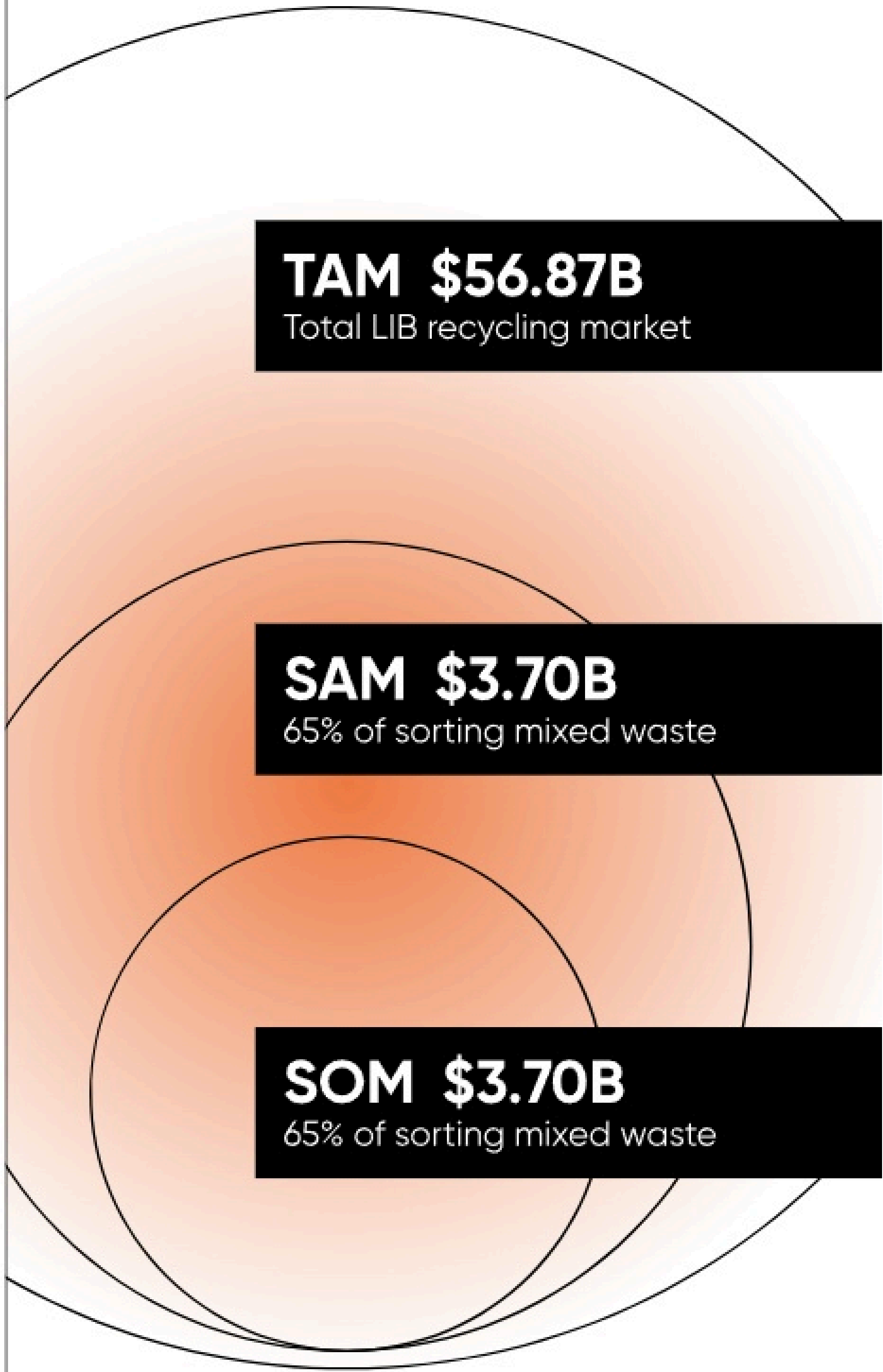
Multiple new plants and retrofits expected 2025–2030, primarily targeting EV packs and industrial batteries.

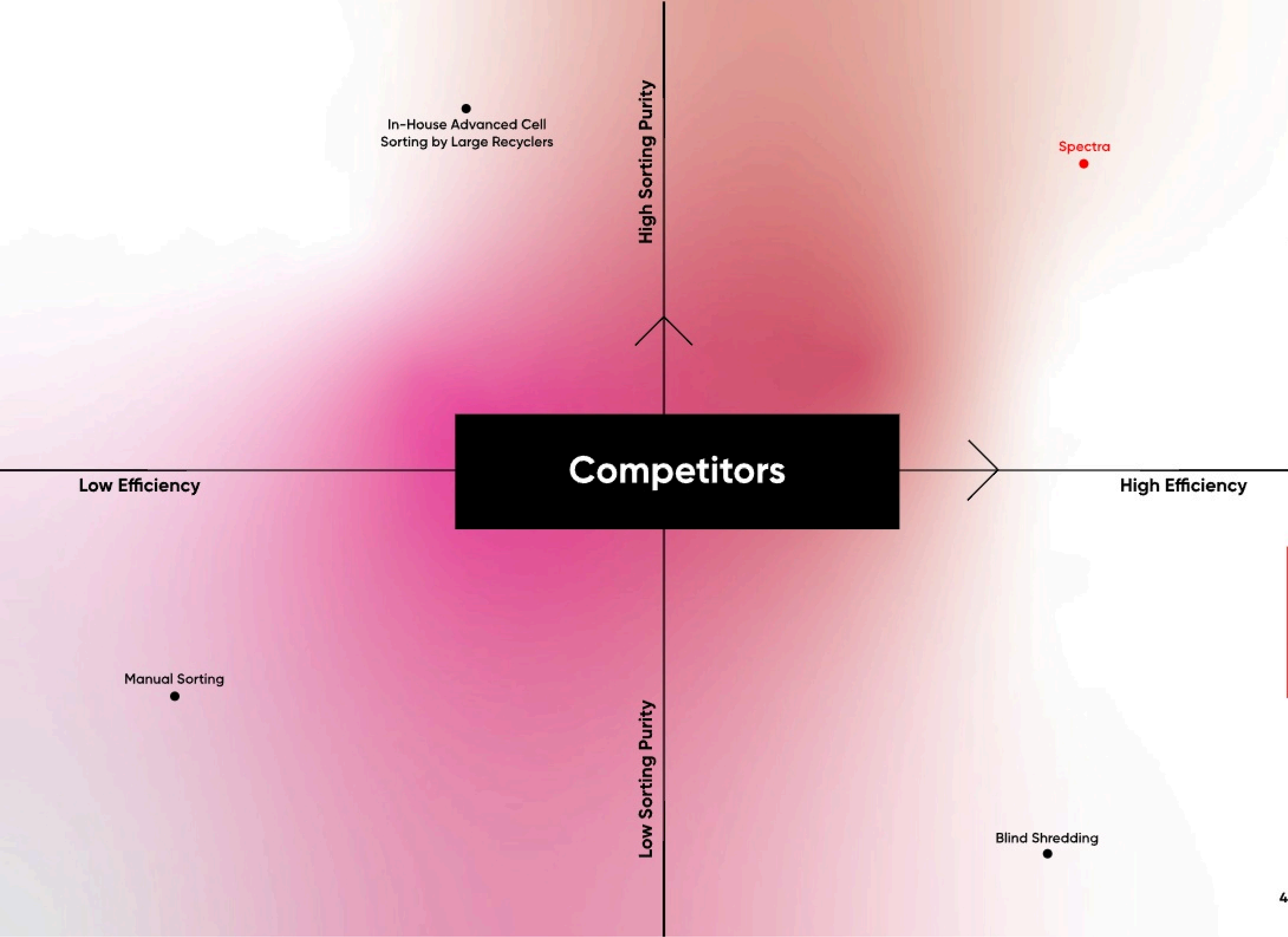
Projections

2025–2030: EVs are still being used. No EoL vehicles yet, meaning the majority of feedstock is homogeneous, well-documented factory scrap from new cell plants (Fan et al., 2020).

Post-2030/2035: Mixed post-consumer streams (diverse EV packs from multiple OEMs, stationary storage, consumer electronics) will increase.

Hundreds of thousands to 1M+ tonnes/year of EoL EVs batteries globally, rising to multi-million tonnes in the 2030s as the 2020s EV cohorts retire (Fan et al., 2020; IEA, 2023).




In-House Advanced Cell
Sorting by Large Recyclers
High Sorting Purity
Spectra
Competitors
Low Efficiency
High Efficiency
Manual Sorting
Low Sorting Purity
Blind Shredding

TRENDS

↗ Elderly care

Photo by Sebastián Vargas

↗ Elderly Care

↗ Demographic & Labour Trends

- → Changing Social Dynamics
- → Labour Market Pressures
- → Care Delivery Model Shift

Changing Social Dynamics

The aging population continues to grow, driving complex challenges in elderly care systems globally.

Demographic and social dynamics are fundamentally reshaping elderly care systems globally. Population aging, rising dementia prevalence, increasing heterogeneity among older adults, structural loneliness, and socio-ethical acceptance constraints together create systemic pressure on care delivery models. These trends are interdependent, collectively reshaping care demand, workforce capacity, and the conditions under which technology can be integrated into elderly care. (World Health Organization, 2024; Richter, 2025; Alzheimer's Disease International, 2020).

Facts

Moving Population Pyramid: The proportion of people over 60 will nearly double globally from 12% to 22% (2.1 billion people) between 2015 and 2050, with even higher rates expected in high-income countries (World Health Organization, 2024; Richter, 2025).

Old Age Dependency: The EU old-age dependency ratio was 33.9% in January 2024 and is projected to reach 56.7% by 2050, meaning fewer than two working-age adults per older person (Eurostat, 2025; Old-Age Dependency Ratio Increases across EU Regions, 2021).

Dementia: Dementia prevalence is projected to double every 20 years, reaching 78 million cases in 2030 and 139 million in 2050. The annual global cost of dementia is expected to rise to US$ 2.8 trillion by 2030 (Alzheimer's Disease International, 2020).

Loneliness: Around one in four older adults in high-income countries experience loneliness, which is associated with poorer physical and mental health, reduced quality of life, and increased mortality (World Health Organization, 2024; Chawla et al., 2021).

Technology Adoption: Research shows that older adults are generally open to technologies supporting independence and safety, but privacy concerns remain the most frequently reported barrier to adoption (Yusif et al., 2016; Schomakers & Ziefle, 2019).

Drivers

Rising dementia prevalence: Cognitive decline is becoming structurally central in elderly care, increasing supervision needs, safety risks, and long-term care dependency (Alzheimer's Disease International, 2020).

Workforce strain from cognitive impairment: Interview data indicate that increasingly common memory disorders create concrete safety risks, including medication errors and reduced situational awareness, requiring closer monitoring and risk management (M. Niemelä, personal communication, January 26, 2026; Senior Physician, Public Healthcare, personal communication, January 30, 2026; Director of Operations, Elderly Homes, personal communication, January 30, 2026).

Structural loneliness: Interviews consistently describe loneliness as a systemic issue in both home care (brief visits, living alone) and institutional settings, where individuals with memory disorders may feel isolated despite being surrounded by others (Nyman, personal communication, January 26, 2026; Rautio, personal communication, January 26, 2026).

Acceptance shaped by benefit–privacy trade-offs: Older adults are generally open to technologies that support independence and safety, but adoption depends on perceived benefit, user control over data, and alignment with personal needs (Yusif et al., 2016; Schomakers & Ziefle, 2019).

Challenges

Heterogeneity of ageing: Functional capacity and digital readiness vary widely in later life, yet innovation often relies on a "simplified" image of older adults, creating a narrative mismatch between design and real-world diversity (World Health Organization, 2024).

Expectation–narrative mismatch: Public discourse oscillates between fear that robots will replace nurses and unrealistic expectations that robots will achieve full human-level autonomy. This leads to both overestimation and underestimation of actual capabilities.

Scope creep and misaligned use cases: Problems arise when technology is expected to operate beyond its intended function, leading to disappointment and perceptions that it "doesn't work." Interviews revealed recurring issues including insufficient user training and limited manufacturer familiarity with real care workflows.

Privacy & surveillance concerns: Privacy concerns extend beyond data security to include feelings of surveillance and loss of control, particularly regarding camera-based monitoring systems (Yusif et al., 2016; Schomakers & Ziefle, 2019). Continuous monitoring, especially camera-based solutions, may face resistance and regulatory scrutiny even when safety benefits are clear. Successful adoption therefore depends on transparent value propositions, user control, and modular, adjustable system design.

Impact

Rising dementia prevalence, increasing longevity, and a weakening old-age dependency ratio are intensifying care demand while workforce capacity remains constrained (World Health Organization, 2024; Eurostat, 2025; Alzheimer's Disease International, 2020).

As cognitive impairment becomes more common, supervision, risk monitoring, and emotional support needs grow structurally, increasing pressure on care delivery models. This shift elevates the strategic importance of technologies that support independent living, cognitive stimulation, and early risk detection. At the same time, heterogeneity among older adults requires more segmented, adaptive solutions rather than one-size-fits-all robotics.

Loneliness and social isolation further expand the role of socially assistive technologies, while authentic human contact remains the gold standard. Interviews suggest that technology is most viable when positioned as complementary support rather than human replacement, particularly in environments where human resources are constrained. Long-term adoption will depend on aligning technological capabilities with realistic expectations, integrating solutions into real care workflows, and addressing privacy and surveillance concerns through transparent, user-controlled design (Yusif et al., 2016; Schomakers & Ziefle, 2019).

Photo by Vlada Karpovich

Labour Market Pressures

A structural workforce crisis is increasing strain and accelerating digital and automated care solutions.

The global care sector faces a deepening workforce crisis, with Sitra citing worsening labor shortages and accelerating automation as key megatrends (Dufva, Kiiski-Kataja and Lähdemäki-Pekkinen, 2026). This is both a quantitative and qualitative shift toward maintaining autonomy and preventing extreme dependency (Healthcare director, personal communication, January 29, 2026; Robotics researcher, personal communication, January 26, 2026), as failure to close the gap risks public system collapse as the population pyramid flips (Industry association rep., personal communication, January 26, 2026; Tyni and Myllyneva, 2023). The crisis is worsened by declining career attractiveness due to limited progression and inadequate pay (Salminen-Tuomaala, 2024); and while international recruitment is used, it often reveals a "professionalism gap" between foreign training and local requirements (Tilastokeskus, 2025). Consequently, operational strain is driving AI and robotics adoption to handle administrative "meta-work," freeing professionals for direct patient care (Healthcare staffing CEO, personal communication, January 22, 2026; Elderly care operations director, personal communication, January 30, 2026).

Facts

The Finnish Ministry of Finance estimates that the social and healthcare sector will require 200,000 new workers by 2035 (Tevameri, 2021). By 2030, over 50% of municipal personnel are expected to retire, making recruitment a central challenge for care management (Honkanen and Nuutila, 2022).

Applicants to Finnish-language nursing programs have dropped by over 40% since 2016 (Tikkala, 2022). Furthermore, in 2023, 11.3% of social and health care workers in Finland had a foreign background, many facing challenges with qualification recognition and integration into the workforce (Tilastokeskus, 2025).

Generative AI is estimated to raise Finland's productivity by up to 3.6% annually (Dufva et al. 2026). Specifically, current voice documentation applications have demonstrated shift-time savings of approximately 30 minutes per nurse (Private care development manager, personal communication, January 26, 2026).

Drivers

Demographic pressure from an aging population is accelerating demand for solutions that enable independent self-care and autonomous monitoring, helping maintain patient dignity as the global care gap grows (WHO, 2025; Dufva et al. 2026)

Resource and budget constraints in public healthcare are fueling the adoption of automation and efficiency-enhancing solutions, as high staff turnover and retirements create persistent workforce shortages (Tyni and Myllyneva, 2023; Dufva et al. 2026).

Public–private cooperation is driving technology adoption to achieve a 3.6% annual productivity gain by reducing non-value-added "meta-work" and administrative burdens (Dufva et al., 2026).

Challenges

Workplace burnout and ethical stress are critical, as 38% of nurses report high job-related stress and 34% experience modified leave, which restricts the staff capacity required to supervise and adopt complex robotic workflows (Tevameri, 2021).

Financial sustainability is challenged by a 17% projected rise in care costs by 2030, while the lack of dedicated development resources means that efficiency investments are often sidelined by urgent maintenance needs (Tevameri, 2021; Dufva et al. 2026).

Structural barriers limit automation as social care needs grow 30% over 20 years; most facilities require expensive retrofitting for elevators and thresholds that current robotics cannot navigate independently (Tevameri, 2021; Dufva et al. 2026).

Societal inequality will peak by 2050, as 80% of older adults live in low- and middle-income countries, widening the gap between those who can afford private robotics and those dependent on overstretched public systems (WHO, 2025; Dufva et al., 2026).

Impact

Humans are moving away from repetitive "secondary" tasks, like patient handling, transport, and data entry, while robotics automates logistics and documentation (Elderly care CEO, personal communication, January 29, 2026; Robotics researcher, personal communication, January 26, 2026). Caregivers focus on emotional support, complex interaction, and clinical supervision, as older adults adopt more independent self-care (Healthcare staffing CEO, personal communication, January 22, 2026; Robotics researcher, personal communication, January 26, 2026). Adoption is risk-stratified: low-risk tools like transport robots and automated dispensers are deployed first, with direct-interaction devices following, while human touch remains vital in critical and end-of-life care.

Care Delivery Model Shift

Global healthcare is shifting from hospital-based acute care to AI-enabled home care to ease pressure from aging populations and chronic disease. Success depends on overcoming investment barriers and making complex tech safe and usable for non-experts at home.

Global healthcare delivery is undergoing a fundamental paradigm shift driven by a dramatic demographic transformation. Moreover, the exponential rise in chronic diseases is overwhelming traditional sanitary infrastructures, which were originally designed for episodic and acute care, rendering them increasingly unsustainable for current demands. The old 'fee-for-service' model, which pays for the number of procedures done, is failing. Success is no longer about filling hospital beds but about keeping patients healthy at home. This shift is pushing healthcare toward a more sustainable model that focuses on long-term well-being and efficiency.

Facts

The Sector Ultimatum: Projections indicate that the rate of dependent elderly people will triple by 2050. As one interviewee from Spain put it, the care sector is at a crossroad: it must transform now or risk failing to meet the growing need.

Chronic and Multi-Morbidity Prevalence: More than 80% of elderly Americans have at least one chronic disease (Fong, 2019).

Economic and Capacity Pressure: In the UK, over 14,000 hospital beds were occupied in 2024 by patients medically fit for discharge but lacking community support (The Guardian, 2024).

Drivers

Seniors prefer staying at their Homes: Success is now defined by keeping the patient out of the hospital. Staying at home is viewed as essential for the financial survival of the system, this was confirmed also in our interviews.

Hospital-at-Home (HaH) and AI Integration: The HaH model uses AI to monitor patients and prevent emergencies, cutting care costs by over 30% (Commonwealth Fund, 2024).

Proactive Data Monitoring: Remote Patient Monitoring (RPM) empowers patients by using algorithms to predict health deterioration before it becomes an emergency (Healthcare World, 2024).

Challenges

The CapEx issue: As highlighted in our interviews with a policy stakeholder, the sector requires technology-driven efficiency to survive, yet often lacks the initial capital to invest in the tools that create those savings.

Non-Expert Device Design: As medical devices move into the home, a major hurdle is designing complex technology that is safe for "non-experts" like family caregivers (ECRI Institute, 2024).

Impact

Instead of focusing only on clinical outcomes in hospitals, the goal is to help patients stay healthy and independent in their own communities. This shift is supported by new hybrid workforce models, where AI takes care of routine monitoring, and healthcare professionals focus on making important clinical decisions.

Elderly Care

Economic Trends

Industry and Project Costs

Industry and Project Costs

Market Realities and Strategic Focus: Navigating Growth vs. Implementation Depth

The elder care robotics sector is entering a transformative phase, driven by the structural necessity to address global caregiver shortages and an aging population. While market prospects are robust, the industry faces a critical utility gap where potential meets reality. Despite interest from venture capital, the transition from pilot projects to scalable autonomy is frequently hindered by high entry costs, complex regulatory frameworks, and the heavy infrastructure demands of physical AI deployment.

Facts

The global elder care assistive robots market size was estimated at USD 3.38 billion in 2025 and is projected to reach USD 9.85 billion by 2033, growing at a CAGR of 14.20% (Grand View Research: Elder Care Assistive Robots Market). Robotics funding remained resilient in 2025, with over $4.35 billion invested in 93 rounds in the broader robotics sector in mid-2025 alone (The Robot Report: Robotics investments top $4.3B in July 2025).

Specific "ElderTech" startups focusing on autonomous mobility and social AI have seen a 25% year-on-year increase in Seed and Series A activity (Crunchbase: Global Venture Funding In 2025 Summary; PitchBook: 2025 Vertical Snapshot: Robotics).

Physically assistive robots for mobility, lifting, and hygiene command 55–60% of the market share (Roots Analysis: Global Eldercare Assistive Robots Market Size & Share). However, socially assistive robots for companionship and cognitive therapy are the fastest-growing segment due to breakthroughs in Multimodal AI (Grand View Research: Elder Care Assistive Robots Market Report).

Drivers

Technological Convergence: The integration of generative AI with autonomous navigation has lowered the cost of developing sophisticated, "plug-and-play" home care robots (MIT Sloan: What's next for generative AI: Household chores).

Adoption of Subscription Models (RaaS): Instead of high upfront costs, "Robotics-as-a-Service" allows for predictable monthly payments. This makes technology affordable for smaller organizations and significantly expands the total addressable market (IFR: Service Robots Report 2025).

Challenges

Procurement and Tendering: In markets like Finland, competitive tendering often over-prioritizes the lowest price. Market growth is stifled unless tenders explicitly award points for innovation or staff wellbeing, as the market remains highly controlled by governmental decisions.

High Consumer Entry Barrier: The private "aging in place" market is underdeveloped due to the high price-to-value ratio for average households, leading to a thin customer base and a lack of economies of scale.

Certification Hurdles: Navigating the Medical Device Regulation (MDR) in the EU remains a costly and time-consuming barrier, often delaying the transition of autonomous features from pilot phases to actual care environments.

Recent Series A Rounds

Gardia: Raised EUR 8.5 million ($9.98M) of Series A venture funding led by Peak XV Partners on February 5, 2026, to scale AI-driven computer vision for fall prevention (PitchBook: Gardia Company Profile).

Tucuvi: Raised USD 20 million of Series A venture funding led by Cathay Innovation and Leadwind in January 2026 to expand its "LOLA" clinical voice AI agent internationally (Tucuvi: Series A Investment Announcement).

Isaac Health: Raised USD 10.5 million of Series A venture funding led by Flare Capital Partners in August 2025 to scale its AI-enabled virtual brain health clinic (PitchBook: Isaac Health Company Profile).

Impact

Humans will increasingly stop performing repetitive, mechanical, and non-value-added "secondary" tasks. This includes the heavy manual labor of lifting and turning patients, transporting laundry or waste, and manual data entry. (Nursery Home CEO, personal communication, January 29, 2026; AI and robotics researcher, personal communication, January 26, 2026).

Instead, human caregivers will shift toward roles focused on emotional support, complex social interaction, and high-level clinical supervision, while older adults use technology for more significant independent self-care (Healthcare staffing CEO, personal communication, January 22, 2026; AI and robotics researcher, personal communication, January 26, 2026). Insights from interviews with healthcare and technology professionals suggest that robotics will also transform workflows by automating documentation through speech recognition and managing internal logistics, reducing the time currently spent on administrative tasks.

In addition, adoption of robotics is expected to follow a risk-stratified approach; technologies that address clear labor gaps with minimal safety concerns, such as transport robots for supplies or automated medicine dispensers, are already being deployed. Devices involving direct patient interaction, such as those supporting social engagement or assistance with eating, are likely to follow as the technology matures. In these contexts, human presence and touch remain essential, particularly in critical care and end-of-life scenarios.

Photo by Markus Spiske

↗ Elderly Care

↗ Regulatory & Policy Trends

→ EU Rules for Medical AI & Robotics

EU Rules for Medical AI & Robotics

EU Regulatory Frameworks: Balancing High-Risk Safety with Healthcare Innovation.

Navigating the regulatory landscape is a critical step for any healthcare technology provider. The European Union operates under a "Safety and Prevention" philosophy, requiring rigorous standards to be met before a product can enter the market. This framework ensures that high-risk technologies, such as AI-driven records or medical robots, are safe for public use while also providing a structured environment for innovation through better data access.

Facts

Simplification of MDR: Recent 2026 EU proposals aim to simplify Medical Device Regulations (MDR) to reduce re-certification burdens and introduce "regulatory sandboxes" for testing emerging tech in real-world conditions.

Mandatory EUDAMED Usage: As of May 28, 2026, the first modules of the European Database on Medical Devices (EUDAMED) become mandatory, requiring all manufacturers to register devices and certificates for improved market transparency.

High-Risk AI Oversight: The EU AI Act classifies medical AI and robots as high-risk, requiring strict data governance, human oversight, and formal risk management throughout the product's life (European Commission, 2024a)

Pre-Market Safety Barriers: In the EU, rigorous standards must be met before market entry to mitigate risk. Conversely, the U.S. system relies on market forces and the threat of litigation to filter out dangerous products, shifting the burden of vetting technology to the employer or consumer. This fundamental difference was a sentiment strongly confirmed during our interviews.

Drivers

Transparency and Logic: High-risk systems require transparency through clear instructions and understandable explainability for the AI's logic, alongside human oversight that allows a person to interrupt or overrule the AI at any time.

Workplace Violence & Safety: Between 2011 and 2021, reports of workplace violence in hospitals surged by 30%, with many nurse leaders directly witnessing such incidents (American Organization for Nursing Leadership, 2025). This alarming trend has increased the demand for automated monitoring systems, technologies designed to enhance staff safety while ensuring continuous patient care and oversight.

Challenges

Classification Complexity: Many companies actively try to avoid being classified as a "medical device" to bypass the rigorous and expensive testing required under EU law (Fimea, n.d.).

Impact

Strict data governance and mandatory human oversight ensure that healthcare AI remains unbiased and safe, building the trust necessary for widespread adoption. By balancing these high safety standards with legal access to anonymized research data through the EHDS, the regulatory framework effectively lowers barriers for startups while maintaining a high level of patient protection.

Elderly Care
Technology Trends

- Telemonitoring and Ambient Sensing in Remote Care
- AI-Automated Healthcare Record Systems
- Social Robotics in Elderly Care
- Assistive and Logistical Robotics

Telemonitoring and Ambient Sensing in Remote Care

Advancing Remote Care Through Wearables and Privacy-First Ambient Sensing

Telemonitoring has evolved from a clinical necessity confined to hospitals into a sophisticated, multi-layered ecosystem that supports patients in their own homes. While traditional healthcare relied on bedside devices like ECGs, the modern landscape is dominated by a dual approach: wearables and ambient sensors. This shift reflects a move toward more discreet, continuous monitoring that balances clinical accuracy with user security, allowing healthcare providers to track vitals and respond to emergencies without patients having to move to a medical facility. Finally, there's a rising effort to treat chronic diseases in people's own homes.

Facts

Diverse Monitoring Modalities: Modern monitoring utilizes three primary tiers: clinical hospital devices (e.g. ECG), consumer-grade wearables for home tracking, and installed spatial sensors like Qumea's based on LiDAR systems (Light Detection and Ranging)

Rapid Market Adoption: Both wearable and sensor-based solutions are seeing accelerated integration across hospitals, professional care facilities, and private residences to meet the surging demand for remote patient management (Fortune Business Insights, 2024).

Privacy-First Sensing: New LiDAR systems allow for fall detection and movement monitoring without the use of invasive cameras, preserving patient privacy while maintaining high safety standards.

Drivers

Growing Demand for Remote Care: An aging global population, a preference for "aging in place" and overcrowded hospitals are pushing healthcare providers to adopt tools that allow for high-quality care outside of traditional clinical settings.

Technological Convergence: Improvements in sensor miniaturization and battery life have made it easier to deploy sophisticated monitoring tools in everyday environments.

Challenges

User Adherence and Logistics: Our interviews highlighted that wearables face significant bottlenecks; devices are frequently forgotten, left uncharged, or actively avoided by seniors who feel the equipment makes them look frail or "medicalized".

Infrastructure Requirements: While installed sensors are more discreet, they require professional setup and a robust digital environment to function effectively within a home or facility.

Impact

The shift toward telemonitoring enables a move from reactive emergency response to proactive health management, catching fluctuations in vital signs before they result in hospitalizations. This automation of high-risk patient monitoring significantly reduces the burden on caregivers, allowing them to focus on meaningful personal interaction rather than constant observation.

AI-Automated Healthcare Record Systems

AI-Driven Interoperable Health Records and the Future of Digital Diagnostics

The healthcare industry is currently undergoing a massive digital overhaul, driven by a combination of strict European mandates and the rapid maturation of LLMs. By transitioning from fragmented paper logs to secure, interoperable electronic health records (EHR), the sector aims to create a borderless data environment. The integration of AI into these systems is no longer a luxury but a necessity, transforming the way patient data is logged, stored, and analyzed to improve both administrative efficiency and diagnostic accuracy.

Facts

Mandatory Digitalization: By March 2029, the European Health Data Space (EHDS) regulation will require all EU healthcare facilities to maintain digital, interoperable records with immutable audit trails for patient safety and accountability (European Commission, 2024b).

AI Integration: Leading platforms are now integrating Generative AI, such as the partnership between Epic and Microsoft's Nuance DAX Copilot, which automates clinical documentation via voice-to-text and NLP directly within the patient's record (Microsoft, n.d.)

Secondary Data Access: The EHDS framework allows startups and researchers to legally access anonymized "secondary data," which refers to information collected for purposes other than the current research, such as patient records, administrative databases, or previous studies. This significantly lowers the barrier to entry for training new medical AI models (European Commission, 2024b).

Drivers

Regulatory Compliance: The strict timeline of the EHDS is a primary driver, forcing hospitals to modernize their data infrastructure to meet EU-wide standards for interoperability.

Administrative Burnout: The convergence of clinical necessity and high-performance LLMs has created a surge in adoption for voice-to-text tools, designed to relieve medical staff of the heavy documentation burden.

Challenges

Infrastructure Gaps: A significant bottleneck identified in recent clinical interviews is the lack of stable, high-speed Wi-Fi in many older hospital buildings, which prevents the effective use of cloud-based AI tools.

High-Risk AI Classification: Under the EU AI Act, AI systems used in medical records are classified as high-risk, requiring rigorous data governance to prevent bias and mandatory human-in-the-loop oversight (European Commission, 2024a).

Impact

AI transforms raw data into actionable medical insights, allowing for faster and more accurate clinical decisions by automating the logging of vitals and progress notes. Furthermore, because digital records are now standard and shared across the EU, a patient's medical history and test results follow them instantly, ensuring that doctors always have the right information regardless of which country the patient is in.

Social Robots in Elderly Care

Human-Centric Social Robotics: Enhancing Mental Wellness and Elderly Care Engagement

Robotics in healthcare is moving away from the "industrial" era and into a human-centric phase. Modern social humanoid robots are being designed with approachable aesthetics, utilizing soft textures and friendly forms, to assist with household tasks and provide social stimulation. Beyond mere automation, these robots are serving as "social bridges," enhancing the quality of life for residents in care facilities by encouraging communication between residents and caregivers.

Facts

Social Bridges: Tools like Paro (the robotic seal) and Lovot are proven to encourage communication between residents and caregivers rather than replacing human contact (Hung et al., 2025).

Clinical Efficacy: Trials show that residents interacting with social robots like Paro experience less delirium and require less medication, even when robot interactions are shorter than human visits (Kocak et al., 2024).

Drivers

Shift Toward "Soft" Design: To improve adoption among seniors, manufacturers are moving away from "cold" plastic and metal in favor of designs that reduce stress and feel more approachable, like the NEO X1.

LLM Integration: Advances in LLMs enable robots to engage in more natural, context-aware conversations, making their interactions feel more human-like and responsive.

Challenge

Ethical Concerns: Despite evidence to the contrary, there remains a persistent fear that robots will replace human empathy and companionship, requiring ongoing transparency and human oversight in design.

Impact

The use of social robots is proving to be a highly effective non-pharmacological solution for reducing cognitive distress and improving the overall mental health of patients in long-term care. By providing specific health benefits like reduced delirium and lower medication dependency, these robots complement human care and significantly improve the daily well-being of residents.

Photo by BOCCO emo

Assistive and Logistical Robotics

Edge AI–Powered Exoskeletons and Autonomous Systems for Safer Mobility and Smarter Care

While social robots focus on emotional well-being, assistive and logistical robots are designed to handle physical tasks and mobility. This category includes wearable technology that supports the human body and autonomous systems that manage facility operations. These devices aim to restore independence for individuals and improve the efficiency of healthcare environments by handling the heavy lifting of modern care.

Facts

Major Cause of Hospitalization: Falls are the leading cause of injury-related hospital admissions for adults over 65, accounting for nearly 90% of such cases and often serving as the primary trigger for a permanent loss of independence (Health Infobase, 2025).

Medical Exoskeletons: Research prototypes and early commercial exoskeleton systems are now emerging as innovative solutions to **prevent falls** and **restore mobility**, offering new hope for improved quality of life and autonomy.

Consumer Exoskeletons: Devices like the **Hypershell X Series** are transitioning from niche experimental tools to general public accessibility, mirroring the early evolution of the smartphone.

Logistical Automation: Delivery robots, such as the **Aethon TUG**, are now receiving more interest in hospitals and nursery homes, handling the repetitive transport of lab samples and linens to free up staff for direct patient care.

Drivers

Labor Shortages: The need for delivery robots is driven by the necessity to optimize human resources, allowing staff to focus on high-value clinical tasks rather than manual chores.

The "Downward Spiral" of Mobility Loss: Preventing initial falls is a critical priority, as a single event often leads to a cycle of fear, decreased activity, and rapid physical decline that necessitates expensive long-term care.

Edge AI and High-Frequency Sensing: modern exoskeletons can now detect instability in real time, predicting falls before they occur, and instantly deliver corrective hip torque to stabilize the user. This breakthrough is transforming fall prevention, enabling proactive, adaptive support for safer mobility

Challenges

Regulatory Barriers: Many companies struggle to navigate the medical device classification, as EU law requires any product intended for diagnosing, monitoring, or treating to meet rigorous safety standards (Fimea, n.d.). In these cases, autonomous robots avoid getting in contact with the patients and commercial exoskeletons are marketed as sport equipment.

Impact

The mass-market adoption of exoskeletons is expected to significantly increase mobility and independence for the elderly, potentially evolving into common daily accessories. Simultaneously, the deployment of logistical robots in clinical settings ensures that repetitive tasks are handled efficiently, allowing healthcare professionals to dedicate their time and energy to direct patient care.

EXPLORATION

↗ Elderly Care

Photo by Andrea Piacquadio

↗ Elderly Care
↗ Exploration

- → Enable Independence to Alleviate Healthcare Pressure
- → Cognitive Companionship as a Solution for Social Isolation
- → Logistics as the Door to Scalable Autonomy in Care
- → Documentation Bottlenecks: Regulation and Language

Enable Independence to Alleviate Healthcare Pressure

- Helping seniors move on their own is the best way to **solve the caregiver shortage and lower healthcare costs**.
- A reframing of robotics from heavy machines to active partners that help keep muscles strong and enable independence.

Enable Independence to Alleviate Healthcare Pressure

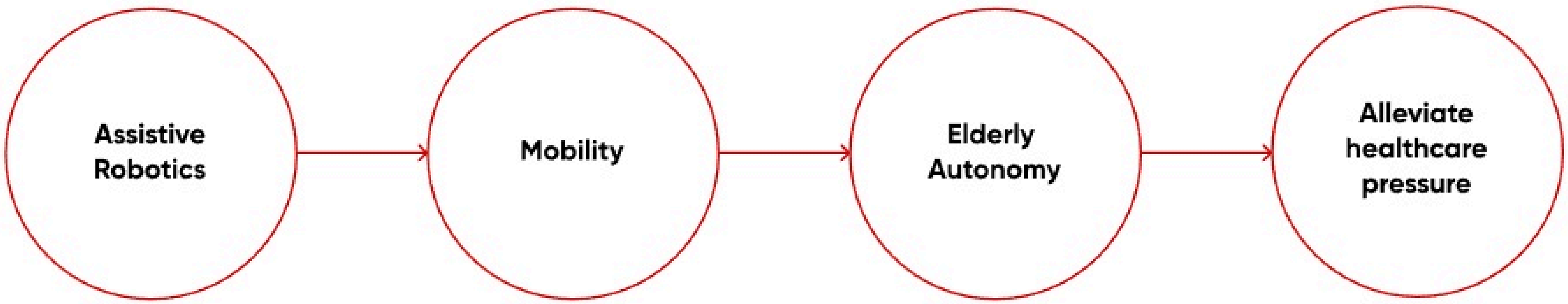
The primary lever for alleviating the burden on our global healthcare system is the preservation of functional autonomy among the elderly. As life expectancy increases, the disparity between the number of people needing assistance and the availability of human caregivers, is widening significantly.

Health experts and caregivers agree: the moment a person struggles to move on their own, they lose their independence. This is the tipping point where they stop living on their own and start needing full-time help (Lin & Cui, 2021). When a senior can no longer perform "Activities of Daily Living" (ADLs), like getting out of bed, toileting, or grocery shopping, their dependence on the system spikes. Emerging trends in robotics suggest that wearable exoskeletons are reaching a price-performance milestone that could revolutionize this sector (Fortune Business Insights, 2026). By shifting from heavy industrial designs to lightweight "soft suits", these devices are positioned to replace wheelchairs not just as a means of transport, but as a tool for Maintenance Training, actively preventing muscle atrophy through assisted movement. There's also the chance that many of these devices avoid the regulatory barrier of being marked as medical devices.

To overcome the high capital expenditure of these technologies, the Robotics-as-a-Service (RaaS) business model is essential. RaaS transforms a heavy upfront investment into a scalable operating expense. Most importantly, this model ensures continuity of value: if a senior's condition declines to the point where they require hospitalization, the exoskeleton is not a "lost" personal investment. The service provider can also reallocate the hardware to another user.

Future advancements must focus on making exoskeletons more user friendly in their design, ensuring they are easy to put on and comfortable enough to wear during daily activities, including showering and personal hygiene tasks. More importantly, some of these exoskeletons now only provide power and don't help with balance.

We identify this as an opportunity for the coming 5-10 years.



Cognitive Companionship as a Solution for Social Isolation

- Social robots focus on conversation and social presence to **provide kindness and interaction when human caregivers are overburdened**.
- Robotic companions act as a spark for people with memory loss, helping them remember the past and share their own life stories again.

Cognitive Companionship as a Solution for Social Isolation

Multiple interviews highlight that social presence and cognitive support may be both high-need and more feasible near-term than fine manipulation tasks. As one interviewee put it: "Caregivers know that they need extra people to provide presence, attention, information, stimulation and support" At the same time, **"the fine manipulation tasks are quite hard for the robots, but the social presence tasks are much easier and tend to deliver significant return on investment too.**" (Samuel Benveniste, Co-founder Enchanted Tools, personal communication, January 30, 2026.)

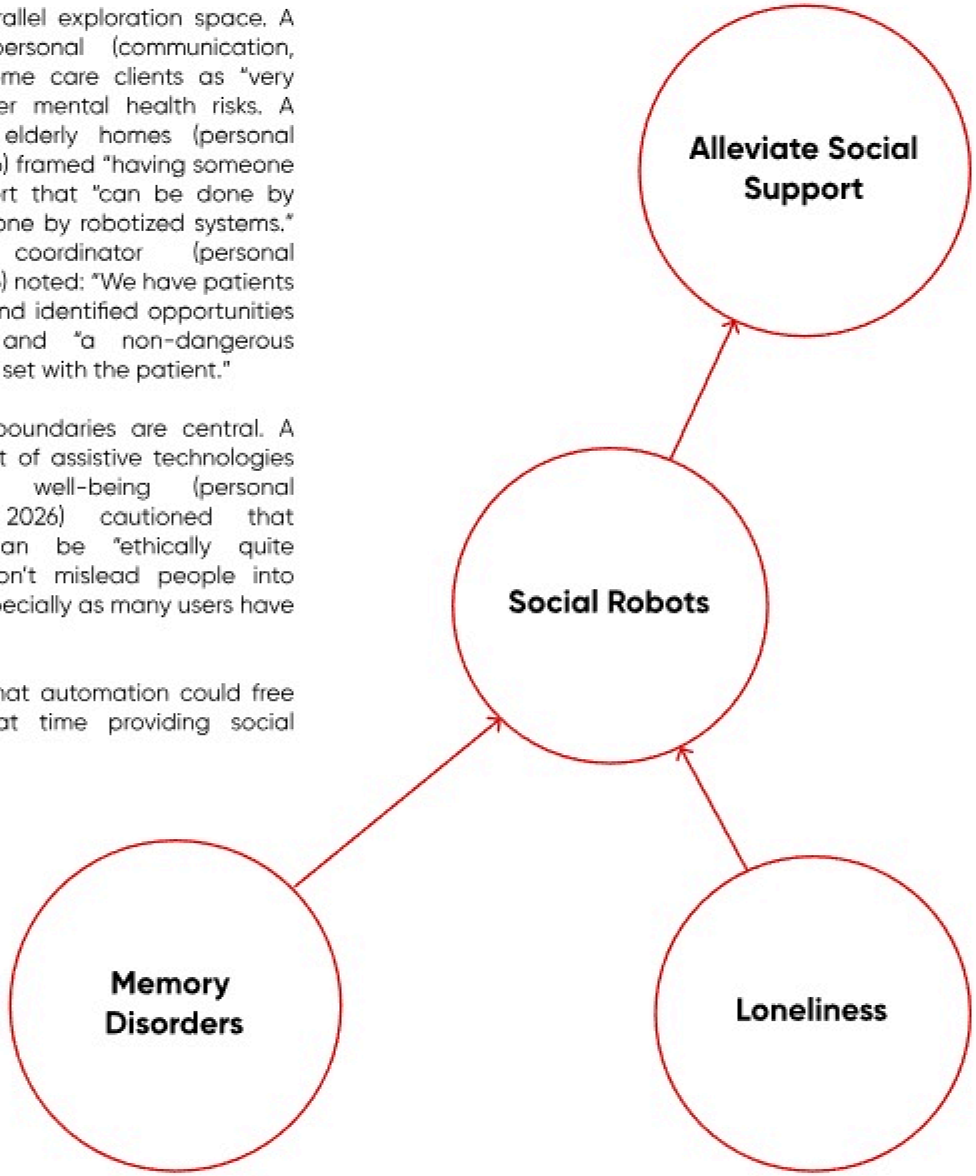
This opens an opportunity space for companionship with cognitive engagement as a complementary layer, and not a replacement for human care.

Concrete exploration areas emerge around memory disorders, where the need is described as growing rapidly and structurally: "There will be a huge need because memory disorders are increasing a lot. It may be that we simply will not have enough people to help, so we need technological solutions." (Niemelä, personal communication, January 26, 2026). Pilots with social robotics show concrete engagement effects. "When there's a robotic animal, people start reminiscing," and "even people with memory disorders have started remembering... then you can get into conversation about their past," creating "a stimulating moment... and bringing meaning into everyday life." (Nyman & Rautio, personal communication, January 26, 2026).

Loneliness emerges as a parallel exploration space. A health care consultant personal (communication, January 2026) described home care clients as "very isolated," leading to broader mental health risks. A Director of Operations in elderly homes (personal communication, January 2026) framed "having someone talk with me" as tele-support that "can be done by people, but it can also be done by robotized systems." Similarly, a hospital coordinator (personal communication, January 2026) noted: "We have patients very alone in the hospital," and identified opportunities in "cognitive stimulation" and "a non-dangerous conversation with parameters set with the patient."

At the same time, ethical boundaries are central. A specialist in the development of assistive technologies for elderly care and well-being (personal communication, January 2026) cautioned that conversational AI tools can be "ethically quite challenging so that you don't mislead people into thinking it's a real person," especially as many users have cognitive impairments.

However, they emphasized that automation could free professionals to "spend that time providing social support."



Logistics as the Door to Scalable Autonomy in Care

- Autonomy in elderly care will depend less on breakthrough technology and more on the logistical systems that quietly support everyday life.
- The future of elderly care may not be decided in hospitals, but in the logistical and infrastructural layers that determine whether independence is possible.

Logistics as the Door to Scalable Autonomy in Care

Another shared view among professionals in both healthcare and technology is that, although progress has been made, there is still a major opportunity to strengthen autonomy through better logistical structures.

At its core, the objective is simple: reduce the time burden on caregivers while enabling more people to age in place with dignity. Robotics is not some distant vision – it's an immediate tool that can improve the logistical flow of care across two key environments.

First, home logistics. These are the repetitive physical tasks that often determine whether an elderly person can remain independent or must move into assisted living. Moving heavy laundry, carrying groceries inside, or supporting hygiene routines may sound simple, yet they frequently become decisive barriers to autonomy.

Second, building logistics offers an equally strong opportunity. Automating the transport of food trays, medical materials, waste, and administrative items can quite literally release the hands of professionals, allowing them to focus on what truly matters: patient-centered care.

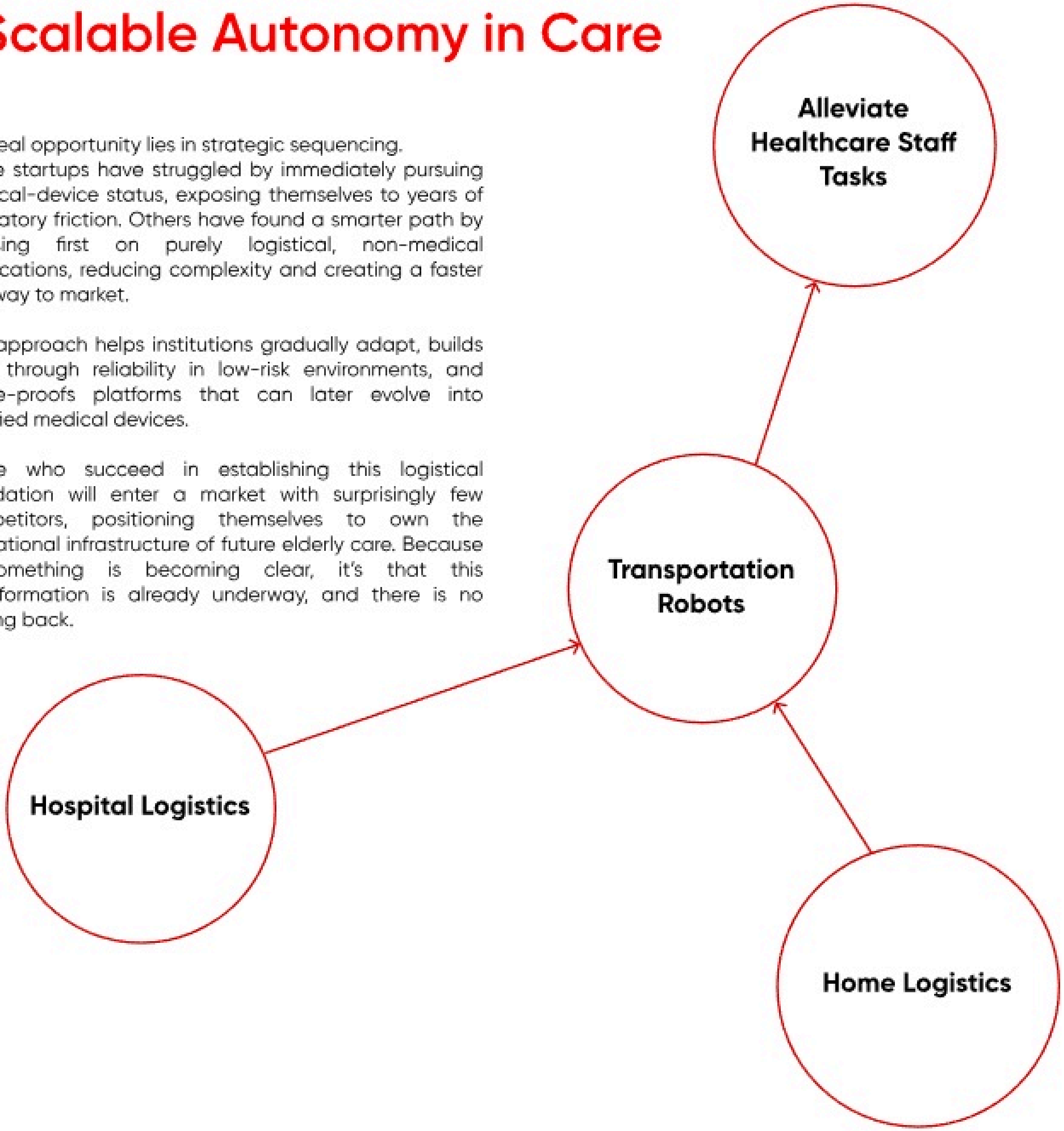
The primary bottleneck we identify, however, is not the technology, or even regulation, but infrastructure accessibility. Most buildings are simply not robotic-ready. They lack automated doors, adaptable elevators, and the spatial logic required for seamless operations.

This has contributed to what could be described as the "prison flat" phenomenon: homes where seniors are limited less by their own mobility than by physical barriers such as high thresholds or missing elevators. In these contexts, robotics can become a critical bridge, ensuring essential goods and services reach the user even when the user cannot navigate the building.

The real opportunity lies in strategic sequencing.
Some startups have struggled by immediately pursuing medical-device status, exposing themselves to years of regulatory friction. Others have found a smarter path by focusing first on purely logistical, non-medical applications, reducing complexity and creating a faster highway to market.

This approach helps institutions gradually adapt, builds trust through reliability in low-risk environments, and future-proofs platforms that can later evolve into certified medical devices.

Those who succeed in establishing this logistical foundation will enter a market with surprisingly few competitors, positioning themselves to own the operational infrastructure of future elderly care. Because if something is becoming clear, it's that this transformation is already underway, and there is no turning back.



Trends
Exploration
Ideation

Documentation Bottlenecks: Regulation and Language

- By late 2026, the shift toward "ambient intelligence" is projected to return up to 40% of the workday to caregivers, transforming senior care from an administrative-heavy utility into a high-touch, resident-centered environment.
- A reframing of robotics from heavy machines to active partners that help keep muscles strong and seniors independent.

Documentation Bottlenecks: Regulation and Language

The heavy reporting burden in senior care has become a critical bottleneck, as increasing regulation forces caregivers to spend more time on documentation than on resident care. Current documentation systems are outdated and slow, lagging behind technological standards and creating a stressful hurdle for an increasingly international workforce. This gives many opportunities. AI converts spoken word into professional, formatted medical text, eliminating the hours caregivers spend typing. By integrating sensors on gadgets or companion robots, the system captures non-verbal data like gait and vitals, syncing it directly into the digital health record for preventative insights.

These advancements in operational speed directly address the industry's most pressing challenges. By automating the reporting process, the platform frees up staff for direct care; A value already proven in care home trials where documentation time was cut in half. This transformation allows caregivers to focus on their primary mission rather than being sidelined by administrative tasks.

The system further supports an inclusive workplace by assisting non-native speakers with instant corrections to grammar and medical terminology. By lowering the linguistic barriers to entry, the technology ensures that all staff members can produce high-quality medical records while reducing the stress associated with complex documentation.

Cost-effectiveness remains a primary driver for the adoption of this technology. Implementing AI-driven solutions is significantly cheaper than relying on manual scribing or absorbing the costs of lost productivity. Furthermore, the inherent efficiency of AI development and the ability to utilize affordable mobile devices make this an economically viable transition for facilities of all sizes.

We also see an opportunity combining AI and sensor based medical examination. By merging physical sensor data with written clinical notes, platform could provide a holistic view of resident health that was previously difficult to achieve. This integration allows for the early detection of health risks, shifting the care model from reactive to preventative. Since these integrated systems are not yet the industry standard, there is a vast market opportunity for those ready to modernize.

However, entering this highly competitive field requires addressing significant technical and security hurdles. The platform must maintain high levels of encryption to ensure data privacy while successfully managing the complexities of AI integration. Mitigating the risk of AI hallucinations is essential to maintain the absolute accuracy required for medical records. Finally, success depends on the seamless integration of modern AI tools with legacy software, ensuring that even facilities with outdated technology can benefit from these clinical advancements.

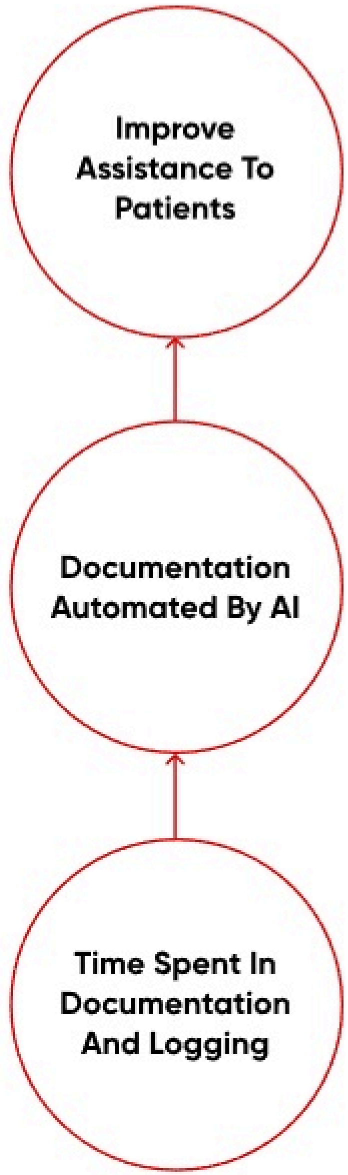
Firms already doing this:

Abridge: Market leader in "ambient" documentation that transcribes and summarizes clinical conversations into structured notes in real-time.

Nuance DAX (Microsoft): The enterprise standard for large-scale health systems, deeply integrated with major EHRs like Epic.

Suki: A voice-first AI assistant optimized for mobile devices, helping with both documentation and administrative tasks.

Heidi Health: A flexible, clinician-first AI scribe that excels at learning individual writing styles and supports multiple languages.



IDEATION

↗ Elderly care

Photo by Andrea Piacquadio

WOLKON

Forget Wheelchairs

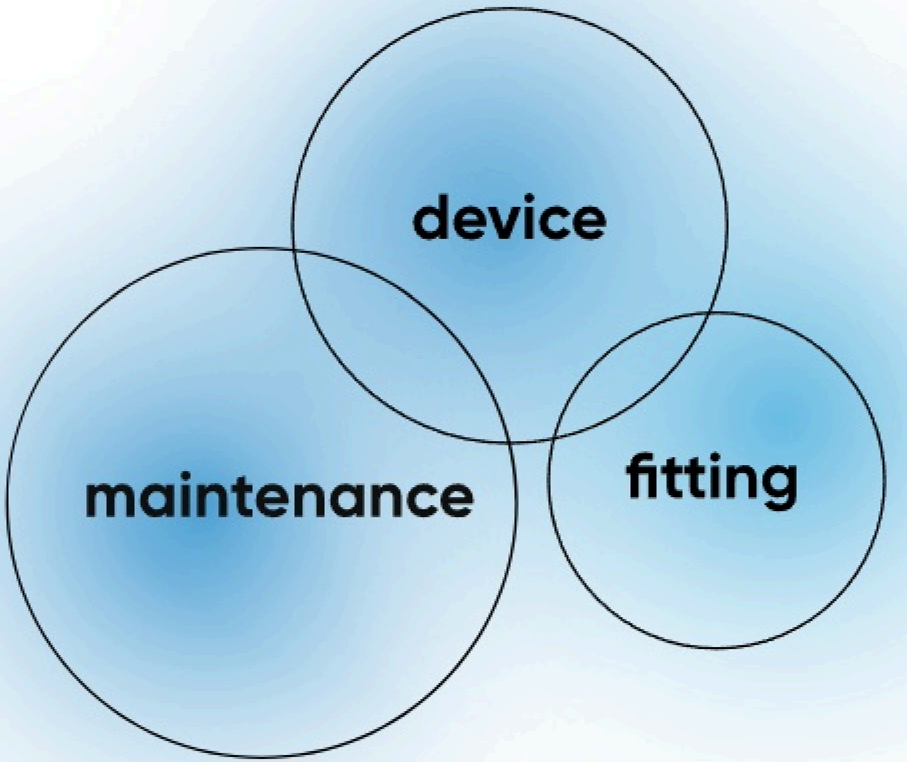
Wolkon helps older adults stay mobile and independent without relying on wheelchairs or full-time caregivers. Instead of selling expensive exoskeletons, Wolkon offers them as a monthly subscription that includes the device, fitting, training, and maintenance. This makes advanced mobility support affordable and flexible, with no upfront cost.

As a person's needs change, they can switch or return the exoskeleton, avoiding wasted investment. The service is designed for seniors who can still stand and walk with assistance, people at risk of falls, and those recovering from rehabilitation. By reusing and refurbishing devices, Wolkon keeps costs low while extending the life of each exoskeleton.

WOLKON

Falls are the leading cause of injury-related hospital admissions among adults over 65	→	Exoskeletons can significantly reduce the risk of falls
Exoskeletons are too expensive for individuals to purchase	→	Subscription access removes high upfront costs
Mobility decline leads to loss of independence	→	Improved mobility increases independence and reduces loneliness
Many older adults prefer to avoid hospitals and care facilities	→	Greater autonomy allows people to stay in their homes longer
Caregivers are costly and often unavailable	→	Monthly subscriptions cost less than professional caregiving

Wolkon Business Model



Customers can upgrade or change exoskeleton type as mobility changes

Devices can be refurbished and reallocated to new subscribers, maximizing asset lifecycle.

Total Addressable Market

According to the World Health Organization (WHO) World Report on Ageing and Health, there are currently 727 million people aged 65 or older worldwide.

The global exoskeleton market was valued at approximately $455 million in 2024 and is projected to grow at a CAGR of 16.8%, reaching about $1.58 billion by 2032, driven by advancements in AI, lightweight materials, and increasing adoption in healthcare, industrial, and defense sectors (SNS Insider).

Serviceable Addressable Market

A service-based model is most viable in high-income regions like the US and EU, where approximately 37 million seniors report significant difficulty walking (CDC 2024/2025; Eurostat 2024).

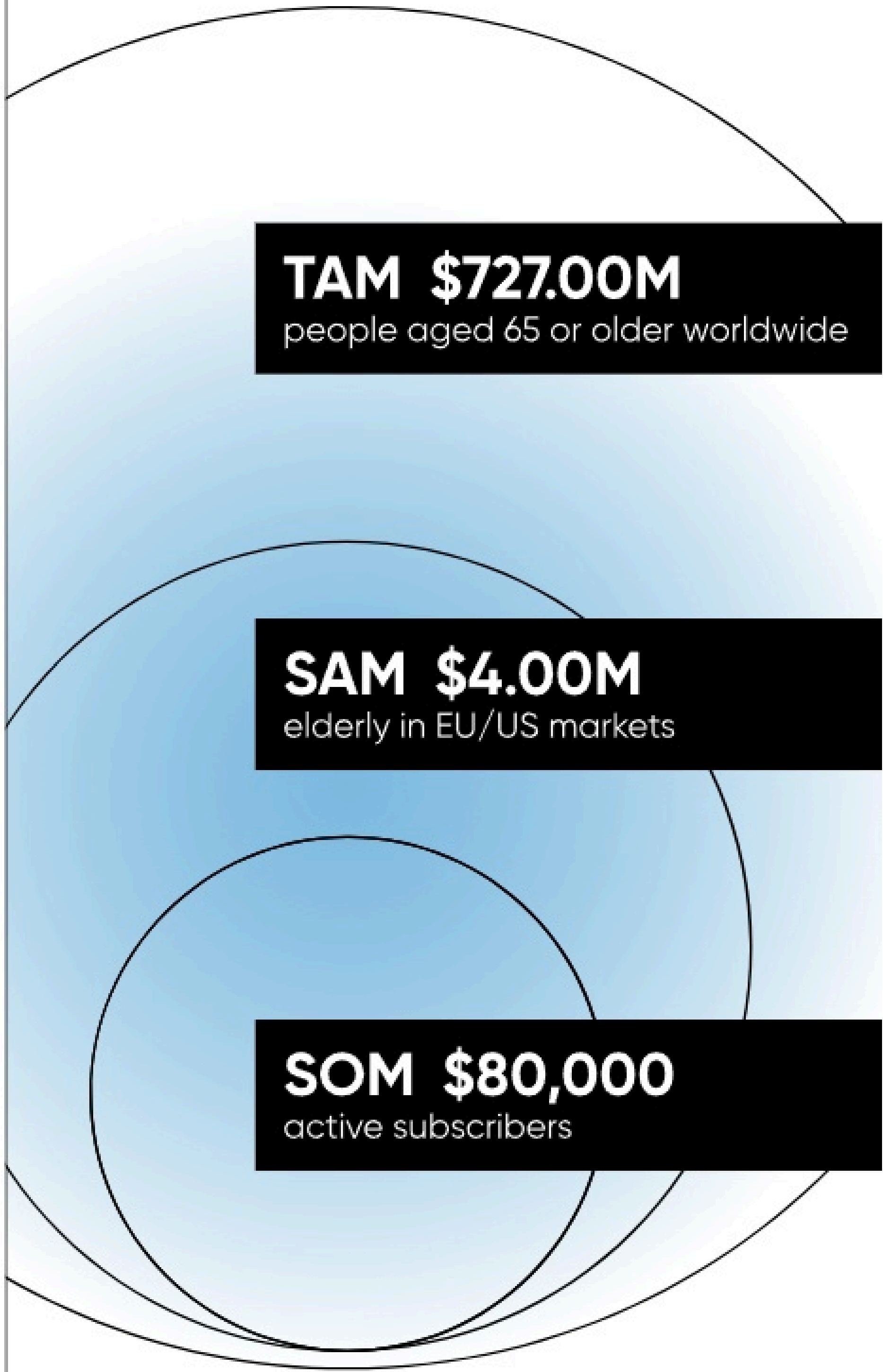
Economically, about 40% of these seniors possess the discretionary income to afford a monthly subscription as an alternative to expensive private care (OECD 2025).

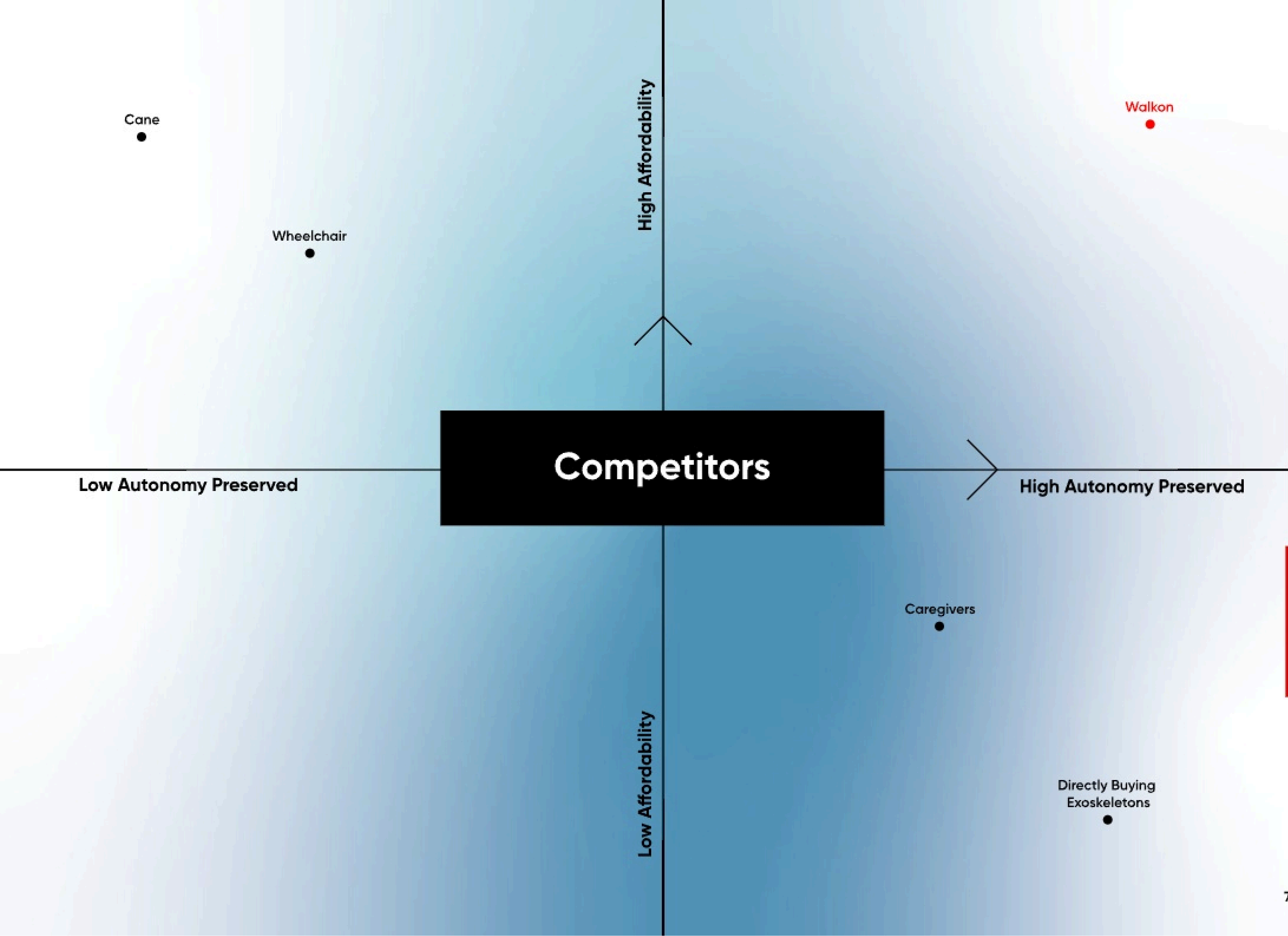
Applying these filters results in a realistic SAM of approximately 3.8 to 4.0 million people who are tech-literate, financially capable, and clinically suited for wearable mobility support.

Serviceable Obtainable Market

In the 2026 health-tech landscape, successful startups typically target a 1% to 5% capture rate of their SAM during the initial scaling phase (Antler, 2026).

Applying a conservative 2% capture rate to the 4 million-person SAM results in a Serviceable Obtainable Market of approximately 80,000 active subscribers.




Competitors
High Affordability
Low Affordability
Low Autonomy Preserved
High Autonomy Preserved
Cane
Wheelchair
Walkon
Caregivers
Directly Buying Exoskeletons

TRENDS

↗ Construction

Photo by Atlantic Ambience

↗ Construction
↗ Technology Trends

→ Multi-Domain Autonomy

→ Mobility, Mapping and Sensors

→ BIM and Data Collection

→ 3-D Printing

Multi-Domain Autonomy

Mobile robotics are enhancing site inspection and safety through autonomous navigation, though widespread adoption is hindered by complex terrains and prohibitive hardware costs.

Mobile robots have increasingly found their way into different industries, particularly in the form of Unmanned Autonomous Vehicles (UAVs) which have proven useful for site inspection purposes (Gupta & Nair, 2023). While ground and subterranean robotics face significant implementation hurdles regarding terrain and data continuity, research continues to advance the capabilities of small mobile robots to navigate complex environments where human risk is high.

Facts

Established Utility of Aerial Systems: UAVs have been validated as useful tools for site inspection during the active project construction phase as well as for regular maintenance inspections thereafter (Medina, 2025).

Advancement in Ground Robotics: Research has continued in the area of small mobile robots designed to implement specific tasks in work sites (Héctor Azpúrua et al., 2023). Furthermore, navigation and control platforms for ground robotics have improved tremendously, enabling better handling of complex terrains.

Drivers

Risk Mitigation in Hazardous Environments: A primary driver for the adoption of autonomous systems is the significant risk attached to human workers operating in difficult terrains. This safety necessity drives the research into small mobile robots capable of navigating these specific, risky work sites (Héctor Azpúrua et al., 2023).

Need for Consistent Inspection: The requirement for regular inspections during and after construction drives the utilization of UAVs, which offer a proven solution for monitoring site progress and conditions (Medina, 2025).

Challenges

Environmental and Operational Constraints: Subterranean autonomous systems are challenging to implement in construction sites due to a lack of continuous data availability, the presence of complex moving platforms, and mobility limitations caused by uneven terrains (Experts in construction site management, personal communication).

Economic Barriers in Low-Margin Industries: Despite improvements in control platforms, the cost of entire robotic systems remains too high for widespread adoption in the low-margin construction industry. These prohibitive costs are primarily driven by the requirement for high-end LiDAR sensors and other expensive unit costs associated with complex sensor suites (Opteran, 2025).

Photo by Atlantic Ambience

Mobility, Mapping and Sensors

Mobile robotics and sensor fusion are elevating construction safety and precision through autonomous navigation.

Mobile robotics have firmly established their utility in construction, particularly through Unmanned Aerial Vehicles (UAVs) which serve as proven tools for site inspection and structural monitoring. However, navigating the complex, changing terrain of active jobsites requires more than simple GPS. To operate effectively in "GNSS-denied" environments like tunnels or indoor sites, autonomous systems must rely on Simultaneous Localization and Mapping (SLAM) and sophisticated sensor fusion. By combining inputs from LiDAR, UWB, and other sensors, these platforms can achieve the high-precision localization necessary to transition from teleoperated machinery to fully autonomous manipulation.

Facts

Established Utility and Navigation Stacks: UAVs act as proven tools for site inspection (Medina, 2025) during project construction and for regular inspections thereafter. In terms of navigation, GNSS-RTK based platforms are used now in control systems to automate control systems for heavy machinery (Lopes & Trabanco, 2022), open-air infrastructure projects and for monitoring structural changes (Jiang et al., 2025).

Role of LiDAR and UWB: LiDAR is used in GNSS-denied environments (like tunnels and indoor sites) to conduct site safety inspections and progress checking (Feng et al., 2025). Since industrial-grade 3D LiDAR sensors typically cost between $3,500 and $8,000 and full surveying scanners exceeding $50,000, these sensors are reserved for accuracy-sensitive tasks such as Floor Flatness/Levelness (FF/FL) analysis and Scan-to-BIM deviation checks. Meanwhile, UWBs are used in lower-level autonomous tasks such as site resource assessment.

Sensor Fusion Integration: Complex environments require multiple sensors working in tandem. By combining data, the computational platform achieves a much more precise understanding of its surroundings than any single sensor could provide.

Drivers

Mitigation of High-risk Labor: Research has continued in the area of small mobile robots which implement specific tasks in work sites (Héctor Azpúrua et al., 2023) since a lot of risks come attached with working in such terrains.

Dynamic Environment Adaptability: The primary driver for SLAM is the need to build a map of the site as the robot navigates it, rather than relying on a pre-loaded map that becomes obsolete the moment, say, a pile of dirt is moved.

Challenges

Environmental and Data Constraints: Subterranean autonomous systems seem to be challenging to implement in construction sites due to the lack of continuous data available, complex moving platforms, and limitations with mobility due to uneven terrains (Experts in construction site management, construction consulting and mobile robotics). Furthermore, GNSS sensors fail to work in "GNSS-denied" environments where signals cannot reach, such as canyons and indoor sites.

High Costs and Industry Inertia: Even though navigation and control platforms for ground robotics have improved tremendously, the cost of entire systems are still quite high to be adopted by a low-margin industry like construction. The high costs come from the requirement of high-end LiDAR sensors and other unit costs associated with these complex sensors (Opteran, 2025). Additionally, issues still remain with adoption due to slow digitization rates in the construction industry and the hard fact that human labour is difficult to replace due to the slow-moving nature of the construction industry (Kelkar et al., 2025).

Impact

Transition to Autonomous Manipulation: On the SLAM platform, the transition for heavy machinery can be from one of tele-operated, single-task machines to autonomous, multi-purpose mobile manipulators (Hsieh et al., 2023).

Enhanced Precision in Adverse Conditions: In construction projects, especially indoor projects where a lot of dust can be produced, it is difficult to rely on just one type of sensor and sensor fusion has proven to be useful in producing better results in construction sites with limited visibility and other limiting factors (Parsons et al., 2024).

BIM & Data Collection

BIM is transforming construction by integrating data across the project lifecycle, enabling autonomous workflows and optimizing resource allocation despite complex adoption barriers.

Building Information Modeling (BIM) is used to produce a digital representation of a project across its entire project cycle, spanning from the planning and design stages to actual construction and operations (Autodesk, 2023). With the fast-paced adoption of BIM and other 3D models, data has proven to be very valuable in all phases of a construction project.

Facts

Lifecycle Integration: Unlike traditional construction projects which use 2D drawings and fragmented data, BIM enables integration and brings together the data into a 3D model (Global Industry Analysts, 2025). 3D Modelling starts even before any material is brought into the site where the inspection is done by using aerial vehicles which make a map of the site to help towards making a BIM model for planning (Wawrzyn, 2021).

Synergy with Autonomy: With increasing BIM integration and the data collection it demands, SLAM integrated applications have started to emerge quickly in the field progressing the usability of autonomous systems (Hsieh et al., 2023). For example, inventory data can be captured through BIM which can prove very useful in maximizing resource allocation in different parts of a site; and collecting this data can be delegated to systems like UAVs and other LiDAR-equipped systems that require minimal human intervention.

Drivers

Market Expansion and Standardization: Due to the lack of quick adoption of technology in the construction industry, adoption of BIM can prove to be advantageous for companies in the EU trying to internationalise (Ciullo, 2024). Implementation of BIM allows firms to standardize processes across borders and can act as a market entry strategy, particularly in developing regions where it provides opportunities for priority government partnerships and reduced competition for early adopters.

Complexity Management: With construction projects growing in complexity, major construction stakeholders have pushed the move to using Building Information Modeling (BIM) during the entire cycle of a project.

Challenges

Data Dependency: To support BIM modelling and to improve productivity, accurate and valuable data is necessary at all stages. This requirement necessitates robust data collection methods, often relying on advanced systems like UAVs and LiDAR.

Impact

Productivity and Workflow Optimization: The usage of BIM data can improve productivity by appropriately sequencing workflows and aiding with resource management (Team OnIndus, 2024). This allows for maximizing resource allocation in different parts of a site.

3-D Printing

3-D printing is curbing construction emissions and enhancing geometric freedom through AI-guided robotic arms, overcoming the logistical constraints of traditional gantry systems.

With cement production contributing to close to 8% of greenhouse emissions (Purton, 2024), there has been an active push to move towards a less consuming method of building. 3-D Printing emerged as a viable solution due to a reduction in the amount of time taken, materials used and assistance from AI to make fail-proof, accurate 3-D printed models.

Facts

Technological Shift: The industry is currently witnessing a shift from traditional gantry systems to robotic arm-based printers (such as 6-axis arms).

Diverse Applications: Across the industry, 3-D printing has been used to build foundations for infrastructure projects, pre-fabricated components for the construction of houses in gated societies and a variety of other use cases.

Drivers

Environmental Urgency: The primary driver is the need to reduce the 8% of global greenhouse emissions contributed by cement production (Purton, 2024).

Operational Efficiency: Adoption is further driven by the reduction in time taken and materials used compared to traditional methods.

Challenges

Logistical Constraints of Legacy Systems: Traditional gantry systems are bulky and difficult to transport, unlike newer robotic arm-based printers which offer easier transport to difficult sites (McClements, 2023).

Impact

Geometric and Logistical Freedom: The move to robotic arm-based printers offers greater geometric freedom compared to their bulky predecessors (McClements, 2023).

Enhanced Accuracy: Assistance from AI helps make fail-proof, accurate 3-D printed models, reducing waste and rework.

Photo by ZMorph All-in-One 3D Printers on Unsplash

↗ Construction

↗ Economic Trends

→ Industry and Project Costs

Industry and Project Costs

The European construction market is projected for strong growth driven by infrastructure investment, yet faces profitability challenges from rising labor costs, material inflation, and heavy regulatory compliance burdens.

The European construction market was valued at $2.75T in 2024, with projections indicating that the market size will reach $4.44T by 2034 (Research and Markets, 2025). The general cost structure of a construction project within this market can be divided into the following costs: labor, materials, equipment and site preparation, compliance, planning, administration and financing.

Facts

Market Growth and Labor Trends: The market is projected to grow at a 4.9% CAGR. However, the costs of a construction project are increasing. Labor costs for construction in Europe are also seen to be increasing – 4.8% between Q2 of 2024 and 2025, which is 1.2% greater than the overall increase in labor costs in Europe (Eurostat, 2025).

Compliance Tools: While extensive databases do exist to aid in calculations for regulatory compliance (examples include co2data.fi, OneClickLCA), they are also hefty expenses for construction companies.

Drivers

Infrastructure Investment: Two primary drivers for the projected growth are the increased investment into infrastructure projects, and increased investment into improving and developing the trans-European transport network (TEN-T) (Research and Markets, 2025).

Geopolitical Factors: Material costs (the actual material, and the procurement logistics) have also been increasing, within the EU. This can be attributed to general shortages, as well as geopolitical measures (tariffs).

Challenges

Regulatory Burden:. Construction companies also have to spend time and money for regulatory compliance. As highlighted by a Founding Engineer of a construction workflows startup, companies must record all CO2 emissions of all involved processes in the construction process of the project, and report them as part of compliance in Europe. Spending time and money on monitoring and calculating such values is expensive.

SME Vulnerability: Thousands of SMEs in Europe are burdened by steel and aluminum tariffs and reduced import quotas, where such SMEs also include construction companies (Group, 2026).

Impact

Rising Project Costs: The combination of labor cost increases (outpacing the general market) and material cost inflation directly impacts the financial viability of projects.

Market Expansion: Despite these rising costs, the industry is poised for significant expansion, driven by large-scale infrastructure initiatives.

Construction
Labour Trends

- Productivity Decoupling
- Demographic Attrition and Shortages
- Costs Attributed to Labour

Productivity Decoupling

Construction productivity is facing a distinct downward trend due to systemic fragmentation and project heterogeneity, lagging significantly behind manufacturing efficiency despite broader European labor growth.

Labor productivity in Europe has increased by +0.9% on an annual basis between 1999-2024. It should be noted that overall labor productivity in Europe has been gradually increasing in an approximately linear manner. However, the construction industry faces a distinct downward trend attributed to technology, fragmentation, and heterogeneity.

Facts

Divergent Productivity Trends: While the general labor productivity in Europe grew, the change in labor productivity in the construction industry is -0.5% annually in the same time frame (Eurostat 2025; ECB Data Portal 2024). In contrast, manufacturing has seen an average annual +2.3% productivity increase between 1999-2024 (Eurostat 2025).

Industry Composition: Construction is a highly fragmented industry which consists of many stakeholders, including: project owner, general contractors, subcontractors, designers and architects, safety inspection consultants. It is also considered a heterogeneous industry because no two projects are ever identical.

Drivers

Repeatability as an Efficiency Driver: Increases in efficiency usually come down to how repeatable a process is—exactly why manufacturing has outperformed construction in productivity metrics.

Economic Constraints on Innovation: The driving factor for the slower transition toward a more digitalized industry is the fact that the construction industry generally struggles with tight margins, causing a lack of R&D investment.

Challenges

Technological Adoption Barriers: In construction, the adoption of ICT has been lower relative to adjacent industries. This can be attributed to multiple factors: lack of skilled labor, aging workforce which hasn't kept up with new technological innovation, and a fragmented industry where tech stacks aren't universal, so benefits aren't seen as much.

Workflow Disintegration: Each party has their own independent workflows, which are disintegrated from each other due to subpar communication.

Inherent Variability: In contrast to manufacturing, construction is an industry which has always been subject to high variability between projects. Factors which cause this variability include: geography (weather, land, likelihood and type of natural disaster), project specifications, local regulations, differences in building sites and design changes (Jaśkowski & Biruk, 2019).

Impact

Systemic Bottlenecks: The heterogeneous nature of projects makes the lack of standardization a systemic bottleneck for productivity.

Operational Redundancy: The fragmentation among stakeholders leads to a tendency for redundant work by each involved party, contributing to the negative annual productivity growth of -0.5%.

Demographic Attrition and Shortages

The construction industry faces a critical labor crisis as an aging workforce retires without sufficient young replacements, deepening the skilled labor gap and stifling innovation across Europe.

As is reflected by the general trend in an aging population in Europe, the construction workforce also experiences problems of an aging workforce with fewer young people who are willing to enter the industry, alongside skilled labor shortages.

Facts

Demographic Shifts: In 2021, 32% of the workforce fell into the 50-64 year old age group (CEDEFOP, 2023), which has only increased as of today. Research by the USP Marketing Agency suggests that the average age of the workforce in Europe is hovering around 50 years in 2025. Key nations like Germany reported an average age of 43 years old in 2020.

Extent of Skilled Labor Gap: Already in 2021, 70% of construction companies in Germany reported a lack of skilled labor as a significant obstruction to construction activities and efficiency, a trend which is also pan-European (Construction Blueprint, 2021). According to the European Construction Industry Federation (FIEC), upskilling and reskilling 25% of the workforce is required to reach the target of 3 million skilled workers between 2022-2027.

Drivers

Workforce Perception: Alongside an aging population, there is a lack of a younger workforce entering the market because construction is looked at as a labor-intensive job without high pay, alongside exposure to health risks.

Broader Labor Trends: Such trends aren't solely subject to construction, but this is a general trend seen in labor-heavy industries, as mentioned by a CEO of a construction technology company.

Policy-driven Demand: The European Union's agenda with green and digital transitions in the construction industry creates an additional skill gap between the current, and desired labor.

Challenges

Imminent Retirement Wave: Issues with labor shortages are already prevalent, but the relevance will be further magnified as a significant part of the workforce gets closer to retirement age (between 60-65 years). Projections indicate that 10% of the workforce in Sweden will retire by 2028.

Skill Miss-Match: This complemented with the aging workforce (and a lower entry of young workers) contributes to a skill mismatch. With general labor shortages, shortages of skilled labor (electricians, plumbers, HVAC, carpenters, etc.) is also prevalent.

Impact

Stifled Innovation and Productivity: Lack of skilled labor also contributes to a lack of innovation, reflected by the productivity decline and stagnated innovation within the industry. This skill mismatch slows down labor productivity.

Operational Obstruction: The lack of skilled labor acts as a significant obstruction to construction activities and efficiency (Construction Blueprint, 2021).

Costs Attributed to Labour

High labor costs in Europe and the US significantly impact construction budgets, accounting for up to 50% of total project costs due to regional disparities and project-specific requirements.

The average cost of labor in Europe, in the construction sector is €30.0 per hour (Eurostat, 2025), only falls below the United States where average labor costs are $40.6 (FRED, 2025).

Facts

Global Cost Comparison: The average cost of labor in Europe is €30.0 per hour, compared to $40.6 in the United States. For comparison, labor costs in India are ₹217/hour (ERI Economic Research Institute, 2026), which is $10.6 when adjusted for purchasing power parity.

Project Cost Proportion: Labor costs account for 20%-50% of the costs of the overall project (Autodesk, 2024).

Drivers

Project-specific Requirements: Labor costs differ by project, based on the project's amount of need for skilled or specialized labor, amount of human labor required, the country where the project is based, and so on.

Challenges

Heterogeneity and Variability: The high variability in the percentage figure stems from the heterogeneous nature of the construction industry.

Impact

Significant Budgetary Weight: Because labor costs account for 20%-50% of the costs of the overall project (Autodesk, 2024), this component represents a substantial financial impact on construction budgets.

Photo by Aidan Hunnisett

↗ Construction

↗ Regulatory & Policy Trends

- → Construction Codes & Safety Regulations
- → Cybersecurity Regulations
- → Certifications & Regulations

Construction Codes & Safety Regulations

Construction innovation faces a dual compliance barrier: navigating generational lags in building codes while meeting strict new EU safety regulations for autonomous machinery.

Construction codes dictate what can be built and how, yet they move at generational timescales that lag behind the technologies now entering the industry. As one interviewee from a construction tech startup explained, "new materials take 50 years to enter building codes" (Founder, construction tech startup, personal communication, 2026). With new EU safety regulations for autonomous machinery taking effect in 2027, construction technology companies face the dual challenge of working within outdated structural codes while complying with rapidly evolving product safety frameworks.

Facts

Construction Codes Evolve at Generational Timescales: Structural glass, fibre-reinforced polymers (FRP), and tensioned membrane structures all have 30 to 50 years of research behind them, yet most are only now partially entering the second-generation Eurocodes expected between 2027 and 2028 (Eurocodes JRC, n.d.). Newer construction methods such as 3D concrete printing and robotically assembled structures do not appear in the second-generation scope at all.

New Autonomous Machinery Safety Regulation Sets Compliance Deadline: The EU's Machinery Regulation (2023/1230) will replace the current Machinery Directive 2006/42/EC on January 20, 2027 with no transitional period (TÜV Rheinland, n.d.). Under the new framework, "machines using self-evolving AI algorithms where outcomes may not be fully predictable at design time" will likely require third-party conformity assessment rather than self-declaration (TechWorks AI, 2025).

Drivers

New Equipment Outpacing Existing Safety Rules: The transition from the Machinery Directive to the Machinery Regulation reflects the EU's recognition that autonomous and AI-driven equipment requires a fundamentally different safety framework. Construction robotics, autonomous vehicles on site, and AI-powered inspection tools all fall under this updated regime, which now explicitly addresses software-defined safety functions and self-learning systems.

Challenges

Software Updates as Re-Certification Events: According to the new Machinery Regulation, anyone who carries out "a substantial modification of machinery or a related product shall be considered to be a manufacturer for the purposes of this Regulation" (Regulation (EU) 2023/1230, Article 18). In Article 3, software is defined as part of the machinery itself, rather than a separate addition (Regulation (EU) 2023/1230, Article 3). For construction robotics companies, or their clients, firmware updates that alter safety-related behaviour could qualify as substantial modifications, making every such update a potential re-certification event.

No Established Regulatory Pathway for Emerging Construction Methods: Companies deploying these technologies must operate without standardised code provisions, adding liability exposure on top of longer wait times for regulatory recognition.

Impact

Dual Compliance Burden Shapes Market Entry: Construction technology companies must simultaneously navigate slow-moving building codes that do not yet account for their innovations and fast-moving product safety regulations with fixed deadlines. This dual burden favours well-resourced companies that can manage parallel compliance workstreams, and creates a structural barrier of entry for startups and SMEs entering the construction robotics space.

Cybersecurity Regulations

Construction is facing a surge in cyberattacks and a strict tripartite regulatory burden, transforming cybersecurity from an operational detail into a mandatory barrier for EU market entry.

Construction has become one of the most targeted industries for cyberattacks. As BIM platforms, IoT sensors, and cloud-based collaboration tools become standard on construction sites, the entry points for attacks expand rapidly while protective frameworks lag behind.

Facts

Construction Ranks Among the Most attacked Sectors Globally: Construction and engineering ranked among the top three industries affected by ransomware worldwide, alongside business services and industrial manufacturing (Check Point Research, 2025). The construction cybersecurity market is expected to grow from $8.58 billion in 2026 to $18.41 billion in 2030 at a compound annual growth rate of 21% (Research and Markets, 2026).

Connected Devices on Construction Sites Expand Security Vulnerabilities: Many connected devices on construction sites "were not designed with top-tier security protocols in mind" and often "run on outdated operating systems or rely on default passwords" (Woodruff Sawyer, 2024). As BIM platforms, IoT sensors, and cloud-based tools become standard, each interconnected stakeholder represents a potential entry point for attackers across the project network.

Drivers

The EU Regulatory Framework Mandates Cybersecurity for Connected Products: Under the upcoming EU regulations, "AI systems that can be updated must demonstrate protection against cyber threats, including tampering and data manipulation" (TechWorks AI, 2025). This is not optional: as the Machinery Regulation classifies software as part of the machinery itself (Regulation (EU) 2023/1230, Article 3), cybersecurity is now a precondition for CE marking, not an aftermarket consideration

Challenges

Tripartite Compliance: A construction robotics company selling an autonomous system in the EU may need to satisfy three separate regulatory regimes simultaneously: the Machinery Regulation for safety, the AI Act for algorithmic risk, and the Cyber Resilience Act for digital security. Each with its own conformity assessment, its own documentation requirements, and its own penalty structure. As TechWorks AI notes, "machinery with embedded AI, especially those capable of autonomous decision-making, will potentially be subject to compliance under the Machinery Regulation, the EU AI Act and the EU CRA" (TechWorks AI, 2025). No unified process exists to assess all three together.

Impact

Cybersecurity Becomes a Market Access Gate: Construction technology companies unable to demonstrate cybersecurity compliance will not be able to place connected products on the EU market from early 2027. For companies already navigating the tripartite compliance burden, failing to meet any one of these requirements is sufficient to block market entry entirely.

Certifications & Regulations

Strict liability regimes and expanding EU certification requirements are creating a verification bottleneck, forcing construction tech companies to navigate fragmented regulations across 27 member states.

Certification is the gateway to the EU construction market. The revised Construction Products Regulation (CPR 2024/3110) has significantly expanded what certification covers, requiring Digital Product Passports (DPPs) across 36 product families. Yet "only 18% of construction suppliers are fully ready for updated EU compliance" (Ecochain, 2025).

Facts

A Trust Deficit Undermines Data Sharing Across the Construction Supply Chain: Each stakeholder in a construction project independently recalculates quantities rather than trusting data embedded in BIM files or provided by other parties. As a Founding Engineer at a construction technology company explained, "No one takes responsibility for the actual value. So everyone has their secret values" (Founding Engineer, construction technology company, personal communication, 2026). This is not a technology problem but a liability-driven behaviour: each party recalculates because they bear legal responsibility for the figures they approve.

Drivers

Regulatory Expansion Turns Certification into a Hard Gate: The revised CPR introduces phased environmental reporting and Digital Product Passports, with compliance mandatory for all priority product categories by January 2028 (Ecochain, 2025). For one construction robotics startup, CE certification on infrastructure components is what unlocks access to major utility clients; without it, market access is structurally impossible regardless of how well the technology performs (Founder, construction robotics startup, personal communication, 2026).

Challenges

Liability Fragmentation Across 27 Member States: The ELIOS study, commissioned by the European Commission to map construction liability regimes, concluded that "the idea of European harmonisation has been abandoned and considered as unrealistic due to the complexity and diversity of the national legal and insurance systems" (Centre d'Etudes d'Assurances & CSTB, 2010). Fifteen years later, the situation has not improved; a 2025 European Parliament study warns that "the worst case scenario is a piecemeal legal landscape that undermines the internal market and disincentivises innovation by increasing regulatory overhead" (Bertolini, 2025). For construction technology companies deploying products across borders, this means navigating not one regulatory framework but 27, each with different fault standards, insurance requirements, and enforcement mechanisms.

More Certification Reinforces the Recalculation Loop: More certification requirements paradoxically add more points of potential liability, reinforcing rather than resolving the cycle where every stakeholder independently re-verifies data they do not trust. The EU's sustainability reporting framework alone costs between "EUR 150,000 for non-listed companies to EUR 1 million for listed ones" (Draghi, 2024), and even within the single market, "market behaviour imposes higher and costlier compliance requirements than EU law" (European Commission, 2014).

Impact

The Emerging Verification Bottleneck: Compliance is becoming a durable competitive advantage, but as the regulatory burden scales, so does the strain on the institutions responsible for checking it. Notified bodies, BREEAM assessors, and building control inspectors face expanding workloads with no corresponding increase in capacity, creating a second bottleneck at the verification layer.

EXPLORATION

↗ Construction

Photo by Atlantic Ambience

Construction
Exploration

- Silos of Data due to Discrete Workflows
- Labour Crisis: Aging Workforce, Hardware Cost Barrier
- Cybersecurity & Verification
- The Schedule Gap: Scope Creep, Delays, and Cost Overruns

Silos of Data due to Discrete Workflows

- **Disconnected Software** causes data silos, breaking workflows.
- **Defensive Redundancy** forces teams to constantly recalculate data.
- **Isolated Workflows** undermine any "Single Source of Truth."

Silos of Data due to Discrete Workflows

"Crack the integration issue and you have a more productive workforce in construction." This insight from the CEO of an Asian construction consultancy highlights the industry's critical struggle with data fragmentation. Data remains siloed between stakeholders, a problem ironically exacerbated by the increasing adoption of disconnected Project Management Software (Roepke, 2019). Although intended to streamline operations, these independent platforms often fail to communicate, introducing further friction into digital workflows rather than resolving it.

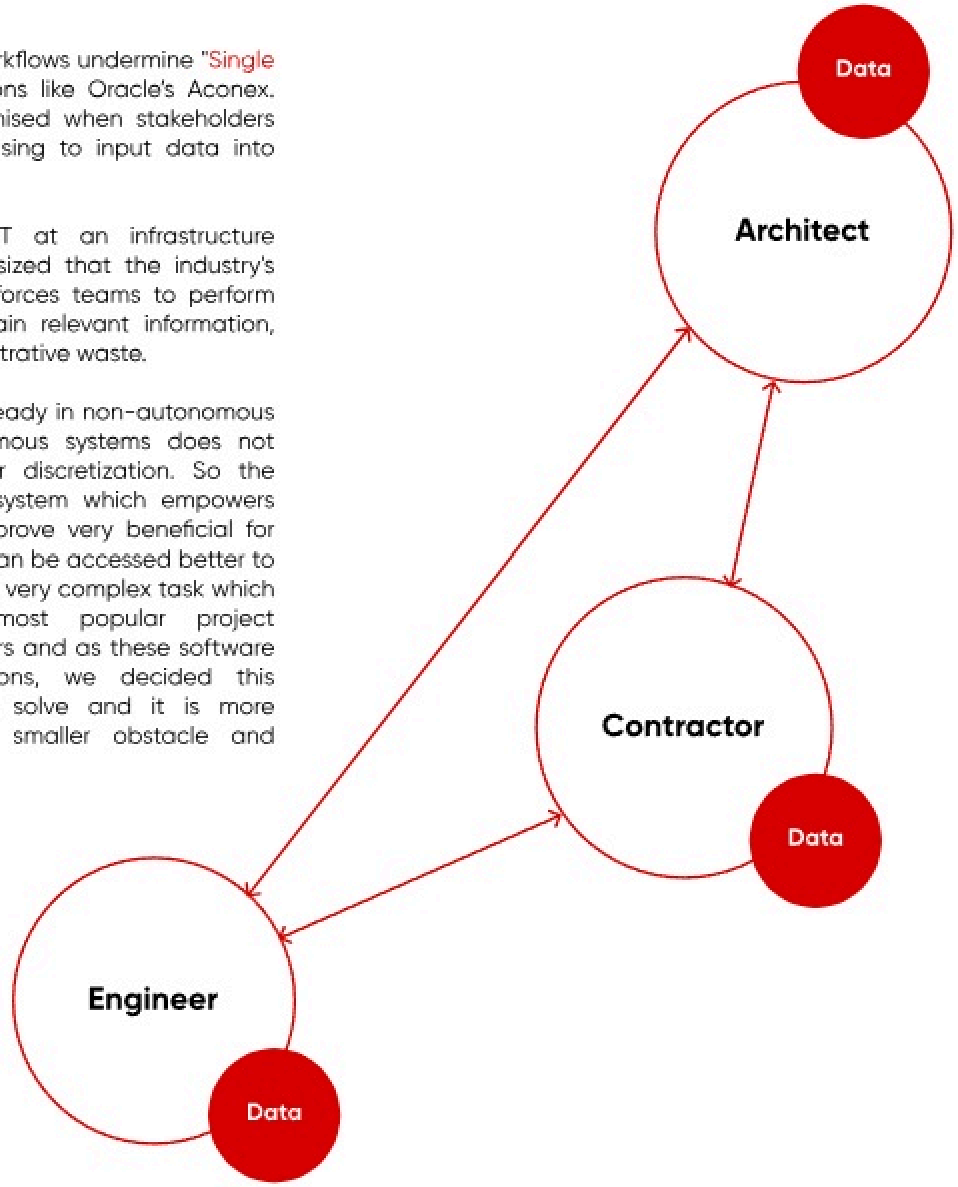
As stated by the former Founding Engineer of a construction workflows company in our interview, members of the construction value chain constantly revisit and recalculate the same values and measurements in order to avoid liabilities. There is a lack of trust between the involved parties, where each party reassesses data received from other parties (e.g. a Building Information Model file) in order to make sure that their execution is based on accurate data (Construction Leadership Council, 2022). The lack of trust stems from avoiding the risk of potential liabilities: the party which incorrectly executes faces the liability, rather than the party which provided the incorrect data.

This technological disconnect fosters a culture of distrust and defensive redundancy. A former Founding Engineer of a construction workflows company noted that value chain members constantly "revisit and recalculate" the same measurements to mitigate risk. This lack of trust compels parties to re-assess data received from others, such as BIM files, to ensure execution accuracy (Construction Leadership Council, 2022). The defensive posture stems from liability concerns: the party that executes the error typically faces the penalty, regardless of whether the source data was incorrect.

Consequently, independent workflows undermine "Single Source of Truth" (SSOT) solutions like Oracle's Aconex. Their effectiveness is compromised when stakeholders cling to isolated systems, refusing to input data into shared platforms.

Furthermore, the Head of IT at an infrastructure construction company emphasized that the industry's lack of data standardization forces teams to perform additional rework just to obtain relevant information, perpetuating a cycle of administrative waste.

Due to such siloing of data already in non-autonomous workflows, putting in autonomous systems does not improve much due to further discretization. So the priorities lie in setting up a system which empowers lossless workflows which can prove very beneficial for autonomous systems as data can be accessed better to train these systems. But this is a very complex task which requires access to the most popular project management software providers and as these software providers are large institutions, we decided this painpoint was too large to solve and it is more worthwhile to first solve a smaller obstacle and understand the market.



Labour Crisis: Aging Workforce, Hardware Cost Barrier

- As the **average 50-year-old workforce retires**, the labor crisis is set to peak in 10-15 years.
- Niche construction robots remain **too expensive** for tight industry margins.
- Hardware viability requires **mass production** and **cost reduction**.

Labour Crisis: Aging Workforce, Hardware Cost Barrier

Labor shortages are already prevalent within the construction industry, and are highlighted as a significant reason for stunted labor productivity. However, the peak of this issue is likely not fully evident yet, and will become extremely prevalent in 10-15 years.

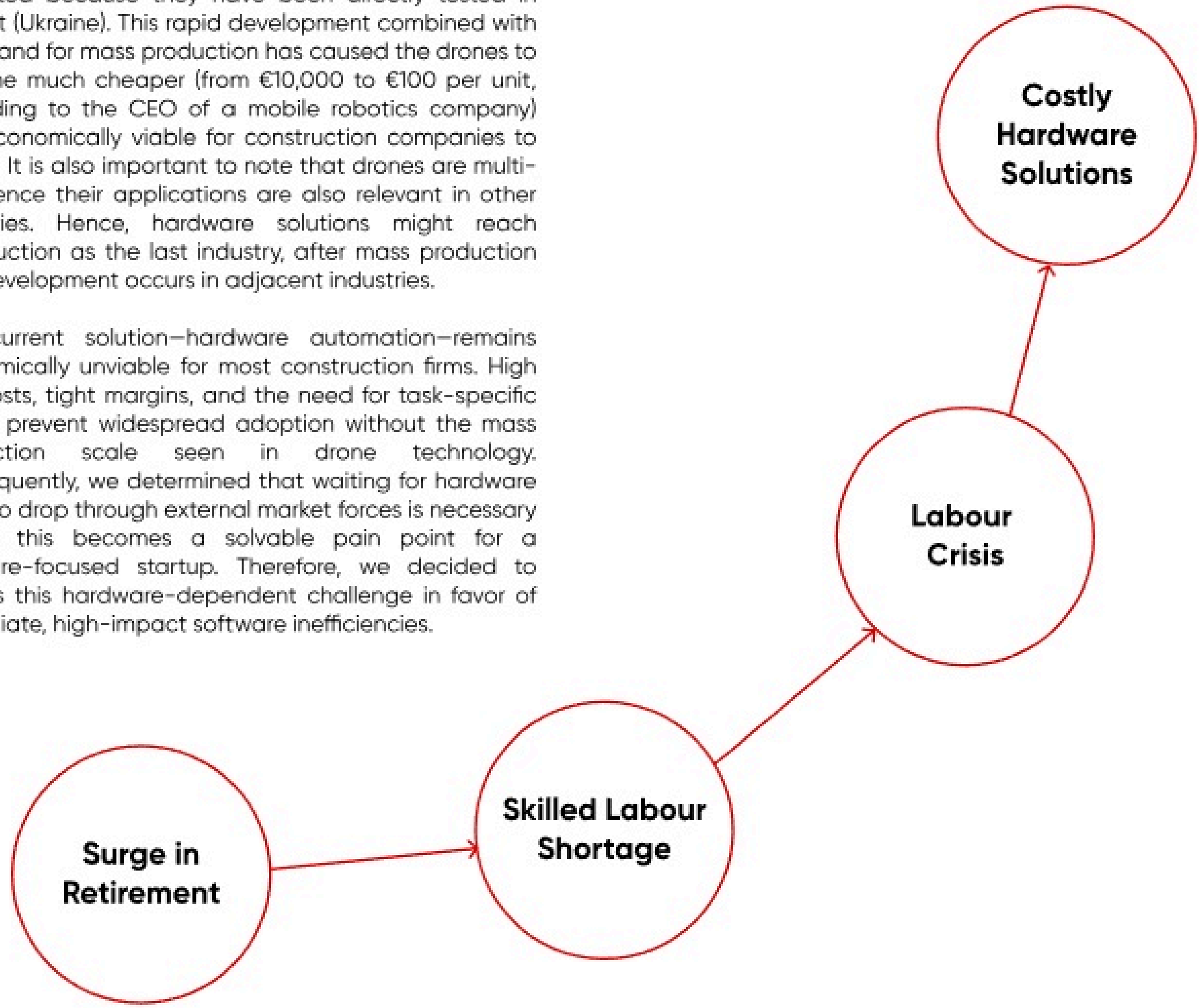
As fewer younger people enter the construction workforce, a surge in labor leaving the workforce in 10-15 years due to retirement (the average age of the labor force was identified to be 50 years old, as per research by the USP Marketing Consultancy, while the average retirement age in Europe is in between 60-65 years). An additional problem which might arise with the surge in retirement after 10-15 years is the lack of skilled labor. There is already an impactful shortage of skilled labor, and the upcoming decrease in skilled labor (as the experienced workforce exits, and the inexperienced younger workforce does not possess the same skillset) is also a significant pain point the industry will soon face.

The potential for hardware based solutions to fill in this gap of a labor shortage is prevalent, especially as the construction market is projected to grow with 4.9% CAGR between 2025-2034 (Research and Markets, 2025). According to a postdoctoral researcher in robotics, such hardware solutions are ready and developed enough for industry use. However the financial feasibility of these sorts of solutions is not certain.

Hardware solutions are still expensive, making investments into such solutions extremely tough for construction companies, due to the tight margins seen across the industry. Additionally, the CEO of a mobile robotics company pointed out that for each function/ task, a specific robot is needed, hence a low volume of each type of robot is required on the construction site. A lack of mass production of certain robots in the construction industry might make it uneconomical for construction companies to be pioneers in the adoption of hardware based solutions.

An example of hardware solutions which has actually been adopted in construction is drones. As identified by a former Founding Engineer of a defense technology company, drones have been rapidly tested and reiterated because they have been directly tested in conflict (Ukraine). This rapid development combined with a demand for mass production has caused the drones to become much cheaper (from €10,000 to €100 per unit, according to the CEO of a mobile robotics company) and economically viable for construction companies to adopt. It is also important to note that drones are multi-use, hence their applications are also relevant in other industries. Hence, hardware solutions might reach construction as the last industry, after mass production and development occurs in adjacent industries.

The current solution—hardware automation—remains economically unviable for most construction firms. High unit costs, tight margins, and the need for task-specific robots prevent widespread adoption without the mass production scale seen in drone technology. Consequently, we determined that waiting for hardware costs to drop through external market forces is necessary before this becomes a solvable pain point for a software-focused startup. Therefore, we decided to bypass this hardware-dependent challenge in favor of immediate, high-impact software inefficiencies.



Cybersecurity & Verification

- Construction cybersecurity is better served by **generalist incumbents** because the core vulnerabilities are standard IT failures rather than sector-specific issues.
- **Increasing EU certification requirements** are creating a liability-driven cycle where the industry risks paralysis from constantly re-verifying untrusted data.
- **The verification layer**, where assessors possess real-world data advantages that compliance generation tools cannot replicate.

Cybersecurity & Verification

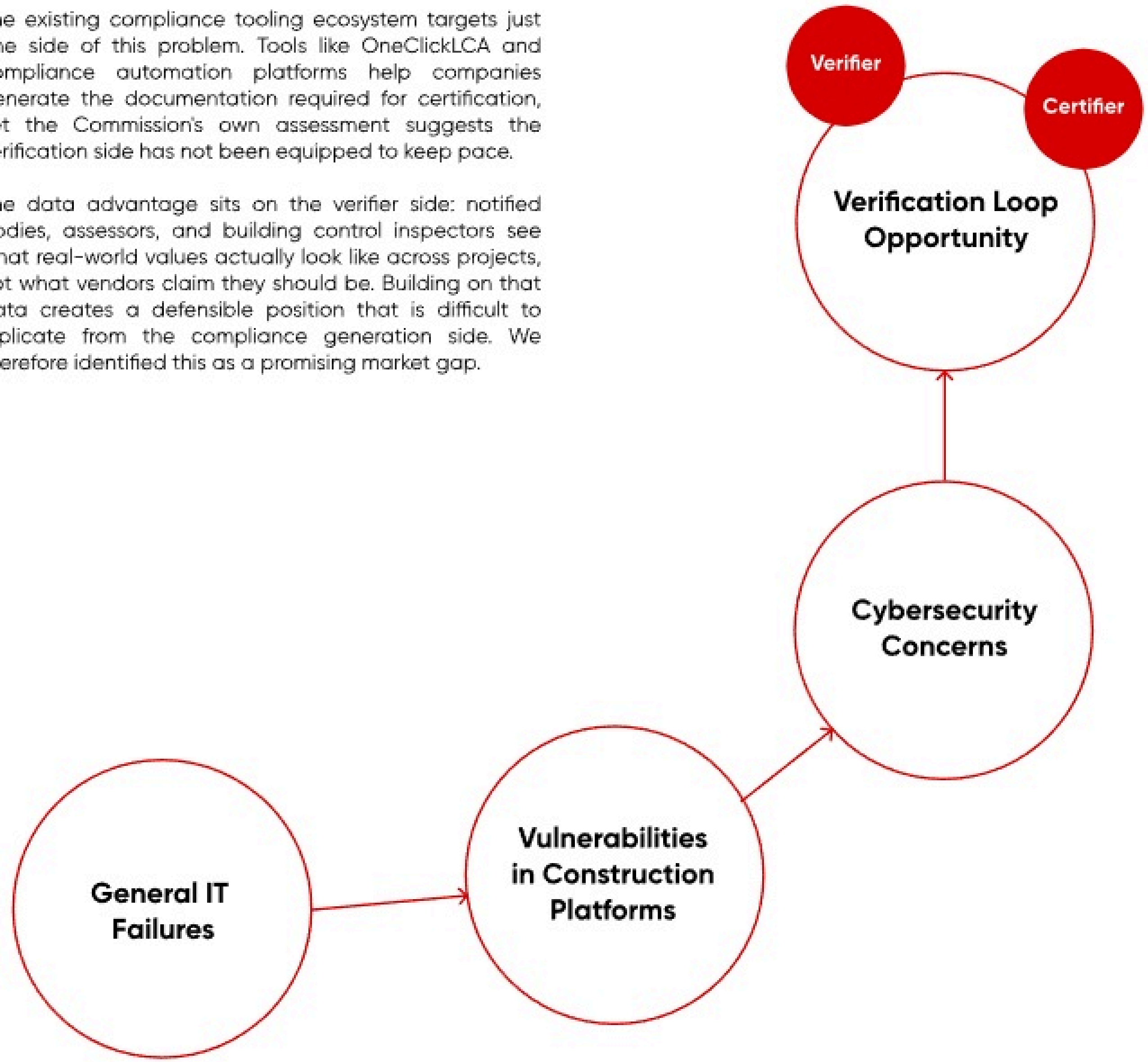
The construction cybersecurity market presents a clear opportunity, with strong regulatory tailwinds from early 2027 and a sector that remains structurally underprotected. However, the core problem is not construction-specific. The vulnerabilities are general IT security failures (outdated systems, default credentials, unpatched firmware) applied to a construction context, and the solutions are general.

Established cybersecurity firms such as CrowdStrike, Palo Alto Networks, and Fortinet are better positioned to serve this market than a construction-focused startup, because the underlying technical challenge is endpoint and network security rather than domain expertise in the built environment. A startup entering this space would compete on cybersecurity capability against incumbents with decades of R&D, rather than leveraging construction-specific insight as a defensible advantage. We therefore decided not to pursue this opportunity.

Another opportunity lies in the verification layer. The EU's expanding certification requirements are intensifying a liability-driven cycle where every stakeholder independently re-verifies data they do not trust. Even before the revised CPR, Machinery Regulation, and Cyber Resilience Act take full effect, the European Commission acknowledged that assessment workloads had progressively increased to the point where the system may even risk paralysing itself (European Commission, 2022).

The existing compliance tooling ecosystem targets just one side of this problem. Tools like OneClickLCA and compliance automation platforms help companies generate the documentation required for certification, yet the Commission's own assessment suggests the verification side has not been equipped to keep pace.

The data advantage sits on the verifier side: notified bodies, assessors, and building control inspectors see what real-world values actually look like across projects, not what vendors claim they should be. Building on that data creates a defensible position that is difficult to replicate from the compliance generation side. We therefore identified this as a promising market gap.



The Schedule Gap: Scope Creep, Delays and Cost Overruns

- A **$50M** project loses roughly **$45,000–$50,000** for every single day of delay.
- Contractors often accept unfeasible additional work within **fixed timelines**
- **"As-built"** schedules essentially always diverge from the original plan

The Schedule Gap: Scope Creep, Delays and Cost Overruns

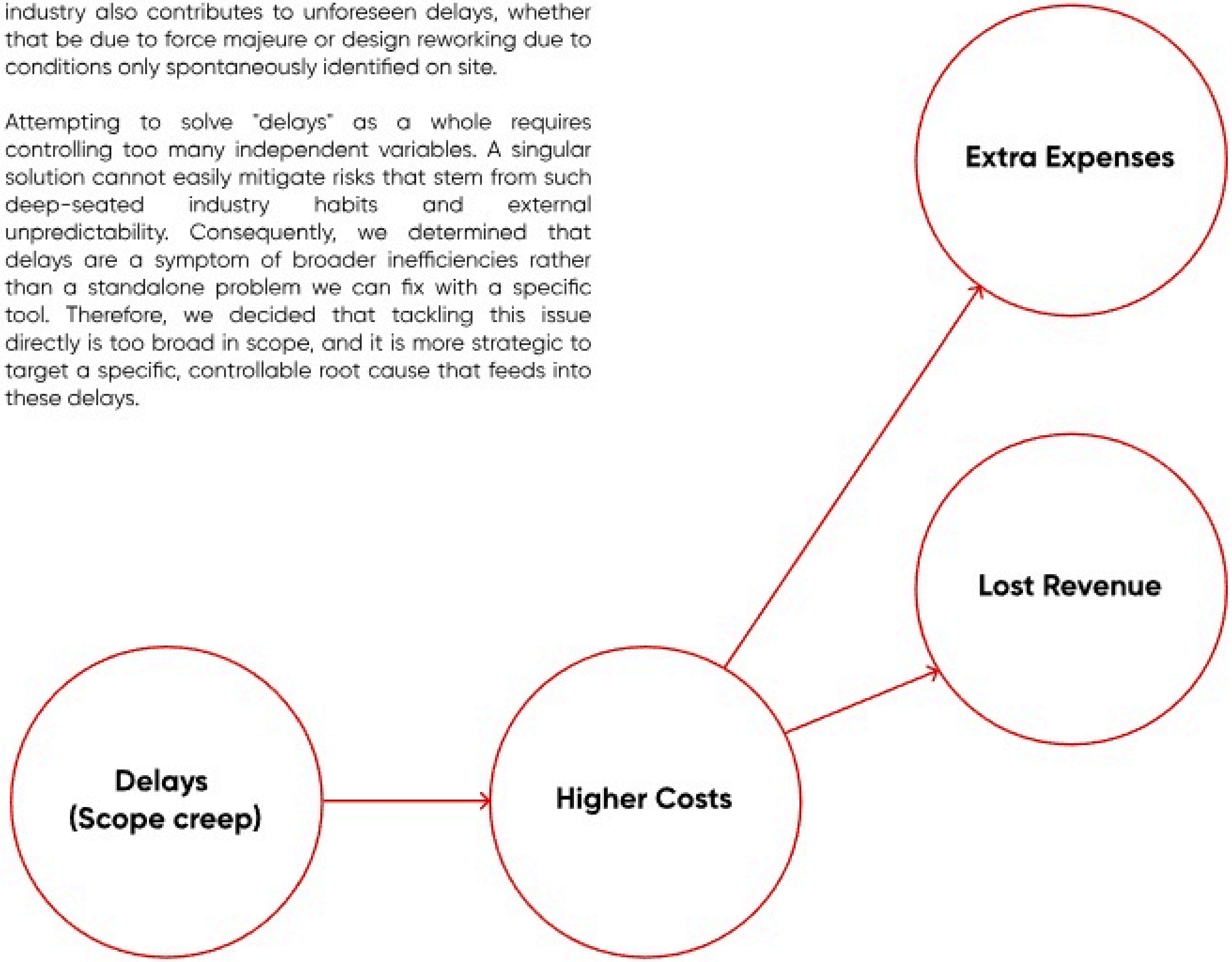
Construction project schedules have two commonly associated terms: as-planned (the originally planned project schedule and budget) and as-built (actual schedule and budget of the project). In most (essentially all) cases, the as-built schedule always deviates from the as-planned schedule (i.e. a delay occurs), as per a Founding Engineer of a construction workflows company.

A significant catalyst for cost overruns on construction projects comes as a result of project delays. As an estimated benchmark, the daily delay burn rate of a $50M project is $45,000-$50,000 per day (Deltek, n.d.). For a larger project such as the London Crossrail (worth £18.8B), the daily burn rate was £3.2M per day (Boscia, 2019). These costs can be distributed into three factors: opportunity cost (lost revenue due to project delays), fixed overhead costs (salaries, site trailers), and equipment (rental costs).

According to a construction Delay Analyst expert, a key cause for delays is referred to as scope creep. The owner might ask a contractor to squeeze in extra work within the same timeline or budget (Ashton, 2025). Despite the contractor potentially knowing that the work within the timeline and/or budget requirements is not feasible, they might accept it anyway in order to allow the project to continue to make sure that they do not lose the project contract, and hence revenue.

Additional causes for delays and cost overruns are linked to slower labor productivity, for the reasons defined in that section. Poor communication between stakeholders and a lack of skilled labor are inevitable causes for delays. On top of that, the heterogenous nature of the industry also contributes to unforeseen delays, whether that be due to force majeure or design reworking due to conditions only spontaneously identified on site.

Attempting to solve "delays" as a whole requires controlling too many independent variables. A singular solution cannot easily mitigate risks that stem from such deep-seated industry habits and external unpredictability. Consequently, we determined that delays are a symptom of broader inefficiencies rather than a standalone problem we can fix with a specific tool. Therefore, we decided that tackling this issue directly is too broad in scope, and it is more strategic to target a specific, controllable root cause that feeds into these delays.



IDEATION

↗ Construction

Photo by Atlantic Ambience

CertifyIQ+

AI Verification Workbench for Construction Compliance

CertifyIQ is an **AI based software platform** designed to address two pain points of construction certifiers

Discrepancies between approved project plans, and the actual project specifications

Discrepancies between everchanging **EU regulations** and **project specifications** in the planning and construction phases.

↗ PROBLEM

No stakeholder in a construction project wants to approve another party's measurements when they then become liable for the result. This is why independent third-party verifiers (notified bodies, building control inspectors, BREEAM assessors) exist: they carry the liability of signing off, so everyone else can move forward. They are not going anywhere. Every new EU regulation, every additional certification requirement, every Digital Product Passport mandate generates more work for the same institutional base of verifiers.

For example, if certifiers approve the CAD file which consists of the planned design of the construction project, and then multiple stakeholders send BIM models of the project as the construction phase progresses, CertifyIQ is able to highlight the discrepancies between the CAD file, the BIM files, and the EU regulations to eliminate certifiers manual labor.

But the tooling has not followed. Academic research on automated compliance checking in construction has found, "...currently no unifying standards or integrating technology to tie regulatory efforts together to enable the widespread adoption of automated compliance processes. This has left many current technical approaches, while advanced and robust, isolated" (Beach et al., 2024). The compliance software that does exist, namely tools like OneClickLCA, Ecochain, and Autodesk's compliance features, is built for the parties generating documentation, not for the parties formally verifying it. As previously outlined in Section 2, the European Commission has acknowledged that the current assessment system is approaching capacity constraints even before the revised CPR fully phases in (European Commission, 2022). Additionally, up to 30% of initial project data is lost by closeout (Autodesk, 2025), compounding the problem for verifiers who depend on that data being complete and consistent.

↗ SOLUTION

CertifyIQ is an AI-powered verification workbench built for the regulator side of EU construction compliance. While competing solutions from providers like Autodesk target architects, engineers, and contractors, their adoption by independent certifiers creates conflicts of interest. CertifyIQ is positioned on the certifier side, which avoids this conflict and, over time, builds a dataset grounded in verified third-party assessments rather than potentially biased manufacturer self-reports.

CertifyIQ starts with BIM-based plan-to-actual verification, where adoption is highest and the recalculation problem is most acute, then graduates into the regulatory document layer as the revised CPR phases in through 2032.

Phase 1: Accelerate Verification for Independent Assessors.
A certifier uploads the approved project plan (CAD/BIM) as the assessment baseline. As stakeholders submit files during construction, CertifyIQ cross-references each submission against the baseline, flagging deviations by severity so certifiers focus on anomalies rather than reading every document manually. This produces an audit-ready report documenting all flagged discrepancies and the certifier's decisions. In comparable compliance domains, AI-assisted document review has reduced manual analysis time by 30–40% (McKinsey, 2024). For capacity-constrained notified bodies absorbing an expanding CPR scope, this directly translates to more assessments per auditor.

Phase 2: Simultaneously Build the Data Flywheel.
Phase 1 serves an underserved market, but strategically gives CertifyIQ access to verified, third-party data. Each assessment processed feeds back into the platform, building statistical baselines for what unbiased, real-world values actually look like across product families and geographies. Because this data comes from independent certifiers rather than manufacturers, it is not skewed by vendor incentives. The more assessments processed, the harder the baselines are to replicate from the compliance generation side.

Phase 3: Become the Industry Credit Score.
At scale, CertifyIQ's dataset opens revenue streams beyond the verification workflow itself. Since the baselines are built from independent third-party assessments rather than self-reported data, they carry inherent credibility. Manufacturers preparing submissions could pre-screen against aggregate benchmarks to reduce rejection risk. Insurers could reference verified norms when pricing liability exposure. Public procurement bodies could evaluate claims against real performance distributions rather than vendor declarations. None of these applications require CertifyIQ to move into the compliance generation side or compete with AEC platforms. The product becomes shared industry infrastructure that all sides of the transaction reference.

3. Industry Benchmark

Construction teams pre-check BIM data against verified ranges before submitting to certifiers; Catching issues early, avoiding time-consuming rejection cycles and costly project delays.

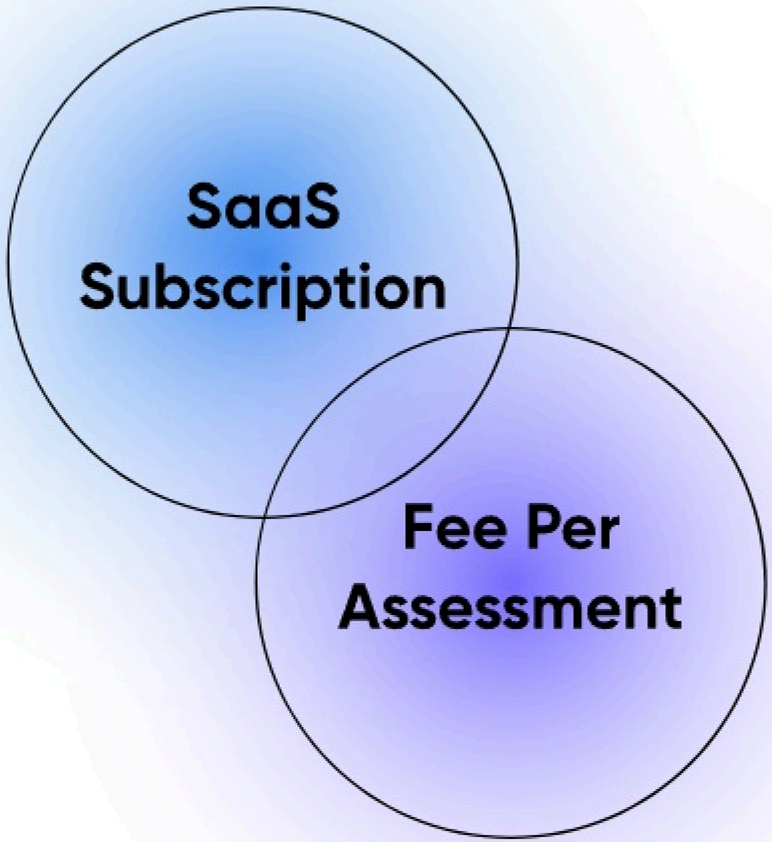
2. Credible Data Flywheel

Each certifier assessment builds CertifyIQ's CredibilityScore: A baseline of trusted ranges derived from independent third-party approvals, not self-reported data.

1. Faster Certifier Assessments

AI flags deviations against approved baselines so certifiers spend less time looking for anomalies, and more time addressing them.

CertifyIQ Business Model



Low fixed commitment reduces switching friction for cyclical workloads.

Revenue grows naturally as regulatory scope expands through 2032.

Total Addressable Market

The European market for Testing, Inspection and Certification (TIC) is valued at $66.61B in 2025, with an estimated CAGR of 4% between 2026-2031 (Mordor Intelligence, 2025). The Building and Construction market is valued at $9.95B, with estimated projects for growth with a CAGR of 6.4% until 2028 – equating to the valuation of $11.3B (Data, 2021).

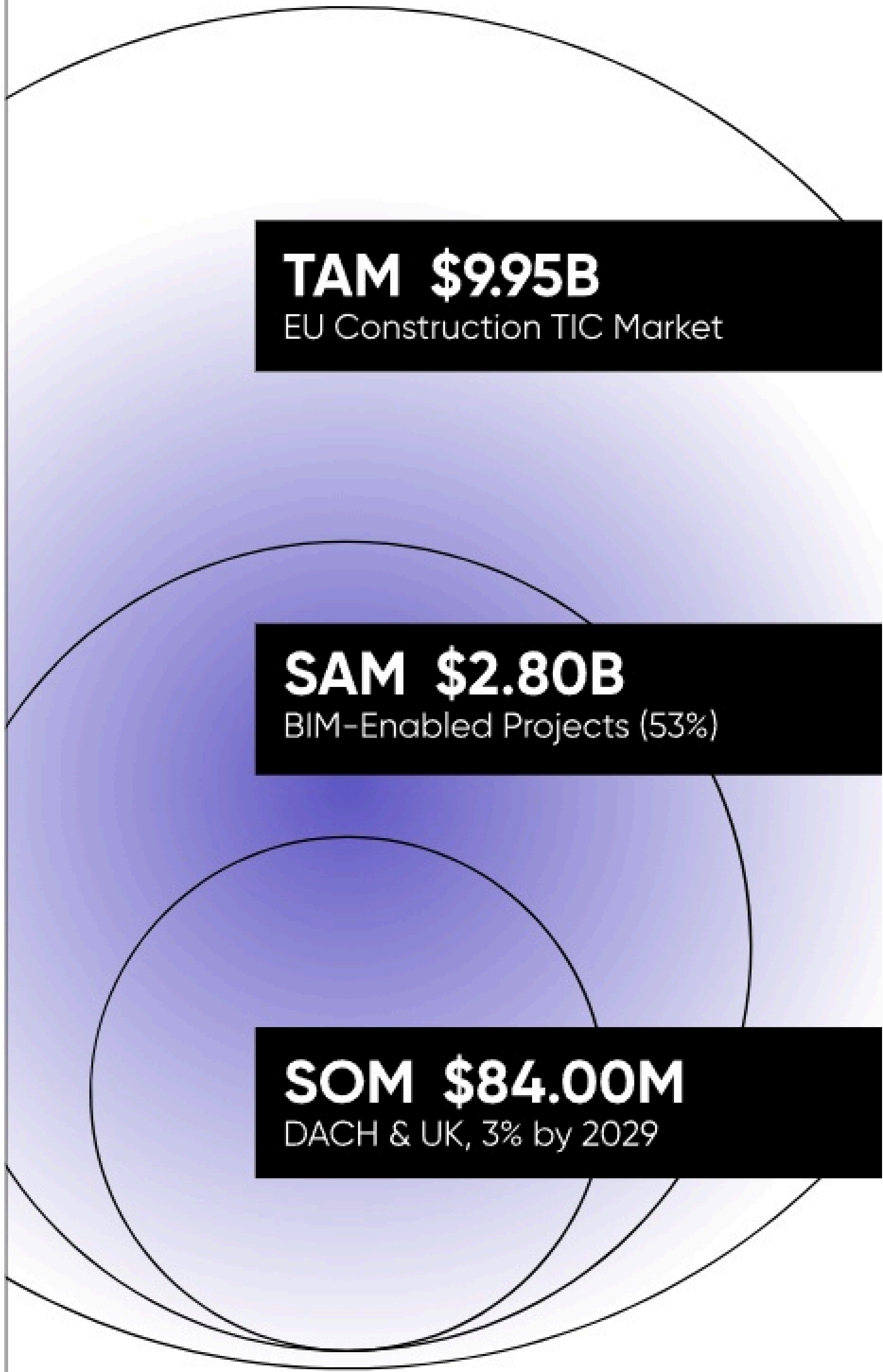
Serviceable Addressable Market

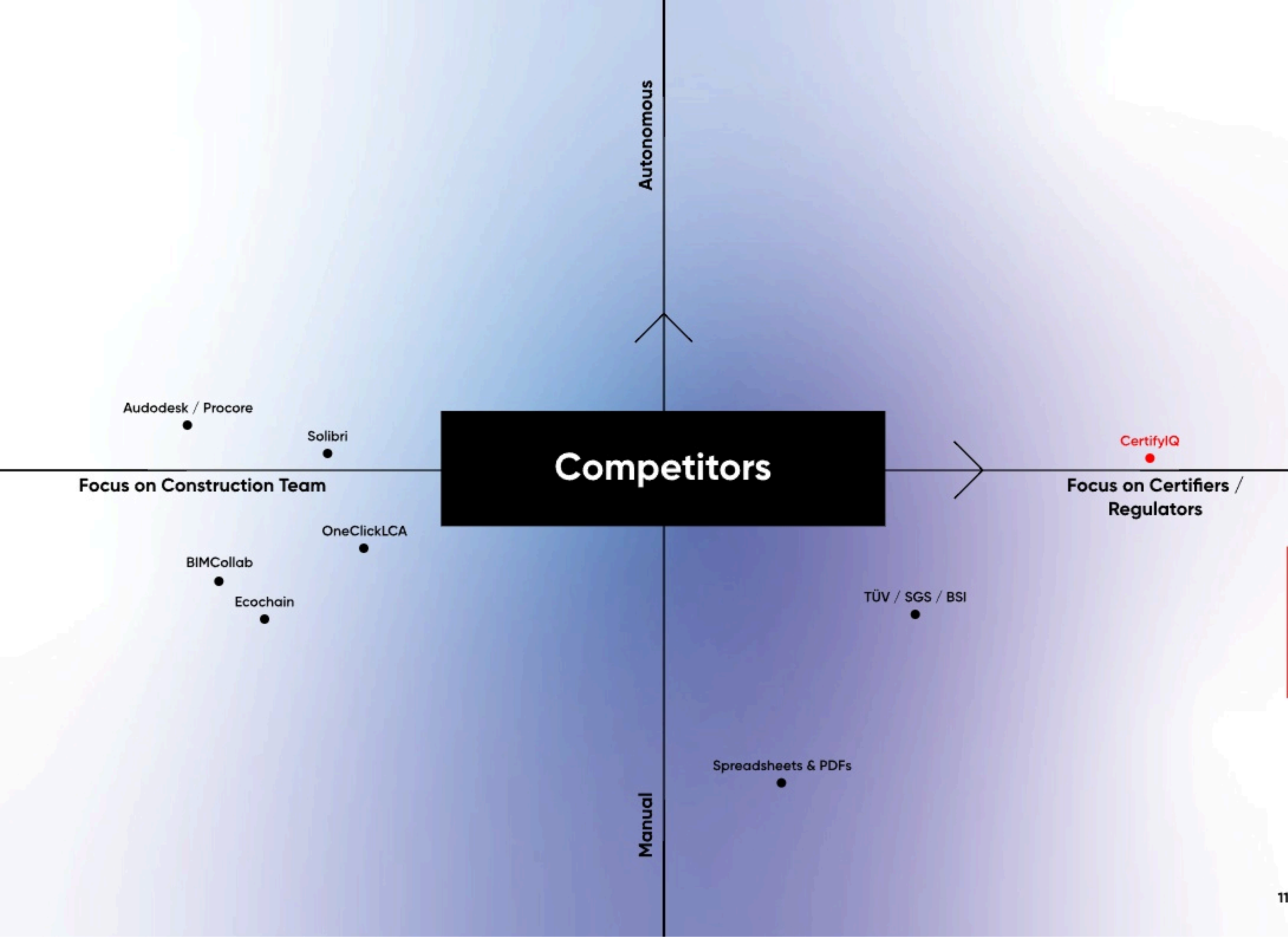
Civil engineering and non-residential projects made up 53.4% of construction projects in 2024 ($5.3B) (FIEC, 2025). It is these larger scale and complex projects which currently lead the digital transition of the industry. This leads to our serviceable market being valued at $5.3B. Approximately 53% of construction projects utilize BIM models, hence our serviceable addressable market is $2.8B (360 Research Reports, 2026).

It is also important to note that renovations (making up 27% of total construction activities in 2024) of bigger projects under new mandates provides another valuable use case of CertifyIQ, which will be a factor of growth of our SAM as digital adoption increases throughout the industry.

Serviceable Obtainable Market

Because construction is generally a slow moving industry, and the legal industry is rather risk averse, 3% market share is assumed (within the next three years). This is because the timing for this solution is right, as upcoming EU mandates require digital compliance, hence adoption of CertifyIQ on the legal side has potential over the coming three years, especially in the DACH region and the UK. This makes our serviceable obtainable market to $84M by 2029.




Competitors
Autonomous
Manual
Focus on Construction Team
Focus on Certifiers / Regulators
Audodesk / Procore
Solibri
OneClickLCA
BIMCollab
Ecochain
CertifyIQ
TÜV / SGS / BSI
Spreadsheets & PDFs

Conclusions

Demographic Pressure

Waste Management

Labor shortages intensified post-COVID due to cross-border workforce disruption (Andriescu, 2020; Ruxandra, 2020).

Elderly Care

Rapid population aging (60+ share doubling 12% → 22% by 2050) and worsening old-age dependency ratio increase care demand while workforce shrinks (WHO, 2024; Eurostat, 2025). Dementia prevalence projected to double every 20 years, reaching 139 million by 2050 (Alzheimer's Disease International, 2020).

Construction

Aging workforce; 32% aged 50–64 in 2021 (CEDEFOP, 2023). Significant skilled labor shortages reported across Europe (Construction Blueprint, 2021).

Key Differences

Waste Management

- AI improving throughput and 24/7 consistency.
- Replaces manual work.

Elderly Care

- Productivity gains possible via AI (Sitra 2026).
- Replaces "meta-work" and logistics; complements emotional labor.

Construction

- -0.5% annual productivity (Eurostat 2025).
- Augments inspection & heavy machinery

Conclusions

CapEx Requirements

Waste Management

High LiDAR and sensor costs limit adoption in low-margin industry (Opteran, 2025).

Elderly Care

High entry costs and regulatory barriers delay scaling from pilot to deployment (MDR, AI Act). Consumer entry barrier due to price-to-value ratio (Grand View Research; EU MDR context).

Construction

AI sorting systems require $500,000–several million upfront investment; ROI difficult due to long renovation cycles (Former CEO, Jan 26, 2026).

VC Funding

Conclusions

Progression of Autonomy

Waste Management

AI-powered robotics are already deployed at scale in sorting facilities (AMP Robotics; ZenRobotics), operating 24/7 with measurable throughput and accuracy gains (Krizhevsky et al., 2012; Redmon et al., 2016; ZenRobotics, 2025). Chemical and direct recycling technologies are scaling but remain capital intensive and technically sensitive (Grand View Research, 2024; Harper et al., 2019).

Elderly Care

Technological readiness is strongest in documentation automation (voice-to-text, NLP), logistics (transport robots operating in back-of-house environments without direct patient or customer interaction) and Social robotics.

Construction

UAV-based inspection is validated and in operational use (Medina, 2025), while ground/subterranean autonomy remains constrained by terrain variability and GNSS-denied environments (Feng et al., 2025; Zheng et al., 2023). BIM integration and SLAM are enabling greater data-driven coordination (Autodesk, 2023; Hsieh et al., 2023).

Key Differences

Waste Management

- AI sorting already industrial-scale
- Heavy hardware dependency (LiDAR \$3,500–\$50,000+; Opteran, 2025).

Elderly Care

- Mixed maturity – documentation ready; social robotics scaling; medical AI highly regulated.
- Significant opportunity in low-physical-complexity domains (social presence), logistics clear pain point due highly variable environments

Construction

- Strong in inspection (UAV), weaker in full autonomy due to terrain, cost, fragmentation.
- Heavy hardware dependency (LiDAR \$3,500–\$50,000+; Opteran, 2025).

Conclusions

Regulations

Waste Management

EU Regulatory Tightening: CSRD, landfill directives.

Compliance Increasing Operational Costs: CSRD auditability

Regulatory Severity: Environmental compliance; reporting-heavy but not high-risk AI.

Elderly Care

EU Regulatory Tightening: AI Act (high-risk), EHDS.

Compliance Increasing Operational Costs: MDR & AI Act classification

Regulatory Severity: High-risk AI classification; medical device barriers (European Commission, 2024a).

Construction

EU Regulatory Tightening: CO_2 reporting requirements, Green Deal alignment.

Compliance Increasing Operational Costs: Mandatory CO_2 monitoring (Founding Engineer interview).

Regulatory Severity: Regulatory burden mainly environmental & reporting-based.

↗ References

360 Research Reports. (2026). Building Information Modeling (BIM) Market Share & Trends [2034]. 360researchreports.com. https://www.360researchreports.com/market-reports/building-information-modeling-bim-market-203631

AI Waste Sorting Robots Market Forecast and Outlook 2025 to 2035. (2025, October 23). Futuremarketinsights.com. https://www.futuremarketinsights.com/reports/ai-waste-sorting-robots-market

Alzheimer's Disease International. (2020). Dementia statistics. Alzheimer's Disease International. https://www.alzint.org/about/dementia-facts-figures/dementia-statistics/

American Organization for Nursing Leadership. (2021, October 7). Nursing Leadership Insight Longitudinal Study | AONL. Www.aonl.org. https://www.aonl.org/resources/nursing-leadership-survey

AMP Robotics - Crunchbase Company Profile & Funding. (n.d.). Crunchbase. Retrieved February 6, 2026, from https://www.crunchbase.com/organization/amp-robotics

AMP to Operate Waste Connections Recycling Facility with AI-Powered Sortation Technology | AMP. (2024, November 18). Ampsortation.com. https://ampsortation.com/articles/first-of-its-kind-facility-featuring-fully-integra

Anderson, D., Quinn Choi, B., & Valdez, J. (2024, March 19). Building Defenses Against Cyber Risk in the Construction Sector | Woodruff Sawyer. Woodruffsawyer.com. https://woodruffsawyer.com/insights/cybersecurity-in-construction

Andriescu, M. (2020, May 1). Under Lockdown Amid COVID-19 Pandemic, Europe Feels the Pinch from Slowed Intra-EU Labor Mobility. Migrationpolicy.org. https://www.migrationpolicy.org/article/covid19-europe-feels-pinch-slowed-intra-eu-labor-mobility

Annual CO2 emissions from cement. (2024). Our World in Data. https://ourworldindata.org/grapher/annual-co2-cement

Antler. (2026). Prime opportunities for startups. Antler.co. https://www.antler.co/blog/prime-opportunities-for-startups

Ashton, D. (2025, May 26). What is scope creep (and how can you prevent it)? University of the Built Environment. https://www.ube.ac.uk/whats-happening/articles/scope-creep/

Autodesk. (2024, July 23). Construction Labor Burden Explained - Digital Builder. Digital Builder. https://www.autodesk.com/blogs/construction/construction-labor-burden-explained/

Azpúrua, H., Saboia, M., M. Freitas, G., Clark, L., Agha-Mohammadi, A.-A., Pessin, G., F. M. Campos, M., & G. Macharet, D. (2023). A Survey on the autonomous exploration of confined subterranean spaces: Perspectives from real-word and industrial robotic deployments. Robotics and Autonomous Systems, 160, 104304–104304. https://doi.org/10.1016/j.robot.2022.104304

Battery recovery solutions. (2026). Steinert. https://www.batteryrecoverysolutions.com

Beach, T., Yeung, J., Nisbet, N., & Rezgui, Y. (2024). Digital approaches to construction compliance checking: Validating the suitability of an ecosystem approach to compliance checking. Advanced Engineering Informatics, 59, 102288. https://doi.org/10.1016/j.aei.2023.102288

Bentley, R. (2025, December 11). Automated vs. Autonomous: Why the Difference Matters for Modern Cloud Operations | Sedai. Sedai. https://sedai.io/blog/automated-vs-autonomous-why-the-difference-matters-for-modern-cloud-operations

BIM's Strategic Return on Investment (ROI) In Indian Infrastructure Projects In association with. (2023). Autodesk. https://damassets.autodesk.net/content/dam/autodesk/www/pdfs/bims-strategic-return-on-investment-in-indian-infrastructure-projects.pdf

Boscia, S. (2019, November 21). Crossrail delay until 2021 may cost London £2bn. City AM. https://www.cityam.com/crossrail-delay-until-2021-may-cost-london-2bn/

Bradford, A. (2019). The Brussels Effect: How the European Union Rules the World. Oxford University Press. https://doi.org/10.1093/oso/9780190088583.001.0001

Brooks, A. L., Wang, S., & Jambeck, J. R. (2018). The Chinese Import Ban and Its Impact on Global Plastic Waste Trade. Science Advances, 4(6). https://doi.org/10.1126/sciadv.aat0131

Building Information Modeling (BIM). (2025). Marketresearch.com. https://www.marketresearch.com/Global-Industry-Analysts-v1039/Building-Information-Modeling-BIM-42591272/

Cameron, S. (2021, November 10). China: rejecting rubbish | Lowy Institute. Www.lowyinstitute.org. https://www.lowyinstitute.org/the-interpreter/china-rejecting-rubbish

CDC. (2024, December 13). Disability and Health Data Now. Disability and Health. https://www.cdc.gov/disability-and-health/articles-documents/disability-and-health-data-now.html

CES 2026 Trends: AI, Robotics & Longevity Tech | VML. (2026). VML. https://www.vml.com/insight/ces-2026-trends-ai-robotics-longevity-tech

Chawla, K., Kunonga, T. P., Stow, D., Barker, R., Craig, D., & Hanratty, B. (2021). Prevalence of loneliness amongst older people in high-income countries: A systematic review and meta-analysis. PLOS ONE, 16(7), e0255088. https://doi.org/10.1371/journal.pone.0255088

Check Point Research. (2025, July 17). Global Cyber Attacks Surge 21% in Q2 2025 – Europe Experiences the Highest Increase of All Regions. Check Point Blog; Check Point Software. https://blog.checkpoint.com/research/global-cyber-attacks-surge-21-in-q2-2025-europe-experiences-the-highest-increase-of-all-regions/

References

Ciullo, A. (2024). Effects of BIM adoption to a construction company's internationalization in Asian markets. Lutpub.lut.fi. https://lutpub.lut.fi/handle/10024/168054

Construction Leadership Council. (2022). Trust and Productivity The private sector construction playbook. https://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2022/11/Productivity-Taskforce_Private-Sector-Construction-Playbook-2022.pdf

Construction workers: skills opportunities and challenges (2023 update). (2023, December 19). CEDEFOP. https://www.cedefop.europa.eu/en/data-insights/construction-workers-skills-opportunities-and-challenges-2023-update#_employment_and_job_demand

Contract No: SI2.ACPROCE021941000 Publication in the Official Journal of the European Union of 02/12/2008 Special report on liability and insurance regimes in 27 EU Member States Liability and insurance regimes in the construction sector: national schemes and guidelines to stimulate innovation and sustainability Consortium formed by Centre d'Etudes d'Assurances (CEA) and Centre Scientifique et Technique du Bâtiment (CSTB). (2010). http://www.elios-ec.eu/sites/default/files/pdf/Eliosspecialreporton27MemberStates.pdf

Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., & Dudas, S. E. (2019). Human Consumption of Microplastics. Environmental Science & Technology, 53(12), 7068–7074. https://doi.org/10.1021/acs.est.9b01517

Crowe, S. (2025, August 26). Robotics investments top $4.3B in July 2025. The Robot Report. https://www.therobotreport.com/robotics-investments-top-43b-in-july-2025/

Decade of Healthy Ageing 2020-2030. (2019). https://www.who.int/docs/default-source/documents/decade-of-health-ageing/decade-ageing-proposal-en.pdf

Definition of medical devices - Fimea. (n.d.). Fimea. Retrieved February 8, 2026, from https://fimea.fi/en/medical-devices/what-are-medical-devices-/definition-of-medical-devices

Deloitte. (2023, August 17). #DeloitteESGNow — Frequently Asked Questions About the E.U. Corporate Sustainability Reporting Directive (August 17, 2023). Dart.deloitte.com. https://dart.deloitte.com/USDART/home/publications/deloitte/heads-up/2023/csrd-corporate-sustainability-reporting-directive-faqs

Deltek. (n.d.). True Cost of Project Delay. https://www.ceacisp.org/sites/default/files/documents/The-True-Cost-of-Project-Delay-White-Paper.pdf

Dufva, M., Kiiski-Kataja, E., & Lähdemäki-Pekkinen, J. (2026). SITRAN SELVITYKSIÄ 251 – MEGATRENDIT 2026. Sitra. https://www.sitra.fi/wp-content/uploads/2025/12/Sitra_Megatrendit_2026_Selvitys_web.pdf

Elder Care Assistive Robots Market Size, Share Report, 2030. (n.d.). Www.grandviewresearch.com. https://www.grandviewresearch.com/industry-analysis/elder-care-assistive-robots-market-report

Elderly Care Market Size, Share & Trends | Growth Report [2032]. (2024). Fortunebusinessinsights.com. https://www.fortunebusinessinsights.com/elderly-care-market-111477

Ellen MacArthur Foundation. (2023). Circular Economy - UK, USA, Europe, Asia & South America - The Ellen MacArthur Foundation. Ellenmacarthurfoundation.org. https://www.ellenmacarthurfoundation.org

ERI Economic Research Institute. (2026). Worker Construction Salary in the United States (2026). Salary Expert. https://www.salaryexpert.com/salary/job/worker-construction/

Europe Construction Market Size and Share - Outlook Report, Forecast Trends and Growth Analysis 2025-2034. (2025). Researchandmarkets.com. https://www.researchandmarkets.com/reports/5775269/europe-construction-market-size-share-outlook

Europe Testing, Inspection, and Certification (TIC) Market for Building and Construction – Industry Trends and Forecast to 2028. (n.d.). Databridgemarketresearch.com. Retrieved February 9, 2026, from https://www.databridgemarketresearch.com/reports/europe-testing-inspection-and-certification-tic-market

European Commission. (n.d.). Construction. Single-Market-Economy.ec.europa.eu. https://single-market-economy.ec.europa.eu/sectors/construction_en

European Commission. (2018). EUR-Lex - 32018L0850 - EN - EUR-Lex. Eur-Lex.europa.eu. https://eur-lex.europa.eu/eli/dir/2018/850/oj

European Commission. (2023a, July 2). Single-use plastics. European Commission. https://environment.ec.europa.eu/topics/plastics/single-use-plastics_en

European Commission. (2023b, July 12). EUR-Lex - 32023R1542 - EN - EUR-Lex. Eur-Lex.europa.eu. https://eur-lex.europa.eu/eli/reg/2023/1542/oj

European Commission. (2025a). Packaging & Packaging Waste Regulation. Environment. https://environment.ec.europa.eu/topics/waste-and-recycling/packaging-waste/packaging-packaging-waste-regulation_en

European Commission. (2025b, March 5). European Health Data Space Regulation (EHDS). Public Health. https://health.ec.europa.eu/ehealth-digital-health-and-care/european-health-data-space-regulation-ehds_en

European Commission. (2025c, December 9). Corporate Sustainability Reporting. European Commission. https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

European Court of Auditors. (2026). Special report 04/2026: Critical raw materials for the energy transition. European Court of Auditors. https://www.eca.europa.eu/en/publications/SR-2026-04

↗ References

European Parliament & Council. (2016, April 27). Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). Europa.eu. https://eur-lex.europa.eu/eli/reg/2016/679/oj

European Union. (2022). Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting (Text with EEA relevance). EUR-Lex; Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464

European Union. (2025). The EU Artificial Intelligence Act. The Artificial Intelligence Act. https://artificialintelligenceact.eu/

Eurostat. (2024, November). Disability statistics - population with difficulties in basic activities - Statistics Explained - Eurostat. Europa.eu. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Disability_statistics_-_population_with_difficulties_in_basic_activities

Eurostat. (2025, February). Population structure and ageing - Statistics Explained. Europa.eu; Eurostat. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Population_structure_and_ageing

ExxonMobil. (2022). ExxonMobil completes first commercial sale of certified circular polymers using ExxtendTM technology | ExxonMobil. ExxonMobil. https://corporate.exxonmobil.com/news/news-releases/2022/0224_exxonmobil-makes-first-commercial-sale-of-certified-circular-polymers

ExxonMobil. (2022). ExxonMobil completes first commercial sale of certified circular polymers using ExxtendTM technology | ExxonMobil. ExxonMobil. https://corporate.exxonmobil.com/news/news-releases/2022/0224_exxonmobil-makes-first-commercial-sale-of-certified-circular-polymers

Fan, E., Li, L., Wang, Z., Lin, J., Huang, Y., Yao, Y., Chen, R., & Wu, F. (2020). Sustainable Recycling Technology for Li-Ion Batteries and Beyond: Challenges and Future Prospects. Chemical Reviews, 120(14), 7020–7063. https://doi.org/10.1021/acs.chemrev.9b00535

Feng, C., Yu, J., Li, J., Wu, Y., Wang, B., & Wang, K. (2025). LiDAR SLAM for Safety Inspection Robots in Large Scale Public Building Construction Sites. Buildings, 15(19), 3602–3602. https://doi.org/10.3390/buildings15193602

FIEC - Statistical Report 2023. (2023). Fiec-Statistical-Report.eu. https://fiec-statistical-report.eu/

Foulds, S. (2025, September). Humanoid robots are advancing, but a massive "Data Gap" holds them back. Build in Digital. https://buildindigital.com/humanoid-robots-are-advancing-but-a-massive-data-gap-holds-them-back/

Gaines, L. (2014). The future of automotive lithium-ion battery recycling: Charting a sustainable course. Sustainable Materials and Technologies, 1-2, 2–7. https://doi.org/10.1016/j.susmat.2014.10.001

Gill, V., & Stephens, K. (2022, December 2). Batteries linked to hundreds of waste fires. Lithium Battery Recycling Solutions. https://www.lithiumbatteryrecycling.co.uk/news/batteries-linked-to-hundreds-of-waste-fires

Global AI Law and Policy Tracker. (2025). Iapp.org; International Association of Privacy Professionals. https://iapp.org/resources/article/global-ai-legislation-tracker

Government of Canada. (2024). The Artificial Intelligence and Data Act (AIDA) – Companion document. Ised-Isde.canada.ca; Government of Canada. https://ised-isde.canada.ca/site/innovation-better-canada/en/artificial-intelligence-and-data-act-aida-companion-document

Grand View Research. (2024). Chemical Recycling Of Plastics Market Report, 2028. Www.grandviewresearch.com. https://www.grandviewresearch.com/industry-analysis/chemical-recycling-plastics-market-report

Gregory, A. (2024, August 25). More than 14,000 NHS beds in use by patients ready to be discharged. The Guardian; The Guardian. https://www.theguardian.com/society/article/2024/aug/26/more-than-14000-nhs-beds-occupied-by-people-waiting-to-be-discharged

GRINNER Project. (2022, August 5). Homepage - GRINNER. GRINNER. https://grinnerproject.eu

Group, G. (2026, January 28). EU Steel Tariffs: Trade Committee Approves Draft Report. Steel News by Gerber Group. https://steelnews.biz/eu-steel-tariffs-trade-committee-approves-report/

Harper, G., Sommerville, R., Kendrick, E., Driscoll, L., Slater, P., Stolkin, R., Walton, A., Christensen, P., Heidrich, O., Lambert, S., Abbott, A., Ryder, K., Gaines, L., & Anderson, P. (2019). Recycling lithium-ion Batteries from Electric Vehicles. Nature, 575(7781), 75–86. https://doi.org/10.1038/s41586-019-1682-5

Heffernan, M. (2024, January 19). Study quantifies lithium battery threat to infrastructure. E-Scrap News. https://resource-recycling.com/e-scrap/2024/01/18/study-quantifies-lithium-battery-threat-to-infrastructure/

Hoivapalvelun ja terveydenhuollon työntekijöistä ulkomaalaistaustaisia 11,3 % vuonna 2023 | Tilastokeskus. (2025, June 3). Stat.fi; Tilastokeskus. https://stat.fi/fi/julkaisu/cm17rc9hjatcm07w1iinalzo0

Homepage | ECB Data Portal. (n.d.). Data.ecb.europa.eu. https://data.ecb.europa.eu/

Hourly labour costs Statistics Explained Highlights "Non-wage labour costs were highest in Sweden (32.2 % of total labour costs) and France (31.9 %)." (2026). https://ec.europa.eu/eurostat/statistics-explained/SEPDF/cache/23015.pdf

How AI Impacts the 2027 EU Machinery Regulation. (2025, August 5). TechWorks AI. https://www.techworksai.org/how-ai-impacts-the-2027-eu-machinery-regulation/

↗ References

Hsieh, C.-C., Chen, H.-M., & Wang, S.-K. (2023). On-site Visual Construction Management System Based on the Integration of SLAM-based AR and BIM on a Handheld Device. KSCE Journal of Civil Engineering, 27(11), 4688–4707. https://doi.org/10.1007/s12205-023-1939-2

https://pitchbook.com/news/author/ali-javaheri. (2025, September 12). 2025 Vertical Snapshot: Robotics - PitchBook. PitchBook. https://pitchbook.com/news/reports/2025-vertical-snapshot-robotics

Hung, L., Zhao, Y., Hadil Alfares, & Parsa Shafiekhani. (2025). Ethical considerations in the use of social robots for supporting mental health and wellbeing in older adults in long-term care. Frontiers in Robotics and AI, 12. https://doi.org/10.3389/frobt.2025.1560214

IBISWorld. (n.d.). IBISWorld - Industry Market Research, Reports, and Statistics. Www.ibisworld.com. https://www.ibisworld.com/industry-statistics/number-of-businesses/waste-collection-services-united-states/

Industry Data. (2023). American Iron and Steel Institute. https://www.steel.org/industry-data/

International Energy Agency. (2023, April). Global EV Outlook 2023 – Analysis. International Energy Agency. https://www.iea.org/reports/global-ev-outlook-2023

International Energy Agency. (2024, April). Global EV Outlook 2024. International Energy Agency. https://www.iea.org/reports/global-ev-outlook-2024

International Renewable Energy Agency. (2024, September 30). Critical materials: Batteries for electric vehicles. Irena.org. https://www.irena.org/Publications/2024/Sep/Critical-materials-Batteries-for-electric-vehicles

Jaśkowski, P., & Biruk, S. (2019). Minimizing the Duration of Repetitive Construction Processes with Work Continuity Constraints. Computation, 7(1), 14. https://doi.org/10.3390/computation7010014

Jiang, Y., Guo, C., Wang, J., & Xu, R. (2025). Multipath Effects Mitigation in Offshore Construction Platform GNSS-RTK Displacement Monitoring Using Parametric Temporal Convolution Network. Remote Sensing, 17(4), 601. https://doi.org/10.3390/rs17040601

Jowett, P. (2021, January 13). Lithium-ion battery fires costing UK economy £158 million annually. Resource.co. https://resource.co/article/lithium-ion-battery-fires-costing-uk-economy-158-million-annually

Kardash, A., & Gross, W. (2025, December 17). Canada's 2026 privacy priorities: data sovereignty, open banking and AI. Osler, Hoskin & Harcourt LLP. https://www.osler.com/en/insights/reports/2025-legal-outlook/canadas-2026-privacy-priorities-data-sovereignty-open-banking-and-ai/

Katsaus sote-alan työvoimaan. (2021, February). Www.temtoimialapalvelu.fi; Työ- ja elinkeinoministeriö. http://urn.fi/URN:ISBN:978-952-327-812-7

Kelkar, A., Jansen, C., Sjödin, E., Blanco, J. L., Robertson, M., & Reiter, S. (2025, October 17). Humanoid robots in the construction industry: A future vision. McKinsey & Company. https://www.mckinsey.de/en/industries/engineering-construction-and-building-materials/our-insights/humanoid-robots-in-the-construction-industry-a-future-vision

Kim, V. (2025, December 9). Australia's Social Media Ban for People Under 16 Takes Effect. The New York Times. https://www.nytimes.com/2025/12/09/world/asia/australia-social-media-ban-under-16.html

Klein, S. (2024). "Hospital at Home" Programs Improve Outcomes, Lower Costs But Face Resistance from Providers and Payers | Commonwealth Fund. Www.commonwealthfund.org. https://www.commonwealthfund.org/publications/newsletter-article/hospital-home-programs-improve-outcomes-lower-costs-face-resistance

Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). ImageNet Classification with Deep Convolutional Neural Networks. Communications of the ACM, 60(6), 84–90.

Lee, E., Shurson, G., Oh, S.-H., & Jang, J.-C. (2024). The Management of Food Waste Recycling for a Sustainable Future: A Case Study on South Korea. Sustainability, 16(2), 854. https://doi.org/10.3390/su16020854

Leslie, H. A., J. M. van Velzen, M., Brandsma, S. H., Vethaak, D., Garcia-Vallejo, J. J., & Lamoree, M. H. (2022). Discovery and quantification of plastic particle pollution in human blood. Environment International, 163(107199), 107199. https://doi.org/10.1016/j.envint.2022.107199

Li, Y., Ji, C., Wang, P., & Huang, L. (2023). Proactive intervention of green infrastructure on flood regulation and mitigation service based on landscape pattern. Journal of Cleaner Production, 419, 138152. https://doi.org/10.1016/j.jclepro.2023.138152

Lopes, J. M., & Trabanco, J. L. A. (2019). Automated control systems for civil construction machinery using RTK-GNSS: an implementation review. Engenharia Civil UM, 56, 28–33. https://doi.org/10.21814/ecum.4194

Madhavan Nampoothiri. (2023, April 27). How the European CSRD will affect non-EU companies | NordESG. Nordesg.de. https://nordesg.de/en/the-csrd-and-non-eu-companies-the-brussels-effect/

MarketsandMarkets. (2024, August). Lithium-ion Battery Recycling Market Global Forecast to 2030 | MarketsandMarkets. Www.marketsandmarkets.com. https://www.marketsandmarkets.com/Market-Reports/lithium-ion-battery-recycling-market-153488928.html

Martinez, M., & Kraemer, C. (2025, December 18). Germany launches 30 billion euro fund to mobilise private investment. Reuters. https://www.reuters.com/sustainability/climate-energy/germany-launches-30-billion-fund-mobilize-private-investment-2025-12-18/

McClements, D. (2023, May 18). Robotic Arm vs. Gantry System for 3D Printing (P. Keane, Ed.). Www.xometry.com. https://www.xometry.com/resources/3d-printing/robotic-arm-vs-gantry-system-for-3d-printing/

↗ References

McConvey, J. R. (2026, January 5). Age assurance regulation for social media to go global in 2026. Biometric Update | Biometrics News, Companies and Explainers; BiometricUpdate.com. https://www.biometricupdate.com/202601/age-assurance-regulation-for-social-media-to-go-global-in-2026

McQue, K. (2026, February 2). "Marketplace for predators": Meta faces jury trial over child exploitation claims. The Guardian; The Guardian. https://www.theguardian.com/technology/2026/feb/02/meta-trial-new-mexico-social-media

Medina, T. (2025, August 28). Drone Infrastructure Inspection for Bridges, Roads and Buildings. DSLRPros. https://www.dslrpros.com/blogs/drone-trends/drone-infrastructure-inspection-for-bridges-roads-and-buildings?srsltid=AfmBOopO0C5N00gdMmjZxNr8DA2HzL_gUTQE-0dFk9l-TH7pgwrxhby5

Merino-Saum, A., Ribera Jemio, P. A., Hansmann, R., & Binder, C. R. (2023). Drivers and barriers to participation in the sharing economy: Does the environment really matter? A systematic review of 175 scientific articles. Resources, Conservation and Recycling, 198, 107121. https://doi.org/10.1016/j.resconrec.2023.107121

Mohammadreza Najafzadeh, & Yeganeh, A. (2025). AI-Driven Digital Twins in Industrialized Offsite Construction: A Systematic Review. Buildings, 15(17), 2997–2997. https://doi.org/10.3390/buildings15172997

Moravec, H. P. (2026). Robot | Technology. In Encyclopædia Britannica. https://www.britannica.com/technology/robot-technology

Mordor Intelligence. (2025). Europe TIC Market Size & Share Analysis - Industry Research Report - Growth Trends. Www.mordorintelligence.com. https://www.mordorintelligence.com/industry-reports/europe-testing-inspection-and-certification-market

Mordor Intelligence. (2026). Waste Management Market | 2021 - 26 | Industry Share, Size, Growth - Mordor Intelligence. Www.mordorintelligence.com. https://www.mordorintelligence.com/industry-reports/global-waste-management-market

Munsterman, E., Petersen, S., & Newcomb, P. (2024). Use of Socially Assistive Robots to Improve Outcomes Among Hospitalized Older Adults With Dementia: A Pilot Randomized Trial. Journal of Gerontological Nursing, 50(10), 11–16. https://doi.org/10.3928/00989134-20240912-04

Napper, I. E., & Thompson, R. C. (2016). Release of Synthetic Microplastic Plastic Fibres from Domestic Washing machines: Effects of Fabric Type and Washing Conditions. Marine Pollution Bulletin, 112(1-2), 39–45. https://doi.org/10.1016/j.marpolbul.2016.09.025

Navigating Complexity: challenges facing mobile robots. (2025). Opteran.com. https://opteran.com/resources/blogs/navigating-complexity-challenges-facing-mobile-robots

New solvent-based multi-layer plastic recycling process could cut down on millions of tons of plastic waste - College of Engineering - University of Wisconsin-Madison. (2024, March 18). College of Engineering - University of Wisconsin-Madison. https://engineering.wisc.edu/news/new-solvent-based-multi-layer-plastic-recycling-process-could-cut-down-on-millions-of-tons-of-plastic-waste/

News, P. (2026, January 27). French lawmakers approve ban on social media for kids under 15. PBS News. https://www.pbs.org/newshour/world/french-lawmakers-approve-ban-on-social-media-for-kids-under-15

NL Times. (2026, January 28). Over half of temporary workers in Netherlands are from abroad. NL Times. https://nltimes.nl/2026/01/28/half-temporary-workers-netherlands-abroad

Nuutila, L., & Honkanen, E. (2022, January). Tahdon töihin! – Moniäänisiä näkökulmia maahanmuuttajien työllistymiseen - eSignals julkaisut. Haaga Helia. https://julkaisut.haaga-helia.fi/tahdon-toihin/

OECD. (2022). Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options. OECD. https://doi.org/10.1787/de747aef-en

OECD. (2025). Pensions at a Glance 2025. In OECD pension at a glance/Pensions at a glance. Organization for Economic Cooperation and Development. https://doi.org/10.1787/e40274c1-en

Old-age Dependency Ratio Increases across EU Regions. (2021, September 30). Ec.europa.eu; Eurostat. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20210930-1

Parliament, E. (2025). Artificial Intelligence and Civil Liability A European Perspective Policy Department for Justice, Civil Liberties and Institutional Affairs Directorate-General for Citizens' Rights. https://www.europarl.europa.eu/RegData/etudes/STUD/2025/776426/IUST_STU(2025)776426_EN.pdf

Parsons, T., Hanafi Sheikhha, F., Seo, J., & Lee, H. (2024). RGB-LiDAR sensor fusion for dust de-filtering in autonomous excavation applications. Automation in Construction, 168, 105850. https://doi.org/10.1016/j.autcon.2024.105850

PitchBook. (2026). Pitchbook.com. https://my.pitchbook.com/profile/539020-90/company/profile

Policies | Shaping Europe's digital future. (n.d.). Digital-Strategy.ec.europa.eu; European Commission. https://digital-strategy.ec.europa.eu/en/policies

Productivity trends using key national accounts indicators. (n.d.). Ec.europa.eu. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Productivity_trends_using_key_national_accounts_indicator

↗ References

Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL laying down harmonised conditions for the marketing of construction products, amending Regulation (EU) 2019/1020 and repealing Regulation (EU) 305/2011. (2022). Europa.eu. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52022PC0144

Public Health Agency of Canada. (2025, November 28). Falls among Older Adults in Canada – Canada.ca. Health-Infobase.canada.ca. https://health-infobase.canada.ca/falls-in-older-adults/

Purton, M. (2024). Cement Is a Big Problem for the environment. Here's How to Make It More Sustainable. World Economic Forum. https://www.weforum.org/stories/2024/09/cement-production-sustainable-concrete-co2-emissions/

PwC. (2024, December 4). PwC 2024 Global Investor Survey | PwC. PwC. https://www.pwc.com/gx/en/news-room/press-releases/2024/pwc-2024-global-investor-survey.html

Quigley, M., Gerkey, B., Conley, K., Faust, J., Foote, T., Leibs, J., Berger, E., Wheeler, R., & Ng, A. (n.d.). ROS: an open-source Robot Operating System. https://ai.stanford.edu/~ang/papers/icraoss09-ROS.pdf

Ragaert, K., Delva, L., & Van Geem, K. (2017). Mechanical and chemical recycling of solid plastic waste. Waste Management, 69(69), 24–58. https://doi.org/10.1016/j.wasman.2017.07.044

Recycled Materials Association. (n.d.). Economic Impact Study: U.S.- Based Recycled Materials Industry 2024. https://www.recycledmaterials.org/wp-content/uploads/rema-econmic_impact_executive_summary_2024.pdf

Redmon, J., Divvala, S., Girshick, R., & Farhadi, A. (2016). You Only Look Once: Unified, Real-Time Object Detection. 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 779–788. https://doi.org/10.1109/cvpr.2016.91

Research and Markets. (2026, January 28). Construction Cybersecurity Research Report 2026: $18.41 Bn Market Opportunities, Trends, Competitive Analysis, Strategies, Forecasts, 2020-2025, 2025-2030F, 2035F. GlobeNewswire News Room; GlobeNewswire. https://www.globenewswire.com/news-release/2026/01/28/3227402/28124/en/Construction-Cybersecurity-Research-Report-2026-18-41-Bn-Market-Opportunities-Trends-Competitive-Analysis-Strategies-Forecasts-2020-2025-2025-2030F-2035F.html

Richter, F. (2025, July 7). Infographic: Aging Populations. Statista Daily Data; Statista. https://www.statista.com/chart/29345/countries-and-territories-with-the-highest-share-of-people-aged-65-and-older/?srsltid=AfmBOorhPb8MvB1hJ08f2MbIKIb9fWpk0nyFflcSLyViyvqFUuMQ9X4w

Robotics Market Size Share & Global Report 2026–2035. (2026, January 19). Globalgrowthinsights.com. https://www.globalgrowthinsights.com/market-reports/robotics-market-101900

Roepke, A. (2019, September 25). New Construction Report Reveals the "Data Ownership Battle" Between Project Owners and Contractors | Dodge Construction Network. Dodge Construction Network. https://www.construction.com/reports/new-construction-report-reveals-data-ownership-battle-between-project-owners-contractors/

Rosengren, C. (2020, October 23). Waste Management completes $4.6B acquisition of Advanced Disposal, following regulatory approval. Waste Dive. https://www.wastedive.com/news/waste-management-advanced-disposal-gfl-doj-consent-decree/587663/

Ruohonen, J., & Kullas, H. (2024). The Assurance of Corporate Sustainability Reports and the Renewed Role of Certified Auditors. European Company and Financial Law Review, 21(3-4), 442–471. https://doi.org/10.1515/ecfr-2024-0013

Sai. (2025, August 11). The Complete Guide to Construction Products Regulation and EU Compliance Standards. Ecochain LCA Software. https://ecochain.com/blog/construction-products-regulation/

Salminen-Tuomaala, M. (2024). What Factors Affect the Attractiveness of Nursing Profession? ATHENS JOURNAL of HEALTH & MEDICAL SCIENCES, 11(3), 167–178. https://doi.org/10.30958/ajhms.11-3-4

Second Generation of the Eurocodes | Eurocodes: Building the future. (n.d.). Eurocodes.jrc.ec.europa.eu. https://eurocodes.jrc.ec.europa.eu/second-generation-eurocodes

SECTORIAL STRATEGIC APPROACH TO COOPERATE ON SKILLS IN THE CONSTRUCTION INDUSTRY WP2. Status Quo and Sectorial Skills Strategy; Deliverable 2. Status Quo. (2020). https://constructionblueprint.eu/wp-content/uploads/2020/12/D3.-StatusQuo-Report-on-Sectoral-Skills.pdf

Shortage of labour in the construction industry (FIEC position - 2025 edition). (2025, November 16). FIEC. https://www.fiec.eu/fiec-opinions/position-papers-pl/shortage-labour-construction-industry-fiec-position-2025-edition

Singla, A., Sukharevsky, A., Yee, L., & Chui, M. (2024, May 30). The state of AI in early 2024: Gen AI adoption spikes and starts to generate value. McKinsey & Company. https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-2024

SNS Insider | Strategy and Stats. (2025). SNS Insider. https://www.snsinsider.com/reports/exoskeleton-market-3435

Sutton, R. S., & Barto, A. G. (n.d.). Reinforcement learning: An introduction, 2nd ed. Psycnet.apa.org. https://psycnet.apa.org/record/2019-19679-000

↗ References

Tamasiga, P., Miri, T., Onyeaka, H., & Hart, A. (2022). Food Waste and Circular Economy: Challenges and Opportunities. Sustainability, 14(16), 9896. https://doi.org/10.3390/su14169896

Team OnIndus. (2024, September 30). The Impact of BIM on the Construction Industry | OnIndus. OnIndus. https://onindus.com/the-impact-of-bim-in-the-construction-industry/

Teare, G. (2026, January 7). Global Venture Funding In 2025 Surged As Startup Deals And Valuations Set All-Time Records. Crunchbase News. https://news.crunchbase.com/venture/funding-data-third-largest-year-2025/

The Draghi report on EU competitiveness. (2024). European Commission. https://commission.europa.eu/topics/competitiveness/draghi-report_en

Tikkala, H. (2022, September 22). Sairaanhoitajaksi hakevien määrä romahti syksyn yhteishaussa – toiminnanjohtaja Mielityinen: "Hoitajapula ei ratkea aloituspaikkoja lisäämällä." Yle Uutiset. https://yle.fi/a/3-12633574

Top 10 Health Technology Hazards for 2024 Expert Insights from ECRI's Device Evaluation Program. (2024). In www.ecri.org. Ecri. https://www.ecri.org.uk/wp-content/uploads/2024/09/ECRI_2024_Top_10_Hazards_Executive_Brief.pdf

Tucuvi Raises $20M Series A to Accelerate Adoption of Its AI Care Management Platform Across Healthcare Organizations – TUCUVI. (2026). Tucuvi.com. https://www.tucuvi.com/blog/tucuvi-raises-20m-series-a-to-accelerate-adoption-of-its-ai-care-management-platform-across-healthcare-organizations

TÜV Rheinland. (2023). New Machinery Regulation EU 2023/1230. Tuv.com. https://www.tuv.com/world/en/new-machinery-regulation-eu-2023-1230.html

Tyrni, T., & Myllyneva, K. (2023, September 28). Sosiaali- ja terveysalan henkilöstöpula kärjistyy nopeasti – helppoja ratkaisuja ei ole, mutta lisätoimia tarvitaan. Valtiovarainministeriö. https://vm.fi/-/sosiaali-ja-terveysalan-henkilostopula-karjistyy-nopeasti-helppoja-ratkaisuja-ei-ole-mutta-lisatoimia-tarvitaan

U.S. Department of Defense. (2023, December 5). DOD Awards $23.4 Million to Expand Domestic Capability to Upcycle Scrap Material into High. U.S. Department of War. https://www.defense.gov/News/Releases/Release/Article/3606819/

U.S. Department of Energy. (2023). National Blueprint for Lithium Batteries. Energy.gov. https://www.energy.gov/eere/vehicles/articles/national-blueprint-lithium-batteries

U.S. Environmental Protection Agency. (2022, April 9). Solid Waste Infrastructure for Recycling Grant Program | US EPA. US EPA. https://www.epa.gov/circulareconomy/solid-waste-infrastructure-recycling-grant-program

U.S. Environmental Protection Agency. (2024, September 20). Basic Information about Landfill Gas . US EPA; United States Environmental Protection Agency. https://www.epa.gov/lmop/basic-information-about-landfill-gas

Uekert, T., Singh, A., DesVeaux, J. S., Ghosh, T., Bhatt, A., Yadav, G., Afzal, S., Walzberg, J., Knauer, K. M., Nicholson, S. R., Beckham, G. T., & Carpenter, A. C. (2023). Technical, Economic, and Environmental Comparison of Closed-Loop Recycling Technologies for Common Plastics. ACS Sustainable Chemistry & Engineering, 11(3), 965–978. https://doi.org/10.1021/acssuschemeng.2c05497

UNEP. (2021). UNEP Food Waste Index Report 2021. UNEP - UN Environment Programme; UNEP. https://www.unep.org/resources/report/unep-food-waste-index-report-2021

van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., Tamin, A., Harcourt, J. L., Thornburg, N. J., Gerber, S. I., Lloyd-Smith, J. O., de Wit, E., & Munster, V. J. (2020). Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. New England Journal of Medicine, 382(16), 1564–1567. https://doi.org/10.1056/nejmc2004973

Veolia management responded for the first time to the largest merge and acquisition in the global environmental sector. (2021). Veolia China. https://www.veolia.cn/en/veolia-management-responded-first-time-largest-merge-and-acquisition-global-environmental-sector

Veolia, Suez agree $15 billion utilities merger after bitter spat. (2021, April 12). CNBC. https://www.cnbc.com/2021/04/12/french-utilities-veolia-and-suez-strike-merger-deal.html

Wardhana, A. T., Zamheri, A., & Puspa, D. (2023). IMPLEMENTATION OF PLC BASED AUTOMATIC SORTING SYSTEM. AUSTENIT, 15(1), 36–40. https://doi.org/10.53893/austenit.v15i1.6677

Waste Treatment And Disposal Companies In United States Of America. (n.d.). Dun&Bradstreet. Retrieved February 6, 2026, from https://www.dnb.com/business-directory/company-information.waste_treatment_and_disposal.us.html

Wawrzyn, D. (2021, December 1). The Benefits of 3D Modeling throughout the Construction Project Lifecycle. Propeller. https://www.propelleraero.com/blog/the-importance-of-accurate-3d-modeling-in-construction-projects/

Wearable Robotic Exoskeleton Market Size & Global Report [2027]. (2026, January 19). Www.fortunebusinessinsights.com. https://www.fortunebusinessinsights.com/wearable-robotic-exoskeleton-market-104664

Welcome To Zscaler Directory Authentication. (2026). Whitecase.com. https://www.whitecase.com/insight-alert/mind-gap-comparative-analysis-csrd-csddd-and-sfdr-green-deal-20-2024-unfolds

WeSort.AI GmbH. (2023). WeSort.AI GmbH. http://wesort.ai

↗ References

World Bank. (2018, September 20). What a Waste: An Updated Look into the Future of Solid Waste Management. World Bank. https://www.worldbank.org/en/news/immersive-story/2018/09/20/what-a-waste-an-updated-look-into-the-future-of-solid-waste-management

World Health Organization. (2024, October 1). Ageing and health. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

World, H. (2025, February 26). THE RISE OF HEALTHCARE AT HOME - Healthcare World. Healthcare World. https://healthcareworld.com/the-rise-of-healthcare-at-home/

Wyman, O. (2023). How Chemistry Can Break Our Addiction To Single Use Plastic. Oliverwyman.com. https://www.oliverwyman.com/our-expertise/journals/energy-and-natural-resources-journal/2024/the-industry-that-created-plastic-may-fix-its-waste-problem.html

Xu, P., Dai, Q., Gao, H., Liu, H., Zhang, M., Li, M., Chen, Y., An, K., Meng, Y. S., Liu, P., Li, Y., Spangenberger, J. S., Gaines, L., Lu, J., & Chen, Z. (2020). Efficient Direct Recycling of Lithium-Ion Battery Cathodes by Targeted Healing. JOULE, 4(12), 2609–2626. https://doi.org/10.1016/j.joule.2020.10.008

Yusif, S., Soar, J., & Hafeez-Baig, A. (2016). Older people, Assistive technologies, and the Barriers to adoption: a Systematic Review. International Journal of Medical Informatics, 94(1), 112–116. https://doi.org/10.1016/j.ijmedinf.2016.07.004

Zampone, G., & Guidi, M. (2024). Sustainability reporting and assurance practices contribution to SDG disclosure: evidence from communication on progress (CoP). Meditari Accountancy Research, 32(7), 236–265. https://doi.org/10.1108/medar-09-2023-2165

Zampone, G., Sannino, G., & García-Sánchez, I. (2022). Exploring the moderating effects of corporate social responsibility performance under mimetic pressures. An international analysis. Corporate Social Responsibility and Environmental Management. https://doi.org/10.1002/csr.2338

Zeng, X., Li, J., & Singh, N. (2014). Recycling of Spent Lithium-Ion Battery: A Critical Review. Critical Reviews in Environmental Science and Technology, 44(10), 1129–1165. https://doi.org/10.1080/10643389.2013.763578

ZenRobotics and USConveyor to Accelerate Robotics/AI in Scrap Metal Sorting. (2025, September 12). ZenRobotics. https://www.terex.com/zenrobotics/about-us/news/accelerating-robotics-ai-in-scrap-metal-sorting

Zhang, X., Li, L., Fan, E., Xue, Q., Bian, Y., Wu, F., & Chen, R. (2018). Toward sustainable and systematic recycling of spent rechargeable batteries. Chemical Society Reviews, 47(19), 7239–7302. https://doi.org/10.1039/C8CS00297E

Zimmermann, M. (2023, September 26). What Is Industrialized Construction (IC)? | Cemex Ventures. https://www.cemexventures.com/industrialized-construction/

Zorn, M., Ionescu, C., Klohs, D., Zähl, K., Kisseler, N., Daldrup, A., Hams, S., Zheng, Y., Offermanns, C., Flamme, S., Henke, C., Kampker, A., & Friedrich, B. (2022). An Approach for Automated Disassembly of Lithium-Ion Battery Packs and High-Quality Recycling Using Computer Vision, Labeling, and Material Characterization. Recycling, 7(4), 48. https://doi.org/10.3390/recycling7040048

List of Contributors

Daniel Gregorio Cardil
Collaborative and Industrial Design

Erik Gelcich
Human-Computer Interaction and Design

Ilmari Tuominen
Accounting and Finance

Katerina Tchilinguirov
International Design Business Management

Lauri Torvinen
Civil Engineering

Lino Faglia
International Design Business Management

Milla-Maaria Virokannas
Marketing

Pietu Ruska
Architecture

Sreekrishna Praveen
Quantum Technology

Tiia Mäkinen
Human-Computer Interaction and Design

Vedant Maheshwari
Data Science

Vu Trang
Sustainable Entrepreneurship

Publisher

Aalto Founder School

Editors

Daniel Gregorio Cardil
Erik Gelcich
Katerina Tchilinguirov
Sreekrishna Praveen
Tiia Mäkinen

Images

https://www.pexels.com
https://www.unsplash.com
https://www.krea.ai

Year of Publication

February 2026

Aalto
Founder *Sprint*