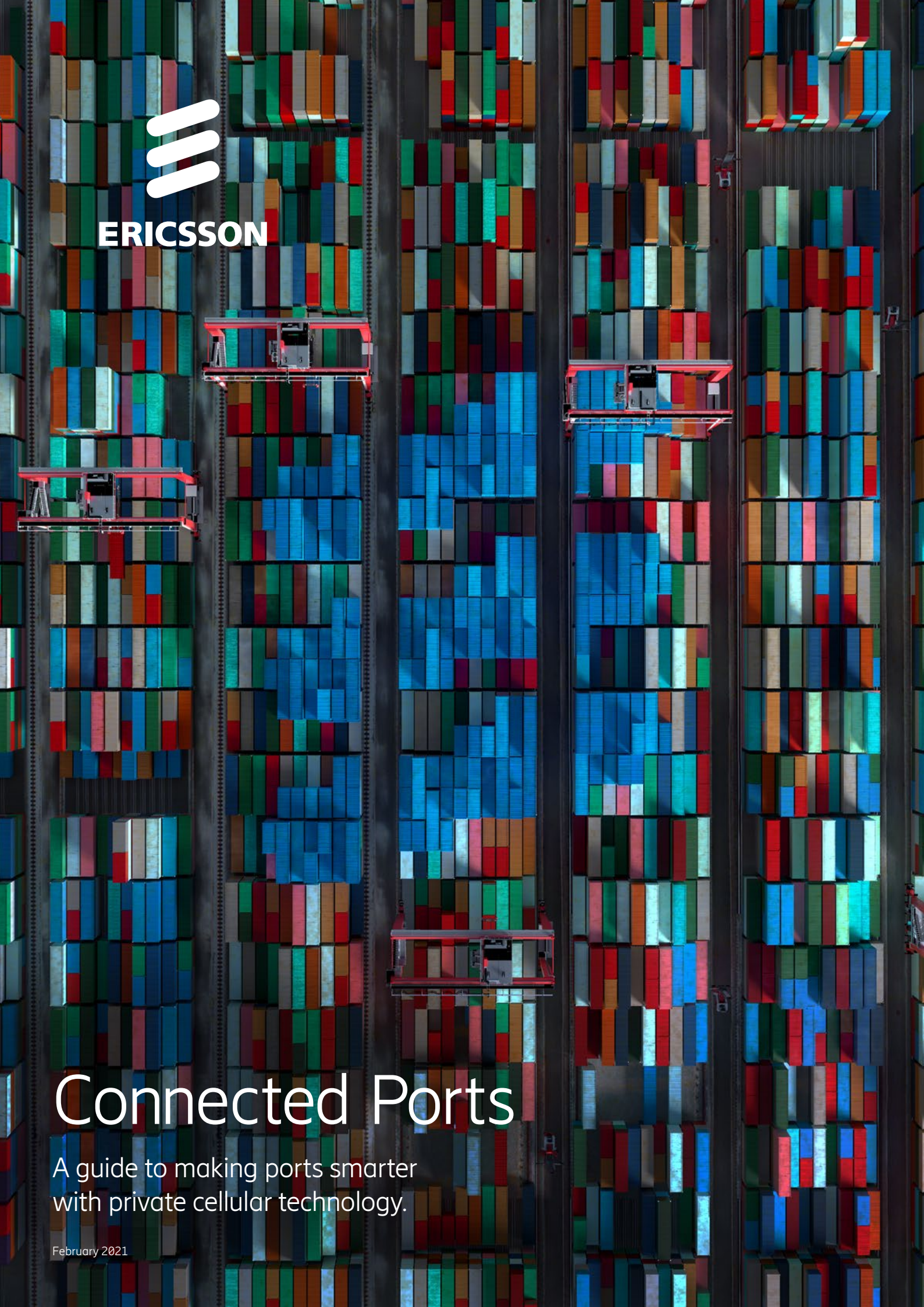


ERICSSON

Connected Ports

A guide to making ports smarter with private cellular technology.

February 2021

In this report

This is a joint report by Ericsson, ifm, and Arthur D Little. It examines and quantifies the potential value of private cellular networks for the ports industry.

Keeping the world's goods flowing

Ports and shipping are vital for a well-functioning global economy.

According to the World Bank, in 2019 trade represented more than 60% of the global gross domestic product (GDP).

Data from The International Chamber of Shipping reveals that shipping plays by far the largest part in this, facilitating roughly 90% of the world's trading.

The ports of the world literally keep its goods flowing.

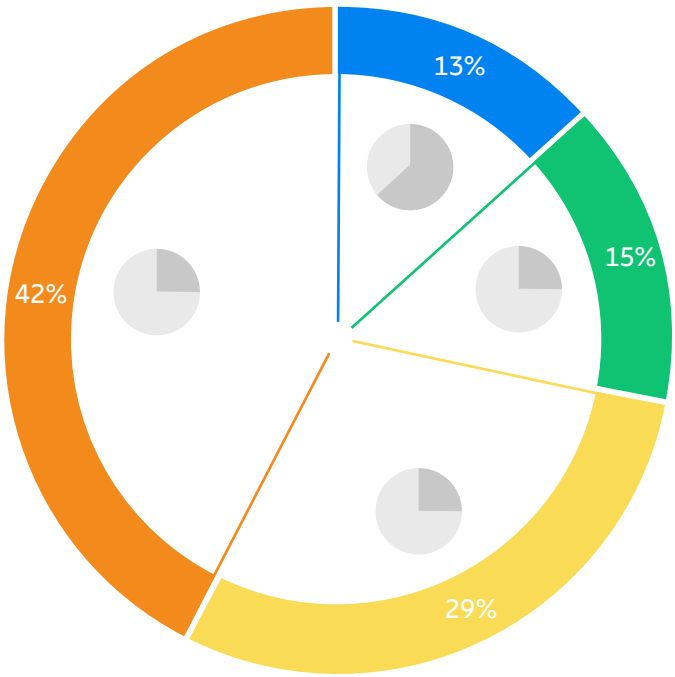
Introduction

World merchant vessel fleet – by type*

- Container ships (13%)
- Oil tankers (29%)
- Bulk carriers (42%)
- Others (15%)

Smart Port maturity**

- Low maturity
- High maturity



*The percentages are from UNCTAD (United Nations Conference on Trade and Development) link: https://stats.unctad.org/handbook/MaritimeTransport/MerchantFleet.html

**Maturity is assessed based on degree of automation and deployment of smart solutions by Arthur D. Little through industry expert discussions.

Today's ports are designed to support specific types of vessels, and there are four main types of shipping vessels:

- Oil
- Bulk cargo (carrying coal, iron, grain)
- General cargo
- Globally standardized containers

The last of these carries most of the world's non-bulk items.

Several ports have successfully added automation elements over the years. But due to factors such as long equipment exchange cycles, smart port maturity is advancing at quite a slow pace.

The maturity of a typical current-day smart port is based on the number of smart solutions it has in operation.

Because they have a standardized and consistent cargo type, container ports have to date made the most strides in automation, and as a result will be the focus of this study.

The ports sector

Charting the course to smarter ports

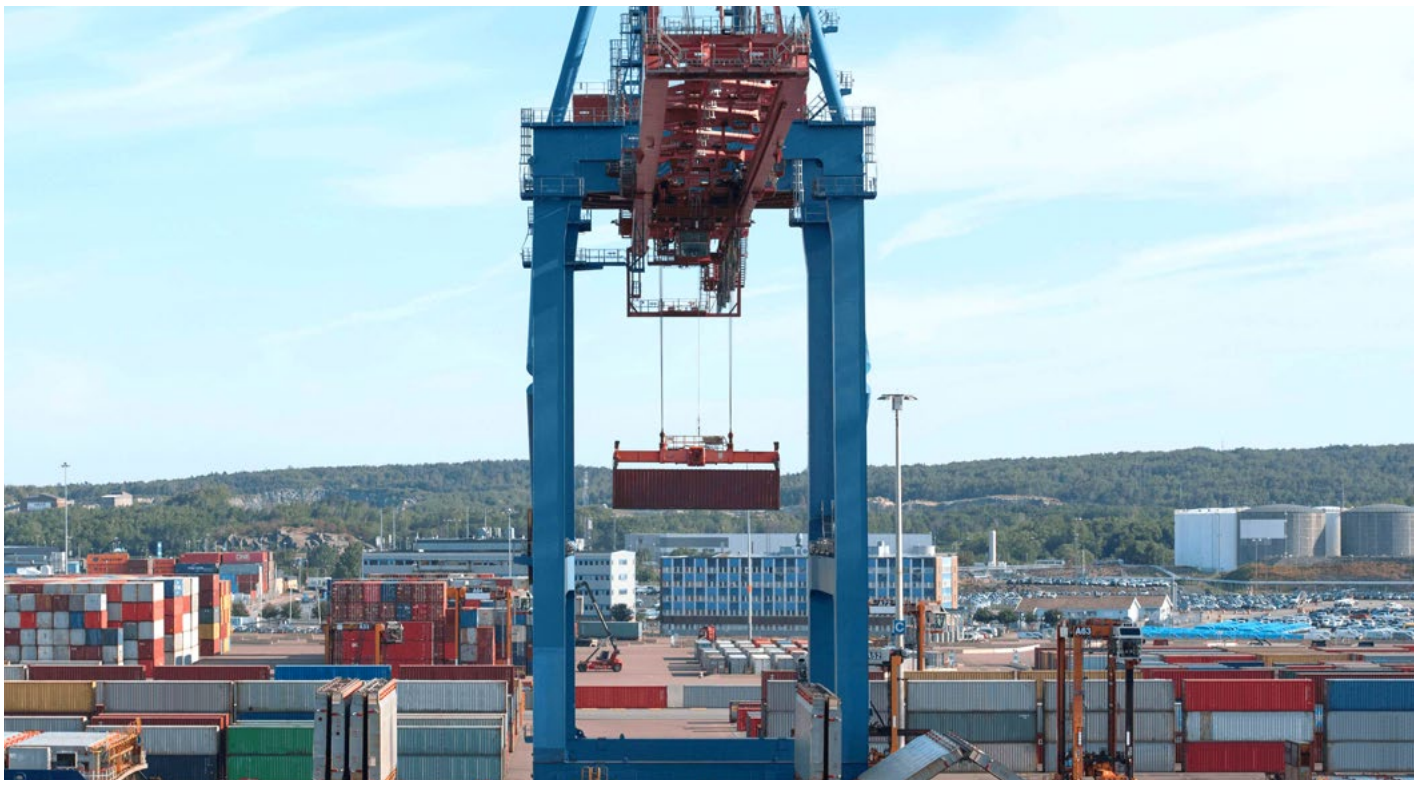
There are around 2,000 ports in the world, with Asia leading the way in shipping. Data from Drewry Maritime Research shows that Asia loads and unloads the highest volume of cargo. Additionally, four out of five of the world's largest terminals are located in Asia, as are its 10 largest container ports.

The shipping industry has experienced recent growth and that trend is set to continue in the coming years. In its 2020 Investor presentation, Cargotec indicated a compound annual growth rate (CARG) of 3.6% for the global container throughput from 2013 to 2024.

The European Union predicts high growth potential in ports, with the European Commission projecting that the amount of cargo handled by EU ports will increase 50% by 2030.

But to accommodate this growth in traffic, ports will need to become more efficient and more automated.

The ports sector



Historically, ports operated independently and there was little international collaboration, but that has changed in recent decades.

Instrumental to this change was containerization in the 1980s. With a globally standardized container, international alliances could enable ports to co-ordinate together and create more automated processes.

Port operators are growing more interested in the benefits and efficiencies gained through connected facilities. In the past, operators have tried various solutions. But it's been challenging to provide the required high quality connection that allows the management of a high density of devices in a mature smart port.

The five largest marine terminal operators in the world are:

1. PSA International (Singapore)
2. Hutchison Ports (Hong Kong)
3. China Cosco Shipping (China)
4. DP World (Dubai)
5. APM Terminals (Netherlands)

Combined, they handle more than 30% of the world's throughput, according to Alphaliner.

Industry challenges

Navigating stormy waters

Ports face several challenges which must be overcome if they are to progress into a more connected world.

Container shipping is having to grow to keep up with demands in consumer and industrial trade as a result of increasing populations and economic development. This growth places greater pressure on ports to be more efficient and sustainable, as well as offer more competitive pricing to keep attracting major shipping lines. According to a Navis survey in Ports Technology, 67% of port operators see reducing operating costs as their priority.

Container ships themselves are also increasing in size. And the emergence of ultra-large container vessels are causing ports to be built larger and deeper to be able to accommodate these bigger ships.

Industry challenges

Four challenges facing the world's ports

Running a tighter ship

The world's ports only have a limited amount of yard space. So as both the volume of shipping trade and the size of vessels increase, ports are being forced to look at how best to utilize their assets. According to Port Technology, 76% of port operators see optimizing yard and terminal operations as their number one priority and challenge.

This makes it imperative to reduce equipment failures and downtime of critical equipment like cranes. According to the European Commission, 22% of port operators believe better asset monitoring can help overcome business and economic challenges.

Unlocking the gridlock

A congested yard is a problematic one. Yard congestion creates not only inefficiencies, but also more environmental impact. Congestion is being compounded by increasing demand as a growing number of vessels and trucks need access to a limited space.

A shortage of port pilots is also creating longer waiting times for boats to be unloaded. According to the data from COREALIS case study in Ericsson's Port of the future report, vessels spend around 36 hours at the dock as they're unloaded and reloaded. And while any ship or vehicle is waiting, their engines are idling, and emitting CO_2.

This problem can be solved with digitalization, which would make this process faster and more efficient, cutting yard congestion and its environmental impact.

People-friendly ports

Along with making their processes run smoother, increasing worker safety is a top concern for ports. Working amongst heavy cargo, dangerous equipment and many other hazards puts port workers at daily risk of injury.

Based on 2018 data from the European Maritime Safety Agency (EMSA), almost 42% of marine casualties or incidents took place in the port area.

But as more ports introduce automation elements that keep workers safe, the need for technology and engineering skills will grow. According to research from McKinsey, 75% of port operators with experience of automation believe that a skills gap is an issue.

Getting greener by getting smarter

Environmental efforts are persuading organizations to use more sustainable transport methods like the sea, rather than the air. Regulatory bodies are requiring ports to reduce their greenhouse gas emissions, as seen in 2016's Paris Agreement, which along with scientific recommendations, are mandating ports cut their emissions in half by 2030.

While a reduction of this nature will come from the sum of many measures taken, every effort will help. For example, with 5G technologies at the Port of Livorno, the COREALIS project estimates an 8.2% reduction in CO2 as a result of improved yard movements in the container terminal processes and KPIs.

"5G technologies at the Port of Livorno led to an estimated 8.2% reduction in CO2 as a result of improved yard movements."

Creating Ports 4.0

Getting on board with Ports 4.0

The many benefits of automation are becoming increasingly clear to port operators.

They are realizing that they can improve all aspect of operations; greater efficiency, lower costs, better monitoring, and increased safety. All of these lead to higher productivity, safer operations, and those all-important stronger bottom lines.

Previous attempts of automation relied on technologies that can no longer handle the bandwidth, device density, and latency capabilities required by today's advanced solutions.

One thing for sure is that port operators can no longer bridge the gap with costly and inflexible legacy technologies like WiFi, Bluetooth, or physical cables.

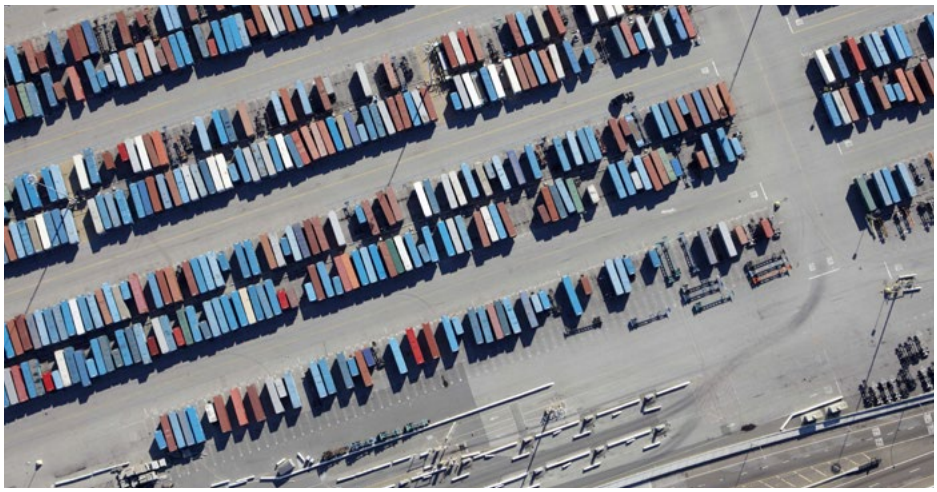
To forge the digitally connected ports of the future, a much more powerful connectivity technology is needed.

"Port operators can no longer bridge the gap with costly and inflexible legacy technologies like WiFi, Bluetooth, or physical cables."

Cellular networks

Cellular: at the helm of smart ports

Cellular networks are the connecting force that is helping steer ports towards the future.



Cellular is the gateway

5G cellular technology is the key tool needed to create a smart port and lay the foundation for using IoT in industrial automation.

Cellular enables mission-critical communication services like voice and data capabilities. These help to prevent injury to workers by keeping them physically distant from potential hazards.

The complete solution

5G is well optimized for IoT, ensuring low energy usage, increased data security, and the ability to support high connection density.

In contrast to legacy networks, 5G provides a complete connectivity solution for licensed and unlicensed spectra, as well as seamless cellular vehicle-to-everything (c-v2x) communication.

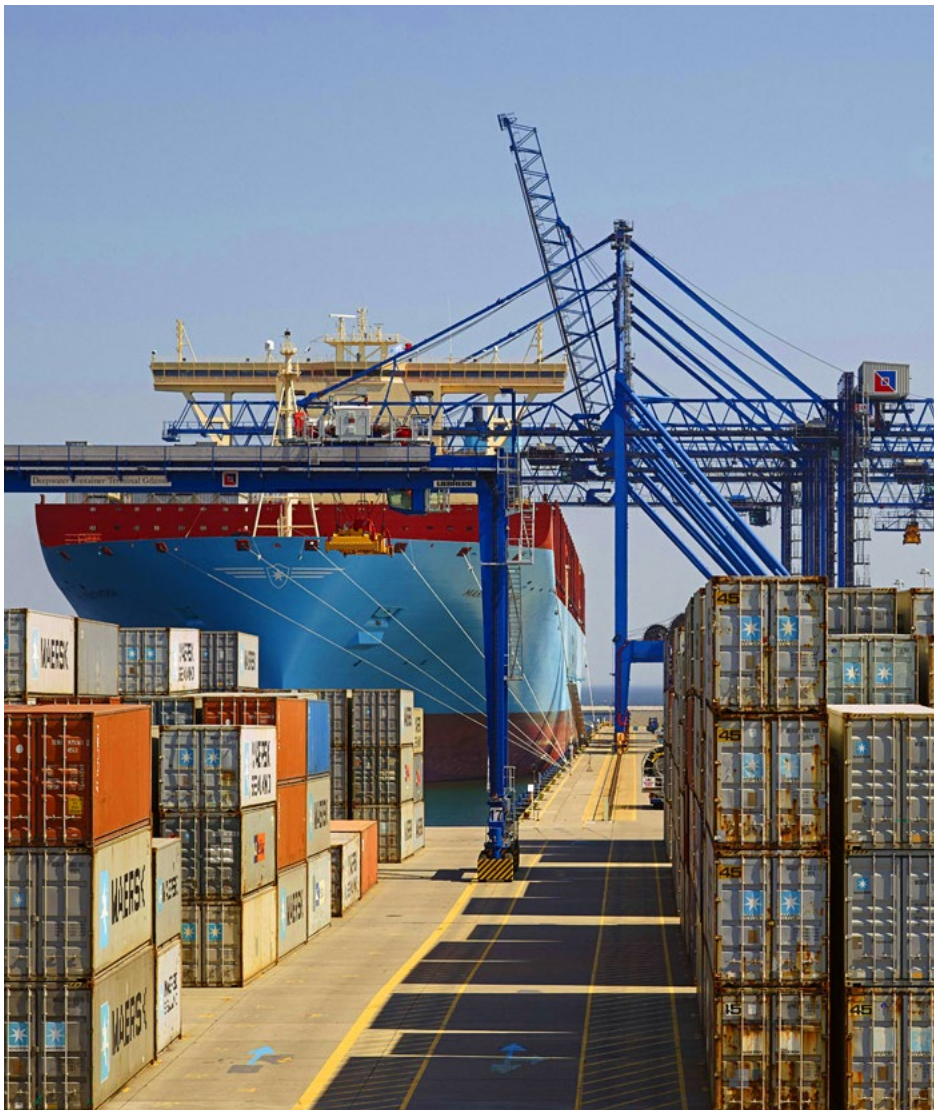
The complete solution allows port operators to only use one backhaul for all services instead of installing several pieces of network equipment on, for example, a crane.

Private cellular networks

Private networks deliver the goods

What is a private network?

- An on-premises cellular network deployed for an organization's exclusive use.
- In ports, this typically includes loading and unloading, stacking, monitoring and surveillance.
- Most private cellular networks today are 4G LTE networks with 5G-ready capabilities. Private networks based on 5G cellular technology are expected to become widely available by 2021.



A smart port's network infrastructure has to be able to handle the large amounts of data that is generated by cranes, vehicles, equipment, and workers.

For example, when operating via remote control, the network produces and transmits a live video feed to a remote operations center, which demands a reliable, high-bandwidth connection.

Providing the highest possible level of connectivity, a 5G-ready private cellular network can provide everything needed to successfully deploy our five use cases.

Use cases

Our five smart ports use cases

What follows are five use cases that our research, in partnership with ifm, have identified as the most beneficial applications for smart port technologies. In each case, we identify how it would benefit the baseline port described on the next page.

This is not an exhaustive list: there are many other use cases that can benefit smart ports, but the five we've chosen are:

1. Remote-controlled ship-to-shore cranes
2. Automated rubber tired gantry cranes
3. Automated guided vehicles
4. Condition monitoring
5. Drones for surveillance and deliveries

Methodology

Since 2017, Ericsson, in collaboration with Arthur D. Little, has released a series of studies examining the value that cellular connectivity and 5G can create for industries.

In this study, we've extended the collaboration to include industry leader ifm, with the aim to further crystalize insights in smart ports.

For this report, five use cases have been selected as potential starting points in the smart port journey. The use cases span the entire container port operation chain and are the most important and relevant cases for the cellular-powered smart port.

To gauge the net economic, social, and environmental value, we defined a baseline port based on concrete and validated KPIs from actual ports and then analyzed from the bottom up, the incremental value created by each cellular connectivity-enabled use case, from deployment until operational steady state*.

The baseline port

Our selected baseline port is a container terminal, with a throughput of approximately 4 million TEUs (twenty-foot equivalent unit) per year. It generates roughly $400 million USD in revenue with an operating margin of around 30%. The baseline port represents one of the top 100 container ports in the world, approximately, the 50th largest.

A port can use the same cellular network for all these use cases, plus other technologies like sensors, cameras, human-to-human communication, and container tracking.

* **Steady state net value** is a combination of the terms "steady state" and "net value". **Steady state** means the use case is fully deployed, so the full benefits are activated, and only the operational costs are active (no additional CAPEX-investments). **Net value** is the value after subtracting all costs from the value of the benefits, i.e. the real "savings".

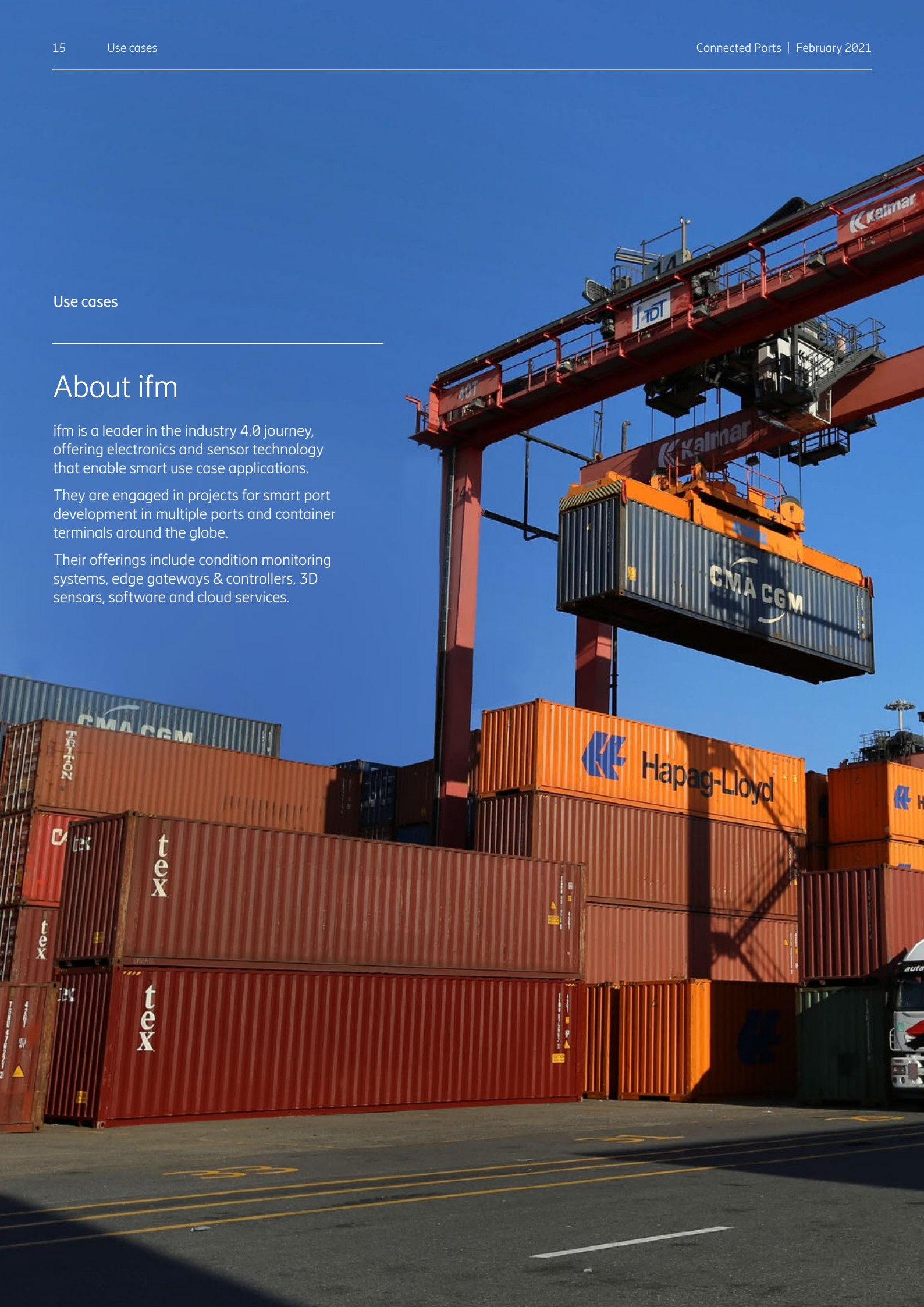
Use cases

About ifm

ifm is a leader in the industry 4.0 journey, offering electronics and sensor technology that enable smart use case applications.

They are engaged in projects for smart port development in multiple ports and container terminals around the globe.

Their offerings include condition monitoring systems, edge gateways & controllers, 3D sensors, software and cloud services.



Remote-controlled ship-to-shore cranes

Making light work of heavy loads

Safer, more efficient dockside cranes.

"22% of crane-related injuries resulting in a fatality in the United States between 2011 and 2015, happened to the crane operator."

Ship-to-shore (STS) cranes do the loading and unloading of containers between ship and dock. This operation demands communication with the deckman to make sure the team moves the right containers. And as loading a ship is like putting a puzzle together it requires very high precision.

The pain of cranes

STS cranes are located dockside and operators need to move through the entire port in order to access the cranes. It takes time for operators to move across the dangerous yard, which is filled with vehicles, containers and cranes. Cranes are 60-70 meters tall, so it can take a long time to reach the crane's driver cabin.

22% of crane-related injuries resulting in a fatality in the United States between 2011 and 2015, happened to the crane operator, according to The United States Bureau of Labor Statistics. As much as 77% of crane operators suffer from neck pain, while up to 86% experience lower back pain from performing their jobs, according to the Port Equipment Manufacturers Association (PEMA).

Although some cranes are fitted with elevators and other measures to get into the crane's driver cabin quicker, shift changes are still both dangerous and time consuming.

Even though being at the top of the crane gives STS crane operators good overall visibility, it's often hard to see all the corners and angles needed to maneuver the containers.

Danger drops with digitalization

Remote-controlled STS cranes are usually connected through a combination of WiFi and fiber. Fiber is a disadvantage because the cables are prone to breaking and are costly to repair. This low level of reliability also increases the risk of danger.

But by fully digitalizing the information exchange between the remote operator, checker, and deckman — the team involved in the use of STS cranes — the entire dockside operation can be digitalized.

Enabled by a cellular network, the crane operator will be able to control the cranes remotely from a control room in real-time.

Checking all the safety boxes

"Checkers" are typically stationed at the STS crane on the dock and work with manual inputs. But by using digital software, like ABB's QuayPro, in combination with optical character recognition (OCR), the checker's job can be significantly evolved. Checkers will then become remote checkers, allowing them to work in the office environment, just like remote crane operators.

According to ABB, this approach improves safety and provides a more ergonomic working environment for the checkers, with one checker becoming able to handle more than one crane. This also minimizes errors since manual inputs are no longer needed.

Heavy loads need heavy data

In order for this solution to work, each dockside container crane needs 3D sensors and a large number of HD cameras. This requires high bandwidth and low network latency between the remote control room and the crane.

Optical character recognition also requires high-bandwidth data transfers and helps in the identification of containers to reduce the need for human checkers. 5G perfectly suits this use case as it supplies the reliability, bandwidth, latency and high security that it demands.

"5G perfectly suits this use case as it supplies the reliability, bandwidth, latency, and high security that it demands."

Remote-controlled cranes pays off

Through the full visibility of operations in the remote control room, this use case enables optimized lifts, resulting in more efficient operations and decreased energy usage.

By removing the need to climb up to the crane's driver cabin, digitalization reduces the number of injuries and increases worker safety. According to Kalmar – one of the world's top crane manufacturers – 70% of the operators could be freed up to do other tasks in quiet times when there are fewer ships to be loaded and unloaded.

There are financial benefits from letting operators work from the comfort of a remote control room and not in the crane's driver cabin. Ports can potentially increase revenue from STS crane tariff charges by halving the downtime related to shift changes.

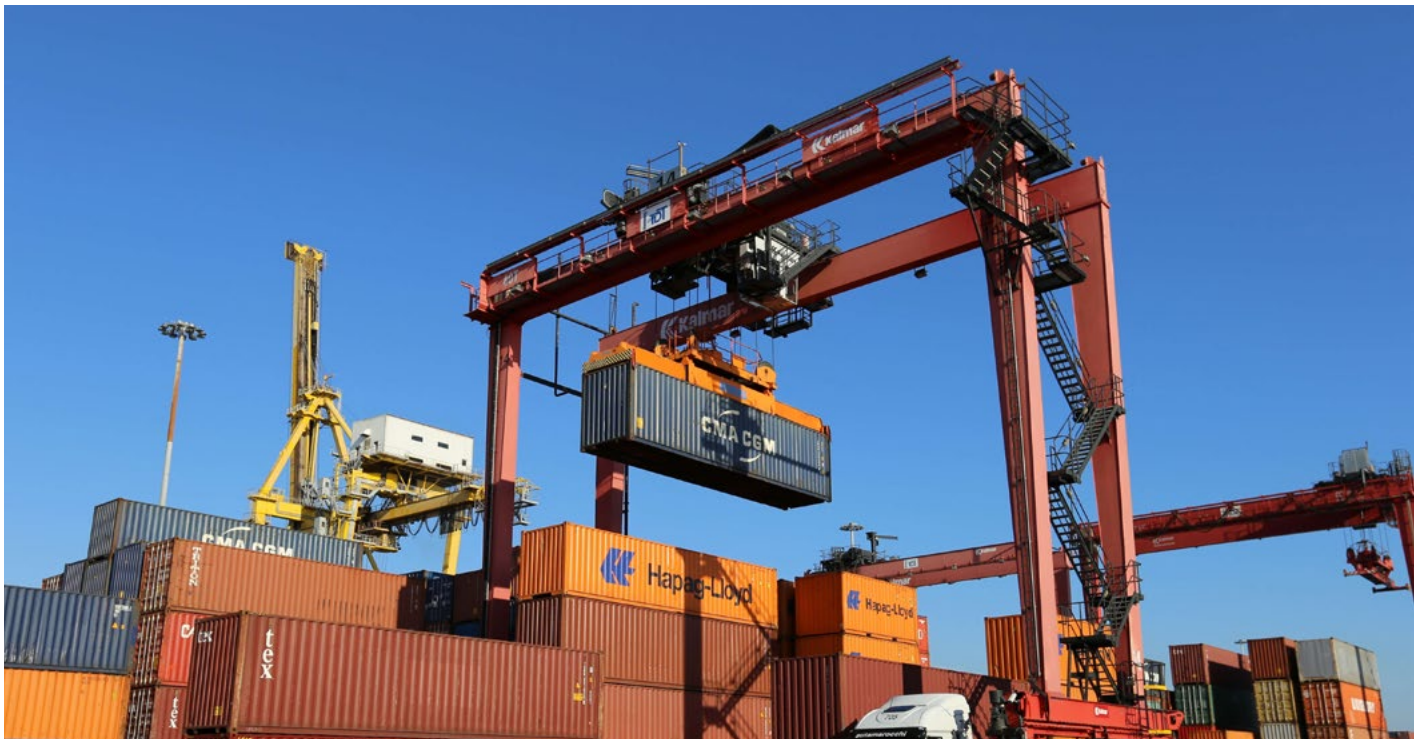
The financial benefit of remote-controlled STS cranes reaches about 4.9% of the revenue as yearly steady state net value.

By comparing the economic impact of remote-controlled STS cranes to the full cost of network deployment, we see a payback of around two years and a return on investment by year five of 156%.

The system productivity benefits are only valid when the STS, RTG, and AGV use cases are simultaneously active for the entire chain from loading/unloading, horizontal transport, and stacking.

"By removing the need to climb up to the crane's driver cabin, digitalization reduces the number of injuries and increases worker safety."

The revenue and ROI benefits come from:	
Increased revenue from decreased downtime	37%
Improved productivity due to system benefits	35%
Reduced cost of operator labor	16%
Reduction in efforts from checkers	12%



Automated rubber tired gantry cranes

Stacking the odds in your favour

Rolling out more flexible port stacking.

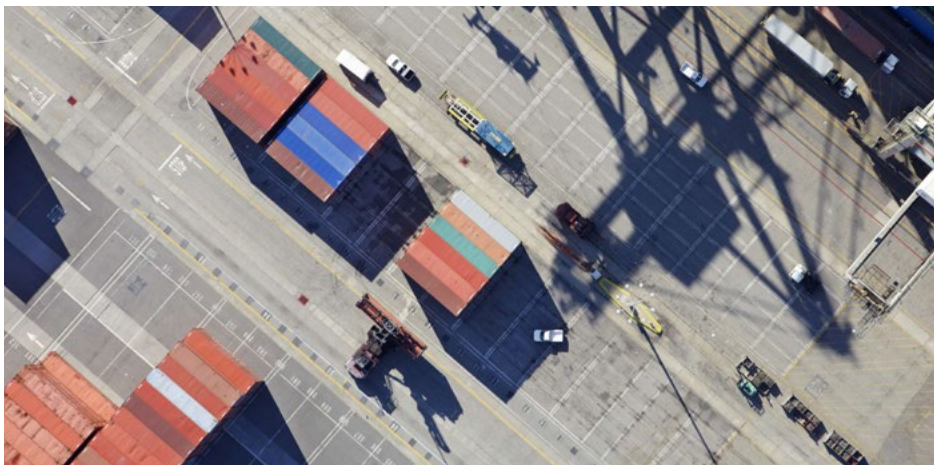
Stacking up the benefits

Mobile gantry cranes are used for equipment transferring and flexible operations, but are usually used to stack containers on the wharf and other places.

Rubber tired gantry cranes (RTG) are more flexible than rail mounted gantry cranes, as rail infrastructure is not needed and ports can move cranes easily.

RTG cranes are the most popular equipment choice for container stacking at terminals around the world, especially ports where high-capacity stacking and good maneuverability are key. Research from Kalmar indicates container ports have a global installation base of roughly 8,000 cranes and an estimated 60% of them use RTGs.

Typically, ports have around three to four times more RTG cranes than ship-to-shore (STS) cranes, which means that this is more labor intensive to operate, according to data from Port Gdansk.



"Human error is the largest reason for port-related accidents and is responsible for 75% of marine liability losses."

Risky business

Most RTGs are operated by on-site, human operators, who need to move through the container yard and then climb up to access the crane's driver cabin. Cranes are also located close to many large machines, trucks and other containers, which adds risk for the operator as they traverse the yard.

As mentioned earlier, 22% of crane-related fatalities in the U.S. between 2011 and 2015 happened to the crane operator.

It takes time for the operators to access the cranes and climb up. Thus, every shift-change or break, resulting in the crane operator having to move from the crane, causes downtime. Downtime is very costly for the port, as any crane not in use is not achieving maximum efficiency.

While the industry is seeing the introduction of more automation, data from Konecranes shows more than 90% of RTGs are still manually controlled, requiring skilled operators, which have been harder to attract in recent years. Unfortunately, human error is the largest reason for port-related accidents and is responsible for 75% of marine liability losses, according to Maritime Journal.

Automation on a new level

Automated rubber tired gantry cranes are the solution as they can solve all of these challenges. Available since 2013, automated RTGs have five levels of crane automation, according to Kalmar:

1. Remote-controlled:
Operator controls all of the moves of the automated RTG from the yard control center.

2. Supervised automatic moves:
Operator supervises automated hoist, trolley, and gantry moves on stack and controls operation in the truck lane.

3. Automatic pick up and place on stack:
Hoist and trolley are executed automatically on stack and the gantry is supervised. Operator controls operation in the truck lane.

4. Automatic gantry:
Hoist, trolley, and gantry movements are executed automatically on stack. Operator controls operation in the truck lane.

5. Fully automated:
Fully automated solution with automatic truck handling and horizontal transport. An operator is only needed for exceptional and complex handling.

Stacks of data required

Today's automated RTGs, like remote-controlled STS cranes, are usually connected through an unreliable combination of WiFi and fiber cables.

Enabled by safety controllers, smart 3D-sensors, and positioning devices, automated RTGs are able to conduct stacking operations automatically. But whenever any irregularity occurs, an operator can take over control from a remote control room.

When automation enters a container terminal, network latency becomes a priority. RTG operation with automation is extremely intolerant of latency and jitter, often requiring sub-50ms latency to operate at its full potential.

The solution puts very high requirements on reliability, bandwidth latency, and high security, which makes a private 5G network suitable for this use case.

Lifting your ROI

Through automated and consistent movement patterns, ports can achieve a 20% reduction of maintenance, according to Arthur D Little. Also, with fewer spare parts, oils and other resources needed, the cranes have less environmental impact. And as workers no longer need to access the cranes and climb to the crane's driver cabin, the number of injuries to crane operators is also likely to decrease.

The financial benefit of deploying automated RTGs reaches about 7.5% of the revenue as yearly steady state net value.

Expect payback in less than three years and a return on investment by year five of 98%.

The revenue and ROI benefits come from:	
Reduced cost for operator labor	73%
Improved productivity due to system benefits	22%
Reduction in labor and maintenance materials	5%

"Through automated and consistent movement patterns, ports can achieve a 20% reduction of maintenance."

Automated guided vehicles

Steering clear of danger

Driving up port safety with automated guided vehicles.

The impact of collisions

Ports can only operate by using a large amount of tractors, all of which require a human pilot to move horizontally across port yards.

But poor communications between tractor drivers results in congestion and collisions, all of which impacts upon the port's productivity. According to ResearchGate, in the past five years, 36% of accidents in ports were caused by pilot error and 42% of accidents were classified as "traffic" accidents.

"36% of accidents in ports were caused by pilot error and 42% of accidents were classified as traffic accidents."

Automatically better

Automating horizontal transport produces several key benefits. Automated guided vehicles (AGVs) use smart 3D sensors and cellular connectivity to navigate throughout the port, acting as driverless forklifts and other material-handling vehicles.

AGVs used in ports are also known as "Intelligent Autonomous Vehicles" (IAVs). IAVs are one of the component systems of the Intelligent Transportation System (ITS) that can operate in confined private spaces, as well as in open and public spaces.

AGVs are used in many industries such as manufacturing. Historically, they've not been smart, instead being operated by following either magnetic tape or inductive wire on the floor, neither of which enables flexibility.

Central intelligence

An AGV that is connected to a cellular network can receive work orders as well as positioning information from a central intelligence. This data supplies collision warnings, and improves the accuracy, safety, and speed of operations.

According to AGV Network, the technology is evolving and industries are using new kinds of navigation systems, including laser, QR codes, and natural feature navigation.

Cellular is the driving force

By using 3D sensors in combination with cellular capabilities, smart AGVs can optimize their routes and their charging, cutting their energy consumption. These newer generations of smart AGVs operate with electricity versus today's more common diesel power.

Each AGV needs various sensors for safe navigation as well as modules for a reliable network connection. Sensor data is mainly processed directly on today's AGVs.

To remotely control the AGVs while complying with safety regulations requires a connection with extremely low latency. 5G cellular can meet these requirements, making it a good solution for the remote control of AGVs in the near future.

"The data from a central intelligence supplies collision warnings, and improves the accuracy, safety, and speed of operations."

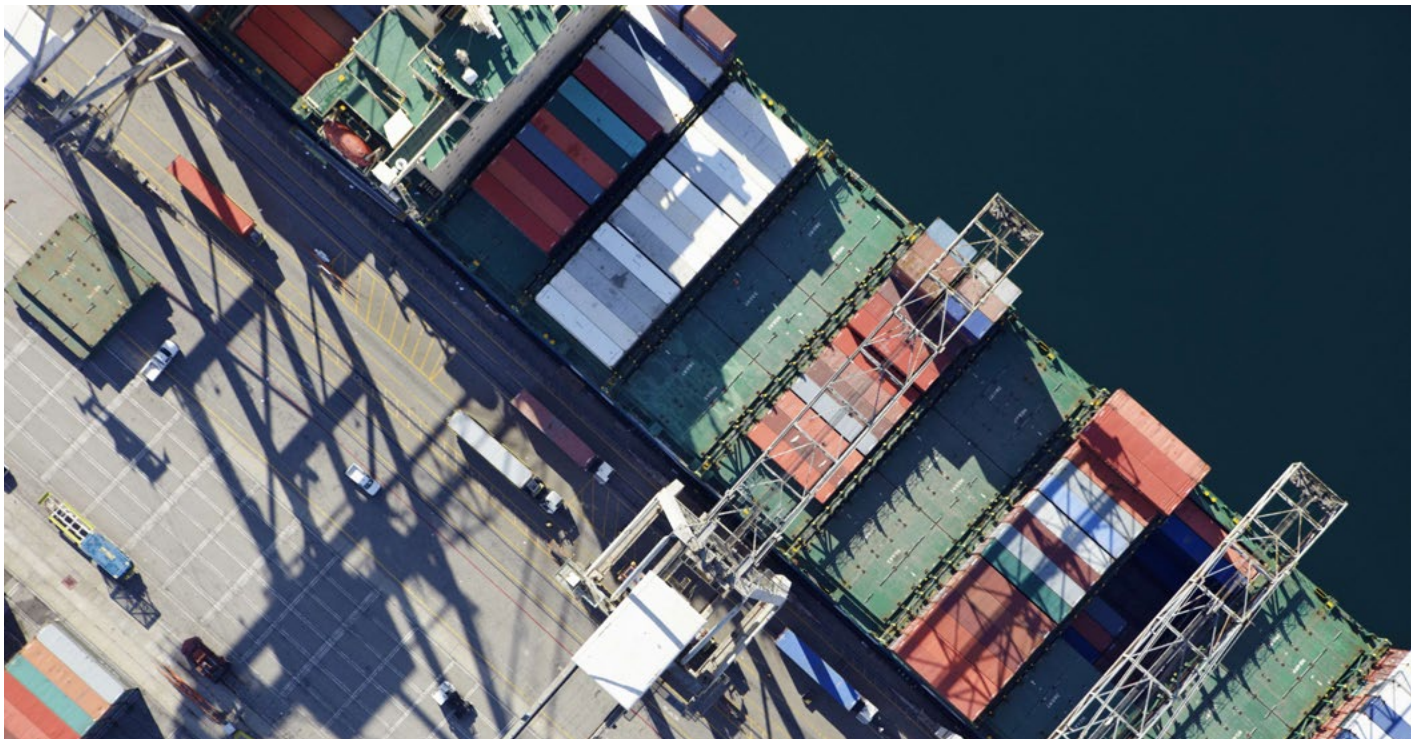
A smoother financial ride

AGVs reduce energy costs by 10% due to optimized routes according to research by Schmidt, Meyer-Barlag, et al (2015). Taking out the human factor also increases safety for workers, as less human errors means less collisions and accidents.

Deploying AGVs will create payback in around two years and a return on investment by year five of 149%. The financial benefit is approximately 7.1% of the revenue as yearly steady state net value.

The revenue and ROI benefits come from:	
Reduced cost for operator labor	74%
Improved productivity due to system benefits	23%
Decrease in energy costs	3%

"AGVs reduce energy costs by 10% due to optimized routes."



Condition monitoring

Keeping port machinery shipshape

Predicting the unpredictable with condition monitoring.

The downside of downtime

When a port experiences downtime in one of its assets, it usually results in a very costly disruption to its operations. A key reason for downtime is the malfunction of a machine that creates an accident or disruption. According to research from Budiyanto and Fernanda (2020), 6% of port accidents in the last five years were due to poor tool maintenance.

A major safety concern in ports is preventing fires. As dangerous goods are often stored in ports, any fires or accidents can result in large disasters. Budiyanto and Fernanda found that in the past five years, 11% of accidents in container terminals were due to fires. The key reason for causing them was equipment damage.

"In the past five years, 11% of accidents in container terminals were due to fires."

High maintenance

Today, port equipment is normally maintained based on a set schedule. In some cases, the condition of the equipment is evaluated through vibration or temperature monitoring, a task most often performed manually by an operator.

Becoming predictably efficient

According to Port Technology, 25% of the cost of equipment damage is due to inadequate or incorrect maintenance. Smarter condition monitoring of equipment, assets, and maintenance services can be handled much more effectively, lowering maintenance costs.

Condition monitoring achieves this by using cellular-connected sensors to monitor the condition of all port assets through factors like vibration and temperature. These assets include cranes, AGVs, and stacks of containers.

The sensors will connect to a cellular network. Condition monitoring software will then detect any abnormalities, while also determining when an asset is in need of maintenance. The most basic application is vibration monitoring to identify anomalous behaviors, which notifies and dispatches a worker to solve the issue.

Catching faults early

Condition monitoring enables early detection of potential faults and their causes on the basis of individual vibration characteristics and other influencing factors. This allows for permanent and continual monitoring of critical machines and equipment.

The integration into the programmable logic controller (PLC) makes it possible to adjust the vibration monitoring to the process of the machine or the plant. This is a natural next step after deploying condition monitoring.

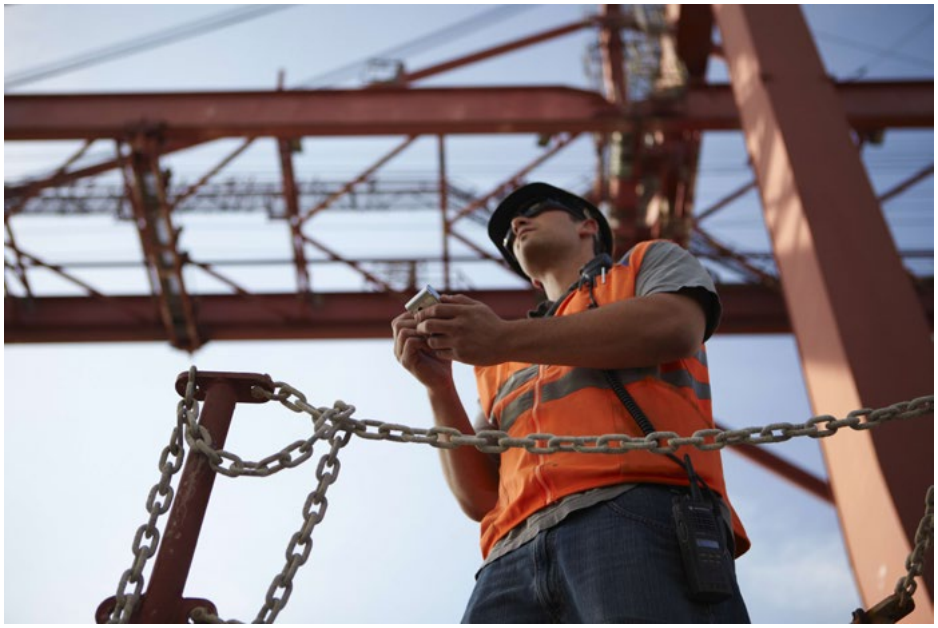
Real-time needs real fast

For condition monitoring, the network needs to be able to manage high connection density and transfer data in real-time with extremely high reliability. Plus, the port site needs to process and analyze the data in the cloud securely.

This real-time process monitoring is what helps protect a port's machinery. The permanent monitoring helps avoid damage to machine components, tools or workpieces, and creates shorter response times.

Cellular-connected sensors and a cloud-based solution enables condition data to transfer in real-time, reducing on-the-ground monitoring efforts by 40%, according to Port Strategy. These sensors require response times as fast as a fraction of a second, making a private 5G network ideally suited for this use case.

"25% of the cost of port equipment damage is due to inadequate or incorrect maintenance."



"Condition-based monitoring of cranes can reduce maintenance costs by as much as 75%."

Good financial condition

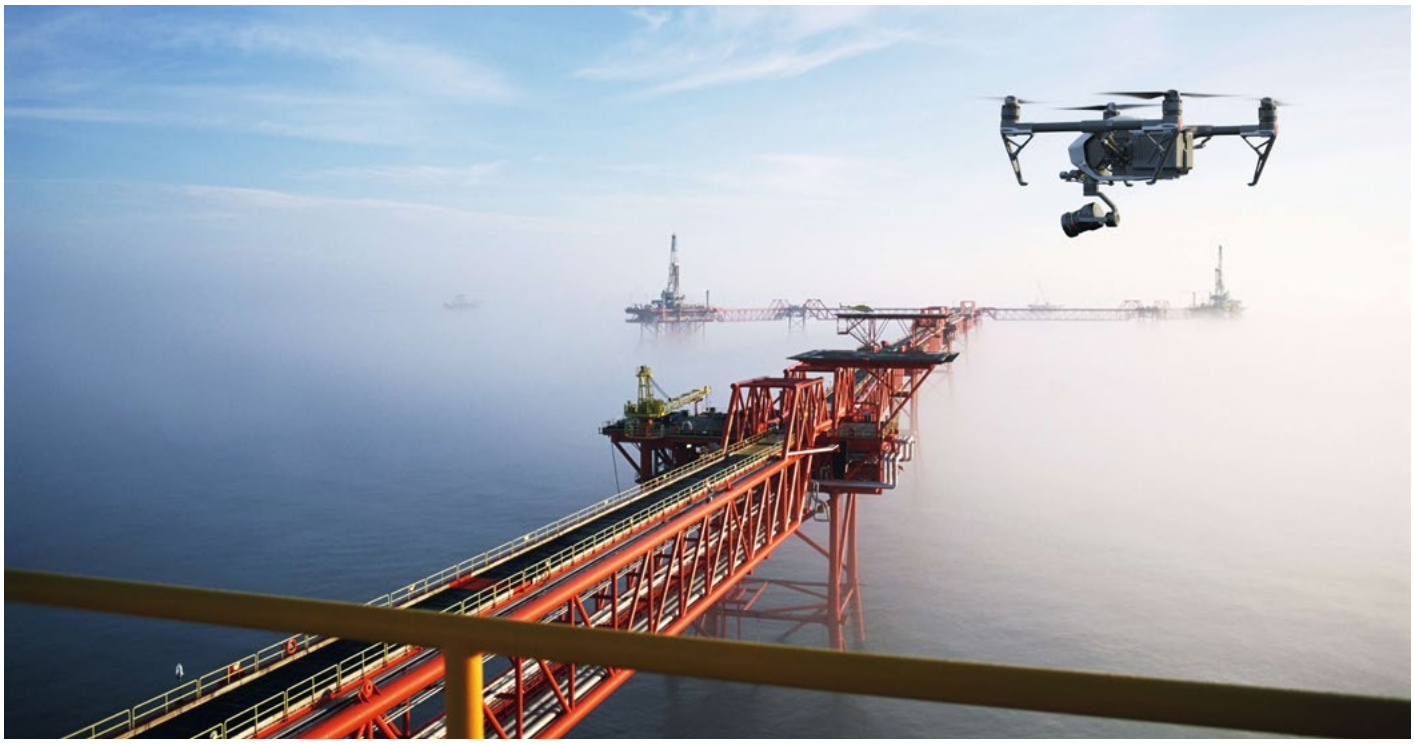
Using condition monitoring allows ports to reduce "over-maintenance" while also lessening the risk that those assets will break down.

This means that ports can cut the spare parts, oils, and resources needed for maintenance by 50%, according to Saab RDS. Data from HBM indicates condition-based monitoring of cranes can reduce maintenance costs by as much as 75%.

As the risk for machine and equipment breakages reduces with correct maintenance, the risk for accidents in the port also decreases, and therefore the risk of injuries to workers.

Condition monitoring's financial benefit is around 2.7% of the revenue as yearly steady state net value. This will give a payback of around two years and a return on investment by year five of 126%.

The revenue and ROI benefits come from:	
Reduction in maintenance labor	53%
Reduction in the cost of monitoring	40%
Decrease in the cost of maintenance materials	7%



Drones for surveillance and deliveries

A safer port of call

Raising port security and sustainability with drones.

Rising to the challenge

Security has become a major concern for ports. Thefts of cargo are common, resulting in disrupted supply chains. According to Shipping & Freight Resource, in 2018, there were an average of 15 cargo thefts reported daily. Research from Björn and Eckwall (2017) shows that 20% of all marine transport thefts happen at the port.

Also, papers and other documentation deliveries need to reach a ship before it arrives at the dock. Traditionally, ports use a tugboat or launch boat for doing these deliveries, even though they might consist of only a single envelope or piece of paper. Maersk Tankers reports that such deliveries typically cost more than $1,000 USD each.

Ports are in need of a technological solution to these problems, and the use cases provided through drones can deliver just that.

"In 2018, there were an average of 15 cargo thefts reported daily."

"Ship-to-shore deliveries in Singapore now happen six times faster than the traditional launch, and cost 90% less."

Drones are taking off

Modern drones use 3D sensors connected by cellular to real-time analytics to navigate and collect data.

This is allowing ports to deploy drones for more effective security surveillance and for the delivery of documents to and from vessels. In both cases, a pilot remotely operates the drone over a 5G network.

Camera-equipped drones collect and stream data to the cloud, where analytics can be used to detect abnormalities, like an unauthorized person moving throughout the port or an incorrect truck picking up a container.

According to the Straits Times, the Port of Singapore is testing 5G-connected drones for better surveillance and security. Beginning in August 2020, a one-year trial is assessing how Airbus drones perform security inspections and manage port incidents. The newspaper also reports that Singapore is using Airbus drones to make ship-to-shore deliveries.

Sky high connectivity

The drones require a network that not only accommodates high resolution video, but also provides high-accuracy positioning over an ultra-reliable connection, especially when the drone is in flight. Very high bandwidth and low latency are needed to transfer huge amounts of data in real-time, making a 5G private network the ideal solution.

Drones are delivering

By using drones instead of launch boats, ports are massively cutting the cost, efforts, and resources to deliver small items to and from approaching ships. According to FreightWaves, ship-to-shore deliveries in Singapore now happen six times faster than the traditional launch, and cost 90% less. They also reduce CO_2 emissions and safety risk to human workers.

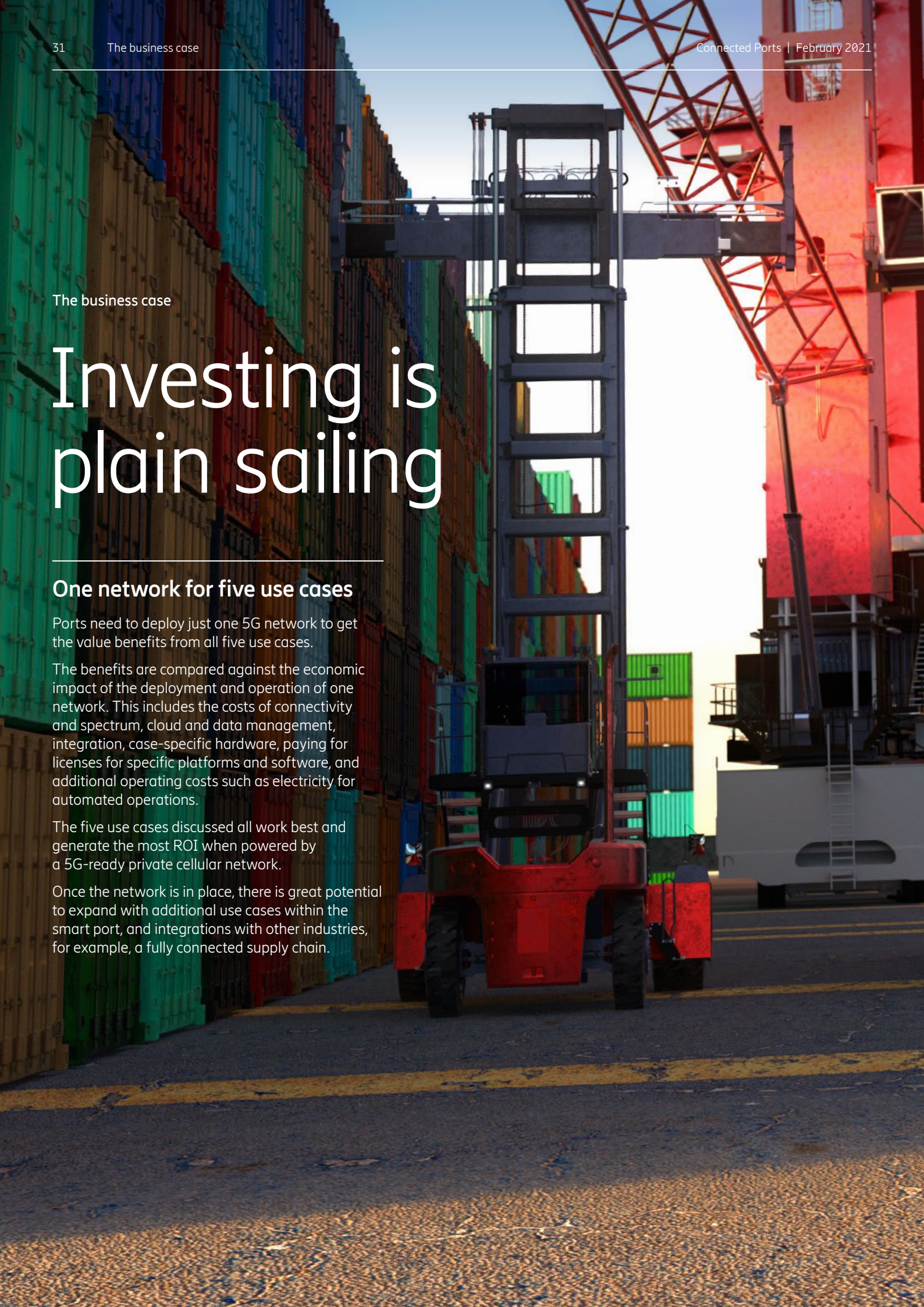
For surveillance, drones can collect data for cloud-based analytics engines that will improve security, incident management, and overall worker safety. Port security operations will become more efficient as they now provide a better vantage point, an ability to instantly identify abnormalities, and the capacity to move faster.

Our data predicts drone surveillance will decrease port theft by 75%, resulting in lower insurance premiums.

The financial benefit of this use case is around 1.6% of the revenue as yearly steady state net value. Payback will come in around two years and a return on investment by year five of 154%.

"Our data predicts drone surveillance will decrease port theft by 75%, resulting in lower insurance premiums."

The revenue and ROI benefits come from:	
Reduced cost for security labor	83%
Decrease in offshore deliveries costs	10%
Decrease in insurance premiums	7%



The business case

Investing is plain sailing

One network for five use cases

Ports need to deploy just one 5G network to get the value benefits from all five use cases.

The benefits are compared against the economic impact of the deployment and operation of one network. This includes the costs of connectivity and spectrum, cloud and data management, integration, case-specific hardware, paying for licenses for specific platforms and software, and additional operating costs such as electricity for automated operations.

The five use cases discussed all work best and generate the most ROI when powered by a 5G-ready private cellular network.

Once the network is in place, there is great potential to expand with additional use cases within the smart port, and integrations with other industries, for example, a fully connected supply chain.

The business case

The smart money is on smart ports

Out of all our use cases, the highest value comes from automated RTG cranes, followed by cellular connected AGVs, and then remote-controlled STS cranes.

In our baseline port, with all five use cases working together, we reached a payback time of less than two years. The annual steady state net value by year five reaches $101 million USD, which is 25% of the baseline port's revenue.

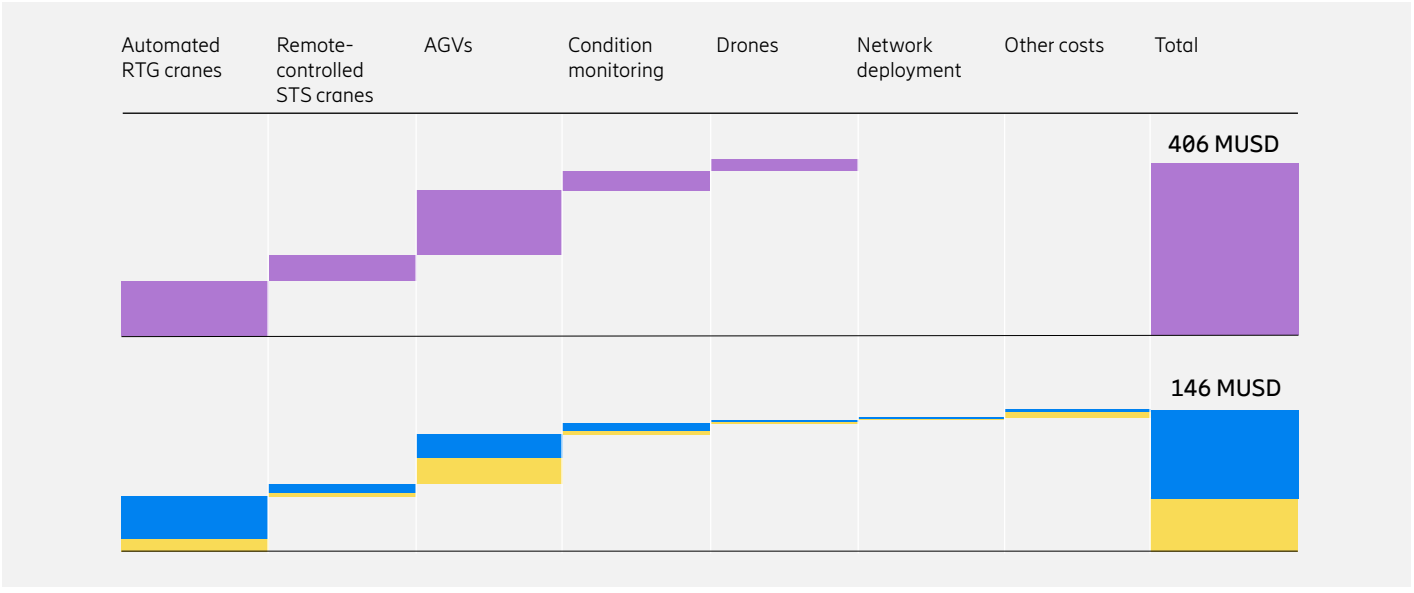
The accumulated net value reaches $260 million USD in year five – 68% of the baseline port's revenue. This figure includes the full network deployment and the cost and benefits from the five use cases.

By year five, the use cases contribute to an accumulated gross value of $406 million USD. The total, accumulated costs for deploying all use cases is around $146 million USD by year five, driving a return on investment of 178%.

The use cases account for the following percentages of yearly steady state net value:	
Automated RTG Cranes	30.8%
Automated guided vehicles (AGVs)	29%
Remote-controlled STS cranes	20.5%
Condition monitoring	12%
Drones for surveillance and deliveries	7.7%

178% ROI

Full port deployment, year 5



Source: Ericsson, Arthur D. Little

Combining the use cases

Ports thrive with all five

Each of the five use cases will enable a container's journey through a port to be faster, safer, and more efficient. But here's what it looks like when all five use cases are working in unison.

01 Ship transport

02 Arrival of ship

03 Unloading ship

Remote control of Ship-to-Shore cranes

04 Transport of containers

Cellular connected Automated Guided Vehicles

05 Stack

Automated rubber tired gantry cranes

06 Inter-terminal transportation

07 Loading other modality

08 Leaving port

Drones for surveillance and deliveries as well as condition monitoring are active in all steps of the process.

01

Remote-controlled ship-to-shore cranes

Remote-controlled STS cranes load and unload container ships, moving containers between the ship and the dock with precision and maneuverability.

02

Automated guided vehicles

AGVs navigate through the port using smart 3D sensors, handling all port materials, and reducing energy costs and risk of accidents.

03

Automated rubber tired gantry cranes

Automated RTG cranes stack containers at terminals, crucial for when high-capacity stacking and good maneuverability are needed.

04

Condition monitoring

Condition monitoring detects faults before they occur, reducing unplanned downtime and maximizing asset productivity.

05

Drones for surveillance and deliveries

Drones deliver documents from ship to shore, reducing costs and environmental impact of manned boats, while also conducting security surveillance of ports.

Final word

The port of the future is a smart one

While there are many potential smart port use cases, our research shows that the five we've identified are the best place to start.

Four out of the five use cases should pay for themselves in around two years, with automated RTG cranes needing less than three. When deployed together, complete payback can come in less than two years.

Beyond the financial benefits — an ROI of 178% in five years for our baseline port — smart ports create a substantial triple bottom line that includes increased productivity and efficiency, improved safety for workers, and a more responsible environmental impact.

Instrumental to putting these use cases into action is fast, reliable, and secure connectivity that only a 5G-ready private cellular network can provide. 5G is best suited to supporting smart ports as it's not only backwards-compatible, but can also be easily upgraded as new generations of cellular connectivity emerge.

Ultimately, it's the power and flexibility of this connecting force that will help ports navigate their way towards Ports 4.0.

"Four out of the five use cases should pay for themselves in approximately two years, with automated RTG cranes needing less than three. When deployed together, complete payback can be achieved in less than two years."

If you'd like to know more, we'd love to talk.

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