

flows, as well as for container traffic on relevant routes and changes in the correlation between gross domestic product and containerised trading volumes.

Research and development

One of HHLA's strategic objectives is to continuously improve the efficiency of its operating systems, and consequently its competitiveness, by developing application-oriented technologies. Due to close collaboration with technical universities, institutes, industry partners and government authorities, joint projects can be planned, managed and developed by working groups.

Container terminal 4.0

The Container Terminal Altenwerder (CTA) is one of the most highly automated container terminals in the world. Since it opened in 2002, HHLA has constantly been researching and working on improving and expanding automation at the site. Right at the start, a paradigm was established whereby automated work areas are separated, isolated and off-limits to staff in order to guarantee occupational safety. This principle has always been upheld. Today, however, this paradigm is preventing the ramping up of automated processes, as it inevitably excludes them from areas used by people. The research project "Container terminal 4.0 – a paradigm shift in the automation of container terminals via human-machine interaction rather than separation" is being conducted as part of the IHATEC subsidy programme (supported by the German Federal Ministry for Digital and Transport). The project's main objective is to develop automation solutions for various container crane systems used at the terminal in work areas shared by people and machines and to implement them as prototypes. At the same time, the experience, knowledge and evidence gathered during this process should play a fundamental role in establishing the safety standards needed to create a reliable framework for future automation projects.

Hamburg TruckPilot

With the Hamburg TruckPilot field test, MAN Truck & Bus and HHLA conducted a highly innovative research and testing project to develop automation solutions in road transport. The aim was to analyse the requirements for the customer-specific deployment and integration of self-driving trucks in the automated container handling process under realistic conditions, and to review its feasibility. The prototype trucks equipped with the corresponding electronic automation systems operated automatically within CTA. The project was split into three phases: the preparation phase, which ran until the end of 2018, served to define the underlying technical conditions. The test phase, which was slated for completion by June 2020, was largely carried out despite the restrictions resulting from the coronavirus pandemic. This comprised the technical development of the system at MAN's testing centre in Munich in

accordance with the specific requirements identified during the preparation phase. The scheduled field test between July and December 2020 could only take place to a limited extent. In 2021, customer-oriented pilot operations were successfully carried out. This involved the automated storing of containers owned by the freight forwarder Spedition Weets GmbH in CTA's block storage unit.

Aerolnspekt

Storage cranes at the automated container yard are the linchpin of HHLA's cutting-edge, high-performance container terminals. The crane rails are subject to extreme requirements in terms of their position and height. However, the geomorphological composition of the port terrain continuously results in significant subsidence and shifts in the track network, which have to be monitored, measured down to the exact millimetre and rectified on a regular basis. The measurement work results in significant operational interruptions. One of the aims of the IHATEC subsidy project Aerolnspekt – which HHLA is running in conjunction with the Technical University of Braunschweig – is to develop software which will enable the use of drones for this measurement work in future. The project was successfully completed in October 2020. Several test flights with various camera lenses, software settings, weather conditions, etc. confirmed that the necessary precision (~ 2 millimetres) could be achieved at an altitude of 30 metres while at the same time reducing interruptions to port operations. The challenge for the future will be transferring the findings and tools developed into regular operations.

Hyperloop transport system

Since December 2018, HHLA has been working with the US-based research and development company Hyperloop Transportation Technologies (HyperloopTT) to explore possible applications of hyperloop technology for transporting shipping containers and to develop technical solutions.

In partnership with HyperloopTT, HHLA has developed a technical, operational and commercial solution for a hyperport for sea containers. This involved simulating the layout and operational processes, establishing models for calculating the economic viability and various operator models, and evaluating target markets. To illustrate the hyperport principle, a conceptual video was released in July 2021. The development results were presented in detail at the ITS World Congress in Hamburg in October 2021.

FRESH

Harnessing consumer flexibility with regard to their energy demands is expected to play an important role in the success of the energy transition. The FRESH project (flexibility management and control reserve provision of heavy goods vehicles in the port, sponsored by the German Federal Ministry for Economic Affairs and Climate Action) builds a bridge between

commercial electric vehicle fleets and the energy market in practice, thus tapping the potential for flexibility. At CTA, transport between the quayside cranes and the block storage units is fully automated with the use of driverless vehicles (automated guided vehicles, or AGVs for short). The entire fleet of these heavy goods vehicles is currently being replaced by battery-powered vehicles using lithium-ion battery technology and fully automated charging stations. On average, however, an AGV spends about a third of its operating time in a waiting position. During this time, it is possible to postpone or interrupt the charging process, vary the charging capacity or even feed electricity back into the grid. The challenge is to continuously forecast the transport capacities that will soon be required of the vehicles and to plan the potential battery capacities and allocations of charging stations and vehicles, thus paving the way for the optimised use of available flexibility.

HITS-Moni

In partnership with the Department of Informatics at the University of Hamburg and DAKOSY, HHLA is conducting the IHATEC-funded project Harbour IT Security Monitoring (HITS-Moni) until February 2022. The project seeks to conduct a port company-specific risk analysis, to design methods and rules for detecting and blocking cyberattacks on IT systems and to implement them in a demonstrator. This also involves conceptualising the linking of IT security tools across different companies in the port sector. The aim is to detect and escalate attacks automatically and in good time. It is expected that the establishment of innovative IT security concepts and technologies within autonomous systems will boost productivity and efficiency by reducing the risk of potential system failures or data manipulation caused by cyberattacks.

UniPort 4.0

Hansaport has set up the IHATEC project UniPort 4.0 in partnership with Brunsbüttel Ports GmbH and other companies. Digitalisation in the field of all-purpose ports is still at an early stage. The often conventional work procedures and comparatively low level of maturity in terms of organisational and information technologies at all-purpose ports represent a significant obstacle. Whereas digitalisation at container ports is developing swiftly on account of global growth in consumer goods and the standardisation offered by containers, the core business of an all-purpose port lies in the handling of all kinds of break bulk, dry bulk and large quantities of general cargo. These pose challenges for the ports in terms of handling technology and in relation to the various shapes, weights, volumes and batch sizes, as well as in terms of storage, safety regulations and the required transport modes. In light of the ever-changing goods and product sizes/weights, the processes at an all-purpose port must be structured in a sophisticated manner and, from a digitalisation standpoint, usually offer significant optimisation potential. The idea behind UniPort 4.0 is to apply digitalisation in a comprehensive manner at the various ports involved.

Artificial intelligence and machine learning

With its artificial intelligence (AI) initiative, HHLA is pursuing three key business aims: tapping additional business potential, boosting customer loyalty and increasing terminal productivity. HHLA also feels that AI offers considerable potential when it comes to increasing occupational safety among the workforce.

The first AI pilot projects have been successfully completed. AI-based forecasts of container collection times and the outgoing carriers result in increased yard productivity.

Performance certified

In order to document its performance, the HHLA Container Terminal Altenwerder (CTA) once again completed certification in accordance with the Container Terminal Quality Indicator (CTQI) in the reporting year. The standard, which was developed by the Global Institute of Logistics and Germanischer Lloyd, checks criteria such as the safety, performance level and efficiency of a terminal on both the water and onshore, as well as its links to pre- and onward-carriage systems. With its successful certification, the terminal once again confirmed its high level of performance and compliance with all quality standards.

ABC-Inspekt

Container gantry cranes that load and discharge ships are a key element of a container terminal. Qualified inspections are therefore exceptionally important for maintaining the uninterrupted, round-the-clock operation of such seaport container gantry cranes (24/7, 365 days a year). The critical parts of a container gantry crane are currently inspected individually by qualified experts. Carrying out and evaluating these inspections is becoming more and more difficult with the steadily increasing size of container gantry cranes, and the amount of image data to be inspected is becoming more extensive.

In order to boost the efficiency and quality of the photographic analysis, as well as improve workplace safety and ultimately the reliability and availability of the container gantry cranes, a self-learning, automated image recognition system based on artificial intelligence is to be used to analyse image material. Over an extended period of time, the system conducts an automatic comparison of any changes in the same areas of the container gantry cranes.

The ABC-Inspekt research project, supported by the IHATEC programme, is being implemented in partnership with the Technical University of Braunschweig with the aim of developing an intelligent image recognition system. This self-learning image recognition system (AI) will be used to analyse image material from the critical points on container gantry cranes.

Cookie

The IHATEC project Cookie, funded by the German Federal Ministry for Digital and Transport, seeks to optimise the process of damage identification and assessment in the empty container depot with the aid of artificial intelligence and 3D digital container twins. The project name Cookie stands for “COntainerdienstleistungen Optimierte durch Künstliche Intelligenz” (container services optimised by artificial intelligence). Together with our research partner, the Fraunhofer Center for Maritime Logistics in Hamburg-Harburg, the aim is to develop an adaptive algorithm for image recognition processes. The aim is to revolutionise the inspection process for identifying and assessing any damage to empty containers with the aid of machine learning methods (specifically, deep learning) and the explicit linking of CEDEX codes, which are subject to syntax rules, in combination with the 3D digital twins. The integration of an AI-based system for identifying damage is expected to reduce error rates, increase the uniformity of damage assessments and improve process speed in order to further boost efficiency and achieve reliable availability planning for containers within the processes at the empty container depot.

BVLOS drone system

HHLA Sky has developed a globally scalable, end-to-end drone system that allows the secure operation of drones beyond the visual line of sight (BVLOS). The industrial drones are extremely robust, very light and equipped with safety technology. Customers can integrate the system into their own business processes independently, or use it as a service operated by HHLA Sky. HHLA Sky has also developed software and related information systems. The HHLA Sky software can be purchased for use on a licensed basis. The control centre is used operationally for drone flights, including to inspect container gantry cranes at the HHLA terminals.

HHLA Sky is also contributing its expertise to the UDVeO (urban drone traffic efficiently organised) research project. The project is being funded by the German Federal Ministry for Digital and Transport (BMDV) from 2020 to 2022, under the leadership of the Helmut Schmidt University in Hamburg. The aim of the project is to develop the basis for a drone management system for efficient and safe transport within densely populated urban spaces. In 2021, the focus was on developing a prototype for a U-Space service provider, which was publicly demonstrated at ITS 21 in Hamburg. HHLA Sky also participated in the U-Space real laboratory in Hamburg in the role of a commercial drone operator.

In 2021, HHLA Sky GmbH won the prestigious German innovation award (an initiative of Accenture, EnBW and Wirtschaftswoche under the patronage of the German Federal Minister for Economic Affairs) in the start-up category.

modility booking portal

Together with eleven partners in the transport and freight-forwarding sector, HHLA has initiated the development of a new booking portal for intermodal transport. As a digital match-maker between providers and customers of intermodal transport in Europe – with a current focus on road and rail as modes of transport – modility aims to become a central access point for intermodal transport and make it easier for companies to switch to more climate-friendly transportation. Operators can use the portal to market their transport capacities, while freight forwarders can easily find them, as in a search engine, and directly book them online if needed.

modility was validated under everyday conditions in a nine-month pilot phase funded by the German Federal Ministry for Digital and Transport (BMDV) and lasting until August 2021. In addition to the expansion of the European network and the further needs-based development of the portal, the main focus was on establishing the solution as an everyday operational tool for dispatchers and actively facilitating the first transports. As a gateway to the world of rail freight transport, modility will continue to generate tangible added value by helping users to find suitable transport partners and providing support in communication and processing.

PortSkill 4.0

The increasing digitalisation and automation of work in the port sector is having a profound impact on processes, requirements and cooperation. And as job profiles change, employees will need to adapt their skill sets to these new requirements. The spectrum of change ranges from medium-term adaptation needs to completely new skills profiles to be developed for employees in the port sector.

This is where the IHATEC-funded project “PortSkill 4.0” comes in, which was launched together with companies in the German port sector and the social partners of the maritime economy. This research initiative is centred on changes in work activities at the port and the resulting impact on the skills which employees need. The focus is on operations as well as on the associated technical and administrative functions. The aim is to analyse and research the skill sets necessary for the port work of the future. This will culminate in the development of innovative learning concepts and environments which will initially be tested in a digital testing and training centre and then rolled out in new training programmes. Alongside this, the socio-economic effects of the digital transformation at German port facilities is being examined, and recommended action identified.

Rymax

As an associate partner, HHLA is part of the “Rymax-One Quantum Optimizer” project. The project will run for five years and has received funding of € 29.0 million from the German Federal Ministry of Education and Research (BMBF).

Quantum computers promise considerable advantages over conventional digital computers for certain tasks. Due to the high degree of technical complexity involved, however, it has not yet been possible to manufacture a quantum computer with an adequate number of qubits which is suitable for everyday use. The approach being pursued here is based on the principle of the so-called quantum annealer. This is less complex and thus less universal in terms of achieving a quantum advantage than a gate-based approach. However, it promises to reach the threshold for practical suitability sooner – especially for optimisation problems.

The network is pursuing the goal of completing a corresponding demonstrator by the project's end. This will be integrated into a high-performance computing environment and made available to interested users via the cloud for HPC/quantum computer-hybrid operation.

If successful, the Rymax quantum annealer can be scaled to practice-relevant sizes in the medium term and can be applied commercially to solve specific industrial problems. In the longer term, individual hardware components and complete systems can be offered on the market.

In close collaboration with its partners Fraunhofer ITWM and the University of Hamburg, HHLA will make challenging logistics use cases available that are particularly suited to quantum optimisation. Fraunhofer ITWM and the University of Hamburg will transfer these problems to the quantum computer and compare them with the best conventional approaches. HHLA will then evaluate the applicability of the solutions in actual operations.

TransHyDE flagship hydrogen project

The German Federal Ministry of Education and Research (BMBF) will approve substantial amounts of funding for three flagship hydrogen projects as part of the implementation of the National Hydrogen Strategy. Their purpose is to facilitate Germany's transition to a hydrogen economy over a period of four years. The three projects are the series production and scale-up of water electrolyzers (H₂Giga), the offshore production of hydrogen and secondary products (H₂Mare) and technologies for the transportation of hydrogen (TransHyDE). More than 240 partners from the scientific and industrial sectors are working together on the flagship hydrogen projects. HHLA is part of this network and is participating in the TransHyDE key project.

As hydrogen is rarely used at the same location as it is manufactured, TransHyDE aims to address this problem by developing a holistic approach to the production, transportation and use of hydrogen. Together with other partners, HHLA is examining the various transport options in relation to this and is involved in the TransHyDE projects “Mukran” and “Helgoland” on the islands of Rügen and Heligoland, respectively, where the transportation of hydrogen in high-pressure containers as well as via LOHCs (liquid organic hydrogen carriers) is being tested.

Bionic Production

Mobile 3D printing factory – Mobile Smart Factory

The increasing global interconnectedness of industrial manufacturing that relies on transportation by land, sea and air is producing an enormous volume of CO₂ emissions. Huge quantities of natural resources are wasted as a result of supplying factories with components that need to be delivered quickly by aircraft, storing tens of millions of needlessly produced safety stocks of components and discarding millions of tonnes of metal in the form of pipes and other technical components which could be recycled using 3D printing repair processes. The Mobile Smart Factory developed by Bionic Production GmbH is the world's first mobile 3D printing factory that can produce urgently needed components autonomously and locally as well as being able to repair large components. Both metal and plastic replacement parts can be rapidly produced or repaired as needed in the Mobile Smart Factory. As a result, logistics flows can be fundamentally avoided. Furthermore, only parts that are actually needed are produced. As such, the Mobile Smart Factory makes a significant contribution to the conservation of resources.

DeMa Token Blockchain

DeMa Token Blockchain offers a network solution for decentralised manufacturing by selling quantity-based NFTs and receiving a DeMa-native cryptocurrency. This involves tokenising the manufacturing files of the replacement parts on a blockchain, thus creating a unique digital twin of the component. This digital twin can be sold and traded as a utility token on a non-fungible basis and provides the supplier with complete control over the number of locally printed and manufactured replacement parts.

Part Screening 3D printing

Bionic Production offers a solution for identifying potential 3D printing components. The aim of the software application is to assess conventional components, determine their potential for additive manufacturing and conduct a cost comparison.

Climate-neutral world heritage site Speicherstadt historical warehouse district

Funded by the German Federal Ministry for Economic Affairs and Energy (BMWi), the project aims to determine whether climate neutrality can be achieved in landmarked buildings. It does so on an application basis using a reference storage unit in the Speicherstadt historical warehouse district. The project will look into how the energy required to run a property can be generated, stored and used in the building itself. In addition to HHLA Real Estate, the project participants are the Institute of Construction Materials (IWB) at the University of Stuttgart, HafenCity University Hamburg (BIMLab) and RWTH Aachen University (EONERC).

Purchasing and materials management

Purchasing is a shared service provided by the HHLA Group's management holding company in Hamburg. HHLA Group purchasing supports corporate strategy by means of its professional management of procurement activities. The aim is to establish a consolidated supplier base that is characterised by maximum value added, top quality and optimum life cycle costs.

HHLA's supply chains comprise capital goods (such as port handling equipment) as well as consumables and other services (such as maintenance). The overwhelming majority of suppliers are from Germany and other European countries.

The strategic purchasing function supports and advises Group companies as part of its holistic management of product groups, suppliers and contracts so that the service and performance requirements of internal customers are met as completely as possible. Market developments relating to new technologies, innovations and the service performance of specific suppliers are considered in close cooperation with the operations and technology departments. Now that the transformation of the purchasing department has largely been completed, it is firmly established as a strategic partner within the Group. It is involved in procurement projects at an early stage, providing value-adding support and expert advice on market, supplier and innovation developments. In this regard, the purchasing department ensures that all Group requirements for the procurement processes are observed in accordance with the framework guidelines. These guidelines are binding for all employees.

In order to develop viable future solutions for port infrastructure, HHLA remains committed to its strategic and collaborative partnerships with selected suppliers while taking into account both economic and ecological aspects. Products, facilities and processes are systematically enhanced by drawing on the potential of digitalisation.

When selecting partners, great importance is attached to reliability, quality, innovative strength, cost structure, economic stability, sustainability and compliance. Compliance with these criteria is monitored by an IT-based supplier management system. This also facilitates a continuous review of the degree of fulfilment and the supplier base.

A comprehensive project for the consolidation of the existing product groups was launched in 2021. As a result, there will be three main product groups in future: technical purchasing (generally comprising the previous equipment & energy and MRO groups), construction purchasing, information technology (IT) and indirect purchasing. In 2021, the technical product group accounted for 43.9 % of the Group's managed purchasing volume, while IT, indirect services and materials accounted for 25.4 % and construction for 30.7 %. The total managed purchasing volume amounted to approximately € 232 million.

The challenges resulting from the pandemic, such as price increases and capacity shortages, have been effectively counteracted so far by the Group's preventive risk management. For example, alternative suppliers were swiftly turned to when needed, and their numbers increased.

We continued to drive the automation of purchasing processes for day-to-day requirements. In the reporting period, 56.5 % of all purchasing processes were handled fully automatically by means of the systems (previous year: 48.1 %). The main increase was in the automation of procured stock items. This enables us to streamline processes and ensure both non-bureaucratic procedures and compliance with process standards. By systematically continuing these optimisation and automation measures, further automation potential is expected for the 2022 financial year, in particular as a result of an updated e-procurement system that went live at the start of 2022.

The automation of processes is also continuing in materials management. A system was rolled out to support mobile working. The first stage involved mapping the inventory processes. Further activities like incoming and outgoing goods are to be gradually switched over.

In the area of process optimisations, vehicle fleet management was improved in 2021. The previously decentralised structures were revised and centralised as part of a project managed by employees of the department. Another example is the optimisation of building cleaning services. Uniform Group standards were implemented here, marking the beginning of standardisations in the facility management department.

After mainly focusing on optimising the key procurement topics in 2019 and 2020, the purchasing department concentrated again on strategic alignment and modelling the entire process chain in 2021. Its efforts centred on the issue of product group