I²PANEMA

Bringing smart IoT to ports

Success story

As global trade continues to expand, the pressure on ports to handle increasing cargo volumes efficiently and sustainably is greater than ever. By 2030, European cargo traffic is expected to rise by 50%, but with space limitations, ports must turn to innovation rather than expansion. The I²PANEMA project, gathering 17 partners from Germany, Spain and Türkiye, stepped in to address these challenges by integrating smart Internet of Things (IoT) solutions into port operations. The consortium brought together port authorities, technology providers and research institutions to ensure that real-world challenges were met with practical innovations.

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More information
https://itea4.org/project/i2panema.html

Addressing the needs of modern ports

Ports serve as crucial hubs in international supply chains, yet they face significant challenges such as congestion, urbanisation, and environmental concerns. With an increasing focus on sustainability and digital transformation, there was an urgent need for smarter operations.

I²PANEMA aimed to use IoT technology to create a connected, efficient port ecosystem. The common idea was to optimise media discontinuities in radio, IT and paper processes to enable greater efficiency of port operations. By integrating sensor networks, machine learning, and real-time data processing, the project delivered transformative solutions across multiple use cases.

At the heart of I2PANEMA's success is its three-layer architecture:

- Machine-to-Machine Communication Layer (MCL): Collects data from sensors and devices across the port.
- IoT Interoperability Layer (IIL): Ensures seamless communication between different systems, standardising data exchange.
- Data Management Layer (DML): Uses machine learning to analyse data, extract insights, and support decision-making.

Complementing this is the I²PANEMA reference architecture, which integrates the results from the project's use cases as a best practice example for software implementers to implement a smart port. This architecture enables a seamless flow of information across various port activities, from tracking container movements to monitoring environmental conditions.

Security was another key focus. The project adapted the DREAD/STRIDE approach for IoT security analysis, ensuring robust threat detection and mitigation measures. This enhanced security model is applicable beyond ports, offering potential benefits across various IoT domains.

Improved efficiency, quality and sustainability

I²PANEMA has delivered several impactful innovations, with three standout achievements: (1) the ISO 4891 standard, (2) sensors and AI algorithms that improve efficiency and quality, and (3) noise reduction technology for port terminals.

A new standard for smart applications

The creation of ISO 4891, a new international standard for smart applications such as the Smart Logbook from NautilusLog, is one of the most significant outcomes of I²PANEMA. ISO 4891 is designed to establish a framework for the interoperability of smart applications onboard ships and marine technology systems.

With digitalisation still in its infancy in ports, ships and their processes are highly regulated and dependent on paper-based solutions. The legal framework for a completely digitised logbook was lacking. Thus, a unified standard for digital data exchange between ships and ports was needed. Within I²PANEMA, German partner company NautilusLog led efforts to develop this standard, helping to eliminate data silos and enabling a seamless, real-time data flow. This digitisation reduces the administrative workload for crews, ensures improved compliance with international

maritime regulations, and enhances data transparency by providing real-time access to stakeholders.

The standard has attracted international interest, which had led to adaptations in multiple international systems and follow-up projects. Notably, the solution has been integrated into Singapore's Digital Corridor to coordinate data and processes between ship and shore. A large-scale demonstration of the Smart Logbook is set to take place, with smart applications installed on 50-80 vessels. Furthermore, regulatory authorities and other stakeholders have shown growing interest.

Improved efficiency, safety and quality of life

Efficiency in ferry transport is crucial for both logistics and passengers. I²PANEMA has demonstrated that ferry arrival times in Hamburg, Germany, can be accurately predicted to within 15 seconds, which has resulted in a 100% reduction in average processing time for stop announcements. By integrating IoT sensors with AI algorithms, the Hamburg Port Authority demonstrated the power of real-time data together with the HADAG, which is the operator of the ferry lines in the Port of Hamburg and a 100% daughter company of the Hamburger Hochbahn AG. Now the HADAG has a proven system and a smarter, data-driven approach to managing its ferry fleet, setting an example to other ports worldwide.

In the Assan port in Türkiye, meanwhile, sensor-based container localisation has increased the number of operations in one shift by >10%, decreased completion time for one movement by >15% and reduced accidents by >50%. This has increased profitability for the port as 10% more container movements can be made.

For both sustainability and liveability, the port of Gijón in Spain has implemented AI-based algorithms and sensors for accurate prediction of PM10 emissions (particulate matter that is small enough to get into your throat and lungs) with an error rate of <30%. This overview of air quality, leading to a 100% reduction in average processing time for environmental alerts and emergency protocol activation, allows port operations to change in real time to reduce pollution in the urban area, with a knock-on benefit for tourism, citizen satisfaction and quality of life.

Noise reduction for sustainable port operations

Noise pollution is a significant challenge in ports, especially those located near urban areas. The constant movement of containers and machinery generates high noise levels, which affects the quality of life for nearby residents.

I²PANEMA's innovative Active Noise Control (ANC) solution, developed in collaboration with TriCon Container-Terminal Nürnberg and with the Fraunhofer Institutes for Material Flow and Logistics (IML) and Structural Durability and System Reliability (LBF), has successfully reduced port noise by over 15 decibels under laboratory conditions. This technology uses real-time sound wave cancellation techniques to neutralise noise and thereby enables extended operating hours for port terminals as they now can increase nighttime handlings. These used to cause problems because of the noise generated. Thanks to this breakthrough, the Fraunhofer researchers and TriCon received the 2021 CNA 'Intelligence for Transport & Logistics' Innovation Award, recognising their contribution to sustainable port operations.

Fraunhofer has continued advancing ANC technology through various project-based initiatives, exploring new fields of application. In the LOLA project , research focused on inland ports, demonstrating ANC's potential to reduce engine noise from cranes and reach stackers. Similarly, the ANC Rail project, conducted in collaboration with Dortmunder Eisenbahn, confirmed that while full coverage is not feasible, ANC can effectively mitigate engine noise.

Exceptional excellence

Next to these impressive innovations and standardisation results, I²PANEMA showed exceptional excellence as they also created strong business impact, which is one of the main ambitions of ITEA. As shown, ports can increase profitability thanks to the I²PANEMA solutions, but project partners also showed rapid exploitation of the project results as four new products and four enhancements of existing products have been created.

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Companies of all sizes can benefit from the project, as SME NautilusLog has shown with the ISO 4891 standard. By completely digitalising logbooks for the first time, they offer savings on both time and paper and have attracted the attention of many ship owners. This has directly led to a growth from five to more than 25 international employees. Today, NautilusLog serves more than 130 shipping lines, as well as the German Federal Ministry of Transport and esteemed maritime brands such as MSC, Oldendorff, SGS, and Bernhard Schulte Management.

Driven in part by the efforts of I²PANEMA, Prodevelop has extended their Posidonia Port Solution Suite with seamless sensor integration, cloud edge computation and AI analytics. Since the project's completion two years ago, Prodevelop has experienced a 70% revenue growth and a 25% increase in its workforce.

Within the I²PANEMA project, VTEK developed a container localisation use case in the Assan port as part of the Terminal Operating System (TOS), enabling real-time data collection from the field. Although this functionality has proven highly useful for port operators, the current GPS modules do not always provide slot-level accuracy with 100% reliability. As a result, operators still need to manually verify positions, which limits the full automation potential of the solution. For this reason, the solution has not expanded as widely as initially expected. However, new-generation GPS modules now incorporate advanced algorithms for improved accuracy, which could significantly enhance the reliability of container localisation. Once these modules reach the necessary level of precision, VTEK is ready to scale the solution immediately in a plug-and-play manner.

Finally, the project has opened future innovation pathways and potential markets, such as the development of Industrial Data Spaces into Port Data Spaces through the combination of findings from I²PANEMA and new developments like Gaia X.

A lasting legacy for the maritime industry

With its pioneering of IoT applications in port environments, the new ISO 4891 standard for Smart Applications for Ships, and real-world business cases, I²PANEMA has demonstrated the power of digital transformation in ports. I2PANEMA was also a golden opportunity to network with multiple ports, stakeholders and industry partners to inspire and empower port stakeholders both during and after the project. This increase in attention on the need for greater interoperability, data exchanges and data merging will serve as a foundation for future solutions and reference architectures. In turn, this will help to strengthen the international maritime network (including service providers outside of the port industry) with new trends and potential business models, knowledge from other sectors and transformative solutions that involve both stakeholders and end users of ports.

The ITEA project Optimal-LOADS builds on elements of I²PANEMA by handling data (including from IoT devices) within a sovereign data space. The project plans to optimise and digitise logistics and aims to create trust among data providers and users by developing data spaces in various sectors, ensuring data sovereignty and enabling interoperability in multi-stakeholder environments. This will contribute to an improved efficiency of the multi-modal logistics supply and transport chains and the valorisation of data in the logistics sector.