UNLOCKING THE VALUE OF INDUSTRY 4.0

Why and How Connectivity Drives Future Profitability and Growth

IN ASSOCIATION WITH:

ABIresearch for visionaries | ERICSSON

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The move to private cellular has the potential to boost gross margin by 5% to 13% for factory and warehouse operations that fully embrace Industry 4.0.

EXECUTIVE SUMMARY

Factory and warehouse managers need to reduce the cost of operations by minimizing downtime, synchronizing inventory management, and efficiently organizing personnel and equipment. To do this, manufacturing and supply chain operations are increasingly looking to deploy new technology as part of their digital transformation strategy to reduce costs but also enable new services. **ABI Research forecasts that the smart manufacturing market will grow to US$1 trillion with 4.3 billion wireless connections by 2030.** Further, the move to private cellular has the potential to boost gross margin by 5% to 13% for factory and warehouse operations that fully embrace Industry 4.0.

ABI Research has conducted an operations assessment of the smart manufacturing and smart warehousing sectors within the **automotive, electronic goods & components, retail distribution hub, and Third-Party Logistics (3PL)** industries to quantify the Return on Investment (ROI), as well as the Cost of Inaction (COI) on *status quo* manufacturers and warehouse managers that do and do not adopt cellular-connected Industry 4.0 tools.

Private cellular networks, based on 4G LTE and 5G, enable a diverse set of Industry 4.0 tools for the manufacturer and warehouse manager. These include **Condition-Based Monitoring (CBM), Real-Time Location System (RTLS)/asset tracking, inventory management, Augmented Reality (AR) glasses, wearables, building automation, robotics, and more.**

ROI/COI Insights

- **Overall Impact of Cellular-connected Industry 4.0**
  1. Automotive Vendors can achieve 5% increase in gross profit from the commissioning of cellular based Industry 4.0 solution.
  2. A tier one US based Electronics good maker could save over $1 billion in operational costs over 5 years by utilizing cellular Industry 4.0 solutions.
  3. Failure to embrace cellular Industry 4.0 could mean that a tier one warehouse owner could handle between 10mn and 16mn less pallets over a 5 year period.
  4. A tier one 3PL warehouse operators could see up to a 12% increase in gross profit over 5 years from the adoption of Industry 4.0 cellular based solutions.
  5. Manufacturers could expect to see a 10x ROI on cellular Industrial 4.0 solution investment.
  6. Warehouse owners and operators could expect to see a 14x ROI on cellular Industrial 4.0 solution investment.
- **Automotive Vehicle Manufacturing:** Factory size tends to be very substantial for automotive manufacturers (the main VW factory in Germany is 6.5 million m^2), where cellular connectivity can make manufacturer equipment and infrastructure more modular and flexible. From ABI Research's analysis, over a 5-year period, a Tier One automotive factory measuring 500,000 m^2 in Germany could incur a cost of inaction equivalent to 17,500 vehicles or US$495 million in monetary terms.

- **Electronic Goods & Component Manufacturing:** Tier One electronic goods manufacturers often have a footprint of 200,000 m^2 and above. A Tier One electronics product manufacturer in Japan that fails to adopt connected cellular Industry 4.0 solutions could forgo the production equivalent of US$640 million according to ABI Research's analysis of the manufacturer's operations potential from 2021 to 2025. In the United States, the cost of inaction for the same time frame is US$1 billion.
- **3PL:** In China and the United States, there are more than 5,800 and 3,000 3PL firms that already have a number of tethered or short-range tracking solutions using barcodes and scanners. ABI Research does anticipate that operational cost savings will add up to US$248 million over a 5-year period for a Tier One 3PL warehouse in the United States or US$210 million for a Chinese Tier One 3PL warehouse.
- **Retail Distribution Warehousing:** Improvements in inventory management, deployment of asset tags, and personnel-centric tracking can help streamline operations, reduce theft and optimize location of inventory. In the case of a Tier One retail distribution warehouse in the United Kingdom, up to 10 million pallets of goods could be more effectively managed over a 5-year time frame (2021 to 2025). By not implementing connected cellular Industry 4.0, a tier one retailer managing distribution center could forgo US$216 million, which is effectively the Cost of Inaction.

Recommendations

ABI Research's recommendations for smart manufacturing and warehousing establishments include:

- **Embrace Connectivity:** The proliferation of mobile and connected assets in manufacturing and supply chain operations calls for more robust wireless connectivity solutions. This is being driven by the economies of scale within cellular.
- **Optimize Deployments of Private Cellular:** Manufacturing and warehouse managers can optimize the deployment of additional access points (APs) in relation to the gateways to either boost coverage or the link budget with a cluster of sensors and tags in a particular area of the factory/warehouse.
- **Meet with Diverse Stakeholders:** Alignment is essential to get from a proof of concept to pilot and ultimately production which means meeting with a broader set of stakeholders across the IT/OT domain.
- **Prioritize the Business Case:** Manufacturers are looking to reduce the cost of output by modernizing and compacting their sites, but neither these companies nor their suppliers will gamble on unproven technologies when it comes to live production.
- **Think Holistically:** Businesses and enterprises should remember to carry out not just a **ROI assessment**, but also a **COI assessment**. ROI is an effective financial tool to quantify the financial effectiveness of capital, assets, tools, and personnel; COI assesses the impact of inefficiencies and downtime on operational processes and quantifies the opportunity costs.

INTRODUCTION

This whitepaper focuses on **connectivity as a driver of Industry 4.0**, presenting use cases and ROI, as well as COI analyses. Smart factories and warehouses are poised to become a multi-trillion-dollar industry by 2030, and manufacturing and warehousing executives need to understand *why* and how *they* should develop the right connectivity strategies to unlock this value.

KEY FEATURES OF SMART MANUFACTURING

Smart manufacturing is a subset of Industry 4.0 and includes the usage of the Industrial Internet of Things (IIoT), real-time data analytics, and sensors-based monitoring. Example applications include:

1. **Additive manufacturing** for rapid prototyping and customized mass production
2. **AR** to increase operational efficiency through AR-based manual assembly guidance, asset diagnostics for technicians, and training
3. **Collaborative Robots (cobots)**, which are robots that can work safely alongside humans to increase productivity and reduce repetitive tasks
4. **Code-free logic configuration** to increase scalability and speed up deployment
5. **Digital twins** for real-world simulation and modeling
6. **Edge computing** to process data closer to where it originates and is needed
7. **Predictive maintenance** which uses IIoT sensors and predictive analytics to analyze data anomalies, decreasing downtime and increasing Overall Equipment Effectiveness (OEE)

Enabling Technologies for Smart Manufacturing

Manufacturers are already taking advantage of wireless connectivity technologies, such as cellular networks, to enable Industry 4.0 processes. An example would be Osram, a lighting manufacturer, which deployed a campus network with Deutsche Telekom that runs on a 4G core. They expect productivity to increase by 5% to 10% within the next 2 to 3 years with the deployment.

- **Connectivity:** There are multiple ways to connect a factory. These include using fixed wired connections and wireless solutions, such as cellular, Low-Powered Wide-Area Networks (LPWANs), and Wi-Fi. While most factories are currently connected by wired connections, ABI Research forecasts a Compound Annual Growth Rate (CAGR) of 55% for the number of wireless connections in factories between 2019 and 2030, outpacing that of factory wired connections (12%) for the same period. The full suite of 5G will eventually be able to enable many more smart manufacturing applications. However, 5G is still in its trial phase for industry 4.0 applications, with more industry 4.0-enabling features scheduled to be released periodically. The additional features will be introduced when the cellular industry standardization body, 3rd Generation Public Partnership (3GPP), introduces Releases 16 and 17 scheduled between 2020 and 2024. 4G/LTE solutions are available today, enabling factories and warehouses to implement many of the use cases that will benefit from cellular before 5G becomes available in industrial environments.

An example of an edge intelligence deployment is an automotive manufacturer who deployed Software AG's Apama software for streaming analytics and Cumulocity IoT to train Machine Learning (ML) models for paint job defect detection. This allowed the client to improve quality monitoring in real time, making the function of scientific measurement an active process. Currently, most edge intelligence deployments in smart manufacturing are in the United States and Europe.

- **Edge Intelligence:** The network edge enables low-latency applications, data security, custom workflows, and local processing for IIoT in the smart factory. When paired with Artificial Intelligence (AI), along with training and inference done at the cloud or inference done at the edge, edge intelligence is enabled. This has created many successful use cases, such as improving capacitor production yield and optimized steel manufacturing. Stream processing at the edge also provides more accurate data for predictive maintenance.

KEY FEATURES OF SMART WAREHOUSING

Smart warehousing is still in its nascency, but gaining traction. Smart warehousing includes IIoT-enabled inventory management, RTLS, and Autonomous Mobile Robots (AMRs) that can navigate and move without external guidance. Example applications include:

1. **AMRs** to move goods around the warehouse and scan Radio Frequency Identification (RFID) tags for automatic continuous inventory counting and increase mobility
2. **AR** to increase employee efficiency and reduce errors through smart glasses that provide real-time directions, information, training, automated barcode scanning, and stock updates
3. **Cobots** to move, palletize, and pack goods, performing tedious and dangerous tasks
4. **Digital twins** for warehouse optimization through analysis of real-time data from drone-based stock counting systems, AMRs, and Automatic Storage and Retrieval Systems (AS/RS), as well as trialing and testing new layouts, equipment, and processes
5. **Supply chain optimization** through cloud-based tracking and analysis of 3PL providers
6. **Warehouse monitoring and indoor asset tracking** using wireless technology

Ocado uses more than 1,000 Sawyer robots over an unlicensed 4G spectrum for its automated grocery warehouse through a single base station, circumventing the limitation of the number of connections on a single Wi-Fi AP and low latency and unreliability from interlinked APs during handovers.

ADLINK's edge IIoT solution uses sensors and cameras installed above the pallet to automatically scan and detect them. The system can collect, compute, and transmit data at the edge, creating instant inventory reporting.

Enabling Technologies for Smart Warehousing

- **Connectivity:** Smart warehouses are evolving to become more connected and configurable. One use case is using mobile storage racks to increase order fulfilment rates, maximize warehouse space, and optimize labor resources. An example would be Bastion Solutions' Robotic Shuttle System, which is a hybrid AS/RS and AMR that is mobile across the shop floor and within retrieval racks. This requires an environment with reliable coverage and predictable latency for Machine-to-Machine (M2M) communication, which coordinates mobile storage racks with packing or control centers. Connectivity also allows AR glasses to scan packages and automatically update stock in the Warehouse Management System (WMS).
- **Edge Intelligence:** Edge intelligence will enable smart warehouse applications, such as AMRs, to detect their surroundings and avoid collisions, as well as connected cameras that run AI models to predict defects and analyze packing behavior. Cellular connectivity could complement edge intelligence and reduce the cost of AMRs in the long term by alleviating the need for expensive onboard analytics processing hardware that could otherwise be supported by an intelligent edge cloud.

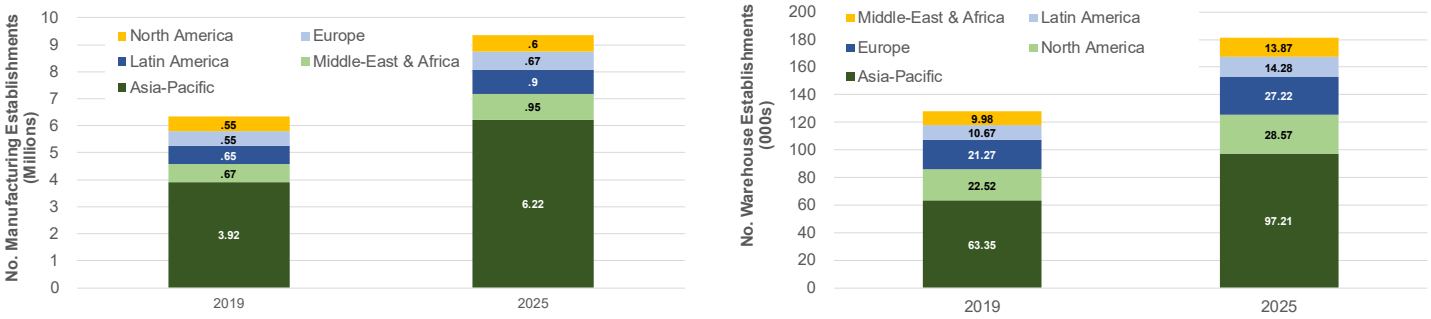
INDUSTRY 4.0 LANDSCAPE

SMART MANUFACTURING

ABI Research forecasts that the smart manufacturing market will grow to US$1 trillion by 2030. This market refers to factories that adopt Industry 4.0 solutions, such as AMRs, asset tracking, cobots, industrial robots, and smart glasses. Smart manufacturing connection revenue is forecast to grow at a CAGR of 21% from 2018 to 2030, reaching US$35 billion by 2030. Of this US$35 billion, wireless connections contribute to most of it at 72%. There are just over 6.3 million manufacturing establishments and 127,000 commercial warehouses worldwide. While these figures are expected to increase at an average of 6.7% and 5.4%, respectively, per annum over the next 6 to 8 years, the number of wirelessly connected endpoints within them will grow more than 36X in 8 years and more than 100X by 2030. In terms of automation, the automotive industry leads, having automated close to 50% of operations.

Figure 1. Worldwide Manufacturing and Warehouse [1]Establishments, 2019 versus 2025

(Source: ABI Research)



SMART WAREHOUSING

For warehousing, close to 50% of the top 200 retail brick & mortar and e-commerce companies in the world use some form of robotics for delivery and order fulfilment. In 2019, e-commerce fulfillment centers made up almost 13% of all commercial warehouses across all verticals, and this number is forecast to grow to 37.5% by 2027. Smart warehouses are becoming more essential, driven by the growing demand of e-commerce, which requires rapid and flexible deliveries. In China, Alibaba alone has announced investments of up to US$15 billion to digitally upgrade its logistics affiliate, Cainiao.

The global WMS market will be worth US$5 billion by 2025, growing at a CAGR of 13.9%. Over the same analysis period, 57,000 more warehouses will be in operation than in 2018, which is driven primarily by the growth of e-commerce fulfilment centers (22% CAGR). ABI Research estimates there will be 135,900 commercial warehouses globally by 2020, with Asia-Pacific contributing to most of that at 73,800, followed by North America at 23,500, and Europe at 21,300. WMS market leaders, such as JDA Software, High Jump, and Manhattan Associates, are driving AI-innovation in WMS and Warehouse Execution Systems (WES), an increasingly important orchestration layer linking the Information Technology (IT) layer with connected machines at the Operational Technology (OT) layer.

STATE OF CONNECTIVITY

While industrial Ethernet is still the backbone of most factories and warehouses, wireless connectivity is gaining traction as private cellular will introduce mobility, reliability, deterministic networking, and standardized technology in these markets. To date, industrial Ethernet has primarily connected Human-Machine Interfaces (HMIs) and Programmable Logic Controllers (PLCs). Wireless connectivity will enable Industry 4.0 applications like AMRs, asset tracking, cobots, industrial robots, and smart glasses.

Industry 4.0 factories and warehouses will need to connect a massive number of data inputs, with each input sometimes requiring an extensive usage of data, and cloud services for real-time analytics of the data at scale. They must also be able to mesh data from other factories or sources beyond the factory, such as asset location from 3PL providers, real-time price data, production planning systems, and Customer Relationship Management (CRM) systems, with key business personnel being able to access and make actionable decisions based on these real-time data.

[1]Warehouse count excludes Do-It-Yourself generic/personal storage facilities

Reconfiguration is a key aspect for the automotive manufacturing industry. The time to reconfigure a factory may take close to a year due to existing cabling for a new model. A wireless configurable factory can reduce lead time to 1 to 2 months. For warehouses, AMRs will require wireless connectivity in order to navigate and upload data to a smart swarm robots control system.

PRIVATE CELLULAR NETWORKS FOR INDUSTRY 4.0

Industry 4.0 factories and warehouses cannot depend on wired connections to enable these use cases, as the factory of the future needs to be reconfigurable with many mobile components. Wi-Fi also has limitations in the number of clients that can connect to an AP and has unpredictable latency as more devices are added to the network. LPWANs are gaining traction as a solution, and **ABI Research forecasts that LPWAN-LTE connections will be primarily driven by asset tracking, reaching 3.8 billion asset tracking connections worldwide for the smart factory by 2030**. However, LPWAN solutions, such as NB-IoT and LTE-M, are not interoperable with each other, making it costly to manage multiple networks and to have multiple chipsets for different LPWAN solutions. A LPWAN is also currently not suitable for data that require large bandwidths.

Private cellular networks[2] are needed to provide reliable coverage, predictable connectivity, and mobility for enterprise IIoT use cases. They can deliver the capacity to support both high and low-data requirements, up to the range of 300 Megabytes per Second (Mbps) for downlink and 150 Mbps for uplink. With Long-Term Evolution (LTE), they also provide predictable latency in the range of 30 Milliseconds (ms), even when there are many devices on the network.

Private cellular networks also offer additional features over public networks, such as a dedicated network that has a robust traffic and device management model, giving users full control and privacy of their data. Private cellular network deployment is also flexible as the Evolved Packet Core (EPC) can now be virtualized in a physical or cloud server. It also can be fully private, with the enterprise owning their own Random-Access Network (RAN), core, and applications.

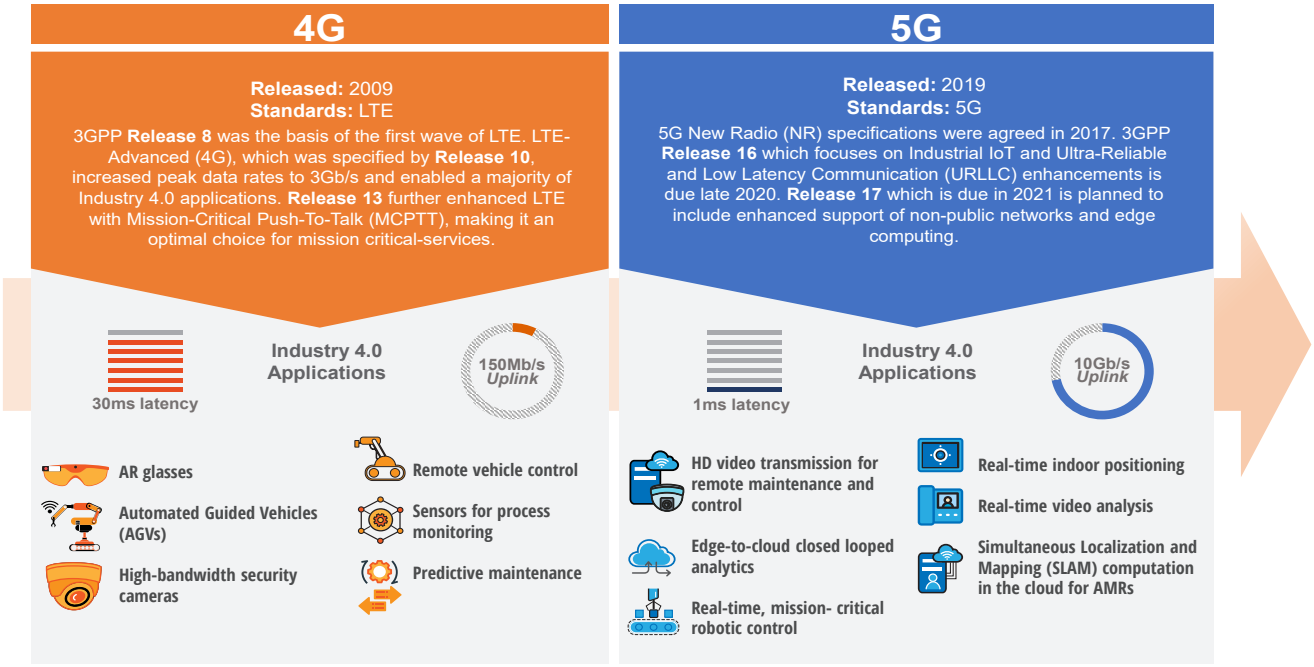
Factories and warehouses using private LTE networks can support the deployment and connection of an increasing number of devices and applications with different bandwidth requirements, enable end-to-end security with additional hardware security *(Subscriber Identity Module (SIM)-based authentication).* Recent developments and improvements in LTE technology have enabled multiple applications and benefits from private LTE deployment. Some of these include:

- Configurable Quality of Service (QoS) layer, with support for multiple layers of QoS prioritization
- Edge computing
- Group broadcast
- Indoor and outdoor coverage, potentially connecting with the public network through solutions like dual slicing
- Industry-grade reliability for handovers
- Mission-Critical Push-To-Talk (MCPTT)
- Over-the-Air (OTA) encryption and SIM-based authentication
- 3GPP standardization, which allows economies of scale for RAN and user equipment

[2]Private cellular networks also refer to non-public cellular networks.

Figure 2. Private LTE as a Road to 5G

(Source: ABI Research)



These features make private LTE a suitable option for driving Industry 4.0, providing flexibility and customizability for enterprise needs. An upgrade to 5G from a private LTE network through software is possible, and older equipment can be retrofitted for 5G once it is deployed.

Private LTE could be a first step toward 5G, ensuring that the infrastructure and enterprise experience for cellular networks is in place before 5G arrives in the industrial space. Initial deployments of private LTE could also be complementary to 5G when it rolls out.

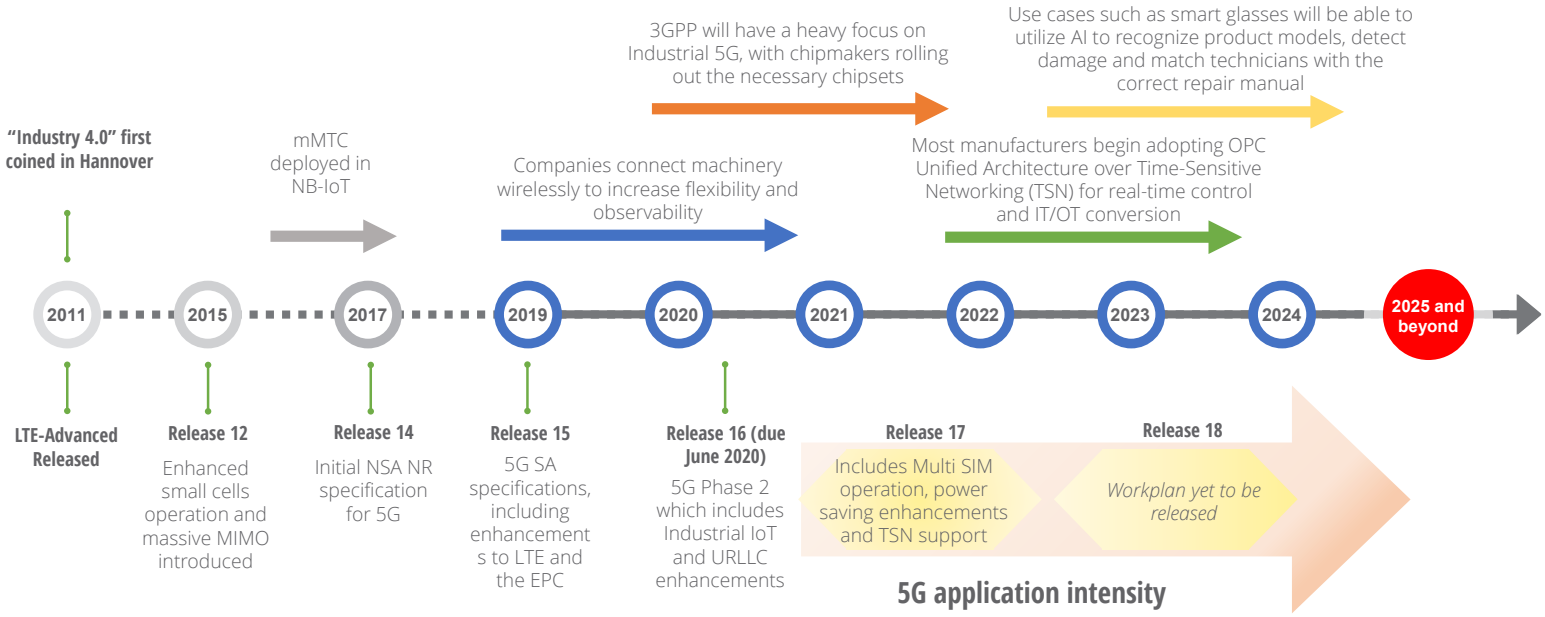
WHAT IS NEXT?

In the future, factories and warehouses will have an increasing number of connections. 5G will eventually support layer 1 to 2 performance, such as scheduling, latency, and jitter. It will also enable time-critical robotic motion control, with a 2-ms cycle time and low error rate. Machine vision video and Simultaneous Location and Mapping (SLAM) processing will be outsourced to the cloud with the bandwidth and latency that 5G promises to provide, enabling real-time navigation and route optimization capabilities for AMRs.

Currently, 5G is being deployed for consumers, initially on **Non-Standalone (NSA) architecture**. However, once Mobile Service Providers (MSPs) have completed their **Standalone (SA) architecture**, which includes a 5G updated core network, industrial functionalities, such as enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), and massive Machine Type Communications (mMTC), can be enabled. Network slicing will also allow dedicated virtualized networks to serve resource-intensive industrial applications, and to offer personalized Service-Level Agreements (SLAs), personalized billing, faster customization, and self-service.

Figure 3. Cellular Networks Will Enable Many Use Cases

(Source: ABI Research)



DRIVERS AND INHIBITORS

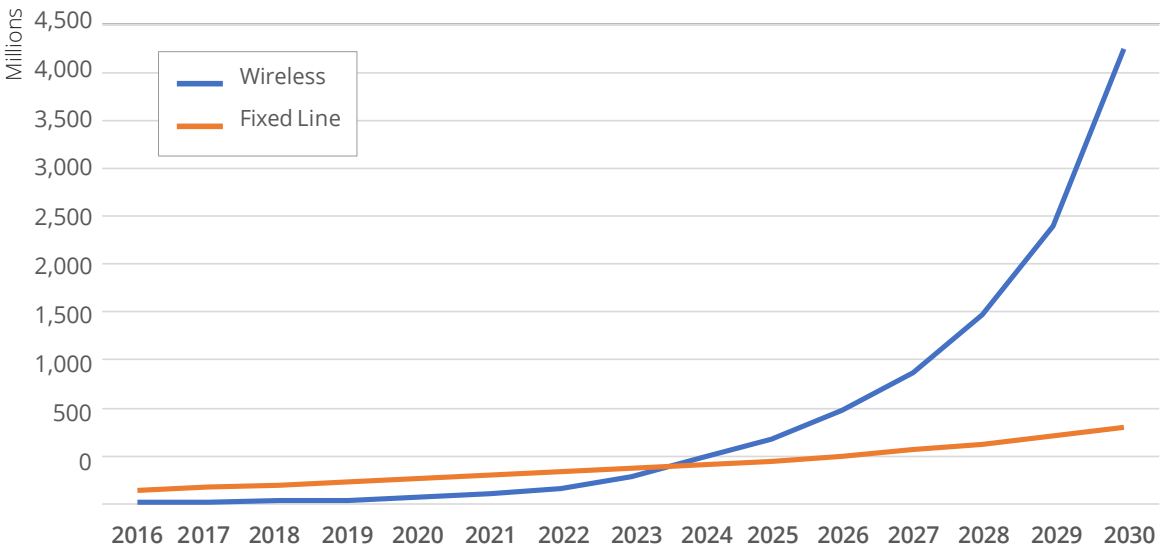
The following market drivers are propelling this next wave of innovation:

- **Reliability and Performance:** There are just over 6.3 million manufacturing establishments and 127,000 commercial warehouses worldwide. This installed base of manufacturing establishments is expected to drive the number of wirelessly connected endpoints within them at more than 36X in 8 years and more than 100X by 2030. Most of these connected endpoints are entirely new—AMRs, cobots, smart glasses, modern HMI/industrial Personal Computers (PCs), sensors, *etc.*—and in some way need to work not only with each other, but also with existing infrastructure and equipment. In many cases, this includes equipment that was never meant to be connected and infrastructure that is unable to support the network density and data volumes demanded by Industry 4.0 applications.

  Self-powered wireless devices can help alleviate these challenges, and new IIoT use cases driven by the availability of wireless are constantly emerging. ABB, for example, is using Atlas Copco-connected torque wrenches and Cognex machine vision to track and validate the step-by-step completion of work. For applications like AR-enabled vision picking or guided product assembly, both of which are geared toward reducing human error and operator fatigue, efficiency gains start between 5% and 25%.

Figure 4. Global Digital Factory Connections, 2016 to 2030

(Source: ABI Research)



- **Enhanced Flexibility:** The global logistics market generates about US$12 trillion in revenue and is expanding at a breakneck pace. Developments in e-commerce are fueling a growing demand for warehouse fulfillment, while the complexity of global supply chains and the growing capabilities of cloud platforms are leading to increased automation in freight. As competition intensifies, e-retailers and 3PL giants are spurring innovation in short-range urban delivery transportation.

  Wireless technologies, such as WiFi 6, LTE, and soon 5G, help production plants and intralogistics operations stay nimble in the face of these kinds of complexities. Wireless eliminates the need for costly wiring and cabling, which is more expensive and time-consuming to implement (US$1,500 per workstation). For process industries, an hour of uptime could be worth US$5,000 to US$12,000 per asset (*e.g.*, per Computer Numeric Control (CNC) machine). For high-value, high-volume/high-mix discrete industries like automotive, it can be as much as US$30,000 per minute.

- **Data Security and Control:** When connecting legacy assets on a factory floor, manufacturers face the challenge of bridging the gap between IT and OT. They must consolidate data from multiple types of machines and from multiple manufacturers with proprietary communications protocols and a variety of operating systems. Often, the smart manufacturing vendor has to work closely with a number of IT and OT professionals who have never spoken to each other.

  In any event, the industrial landscape as a whole is undergoing a behavioral shift, whereby application- and data-generating activities once reserved exclusively for local operations (PLCs, Supervisory Control and Data Acquisition (SCADA), Distributed Control Systems (DCSs) for manufacturing, and WMSs for logistics) are finding their way to the cloud.

IMPLEMENTING SMART MANUFACTURING

Businesses and enterprises now have a range of smart manufacturing tools and solutions that can leverage either private or public cellular connectivity. Key solutions include:

- **Asset Tracking:** Better asset monitoring means better overall equipment effectiveness (OEE) and, therefore, better deployment of capital. It means knowing the location of tools when and where they are needed; minimizing unnecessary inventory; maximizing turns; reducing human error; and keeping workers safe. **By 2030, more than 3.8 billion assets will be connected wirelessly within factories.** Companies like Ford and Honda are already using connected asset tracking to ensure that the right raw material is used to make the right part on the right machine, by a properly trained technician.

HIROTEC, a Japanese auto parts manufacturer, connected its CNC machines, inspection robots, force sensors, laser measurement devices, cameras, and robotic arms using PTC Kepware for connectivity and PTC ThingWorx as its on-premise cloud platform, running HPE Edgeline systems. It now generates automatic reports for the entire production line and predicts and prevents failures in critical systems using ML to minimize unplanned downtime, a value of US$1.3 million per hour saved.

- **Predictive Maintenance:** One of the main goals in manufacturing is to maximize production efficiency. It is not productive to send a technician to tend to a machine that does not need tending, nor is it efficient if a machine goes down because it has not received the attention it requires. To solve this, CBM and predictive maintenance applications remotely keep tabs on the status of connected assets, so that maintenance is performed proactively, on a just-in-time basis.
- **Digital Twins:** Digital twins are used everywhere from Computer-Aided Design (CAD) to production planning (Computer-Aided Manufacturing (CAM) and virtual commissioning), and even modeling the plant itself. But to have a true digital twin means getting as close to a real-time model or representation as possible and doing that requires not only a digital platform, but also connectivity. Companies like automotive line builder MINO have saved more than 6 months on automotive line assembly projects through virtual commissioning.
- **Human-Robot Work Flow Integration:** Universal Robots did not think that the automotive industry would adapt to cobots, but it now supplies cobots to 90% of all automotive Original Equipment Manufacturers (OEMs), and even more to suppliers like Continental and Lear. Some, such as the PSA Group, have upscaled deployment of Universal's UR10 cobots for screwdriving applications on the assembly line, where they work alongside humans and have improved the health and safety work conditions, in addition to productivity. The screwdriving applications reach a ROI in an average of 3 to 4 months and improved Geometric Dimensioning and Tolerancing (GD&T) by 10%. The hidden challenge is that anytime you put a robot in the same space as a human and that space is not fenced off, there are safety compromises.

HONDA

Honda's Industry 4.0 Transformation Case Study

In the case of Honda's Alabama plant, which has Omron, Rockwell, and Mitsubishi machines, and a Manufacturing Execution System (MES) built in-house, there was a need to reduce custom coding to free up IT resources. After adopting Telit's deviceWISE IIoT Platform, Honda found that access to code-free app development notably improved its overall production line agility, and that it was able to pick up an average of 1 ms to 3 ms in time savings in the data translation process, which, for Honda's Alabama plant, meant a total of 3,000 additional minutes of uptime per year, or US$90 million, because the facility produces 1,800 cars per day at a value of approximately US$30,000 per minute.

ERICSSON

Ericsson Electronics Case Study

Ericsson's 4G and 5G radio manufacturing facility in Nanjing, China employs more than 2,000 people and produces more than US$2.8 billion in products each year. Ericsson is achieving efficiencies through the use of Automated Guided Vehicles (AGVs), a modular-designed automatic assembly line for 5G radios, and a vision system, in addition to more general-purpose IIoT applications like asset tracking/CBM and predictive maintenance. In the case of the latter, for example, Ericsson has connected more than 1,000 high-precision screwdrivers that previously relied on handwritten records to monitor utilization and maintenance. Each screwdriver, which costs about US$1,500, simply needed a US$20 module to start sending data to a central location. As result of knowing the status of these tools, Ericsson was able to reduce its maintenance staff by two-thirds and allocate those employees to other projects.

SMART MANUFACTURING COI AND ROI ANALYSIS

ABI Research has conducted an operations assessment of the smart manufacturing sectors within the **automotive** and **electronic goods & components** industries, looking at two countries for each sector. ABI Research wanted to quantify the ROI. Furthermore, ABI wanted to quantify the impact of the COI for *status quo* manufacturers and warehouse managers if they fail to adopt connected cellular Industry 4.0 solutions. For the comparative analysis of the status quo factory, the revenue generated was kept constant in order to investigate the impact of operational cost savings provided by cellular-connected Industry 4.0 solutions.

AUTOMOTIVE MANUFACTURING INDUSTRY IN GERMANY AND SOUTH KOREA

The German automotive manufacturing industry is more fragmented than South Korea's, with 138 manufacturing establishments in Germany compared to 33 in South Korea. However, a South Korean automotive manufacturer produces about 3X more cars on average per 500,000 Square Meter (m^2) factory, while having a lower average value per vehicle than a German automotive manufacturer. ABI Research finds that implementing Industry 4.0 applications based on a foundation of cellular connectivity can increase the gross profit margin of each factory in Germany by 490 BPS and 510 BPS for South Korea over a 5-year period between 2021 and 2025.

The following analysis uses a standard 500,000 m^2 automotive factory to represent Tier One factories in Germany and South Korea as the unit of analysis. Each "per factory" calculation for automotive manufacturing refers to this "Tier One" factory measurement.

AUTOMOTIVE, GERMANY			
Per Tier 1 Factory: 2021-2025 (500K m^2)	**Status Quo Factory**	**Cellular-connected 4.0 Factory**	**Comments**
Revenue	$9,335	$9,335	Revenue kept constant for comparison
Initial Operation Costs	($7,468)	($7,468)	Cost of regular factory & product CapEx & OpEx
Connected Cellular & Industrial 4.0 TCO	-	($50)	Covers deployment of Private Cellular and Industry 4.0 sensors
Operational Cost Savings	-	$505	Efficiency savings from cellular-connected Industry 4.0
Net Cost of Operations	($7,468)	($7,013)	Net impact on costs
Gross Profit	$1,867	$2,323	
Gross Profit Margin	20.0%	24.9%	Industry 4.0 impact on gross profit
Cost of Inaction, Lost Vehicle Production	17,500 vehicles	-	Opportunity cost in terms of production of vehicles
Operational Cost Savings ROI	-	$9.2	Indicates how the Cellular 4.0 TCO repays its investment
Percentage COI Impact	-5.0%	-	COI as a percentage of potential revenues (current revenue + COI)
Cost of Inaction Value	**$495**	**-**	Opportunity cost value

All figures in Millions of USD unless otherwise indicated Source: ABI Research

Over a 5-year period, a German automotive manufacturer that adopts private cellular-enabled Industry 4.0 technologies will realize:

- A 4.9% increase in gross profit
- The production of an additional 17,500 vehicles ($495.2 million)
- Operational cost savings of $505 million

Main drivers include the use of:

- Robotics ($173.6 million)
- Better inventory management ($102.7 million)
- Condition-based monitoring of connected equipment ($101.8 million)

Germany's automotive manufacturing industry contributes significantly to its economy, making up 5% of the nation's Gross Domestic Product (GDP). The industry faces headwinds as the Purchasing Manager's Index (PMI) for manufacturing remains in contraction, remaining below the 50.0 mark for the ninth month in a row since January 2019.

Not implementing Industry 4.0 solutions based on a foundation of cellular connectivity **will cost a Tier One German manufacturer US$495 million and 17,500 vehicles** over the 5-year, 2021 to 2025 time frame.

Better and more accurate CBM will lead to a **1.4% operational cost savings** in the German automotive sector. A Tier One German automotive factory is anticipated to **invest US$50 million in private cellular networks** and Industry 4.0 solutions between 2021 and 2025. There will be nearly **17X** more sensors deployed in the entire German automotive industry by 2025 compared to 2020.

German automotive manufacturers must remain competitive. The German automotive market, as a whole, risks **falling behind by 1.4 million vehicles over the 2021 to 2025 time period.** This COI represents an opportunity cost of US$39.6 billion.

SOUTH KOREA

AUTOMOTIVE, SOUTH KOREA			
Per Tier 1 Factory: 2021-2025 (500K m^2)	**Status Quo Factory**	**Cellular-connected 4.0 Factory**	**Comments**
Revenue	$23,099	$23,099	Revenue kept constant for comparison
Initial Operation Costs	($18,017)	($18,017)	Cost of regular factory & product CapEx & OpEx
Connected Cellular & Industrial 4.0 TCO	-	($45)	Covers deployment of Private Cellular and Industry 4.0 sensors
Operational Cost Savings	-	$1,219	Efficiency savings from cellular-connected Industry 4.0
Net Cost of Operations	($18,017)	($16,843)	Net impact on costs
Gross Profit	$5,082	$6,256	
Gross Profit Margin	22.0%	27.1%	Industry 4.0 impact on gross profit
Cost of Inaction, Lost Vehicle Production	44,600 vehicles	-	Opportunity cost in terms of production of vehicles
Operational Cost Savings ROI	-	$26.2	Indicates how the Cellular 4.0 TCO repays its investment
Percentage COI Impact	-4.9%	-	COI as a percentage of potential revenues (current revenue + COI)
Cost of Inaction Value	**$1,195**	**-**	Opportunity cost value

All figures in Millions of USD unless otherwise indicated *Source: ABI Research*

Over a 5-year period, a South Korean automotive manufacturer that adopts private cellular-enabled Industry 4.0 technologies will realize:

- A 5.1% increase in gross profit
- The production of an additional 44,600 vehicles ($1.19 billion)
- An operational cost savings of $1.22 billion

Main drivers include the use of:

- Robotics ($418.9 million)
- Better inventory management ($247.7 million)
- Condition-based monitoring of connected equipment ($245.5 million)

The South Korean automotive manufacturing industry faces a similar situation, with its manufacturing PMI falling below analyst expectations as of September 2019.

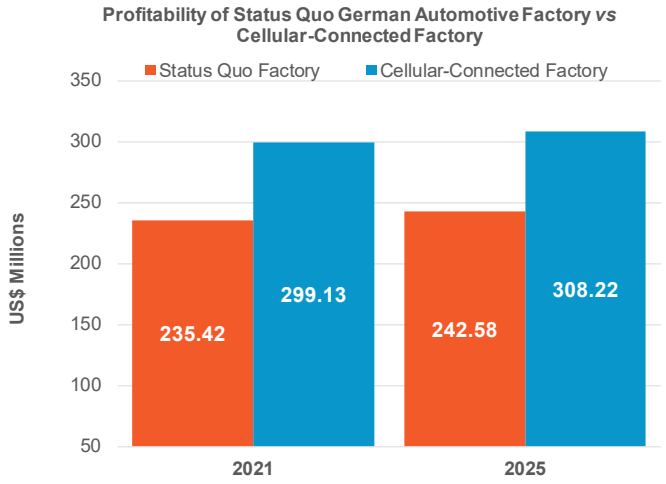
Implementing cellular-connected Industry 4.0 solutions will help save an average of US$1,440 annually per vehicle manufactured in South Korea, contributing to a COI of about US$1.19 billion between 2021 and 2025 for a Tier One automotive factory.

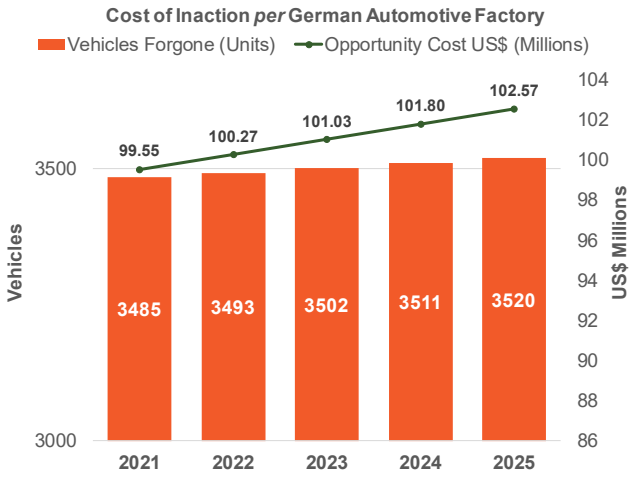
The South Korean automotive manufacturing industry is anticipated to invest US$358.4 million in private cellular networks for Industry 4.0 factory upgrades between 2021 and 2025, a significantly smaller amount than Germany due to its lower total physical footprint of automotive factory space. South Korea's automotive factories are some of the most productive in the world.

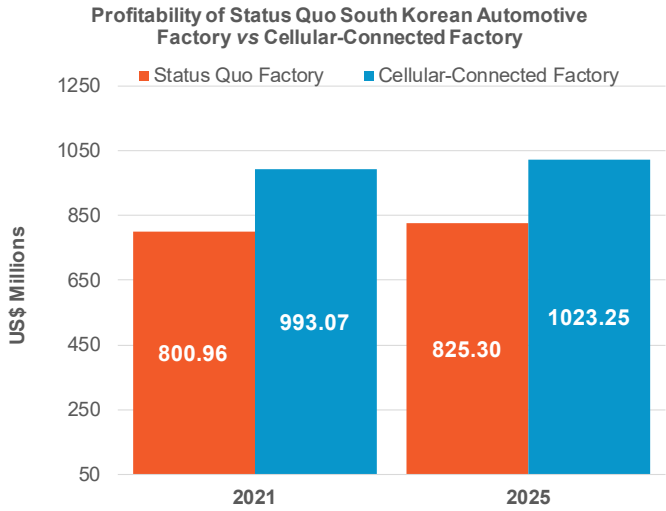
Cellular-connected Industry 4.0 deployments can **reduce operational costs to the tune of a total of US$243.7 million** on a per South Korean factory basis between 2021 and 2025. This number is significantly higher than Germany, as South Korean automotive manufacturers produce more vehicles on average per 500,000 m^2 factory than their German counterparts. **This 5-year COI amounts to a figure of US$28.7 billion** for the entire South Korean automotive manufacturing industry.

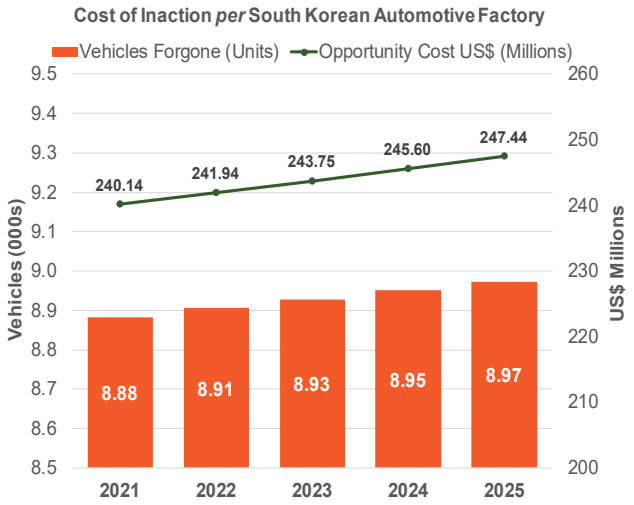
Figure 5. Tier One Automotive Manufacturing Factory COI and ROI Analysis

(Source: ABI Research)









ELECTRONICS MANUFACTURING INDUSTRY IN JAPAN AND THE UNITED STATES

The following analysis uses a 200,000 m^2 electronics manufacturing factory to represent Tier One factories in the United States and Japan as the unit of analysis. Each "per factory" calculation for electronics manufacturing refers to this "Tier One" factory measurement.

JAPAN

ELECTRONIC GOODS, JAPAN			
Per Tier 1 Factory: 2021-2025 (200K m²)	**Status Quo Factory**	**Cellular-connected 4.0 Factory**	**Comments**
Revenue	$8,711	$8,711	Revenue kept constant for comparison
Initial Operation Costs	($7,404)	($7,404)	Cost of regular factory & product CapEx & OpEx
Connected Cellular & Industrial 4.0 TCO	-	($34)	Covers deployment of Private Cellular and Industry 4.0 sensors
Operational Cost Savings	-	$650	Efficiency savings from cellular-connected Industry 4.0
Net Cost of Operations	($7,404)	($6,788)	Net impact on costs
Gross Profit	$1,307	$1,922	
Gross Profit Margin	15.0%	22.1%	Industry 4.0 impact on gross profit
Cost of Inaction, Lost Electronic Goods Production	970K products	-	Potential loss in electronic products shipped for status quo factory
Operational Cost Savings ROI	-	$18.1	Indicates how the Cellular 4.0 TCO repays its investment
Percentage COI Impact	-6.8%	-	COI as a percentage of potential revenues (current revenue + COI)
Cost of Inaction Value	**$637**	**-**	Opportunity cost value

All figures in Millions of USD unless otherwise indicated Source: ABI Research

Over a 5-year period, a Japanese electronics manufacturer that adopts private cellular-enabled Industry 4.0 technologies will realize:

- A 7.1% increase in gross profit
- The production of an additional 970,100 units ($637 million)
- An operational cost savings of $650 million

Main drivers include the use of:

- Robotics ($166.6 million)
- Better inventory management ($148.1 million)
- Condition-based monitoring of connected equipment ($147.2 million)

Japanese electronics manufacturers are anticipated to **invest a total of US$122.5 million in private cellular and Industry 4.0 factory upgrades** between 2021 and 2025 on a country level. The Japanese manufacturing sector has been substantially off its 2010 to 2012 production highs, with its Manufacturing Value Added (MVA) just US$1 trillion in 2017 compared to US$1,224 billion in 2012.

Japanese manufacturers must find solutions to regain their leading position in delivering high-quality, durable products. Between 2021 and 2025, a *status quo* electronics factory, 200,000 m² in size, that does not embrace cellular-connected Industry 4.0 technologies will experience a COI of **nearly US$637 million, equivalent to 970,100 electronic goods**.

Smart manufacturing presents another opportunity to reinvigorate Japanese factories' efficiencies and consequent revenue growth, with **gross profit margins expected to increase by 710 BPS and total operational cost savings approximating US$649 million** between 2021 and 2025 for a Tier One electronics product smart manufacturer.

UNITED STATES

With a forecasted **US$168.1 million investment** between 2021 and 2025 for the U.S. electronics manufacturing industry, U.S electronics manufacturers are equally bullish on the value that private cellular and Industry 4.0 upgrades would bring to their factories.

ELECTRONIC GOODS, USA			
Per Tier 1 Factory: 2021-2025 (200K m²)	**Status Quo Factory**	**Cellular-connected 4.0 Factory**	**Comments**
Revenue	$13,549	$13,549	Revenue kept constant for comparison
Initial Operation Costs	($11,923)	($11,923)	Cost of regular factory & product CapEx & OpEx
Connected Cellular & Industrial 4.0 TCO	-	($21)	Covers deployment of Private Cellular and Industry 4.0 sensors
Operational Cost Savings	-	$1,046	Efficiency savings from cellular-connected Industry 4.0
Net Cost of Operations	($11,923)	($10,897)	Net impact on costs
Gross Profit	$1,626	$2,651	
Gross Profit Margin	12.0%	19.6%	Industry 4.0 impact on gross profit
Cost of Inaction, Lost Electronic Goods Production	1.19 mil products	-	Potential loss in electronic products shipped for status quo factory
Operational Cost Savings ROI	-	$49.3	Indicates how the Cellular 4.0 TCO repays its investment
Percentage COI Impact	-7.0%	-	COI as a percentage of potential revenues (current revenue + COI)
Cost of Inaction Value	**$1,026**	**-**	Opportunity cost value

All figures in Millions of USD unless otherwise indicated *Source: ABI Research*

Over a 5-year period, a U.S.-based electronics manufacturer that adopts private cellular-enabled Industry 4.0 technologies will realize:

- A 7.6% increase in gross profit
- The production of an additional 1.19 million units ($1.03 billion)
- An operational cost savings of $1.05 billion

Main drivers include the use of:

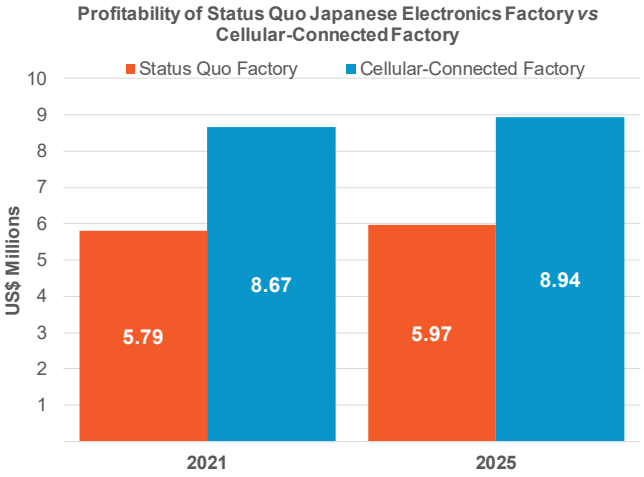
- Robotics ($268.3 million)
- Better inventory management ($238.5 million)
- Condition-based monitoring of connected equipment ($237 million)

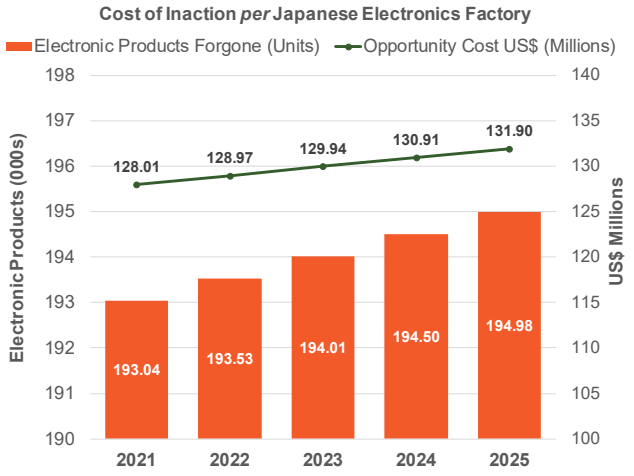
The introduction of Industry 4.0 practices will **save a Tier One U.S. electronics manufacturer an accumulated US$1 billion from 2021 to 2025, which could boost the gross profit margin to 19.6%**. These operational savings would be due to the utility of new and mobile endpoints like AMRs, as well as the improvement in allocation of staff and resources with CBM and predictive maintenance capabilities.

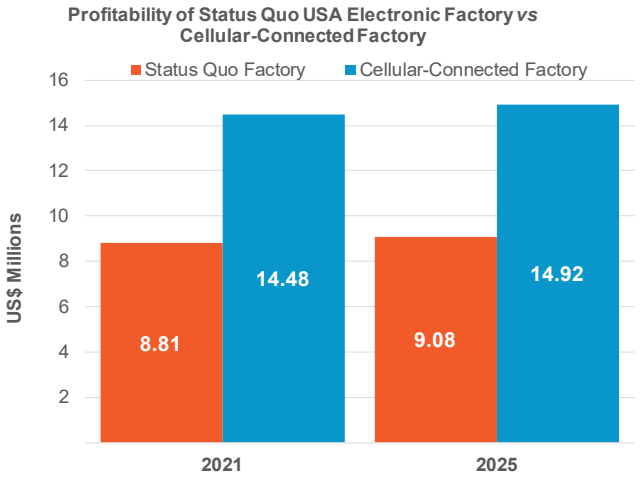
By 2025, if the U.S. electronics manufacturing industry does not embrace cellular-enabled industry 4.0 technologies, it would have missed out on a total of 177 million units of production, or US$152 billion in economic value over the 5-year period.

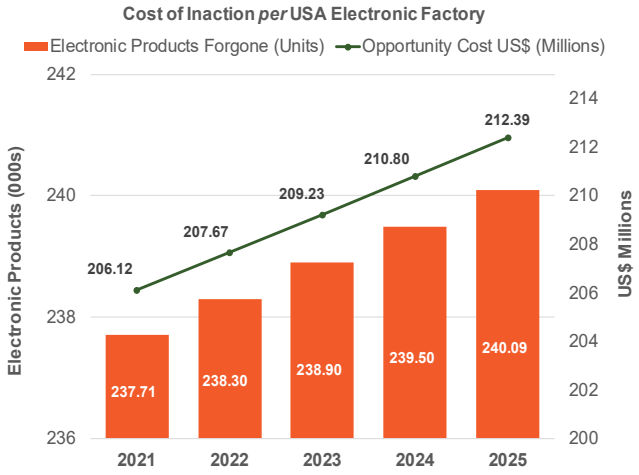
Figure 6. Tier One Electronic Manufacturing Factory COI and ROI Analysis

(Source: ABI Research)







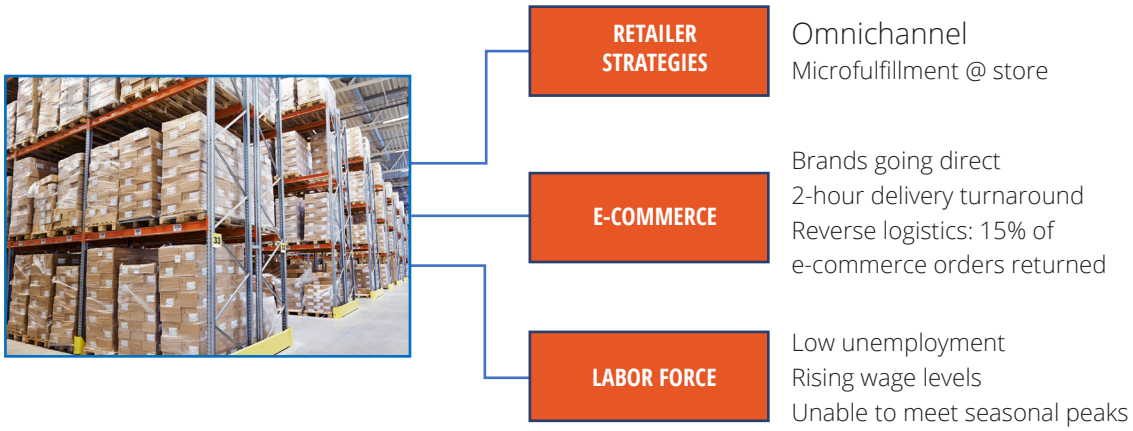


IMPLEMENTING SMART WAREHOUSING

Developments in consumer markets are necessitating that warehousing operators, be they distribution hubs or 3PLs, reconfigure their operations to meet the requirements of today's supply chain and final consumer demand.

Figure 7. Pressures on Warehouse Operators

(Source: ABI Research)



Smart warehousing strategies focus on implementing operational technologies to augment labor force productivity and/or the efficiency of the warehouse facility overall. The following section outlines use cases for various digital technologies in the warehousing context:

- **AGVs and AMRs:** The number of warehouses using robots worldwide will increase from just 4,000 in 2018 (3.2%) to more than 50,000 by 2025 (27.6%). While AGVs only operate in a pre-determined manner, AMRs can navigate autonomously using technologies like Light Detection and Ranging (LiDAR), SLAM, and computer vision to determine the optimal route, while avoiding collisions with objects, humans, and other robots. A further benefit of AMRs is that data generated by the units can be easily integrated with a firm's existing WCS, WES, and WMS software ecosystems. Robot OEM Seegrid reports that its customers in warehouses and distribution centers have reduced manned travel for put-away operations by an average of 20% to 30%.

When training electricians, Boeing has replaced large Two-Dimensional (2D) drawings with AR solutions and attributes a 30% reduction in time spent doing a job and reduced error rates effectively to zero.

- **AR:** AR enables hands-free access to information; improving productivity and efficiency. The number of active users of AR in the logistics industry is forecast to reach 18 million by 2023, up from 1.8 million in 2018. The most prominent use cases in warehousing and logistics includes supporting pick and pack operations by providing workflow guidance, such as step-by-step instruction, information regarding package location, and scanning, which accelerates item picking.
- **RTLS:** An RTLS tracks assets, inventory, and people as it moves around the facility. Key use cases for an RTLS include tracking forklifts to optimize routes and tracking pallets to ensure that the correct products are being transported. An RTLS can also track individual items to prevent packages from being misplaced or lost. In addition, an RTLS can enable warehouse operators to better understand an asset's current condition; when combined with sensors, an RTLS can track temperature, humidity, vibration, and droppages, ensuring greater visibility of the condition of sensitive items before they are shipped and reducing the number of faulty products sent to the customer. For individual workers, an RTLS can ensure that workers do not enter hazardous areas or are alerted in case of an emergency and help coordinate an evacuation of the facility.

Distribution Hub Case Study: Robots Are the Key to Order Fulfilment at Ocado

British online-only grocery firm Ocado processes more than 260,000 orders every week and achieves over 99% order accuracy. The firm's Research and Development (R&D) department has created a fleet of robots that was introduced in its warehouses to assemble orders. The robots can handle crates weighing tens of kilograms and travel at speeds of up to 4 meters per second. More importantly, the robots collaborate with one another, collecting dozens of items in a matter of minutes. The routes taken by the robots feed the company's machine learning-based analytics software and generate operational reports.

The connectivity informing the robots' movements is operating in a single 10-Megahertz (MHz) channel in the unlicensed 5 Gigahertz (GHz) spectrum band and provides 3 Kilobits per Second (Kbps) to each robot. The cellular wireless system supports 1,000 robots per base station. The choice of a private, on-premise network stemmed from the belief that it would deliver lower latency. In addition, the company opted for a private network due to the scope of customizing the network and the security of keeping data on the premises.

3PL Case Study: Smart Glasses Become Integral to DHL's Vision Picking Program

DHL's vision picking program was piloted in 2015 with the objective of enabling staff to be more accurate, productive, and have a more efficient picking process overall. The smart glasses provided the warehouse workers with visual displays of picking instructions, as well as information to help them locate, scan, sort, and move inventory. The picker no longer needed handheld scanners or paper instructions.

During the pilot phase, DHL worked with Ubimax (AR software specialist) and Vuzix (using the company's M100 and M300 glasses) with the devices running the Google Glass Enterprise Edition. Reviewing the pilot in 2017, DHL found that introducing the glasses had improved pickers' productivity by 15% and increased accuracy levels. In addition, the AR in the smart glasses had halved the time it took to onboard and train new employees.

DHL announced in May 2019 that the company was introducing the AR-based vision picking program in its warehouses worldwide. Pickers will be using glasses that incorporate the latest generation of Google Glass Enterprise Edition with a heads-up display that shows key parcel information and relays instructions.

The expansion in the use of smart glasses forms part of DHL's digital supply chain strategy, which also involves the use of other wearable devices, drones, and autonomous vehicles. The firm is investing €2 billion in its digitalization strategy, which is running from 2020 to 2025, and is expected to deliver a return of €1.5 billion.

SMART WAREHOUSING COI AND ROI ANALYSIS

ABI Research has conducted an operations assessment of the smart warehousing sectors within the **retail distribution hub** and **3PL** industries, looking at two countries for each sector. ABI Research intended to quantify the ROI, as well as quantify the impact of the COI on warehouse managers. For the comparative analysis of the status quo warehouse, the revenue generated was kept constant in order to investigate the impact of operational cost savings provided by cellular-connected Industry 4.0 solutions.

RETAIL DISTRIBUTION INDUSTRY IN GERMANY AND THE UNITED KINGDOM

Retailers' their distribution centers and regional hubs are cost centers that need to operate as efficiently as possible so that they are not a drain on the firm's balance sheet. Distribution hubs play a vital role for retailers to meet the challenges of their operating environment; this includes enabling firms to evolve from being just physical outlets to omnichannel operations that can offer rapid deliveries to customers.

A key challenge for supporting the omnichannel strategy is readily identifying the contents on pallets and making sure they are in the correct location for distribution. The number of pallets handled annually by each

Tier One warehouse **in the United Kingdom is forecast to reach 15.3 million in 2025, up from 14.2 million in 2018. For Germany, the number of pallets is set to grow to 24.2 million by 2025, up from 22.6 million in 2018.**

The following analysis uses a standard 50,000 m^2 warehouse unit to represent Tier One retail distribution warehouses in Germany and the United Kingdom as the basic unit of analysis. Each "per warehouse" calculation for retail distribution refers to this "Tier One" warehouse measurement. Note that the warehouse in the retail distribution model is a cost center; the profit analysis chart has been replaced with an Operational Expenditure (OPEX) chart, where cellular-connected industry 4.0 serves to reduce OPEX.

GERMANY

DISTRIBUTION, GERMANY			
Per Tier 1 Factory: 2021-2025 (50K m^2)	**Status Quo Warehouse**	**Cellular-connected 4.0 Warehouse**	**Comments**
Revenue	$2,653	$2,653	Revenue kept constant for comparison
Initial Operation Costs	($2,653)	($2,653)	Cost of regular factory & product CapEx & OpEx
Connected Cellular & Industrial 4.0 TCO	-	($6)	Covers deployment of Private Cellular and Industry 4.0 sensors
Operational Cost Savings	-	$355	Efficiency savings from cellular-connected Industry 4.0
Net Cost of Operations	($2,653)	($2,303)	Net impact on costs
Gross Profit		$350	
Gross Profit Margin*	N/A	13.2%	Industry 4.0 impact on gross profit
Cost of Inaction Lost Pallets Handled (000s)	15.9 mil pallets	-	Potential loss in pallets handled for status quo warehouse
Operational Cost Savings ROI	-	$62.1	Indicates how the Cellular 4.0 TCO repays its investment
Percentage COI Impact	-11.6%	-	COI as a percentage of potential revenues (current revenue + COI)
Cost of Inaction Value	**$348**	**-**	Opportunity cost value

All figures in Millions of USD unless otherwise indicated Source: ABI Research
*Gross profit margin for retail distribution warehouse shows 'N/A' as it represents a cost center, and a cellular-connected 4.0 warehouse yields a gross profit margin as operational costs are reduced

Over a 5-year period, a German warehouse operator that adopts private cellular-enabled Industry 4.0 technologies will realize:

- A 13.2% increase in gross profit
- The handling of an additional 15.9 million pallets ($348.4 million)
- An operational cost savings of $355.5 million

Main drivers include the use of:

- Robotics ($132.6 million)
- RTLS/Asset Tracking ($69.6 million)
- Condition-based monitoring of connected equipment ($51.7 million)

The average German retailer spends about 20% of its revenue on warehousing and distribution. With a lucrative retail revenue of US$927 billion in 2019, a German retailer can increase profit margins by investing in Industry 4.0 strategies with a private network, which is calculated to **save it a total of US$355 million in operational cost savings over a 5-year period per warehouse.**

The German retail distribution industry is set to deploy **5,700 sensors and asset tags by 2025 per warehouse**. If German retail distributers do not seize the opportunity to deploy cellular-connected Industry 4.0 warehouse solutions, **the industry stands to lose out on a total US$7.3 billion potential cost savings between 2021 to 2025. The COI on an industry level for Germany amounts to a total of US$133.2 billion in the same 5-year period.**

German retail distributors should look to cellular-enabled Industry 4.0 solutions to maximize the number of pallets handled per warehouse. The COI amounts to a total of **US$348.4 million opportunity forgone per warehouse over a 5-year period**. The German retail distribution industry is set to invest a total of **US$113.7 million between 2021 and 2025** on cellular-based Industry 4.0.

UNITED KINGDOM

DISTRIBUTION, UK			
Per Tier 1 Warehouse: 2021-2025 (50K m²)	**Status Quo Warehouse**	**Cellular-connected 4.0 Warehouse**	**Comments**
Revenue	$1,648	$1,648	Revenue kept constant for comparison
Initial Operation Costs	($1,648)	($1,648)	Cost of regular factory & product CapEx & OpEx
Connected Cellular & Industrial 4.0 TCO	-	($6)	Covers deployment of Private Cellular and Industry 4.0 sensors
Operational Cost Savings	-	$221	Efficiency savings from cellular-connected Industry 4.0
Net Cost of Operations	($1,648)	($1,433)	Net impact on Costs
Gross Profit		$215	
Gross Profit Margin*	N/A	13.0%	Industry 4.0 impact on gross profit
Cost of Inaction, Fewer Pallets Handled	10.0 mil pallets	-	Potential reduction in pallets handled for status quo warehouse
Operational Cost Savings ROI	-	$36.9	Indicates how the Cellular 4.0 TCO repays its investment
Percentage COI Impact	-11.6%	-	COI as a percentage of potential revenues (current revenue + COI)
Cost of Inaction Value	**$216**	**-**	Opportunity cost value

All figures in Millions of USD unless otherwise indicated Source: ABI Research
*Gross profit margin for retail distribution warehouse shows 'N/A' as it represents a cost center, and a cellular-connected 4.0 warehouse yields a gross profit margin as operational costs are reduced

Over a 5-year period, a U.K.-based warehouse operator that adopts private cellular-enabled Industry 4.0 technologies will to realize:

- A 13.0% increase in gross profit margin
- The handling of an additional 10.03 million pallets ($216.5 million)
- An operational cost savings of $220.9 million

Main drivers include the use of:

- Robotics ($82.4 million)
- RTLS/Asset Tracking ($43.3 million)
- Condition-based monitoring of connected equipment ($32.1 million)

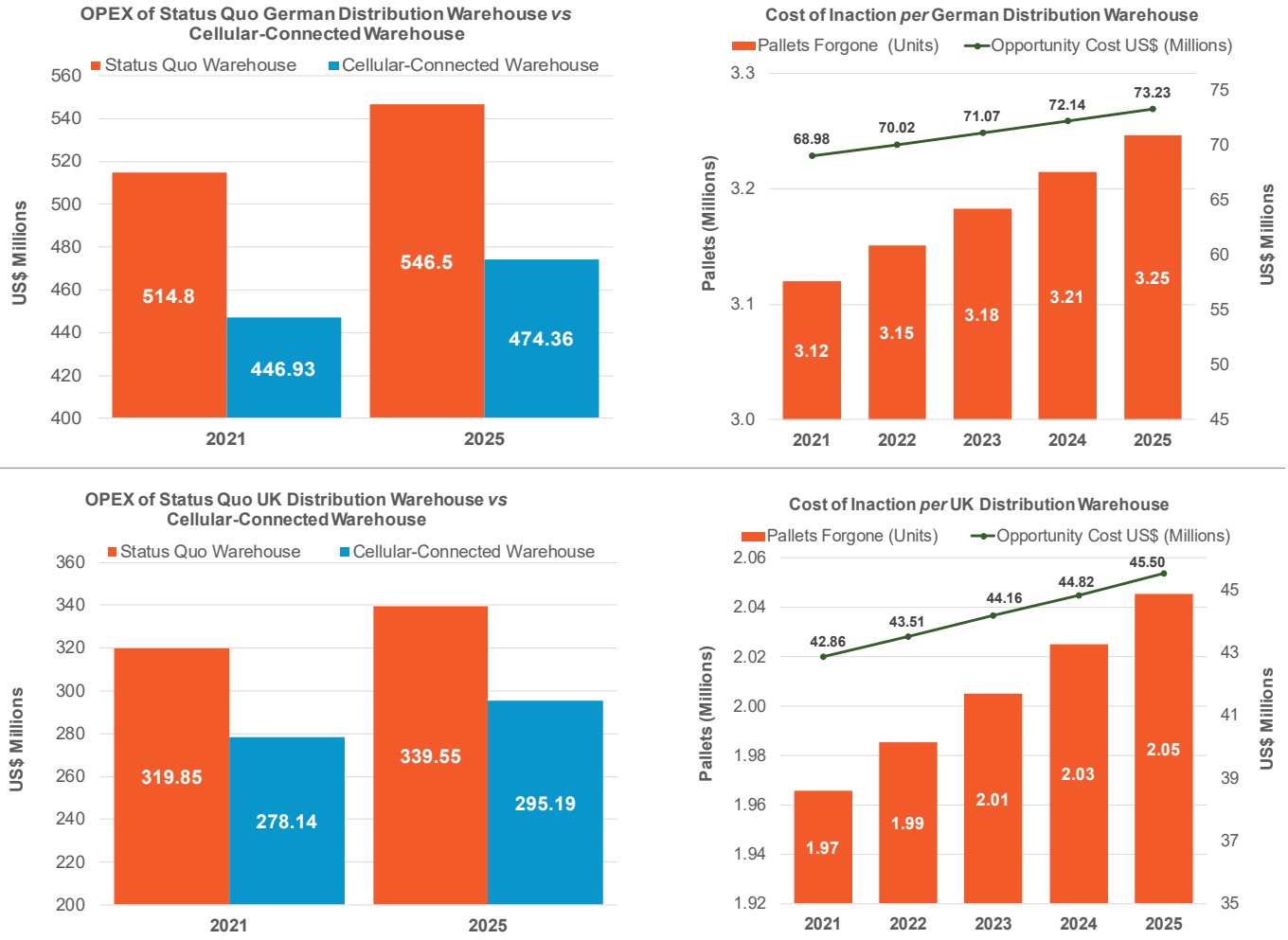
The United Kingdom is set to spend less than Germany on enabling cellular-connected Industry 4.0 warehouse solutions. Investment is expected to total **US$60.9 million between 2021 and 2025**.

The United Kingdom can leverage more economies of scale than German retail distributors. With cellular-enabled Industry 4.0 solutions, the **operational cost savings that the U.K. retail distribution industry will see over the 5-year analysis period is US$221 million for a Tier One retail hub warehouse.**

For a *status quo* Tier One retail hub warehouse, the United Kingdom would forgo an average of US$43.3 million annually in terms of lost opportunity per non-upgraded warehouse. That number increases with each year of inaction. This translates to a **total of 10 million pallets not handled per warehouse** between 2021 and 2025. The COI is equivalent to US$216 million.

Figure 8. Tier One Retail Distribution Warehouse COI and ROI Analysis

(Source: ABI Research)



3PL INDUSTRY IN CHINA AND THE UNITED STATES

In the United States, Amazon's fulfilment centers are exacerbating competition with the company offering 2-hour time delivery slots in many cities. A further challenge is that the number of packages shipped in the United States is forecast to grow only gradually, **from 37 billion in 2018 to just over 40 billion in 2025**. However, facility managers will continue to face the challenge of recruiting and training enough people to meet peaks in demand.

China may have more 3PL warehousing units than the United States (6,000 *versus* 3,100 individual 3PL warehouses, respectively). ABI Research finds that each Tier One 3PL warehouse in China and the United States stands to gain an increase of 880 BPS and 1,190 BPS in gross profit margin, respectively, if they implement Industry 4.0 applications based on a foundation of cellular connectivity for their warehouses.

The following analysis uses a 150,000 m² warehouse unit to represent Tier One 3PL warehouses in China and the United States as the unit of analysis.

CHINA

3PL, CHINA			
Per Tier 1 Warehouse: 2021-2025 (150K m²)	**Status Quo Warehouse**	**Cellular-connected 4.0 Warehouse**	**Comments**
Revenue	$2,213	$2,213	Revenue kept constant for comparison
Initial Operation Costs	($1,837)	($1,837)	Cost of regular factory & product CapEx & OpEx
Connected Cellular & Industrial 4.0 TCO	-	($14)	Covers deployment of Private Cellular and Industry 4.0 sensors
Operational Cost Savings	-	$210	Efficiency savings from cellular-connected Industry 4.0
Net Cost of Operations	($1,837)	($1,641)	Net impact on costs
Gross Profit	$376	$572	
Gross Profit Margin	17.0%	25.8%	Industry 4.0 impact on gross profit
Cost of Inaction, Fewer Packages Shipped)	6.80 mil packages	-	Potential reduction in packages shipped for status quo warehouse
Operational Cost Savings ROI	-	$13.5	Indicates how the Cellular 4.0 TCO repays its investment
Percentage COI Impact	-8.5%	-	COI as a percentage of potential revenues (current revenue + COI)
Cost of Inaction Value	**$206**	**-**	Opportunity cost value

All figures in Millions of USD unless otherwise indicated Source: ABI Research

Over a 5-year period, a Chinese 3PL provider that adopts private cellular-enabled Industry 4.0 technologies will realize:

- An 8.8% increase in gross profit margin
- The shipment of an additional 6.8 million packages ($206.1 million)
- An operational cost savings of $210.3 million

Main drivers include the use of:

- Robotics ($57.9 million)
- Condition-based monitoring of connected equipment ($38.1 million)
- RTLS/Asset Tracking ($36.7 million)

This rise of e-commerce within the region would greatly contribute to the demand for storage space and modernized warehousing to cope with increased Stock Keeping Unit (SKU) counts and sales volume. Chinese 3PLs are projected to **ship a total of 319 billion packages between 2021 and 2025** on a country level.

Industry 4.0 tools, such as inventory management and asset tracking, should benefit the 3PL provider. For a Tier One provider, **total cost of ownership over the 5-year forecast period is estimated at US$14 million**. That investment in inventory management analytics software, asset tracking, CBM, *etc*. should **generate US$210 million in operational cost savings** over the same period.

Warehouses with limited automation often struggle to meet higher throughput needs, resulting in operational "friction" or the COI. **For a Tier One 3PL warehouse to maintain the *status quo*, the COI is US$206 million over a 5-year period**. Adjusting the analysis to account for the full range of 3PL operators, the lack of innovation would equate to **US$72 billion** over the 5-year forecast period.

UNITED STATES

3PL, USA			
Per Tier 1 Warehouse: 2021-2025 (150K m²)	**Status Quo Warehouse**	**Cellular-connected 4.0 Warehouse**	**Comments**
Revenue	$1,946	$1,946	Revenue kept constant for comparison
Initial Operation Costs	($1,654)	($1,654)	Cost of regular factory & product CapEx & OpEx
Connected Cellular & Industrial 4.0 TCO	-	($17)	Covers deployment of Private Cellular and Industry 4.0 sensors
Operational Cost Savings	-	$248	Efficiency savings from cellular-connected Industry 4.0
Net Cost of Operations	($1,654)	($1,423)	Net impact on costs
Gross Profit	$292	$523	
Gross Profit Margin	15.0%	26.9%	Industry 4.0 impact on gross profit
Cost of Inaction, Fewer Packages Shipped	6.02 million packages	-	Potential reduction in packages shipped for status quo warehouse
Operational Cost Savings ROI	-	$13.8	Indicates how the Cellular 4.0 TCO repays its investment
Percentage COI Impact	-11.1%	-	COI as a percentage of potential revenues (current revenue + COI)
Cost of Inaction Value	**$243**	**-**	Opportunity cost value

All figures in Millions of USD unless otherwise indicated Source: ABI Research

Over a 5-year period, a U.S.-based 3PL provider that adopts private cellular-enabled Industry 4.0 technologies will realize:

- An 11.9% increase in gross profit margin
- The shipment of an additional 6.02 million packages ($243.2 million)
- An operational cost savings of $248.17 million

Main drivers include the use of:

- Robotics ($53.8 million)
- Condition-based monitoring of connected equipment ($48 million)
- RTLS/Asset Tracking ($43 million)

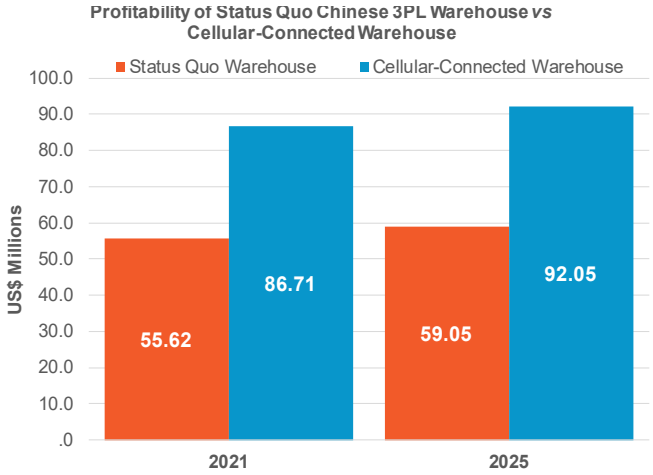
U.S. 3PL companies are estimated to demonstrate heavy initiatives (relative to China) in digitalizing their warehouses. These companies plan to implement **9,800 sensors** and asset tags per Tier One warehouse by 2025 to cope with a total of **47 million packages to be shipped per warehouse between 2021 and 2025**.

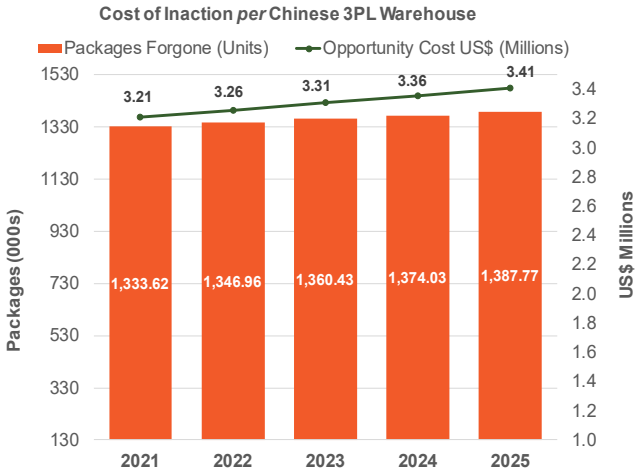
For a Tier One provider, **total cost of ownership over the 5-year forecast period is estimated at US$17 million**. That investment in inventory management analytics software, asset tracking, CBM, *etc*. should **generate almost US$250 million in operational cost savings** over the same period' for a net increase in gross profit of approximately US$230 million over the 5-year period.

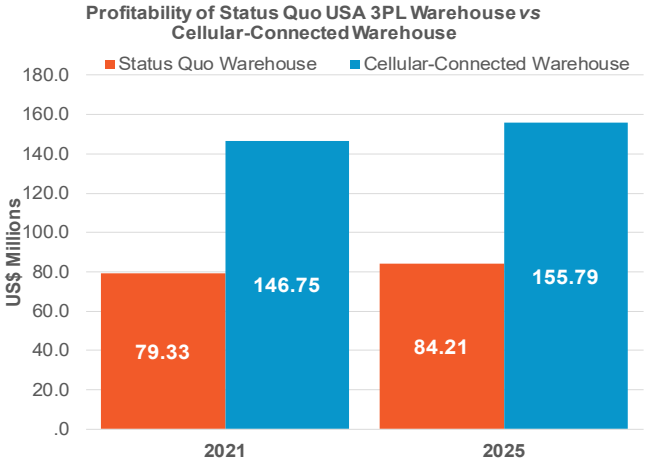
The 5-year **COI of the entire U.S. 3PL industry** stands to be **US$10.2 billion** and the potential **loss of packages shipped would amount to about 1.5 billion**. The Cost of Inaction for a tier one 3PL provider that chose to maintain the status quo and not upgrade to connected cellular industry 4.0 would be equivalent to US$243 million.

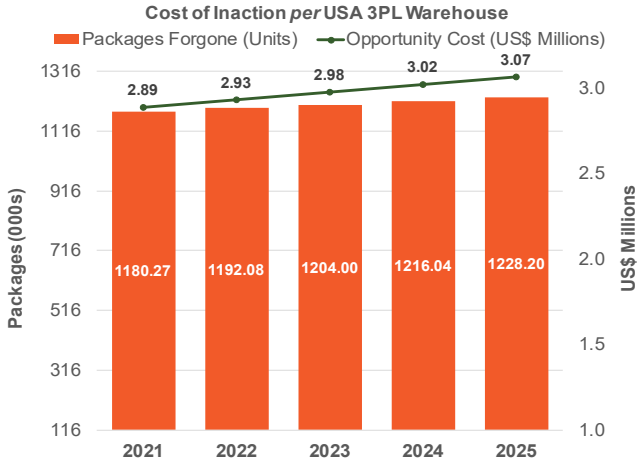
Figure 9. Tier One 3PL Warehouse COI and ROI Analysis

(Source: ABI Research)









SUMMARY AND RECOMMENDATIONS

The ROI/COI analysis provides a number of insights into smart manufacturing and smart warehousing operations management. High value, complex manufactured products that require the supply of multiple, interdependent component parts are ripe for operational cost saving efficiencies through Industry 4.0.

- **Overall Impact of Cellular-connected Industry 4.0**
  - **Operational Cost Savings ROI:** Across the 4 verticals and 8 markets, Operational Cost Savings Return on Investment averaged 28X over the 5-year period of analysis. Being able to deploy modular, flexible command and control sensors and tags allows the manufacturer as well as the warehouse manager to streamline operations, reduce downtime and ensure equipment and personnel are in the right place at the right time.
  - **Gross Profit Lift:** Across the 8 country scenarios, Gross Profit was lifted by an average 8.9%. The Gross Profit Lift was highest for retail distribution hubs (~13.1%) and 3PL Providers (10.3%). Being able to streamline the operational management of packages/pallets, the personnel looking after the packages/pallets as well as the trucks, vans, forklift trucks, etc. can reduce OpEx. Automotive and electronic product manufacturers also generated Gross Profit increases (ave. 6.2%) but it is lower due to existing gains made in the sector as well as the more fixed assembly processes involved.
  - **Percentage COI Impact:** The Percentage Cost of Inaction Impact was -8.3% for a status quo manufacturer or warehouse. The CoI percentage reflects the opportunity cost of falling behind the innovators. Competition waits for no one. Clearly manufacturers and warehouse operators will need to perform in-depth financial and logistical assessments but there is an opportunity cost to inertia.
- **Automotive Vehicle Manufacturing:** For the major automotive brands, the factory footprint tends to be very substantial (the VW factory in Wolfsburg, Germany, is 6.5 million m^2), which lends itself to Industry 4.0 cellular connectivity solutions that can make manufacturer equipment and infrastructure more modular and flexible. In particular, robotics, CBM, and asset tracking have been prominent areas for investment. The COI for an automotive manufacturer can incur ample opportunity costs. From ABI Research's analysis, over a 5-year period, a Tier One automotive factory measuring 500,000 m^2 in Germany could incur a cost of inaction equivalent to 17,500 vehicles or US$495 million in monetary terms.
- **Electronic Goods & Component Manufacturing:** This sector has similar wide-ranging requirements as the automotive sector. While there is often a diverse ecosystem of product and component factories (more than 5,900 in the United States, 4,600 in Japan), the Tier One electronic goods manufacturers often have a footprint of 200,000 m^2 and above. High degrees of automation have been implemented by most electronics manufacturers, but the increasing diversity of electronic product SKUs and maturing markets mean electronic production will need shorter runs, requiring alternative supply inventories. A Tier One electronics product manufacturer in Japan that fails to adopt connected cellular Industry 4.0 solutions could forgo the production equivalent of US$640 million according to ABI Research's analysis of the manufacturer's operations potential from 2021 to 2025. In the United States, the cost of inaction for the same time frame is US$1 billion.
- **3PL:** In China and the United States, there are more than 5,800 and 3,000 3PL firms, respectively, that cover the national, regional, and local delivery markets. 3PL firms already have a number of tethered or short-range tracking solutions using barcodes and scanners. Furthermore, the organization and dispatch of personnel and company vehicles needs optimization. The degree of cost optimization is more limited due to the reduced complexity inherent in 3PL compared to automotive or electronics manufacturing, but ABI Research does anticipate that operational cost savings will add up to US$248 million over a 5-year period for a Tier One 3PL warehouse in the United States or US$210 million for a Chinese Tier One 3PL warehouse.
- **Retail Distribution Warehousing:** Retail distribution warehousing has a number of operational commonalities with 3PL. However, retail goods may experience varying degrees of storage on-site, as well as often being moved to a more localized store room or warehouse. Theft and loss due to accidental damage can affect profit margins. Improvements in inventory management, deployment of asset tags, and personnel-centric tracking can help streamline operations. In the case of a Tier One retail distribution warehouse in the United Kingdom, up to 10 million pallets of goods could be more effectively managed over a 5-year time frame (2021 to 2025). By not implementing connected cellular Industry 4.0, retailers managing distribution centers could incur losses of US$216 million, which is effectively the COI.

CONCLUDING RECOMMENDATIONS

ABI Research's recommendations for smart manufacturing and warehousing establishments include:

- **Embrace Wireless Cellular Connectivity:** Connectivity is crucial for the operation of an automated warehouse because it enables the hardware infrastructure, robots, systems, and controls to connect to a mission-critical WCS or WMS. The same is true for manufacturing. Historically, this was achieved through industrial Ethernet or Wi-Fi. However, device density is a major limitation of Wi-Fi and other wireless connectivity based on unlicensed spectrum. A small number of devices in a trial might work on Wi-Fi, but when you add more devices to go into production, you will hit the limits of Wi-Fi. Furthermore, cellular-based modules and chipsets are being produced at a lower price-point than WiFi. The proliferation of mobile and connected assets in manufacturing and supply chain operations calls for more robust wireless connectivity solutions. This is being driven by the economies of scale within cellular.
- **Optimize Deployments of Private Cellular:** Manufacturing and warehouse managers can optimize the deployment of additional APs in relation to the gateways to either boost coverage or indeed the link budget with a cluster of sensors and tags in a particular area of the factory/warehouse.
- **Meet with Various Stakeholders:** The automotive industry carries a weight of publicity, volume, complexity, and national pride that most other industries do not. In some cases, this means navigating health and safety regulations, especially around cobots or AR on the production line. In other cases, it could mean the government directly invests in or subsidizes the industry. But across the board, alignment is key.
- **Prioritize the Business Case:** Manufacturers are looking to reduce the cost of output by modernizing and compacting their sites, but neither these companies nor their suppliers will gamble on unproven technologies when it comes to live production. This is especially true in industries where the cost of a missed opportunity and the loss of productivity come at a much higher price.
- **Think Holistically:** Businesses and enterprises should remember to carry out not just a **ROI assessment**, but also a COI assessment. ROI is an effective financial tool to quantify the financial effectiveness of capital, assets, tools, and personnel, but the firm should also assess the COI impact. The COI assesses the impact of inefficiencies and downtime on operational processes that quantifies the opportunity costs.

GLOSSARY

Technical Definitions

Acronym	Definition
3PLs	Third-Party Logistics
AI	Artificial Intelligence
AMR	Autonomous Mobile Robots
AP	Access Point
AR	Augmented Reality
CAD	Computer-Aided Design
CBM	Condition-Based Monitoring
CNC	Computer Numeric Control
CRM	Customer Relationship Management
eMBB	Enhanced Mobile Broadband
EPC	Evolved Packet Core
GD&T	Geometric Dimensioning and Tolerancing
GDP	Gross Domestic Product
HMI	Human-Machine Interface
IIoT	Industrial Internet of Things
IoT	Internet of Things
IT	Information Technology
Kbps	Kilobits per Second
LiDAR	Light Detection and Ranging
LPWAN	Low-Power Wide-Area Networks
LTE	4G Technology
M2M	Machine-to-Machine
Mbps	Megabits per Second
MCPTT	Mission-Critical Push-To-Talk
MES	Manufacturing Execution System
ML	Machine Learning
mMTC	massive Machine-Type Communications
ms	Milliseconds
NSA	Non-Standalone (for 5G deployments on existing 4G infrastructure)
OEE	Overall Equipment Effectiveness
OEM	Original Equipment Manufacturer
OT	Operational Technology
PLC	Programmable Logic Controller
PLM	Product Lifecycle Management
PMI	Purchasing Manager's Index
QoS	Quality of Service
ROI	Return on Investment
RTLS	Real-Time Location System
SA	Standalone (for 5G deployments)
SIM	Subscriber Identity Module
SLAM	Simultaneous Localization and Mapping
SLAs	Service-Level Agreements
SMEs	Small-Medium Enterprises
TSN	Time-Sensitive Networking
URLLC	Ultra-Reliable Low Latency Communications
WES	Warehouse Execution System
WMS	Warehouse Management System

APPENDIX

Methodology

ABI Research wished to conduct an operations assessment of the smart manufacturing and smart warehousing sectors within the automotive, electronic goods, retail distribution hub, and Third-Party Logistics (3PL) industries. ABI Research intended to quantify the Return on Investment (ROI), as well as quantify the impact of the Cost of Inaction (COI) on manufacturers and warehouse managers.

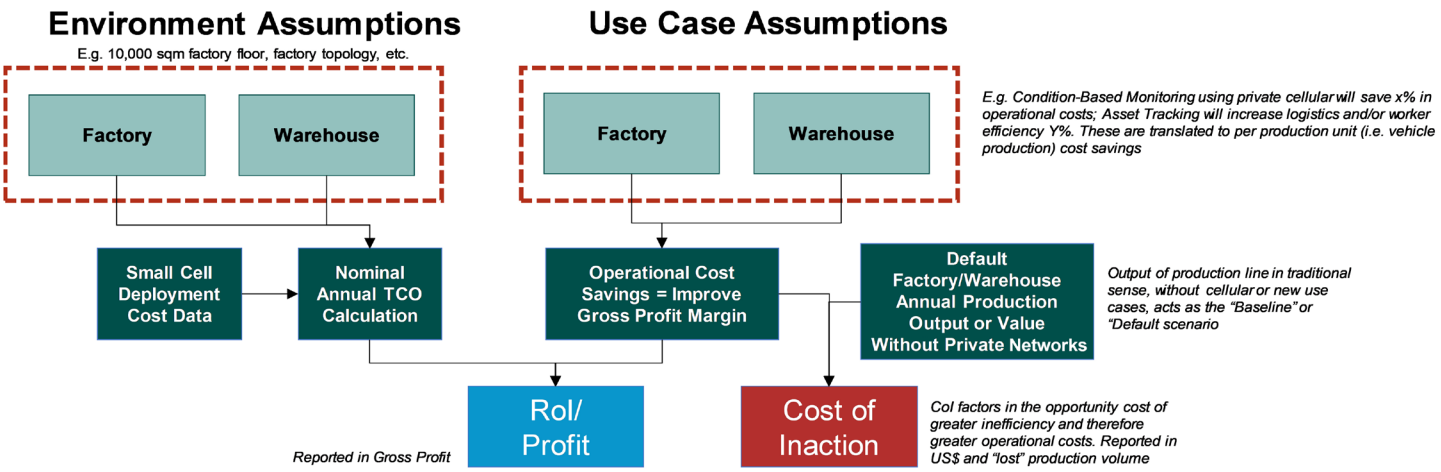
Private cellular networks, based on 4G LTE and 5G, enable not just a private broadband mobility network on the factory floor and/or in the warehouse, but also enable a diverse set of Industry 4.0 tools. These include Condition-Based Monitoring (CBM), Real-Time Location System (RTLS)/asset tracking, inventory management, Augmented Reality (AR)/smart glasses, wearables, building automation, and robotics. ABI Research used the following methodology to quantify not just the operational cost savings from integrating Industry 4.0 tools into the industrial workflow process, but also what would be the opportunity COI.

Key considerations for the reader:

- Any commentary or analysis that refers to "per factory" or "per warehouse" analysis refers to a "Tier One factory" or "Tier One warehouse."
- The size dimensions for Tier One factories and warehouses for each application have been defined in the Glossary above.
- For a country-level analysis, the calculations of an average factory or warehouse are rolled up to the country level.
- In the country ROI/COI summary tables, **revenue for the *status quo* and cellular-connected Industry 4.0 factory/warehouse are kept constant** to act as a baseline (aka constant factory output) so that the operational savings from cellular-connected Industry 4.0 solutions can be seen in the profit & loss analysis. It ensures there is no double counting in the analysis. If the factory or warehouse were running at full operational capacity (all of the time), then additional revenue generation could be found, but it is more transparent to see how streamlining and downtime reduction help to maximize the utilization of factory/warehouse infrastructure and personnel resulting in reduced OPEX and, therefore, improved profits.

Figure 10. Private Cellular Industry 4.0 Financial Analysis (ROI & COI) Methodology

(Source: ABI Research)



General Financial and Technical Definitions

COI	The **Cost of Inaction** assesses how far behind the baseline manufacturers will fall behind Industry 4.0-enabled manufacturers. To make this more meaningful, ABI Research is reporting this in the net difference in the volume of units (e.g. vehicles) produced over 5 years. This figure is then multiplied by today's pricing (2019) to establish value. This report excludes sales and administrative expenses to drill down to the operational expenses related to the running of the factory
ROI	**Return on Investment** = (Gain from Investment – Cost of Investment) / Cost of Investment; Cost of Investment includes both Capital Expenditure (CAPEX) and Operational Expenditure (OPEX)
BPS	**Basis Points**; the incremental change in percentage values reported. One hundredth of one percentage point
Status Quo Factory/Warehouse	This factory/warehouse serves as the Baseline for the comparative analysis. It is fully able to produce the product/service in question (e.g. vehicles)
Connected Cellular & Industrial 4.0 Factory/Warehouse	In the upgraded scenario, the factory/warehouse has invested in private cellular gateways and small cell access points to provide coverage within the industrial space. Cellular-enabled sensors and tags are then deployed to enable Industry 4.0 services. OpEx is also factored in.
Tier One Factory	For automotive manufacturing, refers to a 500,000 m^2 factory; for electronics manufacturing, refers to a 200,000 m^2 factory
Tier One Warehouse	For retail distribution, refers to a 50,000 m^2 warehouse; for 3PL, refers to a 150,000 m^2 warehouse

Key Definitions Used in Analysis Tables and Charts

Revenue	For the comparative analysis of a status quo factory/warehouse versus a cellular-connected Industry 4.0 factory/warehouse, revenues were kept constant for comparison. I.e. for constant factory output
Initial Operation Costs	This relates to any investment and running costs associated with the main fabric of the building as well as regular hardware, equipment and personnel costs of operating the factory/warehouse
Connected Cellular & Industrial 4.0 TCO	Covers deployment of Private Cellular and Industry 4.0 sensors. This is to upgrade the capabilities of the factory/warehouse with LTE (or 5G) equipment as well as sensors for CBM, asset tracking, wearables, etc.
Operational Cost Savings	Cellular-connected Industry 4.0 solutions listed in this white paper serve the purpose of reducing downtime and delivering operational efficiencies. The aggregate impact is reported here
Net Cost of Operations	Net impact on Costs. Takes into account the Operational Cost Savings.
Gross Profit	Revenue minus cost of operations
Gross Profit Margin	(Revenue minus cost of operations)/revenue. In percentage
ProductX Production	ProductX in the case of Automotive is the "Vehicle". For the electronics segment it is electronic goods. This is the opportunity cost value of inaction for the status quo manufacturer/warehouse. It is based on the additional profit the Connected Cellular Industry 4.0 factory/warehouse generates over 5 years divided by the ASP of the products produced (or handled) by the factory/(warehouse)
Cost of Inaction Value	This is the financial value of inaction. This is calculated based on the volume of ProductX produced over the 5 years and based in today's (2019) prices.
Operational Cost Savings ROI	Indicates how the Cellular 4.0 TCO repays its investment. This is calculated based on (Operational Cost Savings minus Cellular 4.0 TCO)/Cellular 4.0 TCO
Gross Profit Lift	In percentage. Comparative increase in profitability of the Cellular 4.0 Factory. Referred to in the text.
Percentage COI Impact	COI as a percentage of potential revenues (Current Revenue + COI). COI is effectively "forgone" operational savings that could have been purposed for the production of (e.g.) vehicles, etc.) and therefore converted into (additional) revenue.

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