discoverLOGISTICS

Magazine of the Fraunhofer Institute for Material Flow and Logistics IML Dortmund #24

Coverstory:

SOCIAL NETWORKED INDUSTRY

How AI and social machines will shape the work of the future

About us

The Fraunhofer Institute for Material Flow and Logistics IML is the partner of choice for integrated logistics research. It works in all fields of internal and external logistics. In keeping with the concepts of the Fraunhofer-Gesellschaft, solutions to problems for immediate use in business are developed on the one hand, but initial research is also conducted on the other hand. Currently 400 scientists as well as 250 doctoral candidates and students work at the institute founded in 1981.

Teams assembled according to project and customer requirements create cross-industry and customer-specific solutions, among other things in the field of materials handling, business process modelling, transportation systems and resource logistics. Artificial intelligence, smart finance and the Internet of Things are also among the current research focal points.

For interdisciplinary projects, the institute has access to a total of 30,000 employees in 76 facilities of the entire Fraunhofer-Gesellschaft.

Locations aside from Dortmund include Frankfurt/Main, Hamburg, Prien am Chiemsee and Beijing.

www.iml.fraunhofer.de

Dear friends of **logistics,**

Bettina von Janczewski
Team leader press and media
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ever since ChatGPT, we have known that artificial intelligence (AI) will enter our everyday lives and change them. It is the most radical megatrend of our time. The scientists at Fraunhofer IML have been researching developments relating to this megatrend for years now. The world of work in particular will change fundamentally – the logistics sector is on the verge of a technological paradigm shift. To guarantee a secure, trustworthy cooperation between humans and AI, Fraunhofer IML started work on the "Social Networked Industry" in 2017: This is a world in which humans and machines collaborate together as partners in social networks.

Since then, AI research has advanced even faster than most people expected. In our coverstory, you can find out what this means for logistics and how Fraunhofer IML is shaping the Social Networked Industry (from p. 6). The visit of Hubertus Heil, the German federal minister for employment, to our institute in the summer of 2023 underscores the important role this research plays for the working world of the future (p. 16). The minister learned about technologies for this future working world, and he clearly sees the use of AI as an opportunity – especially when intelligent solutions are developed in Germany, thus meeting our security and data protection standards.

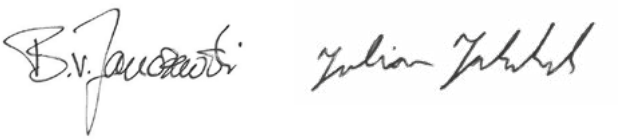
So-called social machines play a major role in shaping this working world. These are robots that increasingly act like colleagues and they are intended to advance the collaboration of humans and AI-based technology. Fraunhofer has already developed and introduced the first robots of this generation with the "evoBOT" and "RAI – Remote AI" (p. 10 and p. 24).

AI developments have also characterized Fraunhofer IML's trade fair season – from social machines to swarm robotics (p. 26), to the smart camera in which AI-based image processing occurs locally on the device (p. 28).

In addition to artificial intelligence, however, there are of course other highly topical issues as well – such as resilience, sustainability and hydrogen – that concern logistics research and drive the economy in particular. The resilience of supply chains has been on everyone's lips and on everyone's agenda at least since the coronavirus crisis (p. 34). This is also a decisive key to more sustainability at the same time (p. 40). We will show you the potential that currently lies dormant in hydrogen research using two examples: the blockchain-based tracking of hydrogen production (p. 36) and a smart hydrogen container for railways (p. 44).

In this issue, you will also read the latest about our joint enterprise lab with the logistics service provider DB Schenker. This lab has existed since 2015 and is now a genuine success story (p. 20).

We hope you enjoy reading this issue.



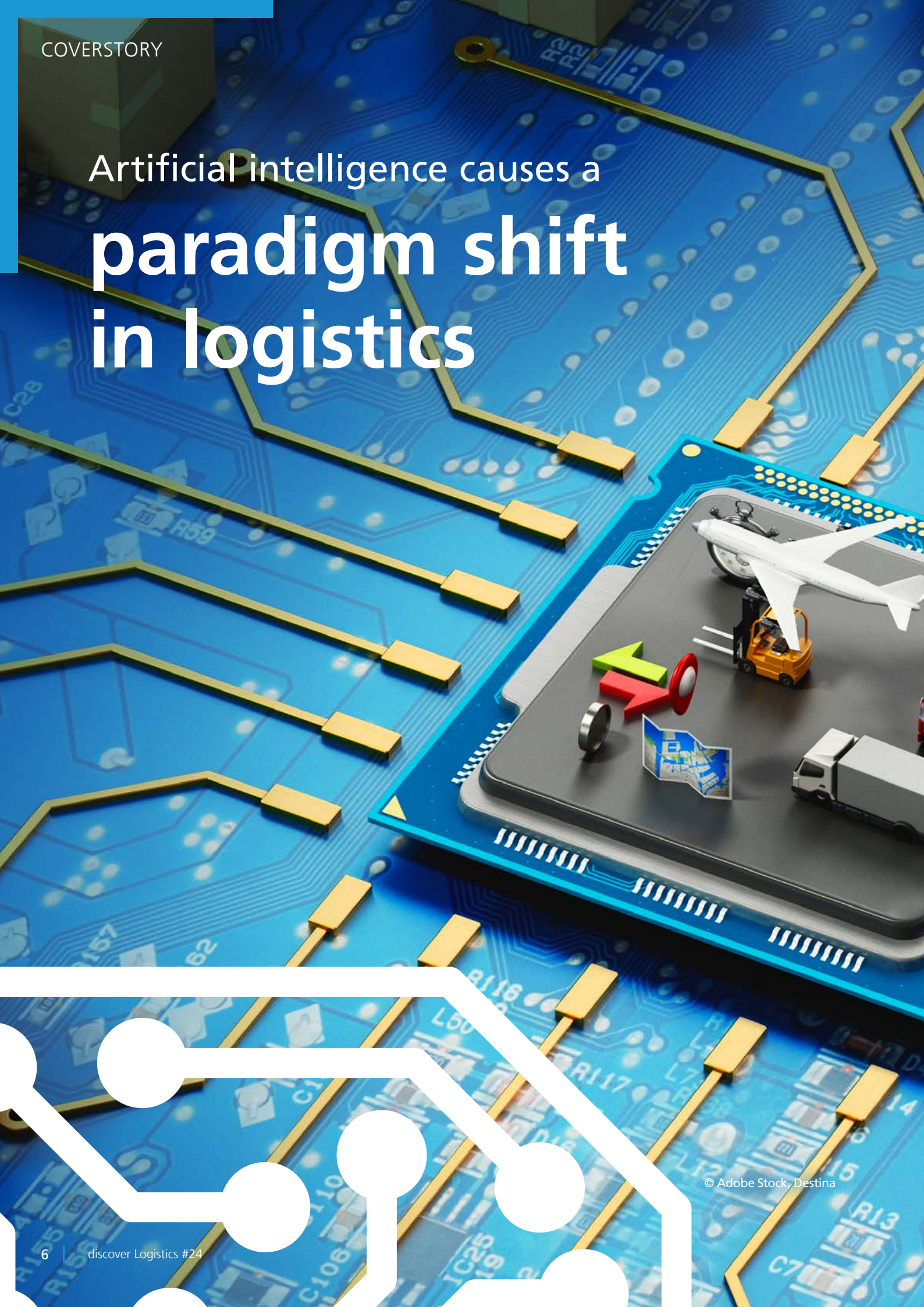
The "discover Logistics" editorial team

Content

discover Logistics #24

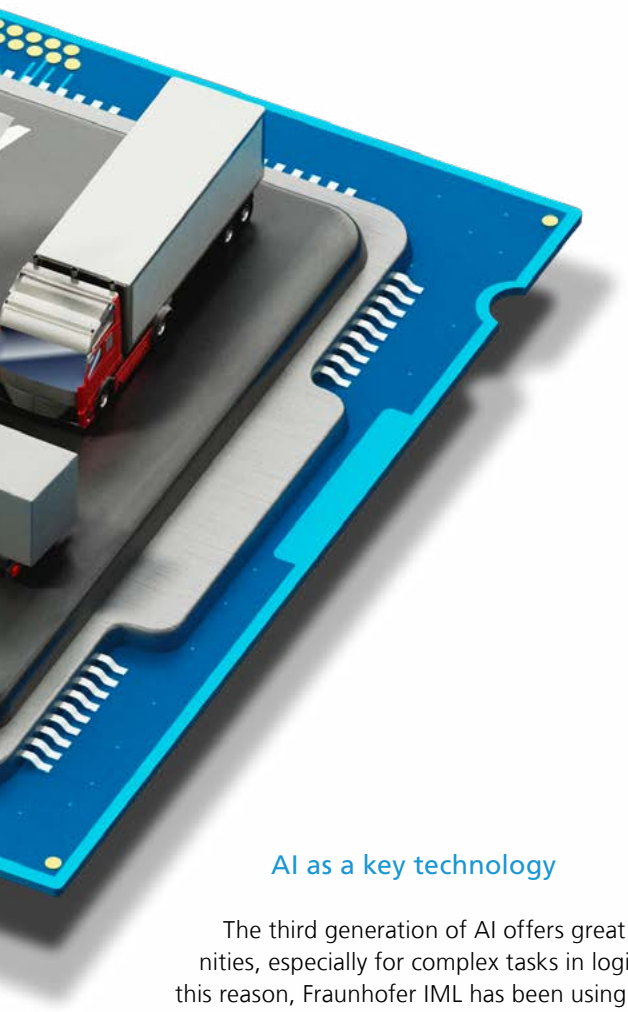
Artificial intelligence causes a

paradigm shift in logistics



The development of artificial intelligence (AI) is unstoppable. Intelligent systems are increasingly controlling processes and making decisions that influence everyday life. Although the future technology has already entered our daily lives, we still face great challenges. In order to meet these challenges, Fraunhofer IML has entered the ring with the "Social Networked Industry," researching and developing AI systems for human-machine interaction. Because one thing is certain: AI is determining the future of logistics.

The most recent examples, such as ChatGPT from the Microsoft subsidiary Open AI, are impressive. They show what machine learning methods and algorithms can now achieve and how incredibly fast they are developing. This is a result of generative artificial intelligences of the third generation. Unlike the rule-based systems of the first generation and the learning-capable programs of the second generation, these are able to autonomously combine knowledge and sometimes context as well with data.



AI as a key technology

The third generation of AI offers great opportunities, especially for complex tasks in logistics. For this reason, Fraunhofer IML has been using artificial intelligence (AI) and open source to research innovations regarding the current megatrends for some time now. As part of the Lamarr Institute for Machine Learning and Artificial Intelligence, the Dortmund institute wants to further develop the third generation of AI, or "triangular AI³," as the researchers call it, in a multidisciplinary way. This is the ultimate technology for developing future technologies for the logistics sector.

The researchers believe that deep learning will make third-generation artificial intelligence become the actively operating part of logistics and production systems in the future, since it can solve more and more complex problems in addition to routine tasks. Deep learning programs are now probably even superior to human intuition – especially in the case of larger data volumes. As a result, these programs would also potentially optimize all processes along the supply chain. In this way, AI could become an actively engaged partner of human beings. It would not only provide information but also be able to control, negotiate and plan more and more actively. It could be used to solve the great problems of our time – starting with geopolitical crises and disruptions in supply chains, to labor shortages and demographic change. "We can already manage some challenges in logistics better with artificial intelligence, and some problems we will even only solve using AI. Whether organizing a swarm of mobile robots, combing through large databases or calculating the next batch, many things in intralogistics cannot be sufficiently described with formulas or controlled with common sense. Here, AI can help and learn some things that we do not understand," explains Prof. Michael ten Hompel, executive director of Fraunhofer IML.

Value-based application of AI

To increase the acceptance of AI-based solutions, an important focus of their research is making machine learning methods transparent and interpretable for people. Decisions and mistakes of AI must be seamlessly traceable. Trustworthiness also means complying with ethical and data protection standards, however. With the slogan "Trustworthy AI," the scientists have therefore focused on an important principle for developing AI: How can machines be programmed so that they act "responsibly," in other words, according to standards and rules? After all, AI should serve humans and not vice versa. As a basic technology, it is supposed to be a helping hand to support people cognitively as well as physically. The institute wants to use AI to holistically establish safe and healthy work practices in process automation and process autonomization, from the shop floor to the value-added level. In addition, existing highly scalable digital and technical solutions for applications are to be systematically interlinked and developed further for all company sizes. Fraunhofer IML wants to create an open-source ecosystem for logistics – a type of "Linux for logistics and AI" – with the company-funded Open Logistics Foundation initiated within "Silicon Economy." The institute wants to use this to pave the way for AI-based technologies for small and medium-sized enterprises as well. Together with the "Social Networked Industry," they want to create a world in which humans and AI cooperate as partners in social networks and thereby shape the world together.

"Social Networked Industry" – a foundation for secure and trustworthy interaction between humans and AI

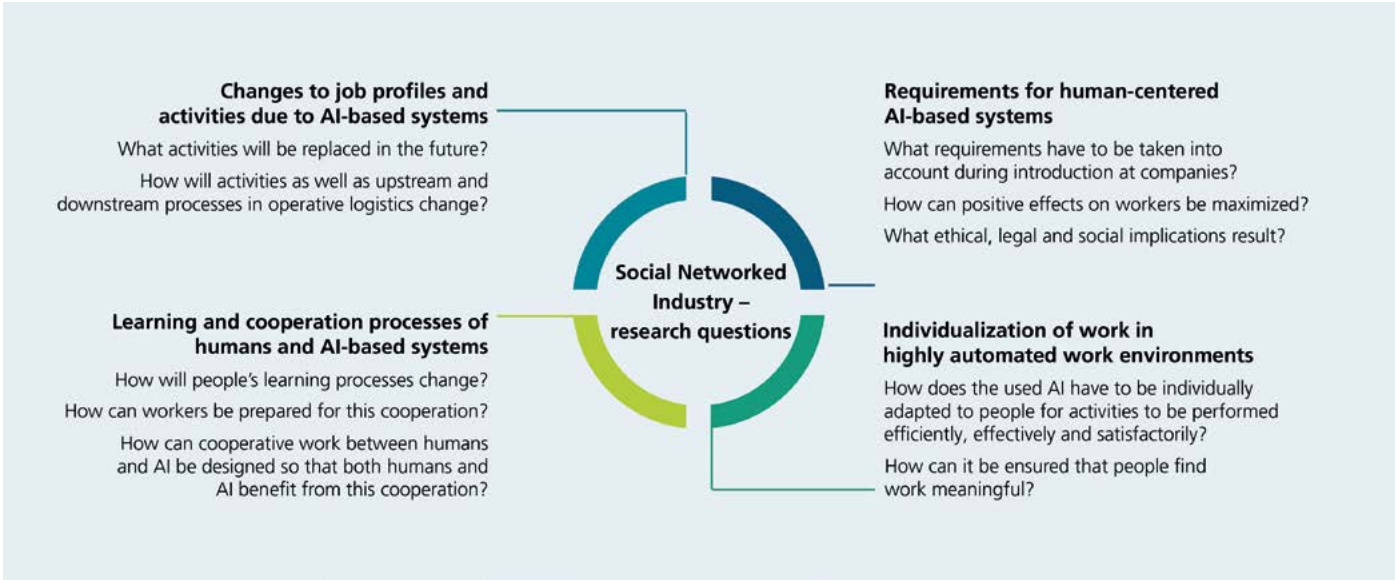
With the project "Social Networked Industry – secure and trustworthy cooperation between humans and artificial intelligence," Fraunhofer IML wants to use AI to create a new type of working world for logistics with humans at its center. Humans become the directors of entire systems and interact with intelligent and networked machines. This results in social networks that connect humans and technology.

Fraunhofer IML launched the "Social Networked Industry" in 2017. The researchers already anticipated that AI would massively change the world. "Digitalization of everything and artificial intelligence in everything will change everything for us. A social networked industry will arise in which humans and machines work together as partners in social networks based on artificial intelligence," Prof. Michael ten Hompel envisions.

How is the Social Networked Industry defined?

The "Social Networked Industry" consists of two components: the networked industry and the social network. Topics such as Industry 4.0 and the Internet of Things deal with the networking of technologies. However, networking is also a significant factor in today's society. Social networks such as Facebook, Twitter, Xing and the like connect people with each other across national and cultural borders. They are decentralized, intuitively usable, scalable, emotional and have a permanent place in our everyday lives. Networking also plays an increasing role in companies. For this reason, the researchers want to transfer this concept to the cooperation between humans and machines. The "Social Networked Industry" stands for a combination of autonomously acting human and machine entities that grow into functioning dynamic networks. These can arise on an ad-hoc basis to solve a concrete problem. The spontaneous networking and fast creation of new structures are essential both within companies as well as across company boundaries. This is the only way that the logistics world can master future challenges and optimally exploit opportunities to leverage competitive advantages.

According to the researchers, human-machine communication allows the positive unique characteristics of humans



and machines to be combined: flexibility and creativity with efficiency. The aim is to relieve people from error-prone and monotonous activities and increase their satisfaction. This requires people to be trained, because the technical and organizational transformation will change activities and job profiles. Lifelong learning is therefore essential to prepare people for their new roles.

Demonstration platform for application-related developments

A research and demonstration platform for application-related developments for logistics is also to be set up within the "Social Networked Industry." Real scenarios and conditions in operative logistics are to be simulated. This will test and evaluate innovative technologies as well as the cooperation between humans and technology. For example, the Embodied AI department of Fraunhofer IML, which deals with robotics, has already been using a new generation of simulation-based AI for quite some time. This is used to develop autonomous solutions such as the highly dynamic robot "LoadRunner" or the transport robot "evoBOT."

The simulation is so exact that it can be used to teach very complex situations. Sensors in the simulation are taught to locate vehicles in a swarm. The connection with control technology produces a digital continuum – a self-optimizing system.

The "Social Networked Industry" is a task for society as a whole

The vision of a human-centered "Social Networked Industry" has to be understood as a task for society as a whole, in which experts from various specialist disciplines work together on equal terms to design it. The graphic on p. 8 shows which research questions have to be addressed for this purpose.

Lamarr Institute for Machine Learning and Artificial Intelligence

The Lamarr Institute concentrates on researching and developing powerful, trustworthy and resource-efficient machine learning (ML) and artificial intelligence (AI) applications. The goal is to establish internationally competitive research that strengthens Germany and Europe as a leading location for AI research, teaching and technology transfer. After successful evaluation by an international expert committee, the Competence Center Machine Learning Rhine-Ruhr (ML2R) became the Lamarr Institute. It now receives long-term institutional funding from the German Federal Ministry of Education and Research (BMBF) and the German state of North Rhine-Westphalia as part of the German federal government's AI strategy. The Lamarr Institute is supported by the Technical University of Dortmund, the University of Bonn as well as the Fraunhofer Institutes for Intelligent Analysis and Information Systems IAIS in Sankt Augustin and Material Flow and Logistics IML in Dortmund.

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Robot colleagues –

How humans and technology become a team

For Fraunhofer IML the cooperation of humans and technology is one of the great challenges of the digitalization process. It affects both the quality of work as well as people's acceptance of digital solutions. Digital assistance systems that support people individually and ergonomically with their work could be the solution here.

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When selecting and designing assistance systems, it is therefore important to find the right design for the respective process and the involved employees. The researchers want to find out what information the employees need in the process and how this information can be provided. For this purpose, they study different types of assistance systems, such as AR and VR goggles or exoskeletons, for example, taking into account the basic rules of cognitive ergonomics. According to Fraunhofer IML, assistance systems are also able to support people as data-based decision-making aids in planning and implementing logistical processes. Simulations and artificial intelligence based on previously recorded data can provide a valuable impetus here.

Fraunhofer IML wants to reduce health risks such as stress and posture problems, increase the acceptance of technological innovations, as well as boost the efficiency of work processes through so-called "social machines" using human-technology interaction. This will make people's interaction with autonomous drones and driverless transport systems as well as the work with virtual reality (VR) and augmented reality (AR) increasingly significant as well.

Social machines are trailblazers for the humanoid future of robotics

With "RAI – Remote AI" and the transport robot "evoBOT," Fraunhofer IML has already launched the first "social machines." These are to advance collaboration between humans and AI-based technology – the latter has even already passed a practical test with flying colors.

"evoBOT" as a freight robot at Munich Airport

With the "evoBOT," Fraunhofer IML shows how autonomous vehicles and robots will shape air freight in the future in times of skilled worker shortage. The robot has two wheels and gripper arms, which always remains balanced. It has mastered its first practical test in the freight terminal and on the apron of Munich Airport. The autonomous robot proved its versatility during its first test runs at Cargogate at Munich Airport. For the researchers, the successful practical test impressively highlighted the potential of this development. A key feature of the transport robot is its arms and the fact that they allow adaptive load handling. The robot can perform many different tasks, such as handling hazardous goods, transporting packages over longer recurring routes, relieving employees from lifting and overhead work, procuring material or even supporting airplane loading and unloading. The maneuverable "evoBOT" can push, pull, turn and pass things, while always keeping its balance. This is a result of the inverse pendulum principle,

which does not require a counterweight. Due to the pendulum movement, the robot can pick up objects such as boxes and packages directly from the ground or lift them off the conveyor and put them back at different heights, as far as its arms allow. With a maximum speed of up to 60 km/h, it can transport loads of up to 100 kg. The "evoBOT" can be operated in various indoor and outdoor areas. It can also operate alone or in a swarm. The Digital Testbed Air Cargo (DTAC), where the current test was performed, and the initial development of the "evoBOT" are programs funded by the German Federal Ministry for the Environment (BMMV). The DTAC project consortium includes Cargogate Munich Airport GmbH and Fraunhofer IML as well as nine other partners from research and industry: CHI Deutschland Cargo Handling GmbH, Flughafen Köln/Bonn GmbH, Frankfurt University of Applied Sciences, Fraport AG Frankfurt Airport Services Worldwide, Lufthansa Cargo AG, LUG aircargo handling GmbH, Mitteldeutsche Flughafen AG, Schenker Deutschland AG and Sovereign Speed GmbH.

The evoBOT deployment in the video

"Artificial brain" recognizes and transports objects

With "RAI – Remote AI," Fraunhofer IML has developed a box with the level of intelligence that a robot needs to fulfill its tasks. The modularity of RAI allows transport vehicles to be autonomized and equipped with numerous abilities. This intelligent box offers everything that a robot's heart could desire, from AI-based image recognition to localization. Optically, RAI also resembles a humanoid robot. The AI box is 5G-compatible and, as a solution similar to the plug-and-play principle, it can be easily connected to AGVs (automated guided vehicles). This requires only low-threshold software adaptations. The robot then supplies RAI with the required energy. Using localization algorithms, the robots can move in dynamic deployment locations and carry out transport tasks. RAI provides vehicles with "lifelong AI," in other words, the learning success of individual vehicles can be transferred to other robots or even to an entire fleet thanks to continuous training. The human-technology interaction can be implemented through direct interaction via the installed display or even via smart glasses. The AI-based object recognition could be used to search for lost packages at a distribution center or for order picking, for instance.

More about RAI – Remote AI on page 24

Machine learning and neural networks fuel development of artificial intelligence

Artificial intelligence imitates human cognitive abilities by recognizing and sorting input data. This can be based on programmed sequences or generated by machine learning. With machine learning methods, an algorithm autonomously learns to perform a task through continuous repetition. The machine focuses on a specified quality criterion and the informational content of the data. Unlike with conventional algorithms, no solution path is modeled. The computer autonomously learns to recognize the structure of data. For example, robots can learn by themselves how to grip certain objects in order to transport them from A to B. They are only told from where and to where they should transport the objects. The robot learns how to grip by repeatedly trying to do it and receiving feedback from successful attempts. The continuously growing amount of data and the technical progress of computing power have helped to make increasingly complex calculations possible using machine learning. As a subfield of machine learning, neural networks consist of artificial neurons. These use algorithms to imitate the nerve cells of the brain. Like nerve cells in the brain, the artificial neurons are interlinked and process information through deep learning. As a result of training with large data quantities, neural networks can learn to recognize patterns and relationships as well as to make predictions. They are able to improve themselves. Neural networks and deep learning are used, for example, in image and speech recognition, automatic translation, prediction of behavioral patterns and automatic decision-making.

"AI is increasingly becoming an actively engaged partner of human beings"

Prof. Michael ten Hompel

Prof. ten Hompel, the Social Networked Industry was already the main topic of the 2017 Future Logistics Congress. In the past years, the focus has been increasingly on artificial intelligence and open source. How do these topics belong together?

In 2017, we said that we were heading towards a world in which humans and machines would work together as partners in social networks. We called this new world "Social Networked Industry" and presented the results of the BMBF-funded project of the same name.

Today we see that artificial intelligence is increasingly becoming an actively engaged partner of human beings. A social networked industry is developing in which AI not only provides information but is actively taking on more and more controlling, negotiating or planning tasks. This development was already foreseeable in 2017 – but the speed at which the change is taking place is still surprising, and logistics is once again in focus. As was said then: "Digitalization of everything and artificial intelligence in everything will change everything for us."

At the same time, we recognize that no company or institute is large enough to face this challenge by itself. This leads to the realization that the time of going it alone is over. For this reason, we initiated the company-financed Open Logistics Foundation. Its goal is to create an open-source ecosystem for logistics – in other words, a Linux for logistics and AI.

The topics of Social Networked Industry, artificial intelligence and open-source technologies are therefore closely interlinked. I am convinced that one cannot exist without the other.

The 2023 Future Logistics Congress had the subtitle "Learning what we don't understand." What does this mean?

In logistics, we frequently deal with very long observation periods, multi-criteria optimization and complex systems. Here, artificial intelligence can help us to arrive at new solutions and control our systems better. In a way, this leads us to a new paradigm of learning, for example, when we feed a large quantity of data and practical knowledge to an AI and see what internal correlations can be learned from that. This knowledge can be used to generate new solutions, for example, for controlling a robot swarm, for the next batch in order picking or for planning a logistics system.

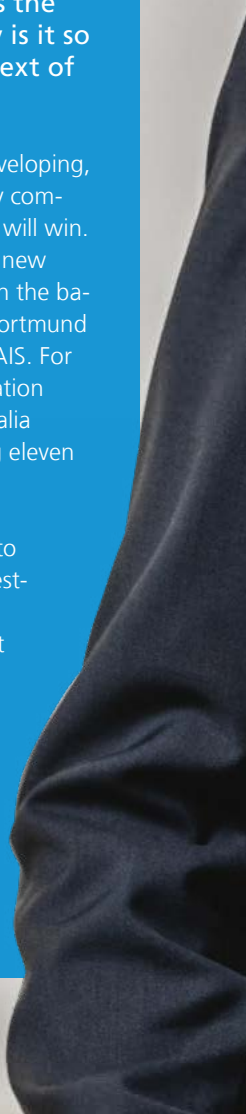
How will the interaction among Social Networked Industry, artificial intelligence and open source change future work?

First, it should be noted that the topic of artificial intelligence has already become established in the industry. 100 percent of the surveyed logistics specialists rate "data analytics & artificial intelligence" as important or very important to them. This topic will change large areas of the working world in the logistics sector: from scheduling, to inventory management, to the area of "embodied AI" – in other words, the "tangible" AI on the shop floor. In a few years, many physically demanding activities will be performed by intelligent, increasingly "humanoid" robots. Our evoBOT is already a small step in this direction. I am convinced that our AGVs will soon have arms.

Artificial intelligence has been in the public eye at least since ChatGPT and is also perhaps the most radical megatrend of our time. Why is it so important to focus on AI now in the context of the Social Networked Industry?

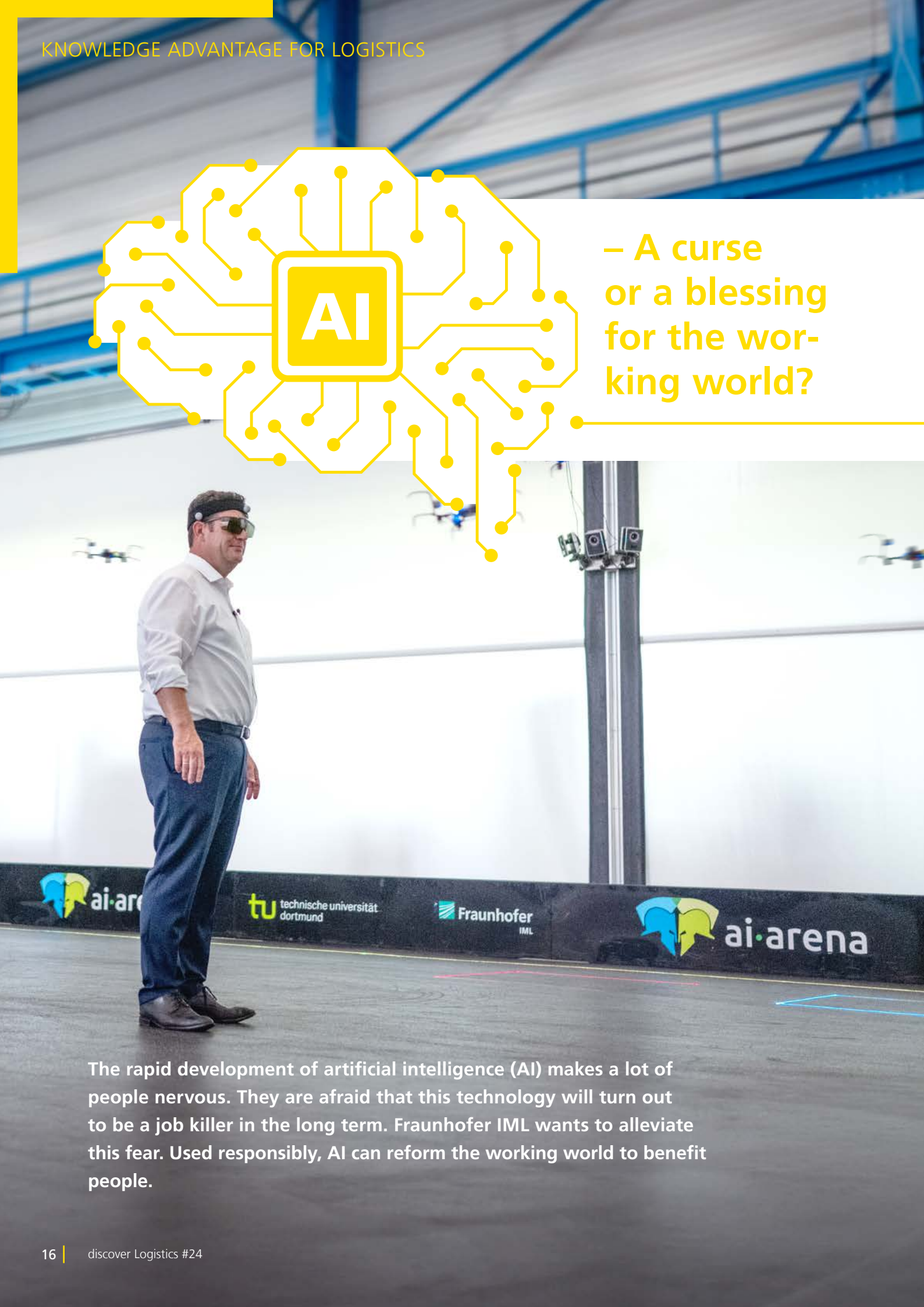
New markets for AI-based applications are now developing, and I am convinced that the ones that meaningfully combine data, knowledge and context with each other will win. This "triangular AI³" is also the central topic of our new Lamarr Institute. At the institute, we are working on the basis for a new AI generation together with the TU Dortmund University, the University of Bonn and Fraunhofer IAIS. For this purpose, the German Federal Ministry of Education and Research (BMBF) and the North Rhine-Westphalia (NRW) Ministry for Culture and Science are funding eleven new professorships and over 100 jobs in science.

Now industry is also called on. If a company wants to open up new markets in this area, considerable investments are necessary. Most developments no longer occur behind closed doors but in large development communities – many of them on an open-source basis, as was the case with ChatGPT as well. However, the open-source area also requires active engagement and investment. Microsoft and co. realized this a long time ago and are investing millions to secure future markets for themselves. Anyone who wants to play now has to leave the spectator seats and go onto the field.



Prof. Dr. Dr. h. c.
Michael ten Hompel

– A curse or a blessing for the working world?



The rapid development of artificial intelligence (AI) makes a lot of people nervous. They are afraid that this technology will turn out to be a job killer in the long term. Fraunhofer IML wants to alleviate this fear. Used responsibly, AI can reform the working world to benefit people.

The Dortmund think tank showed what intelligent future technologies for logistics could look like on the occasion of the visit of the federal minister for employment, Hubertus Heil. He has declared the cooperation of humans and AI in the working world to be a top priority.

Hubertus Heil, the German federal minister for labor and social affairs, went on a summer tour of North Rhine-Westphalia devoted to topics such as occupational safety, the shortage of skilled workers and the cooperation between humans and AI. As part of this tour, he visited Fraunhofer IML among other places, together with journalists. The visit focused on future technologies that will shape the future working world. It was certainly no coincidence that the minister chose the Dortmund institute as the last stop on his tour, because innovative solutions for the working world in logistics have been researched here for many years. Fraunhofer IML had laid the foundation for researching the technologies of tomorrow several years before. They had announced the "Silicon Economy," an open-source infrastructure for the platform economy of the future, and the "Social Networked Industry," in which humans and AI work together as partners in social networks. The federal minister for employment was able to see for himself the great innovative strength of the institute on site.

The logistics world is facing major challenges

The increasing complexity and fast pace in logistics pose major challenges to both companies and employees. Huge quantities of data have to be processed, and this data is used as the basis for decisions that are crucial to companies' competitiveness. On top of this, there is a shortage of skilled workers and demographic change. Staffing levels are becoming lower and lower, and employees are getting older and older. It is more important than ever to make work better for people – more efficient, less strenuous, more sustainable. This is where AI comes into play. In the future, AI will be a decisive factor for competitive advantages, and it will affect the working life of every person. It can help people make the right decisions, organize work more efficiently, and it offers solutions, for example, to counteract the shortage of skilled workers and demographic change.

AI can solve key tasks of the future

Fraunhofer IML regards AI as the decisive future technology of the 21st century. It is helping to create new markets, which are to be discovered. As a key technology, AI offers great opportunities for prosperity and a modern working world. However, companies and employees need security and trust to use AI applications in everyday operations. For this reason, the vision of a "Social Networked Industry," in which humans are at the center and work with machines as partners, is a task for society as a whole. Fraunhofer IML has widely diversified its research work. This ranges from increasing the efficiency of production processes and resource management, the flexibility of logistics processes and systems, to increasing the transparency of decisions and processes, to adapting the processes in a company to work and life models favored by employees. In the "Social Networked Industry," solutions are being developed in numerous projects to implement this positive vision of the future while ensuring that Germany as a business/industrial location can keep pace with the rapid development of AI.

"In the near future, humans and artificial intelligence will work together as partners, and AI will not only provide information but will be actively engaged more and more. The question is according to what principles this will occur. We are heading towards a turning point, the fundamental character of which evokes a "categorical imperative for artificial intelligence" – even if the comparison is still a little misleading. It is our task to ensure a framework for the

cooperation of humans and AI according to our standards and rules, as well as to implement it technically. At Fraunhofer, we are working hard on this together with our partners from science and industry," explained Prof. Michael ten Hompel, executive director of Fraunhofer IML, on the occasion of Federal Minister Hubertus Heil's visit.

AI strategy of the German federal government

The German federal government has also been pursuing an AI strategy since 2018: Germany is to become the world's leading location for AI. This is to be achieved by transferring research results to applications comprehensively and quickly as well as by modernizing the administration. The goal is to secure global competitiveness on various levels. This includes recruiting and training AI specialists as well as establishing important, high-performance research structures. The German federal government is committed to advancing a responsible use of AI in the interest of the common good, together with science, business, the state and civil society. The potential of the new technology should be leveraged on the basis of European values, such as the inviolability of human dignity, the respect for privacy and the principle of equality.

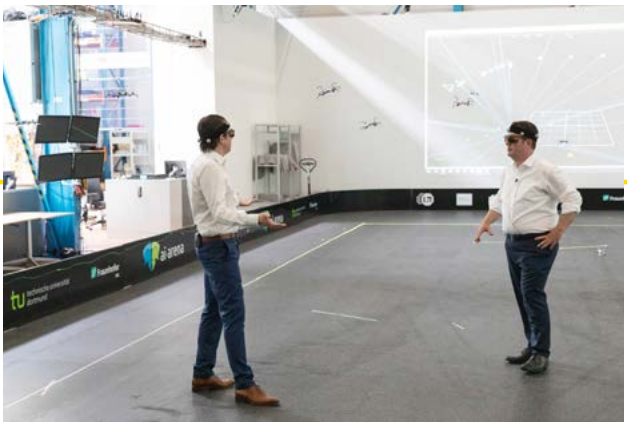
AI must serve humans and not vice versa

With this great responsibility in mind, the federal minister for employment, Hubertus Heil, is championing the topic of "cooperation between humans and artificial intelligence (AI) in the working world." This is because AI is not just any innovation to him. Instead, it is a basic innovation that will change and improve our economy and lives as a whole. He believes that one of the tasks of the German Federal Ministry of Labor is to identify international good examples of human-centered applications of artificial intelligence or intelligent tools and systems in the working world. The focus here is on workers as well as on developing their skills and talents, self-determination, safety and health. According to Heil, AI is producing new occupations, and many work processes are being simplified in such a way as to benefit people.

"Digital technologies, especially AI applications such as ChatGPT, will change the work of many employees. The use of AI in the working world therefore offers many opportunities to simplify work process at companies. In my opinion as the minister for labor, looking for solutions to optimize this further, as yout do here at the Fraunhofer institute, is also an important contribution to counteracting the shortage of skilled workers. I am convinced that this technological development can make working life better. To do this, however, we have to actively shape this technology. Our goal is for AI to serve humans, not vice versa," said Hubertus Heil, the German federal minister for labor and economic affairs, during his visit in Dortmund.

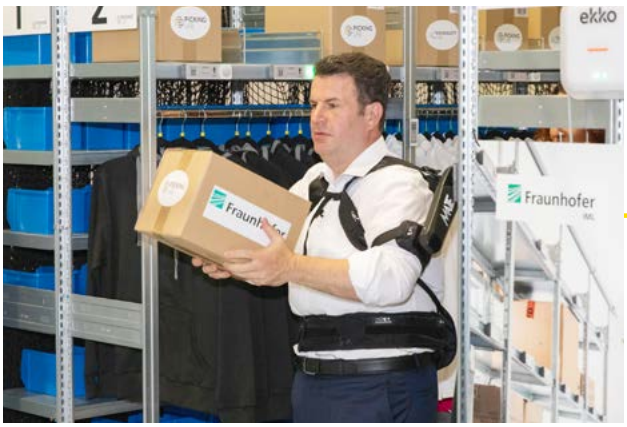
To underscore the common goal of the German federal government and Fraunhofer IML, the group of visitors around Federal Minister Heil received insights into the pioneering technologies from research and application in the research halls of the institute. The minister also had numerous opportunities to interact with machines himself.

AI algorithms for complex logistics tasks



Among other things, Heil was able to control a swarm of bio-intelligent drones. The intelligent drone swarm of Fraunhofer IML and TU Dortmund University imitates the intelligence of a flock of birds and also visualizes virtual behavior as a cyber-physical twin. Testing AI algorithms in a three-dimensional space and a highly dynamic system make it possible to find solutions for complex logistics tasks and transfer them to applications, for example. This research project not only demonstrates the advantages of fast data exchange and ensuring a collision-free path of the drones, it also emphasizes the innovative opportunities that arise when machine learning is integrated in an industrial context.

Exoskeleton: Armor for the work of the future



The minister tested the help of an exoskeleton for various warehouse activities: The (electro-)mechanical support structures worn on the body are intended to reduce the overall physical strain when performing work activities and relieve certain body regions, such as the back. In the long term, this could counteract the high rate of sickness in logistics due to strain on the musculoskeletal system and thus the shortage of skilled workers as well. At the

exoskeleton lab at Fraunhofer IML, various passive and active exoskeletons are being tested for their suitability in logistics in an intralogistics obstacle course. The researchers carry out manufacturer-independent tests and training based on typical activities in a logistics environment. The use of AI allows exoskeletons to be automatically utilized in an individual manner, supporting the workers of tomorrow interactively, intuitively and as required. In this context, AI-based approaches to the real-time recording of activities such as body postures and movements as well as conditions such as fatigue help to improve ergonomics.

Autonomous robot systems are the colleagues of the future

A further highlight was the "evoBOT" developed at Fraunhofer IML – an autonomous mobile robot (AMR) with two arms that establishes a new generation of transport robots. As a result of its high agility and flexibility, the "evoBOT" is not limited to logistics or industry but can be used in a wide variety of application areas. The dynamically stable system is based on the principle of an inverse pendulum. This allows the autonomous robot to maintain its balance at all times. It can therefore function safely on uneven ground. Unlike conventional robot systems, the "evoBOT" is not limited to pushing and pulling goods. The biologically inspired design also makes it ideal for human-technology interaction.

Speed robots demonstrate Formula 1 on the hall floor

With the "LoadRunner," the Fraunhofer IML researchers presented a high-speed robot for sorting and distribution processes. The "LoadRunner" is currently being industrialized together with the KION Group and has already completed several practical tests at the CEP service provider DPD. To develop this technology further and optimize it for industrialization, the "KION Enterprise Lab" was established at Fraunhofer IML. When in use, the "LoadRunner" is especially characterized by its high speed and fast commissioning.

With AI and open source to new possibilities in object recognition

To demonstrate how Fraunhofer IML uses AI and open source to achieve new possibilities in object recognition, the researchers presented a type of COBOT – a 3D sensor demonstrator. This demonstrates a 3D object detection and the gripping of various unsorted items from a container in the area of retail and e-commerce. The use case is based on a typical problem from the area of bin picking (reaching into the box) or belt picking (separating items on a conveyor belt). The randomly arranged objects are detected by a 3D sensor. The sensor data can then be evaluated using AI. For this purpose, AI is used to classify and segment the various objects in the container pixel by pixel.

The currency of the future

Eight years, 50 implemented projects and 21 prototypes – DB Schenker Enterprise Lab at the Fraunhofer Institute for Material Flow and Logistics IML has an impressive record. As one of the first industrial partners DB Schenker has accelerated cooperation between science and industry. Today the "Enterprise Lab for Logistics and Digitization" stands for a unique framework for exchanging ideas, developing solutions and continuously redefining innovation.

Everything starts with an idea. Every problem that has to be solved, every innovation that makes our everyday life easier today was only an idea at the beginning. At the DB Schenker Enterprise Lab, people are aware of the importance of ideas and therefore treat them as the currency of the future. The whole setup and all processes at the Enterprise Lab at Fraunhofer IML in Dortmund are designed to develop ideas and promote collaboration. The 75,000 employees of the long-standing company, founded in 1872, are not the only ones encouraged to identify problems and make suggestions. The logistics service provider looks for solutions of the future beyond the confines of its own industry as well. This interface is precisely where the "Enterprise Lab for Logistics and Digitization," established in 2015, comes in.

The lab itself is divided into three levels that are each staffed by employees of DB Schenker and Fraunhofer IML: the advisory board consisting of Prof. Michael ten Hompel, executive director of Fraunhofer IML, and three other members, the steering committee with six members and the lab management with six members as well. In the individual projects, special expertise is pooled and recombined in each sub-step. This ensures that commercial, organizational and scientific expertise is ideally distributed.

"During the eight years of collaboration, we have been able to continually adapt the lab structure in order to provide the ideal framework for collaboration between industry and science. Even though we have clear competences as a research institute and DB Schenker as a logistics service provider, we go each step of the way together. This is reflected very nicely by the equal distribution of members in the committees," explains Benjamin Korth, member of the lab management.

How it all started

When the group was looking around for a research and development partner in 2014, Fraunhofer IML stood out due to its versatility. The logistics institute combined workshops, test halls and an excellent infrastructure with expert knowledge from a wide variety of disciplines – from engineering to economics. During the eight years of cooperation, this combined expertise has made it possible to implement 50 projects, 9 of which have now found their way into DB Schenker's everyday logistics operation.

One great success story of the lab is the digital training in the packing area and for forklift drivers. In the past, these used to be paper-intensive training courses on specific processes and safety guidelines, but they have now been transformed into digital training with the help of the lab. By using an uncomplicated computer training course and virtual reality goggles, the partners were able to reduce the training period of employees and increase staff satisfaction. Processes are taught in a playful manner – which provides more safety because warehouses and packing areas are not entered until after training has been completed.

> **"During the eight years of collaboration, we have been able to continually adapt the lab structure in order to provide the ideal framework for collaboration between industry and science."**
>
> Benjamin Korth

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In addition, DB Schenker and Fraunhofer IML have achieved successes at interfaces that establish an entirely new business model for the logistics giant. One example is the introduction of a lab project that has surprised everyone: 3D printing. DB Schenker was the first logistics service provider in the world to offer a 3D printing service. In the process, the company has received orders for medical products, robot parts or even packaging materials. The key feature: DB Schenker does not do the printing itself but instead relies on a digital business model that promotes cooperation with corresponding companies. Instead of putting up with enormous transport costs, some required goods can now simply be printed and delivered via DB Schenker.

In addition to purely technical projects, scientific progress is also advanced. Four doctoral positions have already been filled within the lab partnership. In addition, three vision papers have been successfully published.

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Four questions
for Dr. Nuri Morava

From the idea to the prototype

The idea pipeline is fed with challenges from Schenker's day-to-day operations as well as current developments in logistics research. It is currently full and has the potential to provide several years of lab cooperation. To ensure that the limited resources of the lab are distributed to the most promising ideas, there is a two-stage process until an idea becomes a project and is worked on for six months. After this time, the steering committee decides whether to continue, implement or stop a project.

"Even if a project is discontinued after six months or is not adopted for everyday industrial use at DB Schenker, even after long processing, it is not a loss. We also learn a great deal from such projects and use the solutions or ideas for other projects. For us, the focus is solely on the knowledge gain," Korth clarifies.

And they all lived happily ever after

The current lab cycle ends at the end of 2023. DB Schenker and Fraunhofer IML are already negotiating a continuation of the unique format.

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DB Schenker was one of the first companies to collaborate with Fraunhofer IML in an Enterprise Lab. What convinced you about the cooperation between industry and science at the beginning?

The DB Schenker Enterprise Lab for Logistics and Digitalization, which is its full title, has been dedicated to digitalization in the field of logistics and transport since its establishment. When the lab was founded in 2015, we already knew that digitalization would have an enormous effect on our business and we would have to develop capabilities. The cooperation with Fraunhofer IML and ISST has been excellently suited for this. The two institutes contribute expertise from very different specialist fields, from mechanical engineering, to AI programming, to industrial psychology. The cooperative format, which provides for interdisciplinary staffing of project teams with employees from DB Schenker and Fraunhofer, enables us to learn from the expertise at Fraunhofer and thereby develop our own capabilities. The commitment of our executive vice presidents and senior management in the steering committee and advisory board demonstrates the great importance and strategic relevance that we attach to the lab at DB Schenker.

During the almost nine years of cooperation, what were the special highlights at the "Enterprise Lab for Logistics and Digitization"?

The lab's successes take effect on different levels. We are proud of the fact that we have introduced more than 50 project ideas into the lab since its establishment. These ideas have yielded over 20 prototypes, nearly 10 of which have been integrated into our business operation. Considering that early-stage projects with a high degree of uncertainty are started in the lab, these numbers represent an excellent success record. In this context, the solutions developed around the topic of artificial intelligence, video analytics, AGVs and virtual reality especially contribute to the value drivers of the lab. In addition to the development of solutions, meetings with customers and the lively exchange with

them at the lab is a further highlight. With up to ten customer visits at the lab annually, it serves as a platform for DB Schenker to involve customers and suppliers in innovations early on and, together with Fraunhofer IML, to carry out a customer dialogue that would come up short in day-to-day business. In addition, we would like to mention our doctoral program in cooperation with the Graduate School of Logistics of the TU Dortmund University, in which DB Schenker offers employees the opportunity to pursue doctoral studies. This idea also originated at the lab.

How have the cooperation in the lab and its results influenced everyday life at your company?

The jointly developed solutions that have found their way into our business operations improve operational processes at DB Schenker every day and contribute to our advantage over competitors. A concrete example is the VR training for forklift drivers. Whether in the Netherlands, Mexico or Egypt – in numerous subsidiaries, our colleagues are trained on forklift simulators in virtual reality. This reduces training costs and makes learning more enjoyable, as a survey of trainees has shown. Other developments have a direct effect on the efficiency of process flows. In addition, the lab also has an impact on the corporate culture of DB Schenker: The importance of new knowledge and the development of innovations have achieved a special importance and are an elementary component of our working style – also thanks to the lab.


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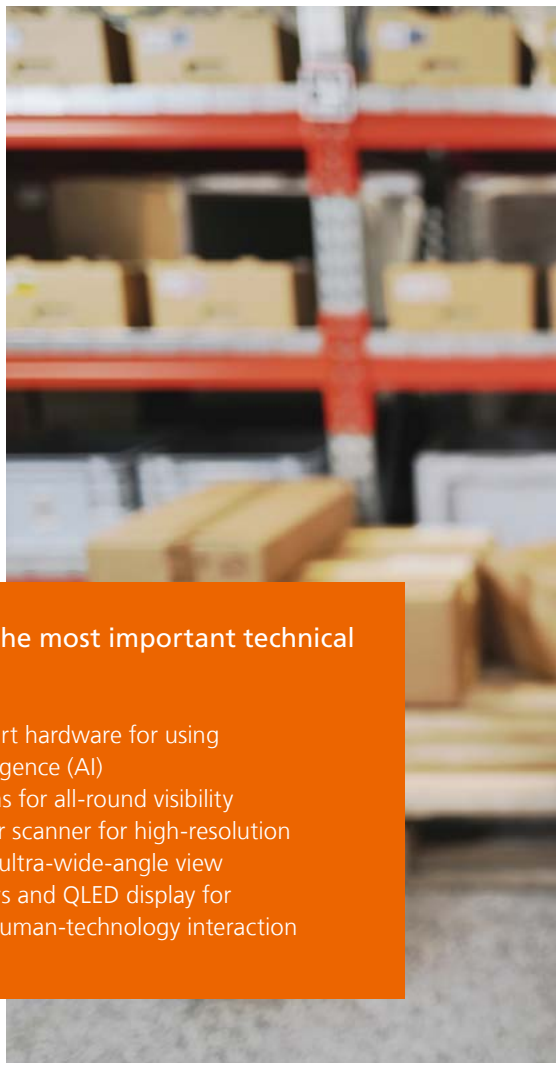
Dr. Nuri Morava
Head of Early-stage Innovation & Lab,
DB Schenker

The next cycle in the Enterprise Lab ends at the end of 2023. What will the future collaboration between DB Schenker and Fraunhofer IML look like?

We want to keep the successful format and are already in communication with Fraunhofer IML and ISST for this purpose. For the next lab period, we would like for the lab to become more international. This means that even more colleagues from outside of Germany should be involved in the projects. We are also striving for an even closer integration with our corporate strategy, so that the lab is embedded here as well as possible without losing its disruptive nature. DB Schenker and Fraunhofer's continuous further development of the format in order to sustainably increase DB Schenker's competitive edge will continue to motivate us in the coming years as well.

AI-Box

breathes intelligence into robots



For Fraunhofer IML humans are still an essential part of logistics because of their versatile abilities for complex tasks. The researchers are therefore working on new forms of human-technology interaction using artificial intelligence (AI), which can be dynamically adapted to humans to optimally use the strengths of both sides. With "RAI – Remote AI" the Dortmund researchers have come a little closer to this goal.

Fraunhofer IML does not regard process automation as an alternative to human beings. To them, it is more about automating activities that are monotonous and do not challenge employees enough, for example, or activities for which there is not sufficient employees. For this reason, their research work focuses on the interaction between humans and technology. "Depending on the application, we weigh which area can be automated and how, and where a process carried out by humans can be improved through collaboration with technology," explains Sebastian Hoose, Department of Robotics and Cognitive Systems, Fraunhofer IML. "In this context, the sensors are an essential link for the automation area as well as for the interaction between humans and technology."

RAI sensor box or artificial intelligence to go

With the help of algorithms for positioning and cameras for all-round visibility, robots can move and perform transport tasks in highly dynamic environments, such as in warehouses or semi-public areas. The interface with the AGV (automated guided vehicle) only requires low-threshold software adaptations that can be implemented quickly and easily. The interesting thing here is that even existing vehicle fleets can be retrofitted. RAI made its first public appearance at the LogiMAT 2023 in Stuttgart. Here, the researchers demonstrated the AI box on an AGV with a lift for shelf transport, as is used in hospitals, for example.

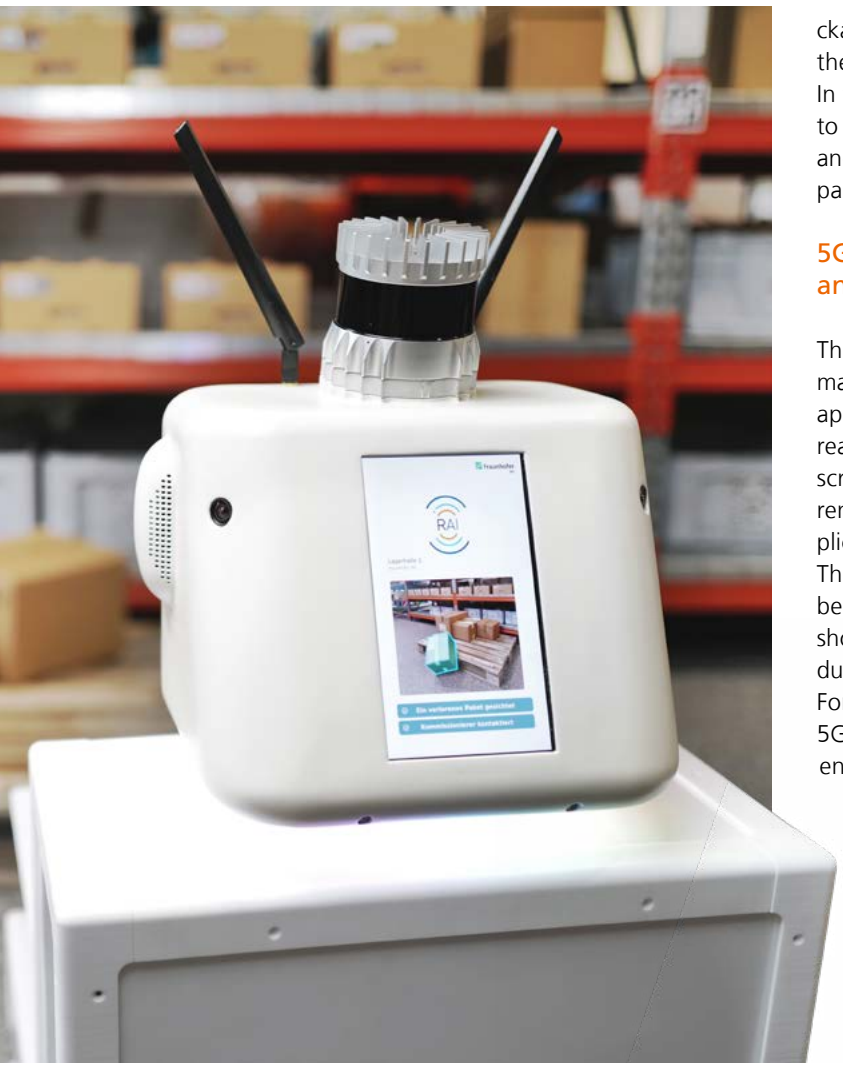
The basic idea for "RAI – Remote AI" came to the Dortmund researchers in the framework of the hospital logistics research project "5G-Remote Assistance for Robotics" ("5G – RemROB" for short), which was funded by the North Rhine-Westphalian Ministry of Economic Affairs. The three-year project based in the "5G.NRW Competence Center" focuses on the automation of service robots for hospitals, among other things. These robots are supposed to move safely in different deployment locations in the hospital that are open to the public and carry out transport tasks. 5G is needed here for remote assistance. The data processing using AI algorithms such as neural networks ensures that robot systems such as AGVs can find their way around in their environment as well as when interacting with people.

Overview of the most important technical details:

- State-of-the-art hardware for using
- artificial intelligence (AI)
- 4 RGB cameras for all-round visibility
- 128-layer laser scanner for high-resolution imaging with ultra-wide-angle view
- 2 loudspeakers and QLED display for unrestricted human-technology interaction

A solution for various application areas

The knowledge collected in the "5G – RemROB" project was then included in the development of RAI. The intelligent sensor box contains the complete computing hardware as well as various sensors and is suitable for a wider range of applications. The 5G-compatible box can be screwed onto any robot system. The user receives an autonomous vehicle with integrated AI and expandable capabilities for the respective application. "RAI – Remote



AI" is a modular solution similar to the plug-and-play principle and offers everything that a robot's heart could desire, from AI-based image recognition to localization. "What is special about RAI, in addition to its modularity, is that augmenting AI algorithms for image recognition, for example, are directly integrated. A robot system therefore not only knows where it is in the environment but also realizes what is actually happening in this environment. A crate is therefore not only an obstacle," says Hoose, "but the robot knows that the obstacle is a crate." The power source is not a problem either: The box does not need its own power supply because it obtains the necessary power from the robot. Upon customer request, Fraunhofer IML can even adapt the software interface between the box and the robot.

The high modularity of the robot allows a variety of application scenarios to be realized, even with increased requirements for human-technology interaction. According to the researchers, the intelligent box is thus the ideal solution for sensor manufacturers, AGV producers or end users. Due to its modularity, "RAI – Remote AI" can be adapted to a large number of further applications. The AI-based object recognition could be used to search for lost packages at a distribution center, among other things. Another conceivable application field for RAI is order picking: In this case, robots could tell order pickers what material to remove from what location next – or they could identify and document what materials have been removed from a particular storage area.

5G real-time communication between human and machine

The design of the box was given human facial features to make the symbiosis of humans and technology visually appealing as well. The interaction with RAI takes place in real time – either via the built-in QLED display (with touchscreen) or via smart glasses. A specialist can thus perform remote maintenance on a vehicle in an easy and uncomplicated manner using the integrated remote assistance. This in turn has the advantage that technicians have to be deployed less often for maintenance work or troubleshooting. In addition, order pickers could also be guided during goods withdrawal or entry (even via loudspeaker). For communication in real time, Fraunhofer IML uses the 5G standard. The use of 5G facilitates integration at the end user. At a hospital, for example, the robot does not have to be connected to the WLAN network. There are no special requirements or adaptations of the WLAN infrastructure that require further investment costs. The network standard allows a fast and secure data transfer in real time among various system components, such as between sensor technology and remote assistance. This is essential for fast troubleshooting.

However, the robot can not only connect with an end user via 5G but can also be trained by a human thanks to neural networks. Various scenarios can be stored in the database, so that it requires the help of its human colleague less and less often. Human colleagues can then concentrate on their own tasks. The learning success of individual vehicles can also be transferred to other robots or even to an entire fleet thanks to the so-called "lifelong AI training."

Ministry of Economic Affairs,
Industry, Climate Action and Energy
of the State of North Rhine-Westphalia

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The dance of the RoboMasters or:
The language of movement

It is a true spectacle of nature: Each year around 50 million migratory birds migrate south to spend the winter there. These "moving clouds" – flocks of over a million starlings – are especially impressive. The birds know how to move in formation to reach their destination, without an individual starling knowing what the flock is doing as a whole. It only looks to the left and to the right: If its neighbors change direction, it does the same. This prevents collision. The same is true of the RoboMasters, a fleet of small, autonomous vehicles.

Of course, robots do not have "eyes" as birds do. Instead, the RoboMasters have laser scanners. These highly developed sensors allow the robots to precisely measure distances to other objects and robots. This not only allows them to avoid obstacles but also to interpret the behavior of other robots and predict their movements. They know whether another robot is going to pass on the left or right side and can react accordingly. This "swarm behavior" allows the RoboMasters to operate smoothly in different environments without colliding with each other.

Carrot and stick

But how does a RoboMaster learn to act in a vehicle fleet and adapt to unforeseeable obstacles at the same time? The answer lies in machine learning, more precisely in Deep Reinforcement Learning (Deep RL). In the case of the RoboMasters, this means that they are trained in a simulation that was specially developed for them. During the training, the robots receive rewards for good actions and punishments for bad ones. For example, they receive the value 1 when they come closer to their destination and the value –1 when they go away from it. They receive an especially high value when they reach their goal and an especially low one when they drive into a wall, for example. The neural network (the artificial intelligence (AI)) learns from these rewards and optimizes its behavior in the various training scenarios to maximize the reward. "You can think of it like a video game in which the objective is to score as many points as possible and not lose any lives," explains Christian Jestel of Fraunhofer IML, who wrote the simulation.

Simulation-based learning: The key to perfection

The simulation has the advantage of being faster and safer than training in the real world. In the simulation, the robots can go through thousands of scenarios without causing physical damage in the real world. This considerably accelerates the learning process. Only after successful training in the simulation is the AI transferred to a real robot equipped with a minicomputer, in the hope that the simulation has described reality accurately enough. This transition from the simulation to reality is decisive; it is one of the greatest challenges in robotics because simulation and reality are never exactly the same. The more accurately the simulation depicts reality, the better the robot will function in the real world.

The term "reality gap" describes the difference between a simulation and reality. The smaller this gap is, the more seamlessly the AI can act in the real world. "Everything depends on how well the simulation depicts the physical characteristics and environments of the real world," explains Jestel.

The path to industry

A special feature of the RoboMasters is their capacity for decentralized navigation. Unlike conventional autonomous robots that are controlled via a central computer, the RoboMasters make their decisions autonomously and based on their perception of the environment. This makes them ideal for use in dynamic environments such as warehouses or transshipment points. As soon as the RoboMaster has a destination, it is able to find its way independently and safely without the need for prior mapping of the environment or for human interventions or complicated repro-

gramming. This could considerably increase flexibility and efficiency in industrial logistics in the future.

"The RoboMasters are robots from the Chinese manufacturer DJI, some of which we have slightly adapted to the requirements of the research project. The vehicles are examples for all smart automated guided vehicles and mobile robots that are to be controlled using algorithms," according to Jestel.

The future of AI-based robotics

The research on the RoboMaster shows what opportunities are offered by simulation-based AI in robotics. Decentralized navigation and the ability to react to non-cooperative elements in the environment could shape the future of industrial automation. As the next step, the team led by Christian Jestel plans to integrate "leaders" in the vehicle fleet and to improve evasive behavior not only among the vehicles but also towards people and stationary objects.

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Smart cameras – the eyes of logistics

It is intelligent, uncomplicated and has awesome eyes. And, best of all: It really exists – the smart camera. In conjunction with the corresponding software for teaching an artificial intelligence, Fraunhofer IML has created a "starter kit" that is as simple as it is ingenious, paving the way for self-sufficient and data protection-compliant image processing in the logistics sector.

But let's start from the beginning: Image processing or computer vision (CV) is no longer a mere buzzword; it has become established as a promising digitalization approach for logistics. CV makes it possible to glean meaningful information from digital images and videos as the basis for efficient process optimizations and cost savings.

The hardware: the intelligent camera

The smart camera is a promising example of the implementation of computer vision in an industrial environment. It consists of a 3D-printed housing, a camera sensor and a lens – all modular purchased parts available on the market. This allows the camera to be adapted to the respective application and the corresponding requirements for the images to be processed.

The camera gets its intelligence from a so-called NVIDIA Jetson board, a minicomputer the size of a credit card with a graphics processor. "As a result of the increasing calculation and graphics power of such embedded boards, smart cameras can evaluate the recorded images directly on the device without the images having to be transferred to a central server," explains Julian Hinxlage, project manager at Fraunhofer IML. "The advantages are obvious: data efficiency and data protection," adds Hinxlage.

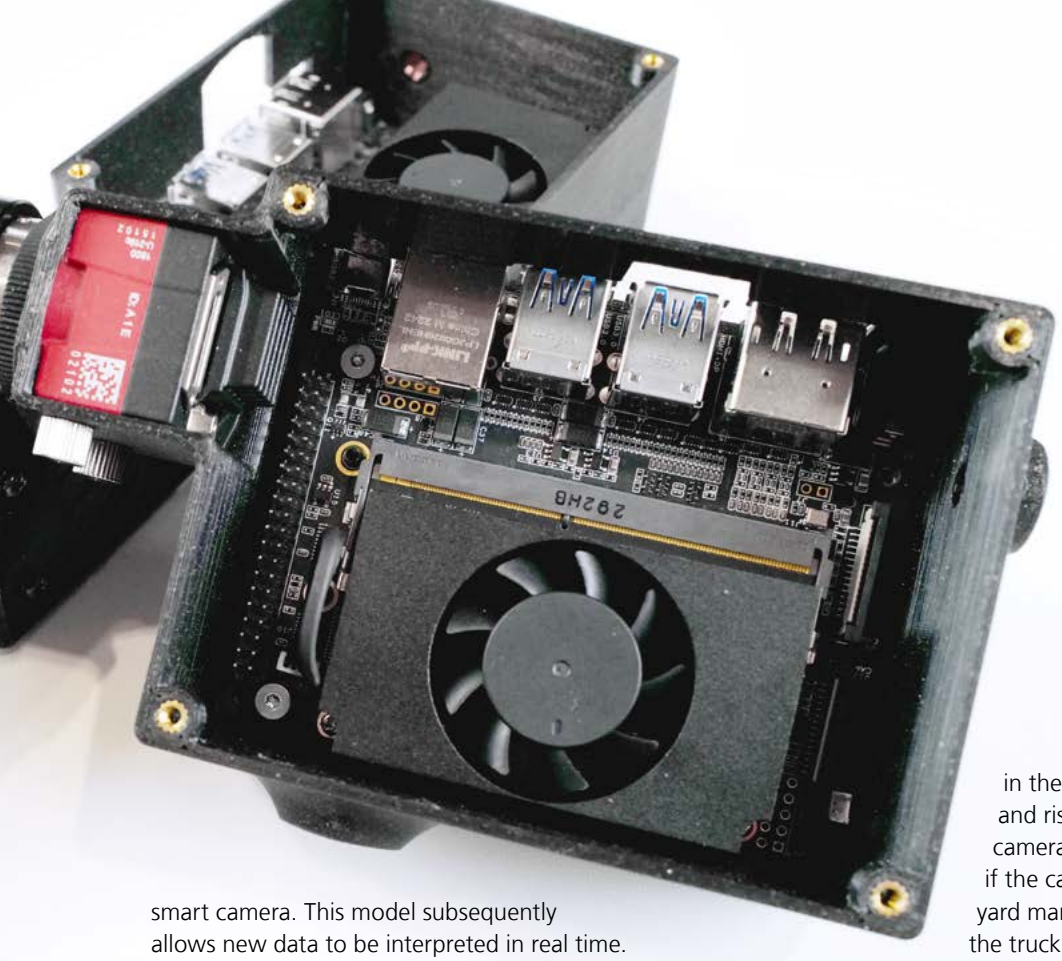
Since the camera only transmits relevant information and not complete image data, the load on the networks is considerably reduced. This leads to a more efficient data transfer. In addition, the camera only needs a current source and can be connected to LAN, WLAN or mobile communications as needed. This makes it optimally suited for use in locations with a limited infrastructure. Since no personal image data is shared, the smart camera is also a data protection-friendly solution. It is able to analyze images and extract relevant information without revealing sensitive data. This is especially advantageous when people are visible in an image. "The works council may have certain reservations or concerns about it, but if an employee is screwing up, to put it that way, or is taking a break that is too long, the camera cannot recognize it. The image data does not leave the camera; it only passes on certain information, ultimately like an entry in a database," Hinxlage points out.

The software: the heart of the AI-based image processing

In addition to the smart camera, the developed software is the heart of the project. This allows AI models to be trained for image processing. It comprises various components and tools for data acquisition and management as well as for training the models.

The process starts with a data recording, followed by the annotation of the image data, in which certain objects or features are marked in the image. "If I want to identify people in a picture, for example, or maybe I simply want to hide people, then the AI has to recognize them as such first. For this purpose, I sort of draw a small box around all people in the image and then assign them to the class "Persons." After training, the algorithm therefore knows what a person looks like and what features it has to pay attention to," explains Hinxlage.

After the annotation, the actual magic takes place: the model training. In this process, an AI model is developed on the basis of the annotated data and transferred to the



Funded by:

Federal Ministry
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and Transport

on the basis of a decision
by the German Bundestag

smart camera. This model subsequently allows new data to be interpreted in real time. "We have trained with existing data, and now the AI has to apply what has been learned to new data. For example, if a person now walks through the image who has never been recorded before, the camera still has to recognize this object as a person. Depending on the application and complexity, the training can take from only a few minutes to several weeks.

The software has many standard components and tools for AI training. What would otherwise have to be laboriously developed through individual components can all be found through the training that is carried out. "I have everything in one place and can generate my own AI in a few minutes. I am actually even faster because I can train new objects at any time," explains Hinxlage. "And this smart camera actually supplements it as well, because I have the software and this individual device that allows me to get started without having to assemble or wire everything. This should basically be the starter set, the start-up package for image processing. Especially when you think of small and medium-sized enterprises," says Hinxlage. For as many companies as possible to benefit from this, both the camera housing and the software are available as open source in the framework of the "Silicon Economy."

Wide range of applications for camera and software

The software can be used to realize a variety of applications in image processing, for example, counting containers or recognizing pallet types during loading checks of incoming and outgoing goods. Quality checks and optimizing storage place occupancy are also possible scenarios. The camera can also be used outside to monitor the position of trucks in the yard. If a truck is at the wrong gate and risks being incorrectly loaded, the camera can report the mistake, especially if the camera is directly connected with the yard management system. This can prevent the truck from having to be unloaded and reloaded or, in the worst case, arriving at the destination with the wrong goods.

The response to the developed software and the smart camera is positive. The simplified image processing and the user-friendly interface allow even non-specialists to create their own AI models and thereby better realize the potential of artificial intelligence in logistics. "It is actually a hurdle for many companies to deal with (AI-based) image processing because they don't have access to it and simply don't know: How do I start with it? What do I have to do for this? I didn't know that before either," says Julian Hinxlage with a laugh. The smart camera and the innovative software are thus the ideal solution for all companies that are looking for efficient and data-minimizing image processing solutions, especially given the increasing data quantities and data protection concerns. With its self-sufficiency, data efficiency and data protection friendliness, the smart camera is a promising innovation for the logistics of tomorrow.

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STUART is looking for a vehicle for life

Hello, I am “STUART” :)

and I am an innovative, diamond-shaped chassis that can cope with any kind of ground.

Are you an automated guided vehicle that handles any situation on four wheels, gets along great with old warehouses and wants to make their expensive renovations superfluous?

Then we make an excellent match.

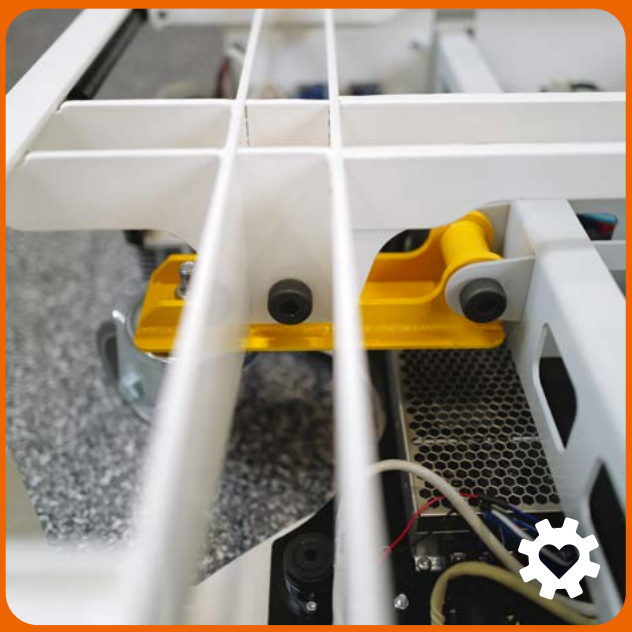
Uneven and undulating floors are a well-known challenge in warehouses. Until now, users have had to make the difficult decision between three-wheeled vehicles that are as maneuverable as possible or four-wheeled ones with more stability. The diamond-shaped chassis "Stable Transport in Uneven And Rough Terrains," or "STUART" for short, developed at Fraunhofer IML solves this conflict and is therefore the perfect partner for vehicles that drive in every warehouse.

"The development of the idea and finally the implementation went more smoothly than in almost any other project. With "STUART," we solved an industry-wide problem quickly and elegantly: Uneven and undulating halls used to be a huge problem for automated guided vehicles. The innovative design of the diamond-shaped chassis eliminates the need for cost-intensive conversion measures, and through a very simple technical principle," explains Jacob Hamm, research scientist at Fraunhofer IML.

The diamond-shaped chassis with its centrally positioned differential drive and support wheels at the front and rear provides the perfect grip when things get bumpy. "STUART" is still extremely maneuverable and offers a very narrow envelope. In contrast to conventional four-wheeled chassis, the diamond-shaped chassis never tilts. This is due to its simply constructed joints and levers, which form two contact triangles articulated around the central differential drive axis.

The chassis is currently in use at Fraunhofer IML in a vehicle that weighs only 100 kg and can nevertheless transport up to 400 kg of Euro-pallets. This darts over uneven ground at a speed of 1 m/s and, with a vehicle height of 230 mm, is also equipped for very narrow spaces. However, the principle of the drive can be used for very different applications and in very different vehicles – for heavier or lighter as well as for larger or smaller load carriers.

"STUART" enables automated guided vehicles to keep pace with all types of surfaces, so that no warehouse has to be restructured or renovated. The diamond-shaped chassis also compensates for unevenness so cleverly that it does not need suspension, and the loading area remains unchanged during loading and unloading. There is thus no need to compromise between empty and loaded models here, as is necessary with commercially available vehicles.



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The curse of oversized cartons

Imagine that you order a small product online – perhaps a memory card or a handmade piece of jewelry. The excited wait starts, but what finally lands outside your front door is a package that is big enough to hold a small dog and filled with a huge quantity of padding material. Frustrating, isn't it? This is where CASTN comes into play, the software for carton set optimization.

We have all experienced it: A tiny product lost in a huge carton. It feels as if you ordered a box of air and got a little product with it. But why does that happen at all? The answer lies with the lack of coordination between items and cartons. Companies collect a large mix of carton types over time to meet the various requirements of their products. This sounds reasonable, but it also often has the result that cartons and items are not coordinated with each other and tiny products end up in cartons that are much too large. The inefficient use of space and material are the results.

To finally change this, there is CASTN – rescue in the form of software. CASTN stands for Carton Set Optimization and is intelligent software that puts together an optimum carton combination for shipping companies, tailored to their individual order and item structure. The idea behind this is to calculate the perfect compromise between variety and volume utilization that can be achieved with a shipping carton set.

Complex interaction of software and data

How that works? Well, it's not really magic but rather a clever combination of data, algorithms and technology. CASTN is based on a wealth of information on products, orders and carton types. The software is therefore based on data and relies on input from customers to create customized solutions. This data includes item and master data, order data and current carton specifications. To take into account seasonal fluctuations and trends, a representative data set collected during approximately one year forms the basis for the calculations. "We have a certain standard for the data that we require because the optimization is always only as good as the master data. Because – to put it bluntly – if you put garbage in, garbage will also come out," explains Lukas Lehmann, project manager at Fraunhofer IML.

For this reason, data preprocessing is carried out in the second step as standard, in order to filter out defective, erroneous or out-of-line data and create a reliable basis. The third step is the status quo calculation in which the degree of volume utilization is determined for the customer's existing carton set. This is frequently less than 40 percent – the rest is air.

The magic behind the scenes

Now the actual magic starts: the carton set optimization. The CASTN software functions based on two linked algorithms that work in a loop. This two-step process aims to iteratively "fine-tune" the cartons for an optimum volume utilization. The first algorithm, CASTN, uses an evolutionary approach to create different carton sets on the basis of parameters such as the number of permitted cartons or the maximum and minimum dimensions. The second algorithm, a bin-packing algorithm, then ensures that the orders are efficiently packed in the selected cartons, as in the game Tetris.

"What we end up with are specific carton sets, for example, the optimum 5-piece set with the length, width, height as well as frequency of use for each of the individual five cartons. We also have this for every other carton set, in other words, for a 6-piece or 7-piece set – just as required," explains Lehmann.

The range of services for CASTN offer a holistic solution that takes into account the customer's individual upstream and downstream logistics processes and goes beyond

mere calculation. It contains a consultation component that ensures that the created carton set is optimally integrated into the company's logistics processes. Industrial projects with the Nordwest and Babymarkt companies already show promising results: On average, the volume utilization increased by 35 to 45 percent, while the number of carton variants in the set decreased at the same time.

More than just cartons

The advantages of CASTN go far beyond mere packaging. The software enables companies to meet future regulations and helps them to reduce complexity and optimize packing processes, which additionally leads to cost savings. "We are currently observing an interesting development in the packaging sector. While the focus used to be primarily on packaging costs, ecological sustainability is now becoming increasingly important. Ecological factors can also have a positive effect on profitability, as seen with the example of CASTN. Therefore, an orientation that used to be mainly counteractive is now becoming complementary. In the long term, sustainability goes hand in hand with economic advantages," explains Lehmann. This development is further underscored by the draft bill of the Packaging and Packaging Waste Regulation: It provides for a maximum empty space ratio of 40 percent for secondary and transport packaging. The EU regulation makes it clear that the topic of ecological sustainability is increasingly a prerequisite for mail-order companies and thus an economic factor as well.

A glimpse into the future

The CASTN team is currently looking for suitable partners and follow-up funding to further develop the software. "Our next goal is to expand the range of functions to include complex geometries and additional item properties. In the long term, there is further great potential here for leaving air out of parcels, saving packaging material and thus ensuring more sustainable parcel logistics," says Lehmann.

After all, CASTN opens the door to a more sustainable future for e-commerce. Less wasted space means lower transport costs and fewer emissions. Less padding material means less waste. This is a glimpse into a future in which companies not only enjoy economic benefits but also help to protect the environment. A future in which tiny products are no longer lost in huge boxes.

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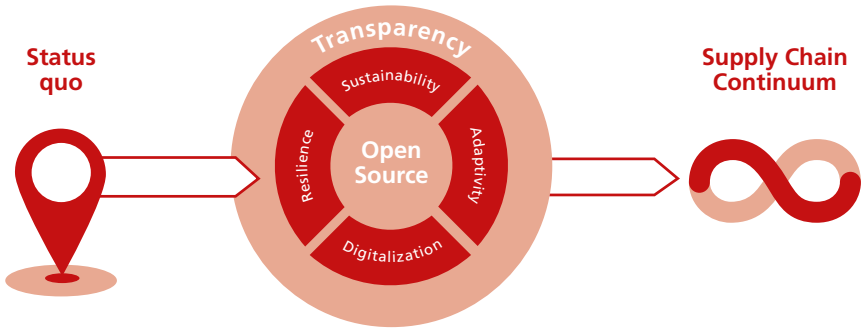

The world of the supply chain continuum

From the Silicon Economy to a digital continuum

The aim of the Silicon Economy is to completely virtualize the entire value creation and its networked logistical process chains: the entire world in virtual. Does that ring a bell?

It sounds a lot like the metaverse! More precisely: like the industrial metaverse. We have to clarify the term here though: The industrial metaverse is a) now used in an inflationary way and b) is not clearly defined, especially in social media. At the science location Dortmund, we prefer to speak of a digital continuum to avoid this vagueness. What is this?

We speak of a digital continuum

A continuum basically describes, in an easily understandable way that is above all free from any vagueness, something that continues uninterrupted. Some people are familiar with the time-space continuum, for example. The continuous and uninterrupted form of this is the basis for the existence of life in the universe. If we consider a continuum as a closed circle that symbolizes an uninterrupted sequence of developments, we soon realize: Something similar is happening right now in the Silicon Economy, in the context of the platform economy, in which process chains are increasingly developing into closed cycles in an automated and autonomized manner; from planning and scheduling to service billing and payment.

All of this is connected, increasingly with the support of artificial intelligence. This results in self-learning, mutually reinforcing and accelerating processes in a perpetual cycle. This is what we mean when we speak of a digital continuum. Such a continuum requires an extensive to complete virtualization of all processes, their continuous transparency, a nearly real-time networking as well as data sovereignty. In other words, everything that we have been studying and transferring into practice for years under the slogan of the Silicon Economy. We can therefore draw a short and clear conclusion from the description of this term: The Silicon Economy is the open ecosystem of the digital continuum. This continuum has different facets, which brings us to the supply chain continuum.

The supply chain continuum

The digital continuum rests on three pillars: The first one, the technology continuum, integrates all current and future developments in high technology. The second one consists of the social networked continuum, which connects people and technology with each other. Despite the rapid development of technology, this will not be able to work without people in the foreseeable future. The third pillar in the digital continuum we understand to be the supply chain continuum, which extends beyond company boundaries into the global value creation networks.

Here in Dortmund, we keep these three continua in sight as a clear vision for the coming years. With the emphasis on “coming years,” because the status quo is different: The metaverse, although often discussed, is still far from existing, and also, most people have seldom heard of continua in practice. So how can we reach the brave new world of the supply chain continuum now, in these times of crisis and war, at the beginning of a recession and in the midst of a climate crisis?

From here to tomorrow

We are clearly being led on the path from the status quo to a better future by a number of transformation processes in the economy as well as in society. Some have already started. The digital transformation, for example, has been going on for a while. The resilience transformation is currently being intensively discussed in the face of crises and wars. We are also living in the middle of a sustainability transformation. These change processes are being accompanied by a clearly necessary transformation towards more adaptive people and companies. This allows us to adapt to the many transformation requirements better, faster and above all

A guest commentary by Prof. Michael Henke

with less friction. So much for the framework – how do we fill it? How exactly do we reach the supply chain continuum via transformation?

We can only do this by familiarizing ourselves with the new technologies, trying them out and letting them support us during the transformation even better than before. These new technologies achieve their fullest effect especially when they are developed in an open-source manner. In this way, they become quasi standards in their applications through the widest possible dissemination. Thanks to these standards, we then also know at which points in the supply chain which technologies can be used in our value creation networks for everyone's benefit, which is of utmost importance for creating transparency.

The sack of rice and our future

There is a saying about a sack of rice in China. However, if I actually learned in real time that it had just fallen down, thanks to new technologies in a completely networked digital continuum – our supply, our networks and our logistics would have a security, resilience and adaptivity that had never existed before in human history. Transparency is the basis for every transformation. The greatest obstacle to this transparency, however, is often not technology: This already exists to a large extent and is developing superbly, especially in Dortmund. The greatest obstacle in my opinion is often the attitude of people and companies. The decisive factor for our future is the mindset, the openness of decision-makers on all corporate levels to actually using these technologies. We need this to actually be able to reach the brave new world of the supply chain continuum in the future.

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Hydrogen and blockchain: The dream team for a sustainable energy supply

From electricity generation to use as a fuel in vehicles – hydrogen offers a wide range of possibilities as an energy carrier. Germany is pursuing the goal of playing a leading role in hydrogen production. This requires international partnerships and supply chains that are transparent and comprehensible. In short: In addition to a hydrogen infrastructure, technologies such as blockchain are also needed to ensure transparency in a reliable and understandable way.

Green hydrogen is a central key to the energy transition – and to achieving a climate-neutral future. The H2 molecule is a versatile energy carrier that can be used in various applications and sectors – from electricity generation to use as a fuel in vehicles. With the "National Hydrogen Strategy," the German federal government is showing how Germany can use green hydrogen in the areas of industry, transportation and energy to maintain competitiveness, achieve climate protection targets and open up new markets. The strategy combines climate, industrial and innovation policy and aims to help Germany achieve a leading global position in hydrogen production. For the widespread use of green hydrogen, the German federal government supports rapid expansion for a nationwide infrastructure. Therefore, production facilities for electrolysis have to be constructed, and the distribution infrastructure such as filling stations, pipelines and storage facilities have to be expanded to use the energy carrier in different sectors.
The strategy on the federal level also enters into the planning of the German federal states. Wide-ranging potentials in the hydrogen environment result especially for North Rhine-Westphalia (NRW) as an industrial location. NRW has a well-developed infrastructure for hydrogen transport, for example. At the numerous companies from the chemical, steel and machine construction sectors, this energy carrier can be used as an energy source as well as a raw material. The construction of electrolyzers and other hydrogen-related technologies (e.g., tank containers, valves, pipelines etc.) could additionally create numerous jobs. By now, the number of hydrogen projects and initiatives in NRW has increased to 300 in the last few years. The initiatives for accelerating hydrogen development in NRW include, for example, H2UB, ProBF, ELEFACT and COSiMa. Fraunhofer IML is also currently planning several projects to develop hydrogen as an energy carrier in industrial applications.

Since the required quantities of hydrogen cannot yet be exclusively produced in Germany, the German federal government also supports the establishment of corresponding international value chains for imports. The state of NRW is also working on an import strategy.

"We want to remain an industrial location while becoming climate-neutral. Therefore, we have to set the right political and business course now. It is important to us to have an import structure that rests on many pillars. A one-sided dependency, such as with gas in the past, must never happen again," emphasized the NRW minister of economic affairs and energy, Mona Neubaur, in a press release in January 2023.

The entire value chain is now considered – from production to transport and distribution to use. Dependencies must be avoided and increased emphasis placed on sustainability targets at the same time. This means: Even when arranging the necessary cooperations for procuring hydrogen from abroad, politicians and companies have to make sure that the so-called ESG criteria are observed in the production countries. The German National Hydrogen Council already noted the following in its position paper on "Sustainability criteria for import projects of renewable hydrogen and PtX products" in 2021: "It is nevertheless necessary to formulate criteria for a sustainable production and use of hydrogen to ensure that the contribution of hydrogen to a sustainable economy is not counteracted somewhere else. Sustainability issues in the entire value chain, including social consequences in production coun-

tries, are of great importance for ensuring the integrity and acceptance of hydrogen (imports) and hydrogen technologies."

Even before the question of how to enforce one's own sustainability standards in third countries, the question arises how to record their observance in the first place and ensure traceability. This is where blockchain technology makes a decisive contribution to the energy transition.

In various research and development projects, Fraunhofer IML has shown how tamper-proof, continuous recording and distribution of information is possible in international supply chains. This is the result of experience in other application fields such as the automated referral of available production capacities with subsequent booking and payment as well as the mapping of hazardous goods transports up to data exchange in customs handling. Researchers have used this as a basis to develop solutions for contract negotiation and payroll services processing as well as for implementing these in practice, for example. In addition, blockchain technology is suitable for implementing the digital product passport, which stores product-specific information from raw material extraction to recycling and provides it to the relevant user groups. This comprehensive knowledge in various application fields and the experience gained can also be transferred to the hydrogen economy.

Here, blockchain technology also has the potential to contribute to more security and efficiency in data exchange and to ensure the necessary trust in the information base through transparency regarding data origins or change tracking. Its technological characteristics allow an end-to-end verification for green hydrogen, for example – from the producer of the renewable energy to the end user. A blockchain also makes it possible to determine what quantity of green hydrogen was used to manufacture green steel, for example – and thereby answer the question of whether it is actually green steel. For a hydrogen-based (energy) economy, there is thus great potential in seamlessly linking information from all parties of the hydrogen supply chain. The result: Process transparency and traceability by third parties is increased, from the end customer to the regulatory authorities.

Documents and certificates regarding the production of green hydrogen and its use in production and transport processes can be securely stored in blockchain networks, for example. Furthermore, payments between the hydrogen producer and the electricity provider can be automated via smart contracts. A "hydrogen" blockchain network creates the technical basis for mapping the complete hydrogen value chain. In addition to information on the product itself, this value chain also shows compliance with the required ESG standards during the production process. Without such a trustworthy, blockchain-based hydrogen network for keeping such records, a climate-neutral import structure and a domestic production landscape bear the risk of not being enforceable.

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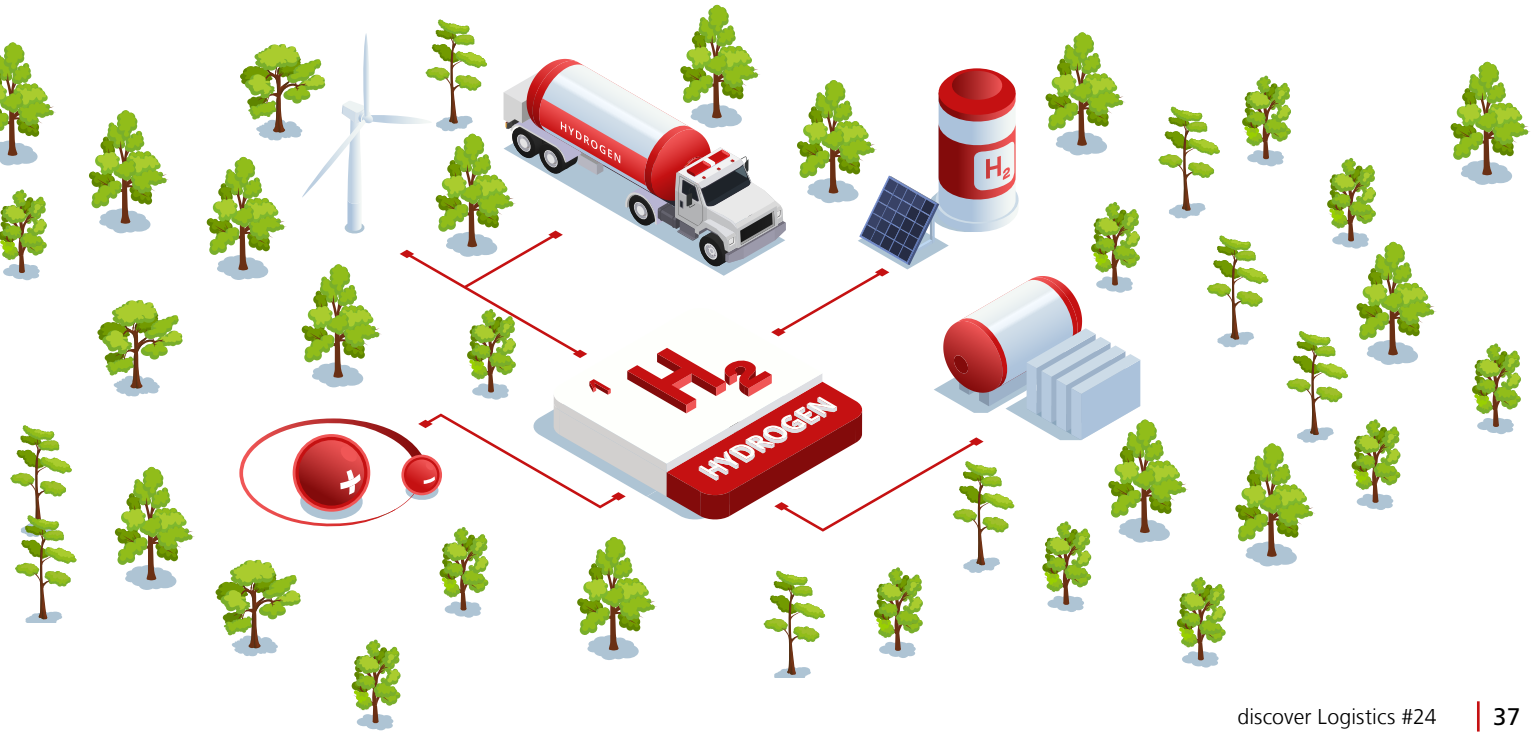

Smart **sheet metal procurement with**

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Ensuring material availability at the lowest possible cost is a challenge for manufacturing companies in an increasingly complex and volatile world. Traditional methods are reaching their limits faster and faster. The solution: the AI software "AI-BOSS" developed at Fraunhofer IML.

The desire of manufacturing companies is clear: Raw materials should always be available in sufficient quantities and, if possible, on time. However, increasingly specific customer requirements mean that the number of material variants to be procured has considerably increased. On the other hand, delivery times and minimum order quantities of suppliers have to be observed. In practice, companies have used traditional methods to plan the procurement of materials: in particular, so-called ABC and XYZ analyses. With these methods, goods are usually classified according to past consumption patterns.

Ideally, the most common materials are stored with uniform requirements. Nowadays, however, material requirements and availability fluctuate strongly at many companies. Although the "ifo shortage indicator for manufacturing" of 31% in June 2023 had decreased since the peak of the Corona lockdown measures, it was still significantly higher than in 2016 (2.1%).

The traditional methods of material planning are not well suited to the new so-called VUCA (volatility, uncertainty, complexity and ambiguity) world in which we live. Artificial intelligence (AI) methods can help here – Fraunhofer IML has therefore developed an AI solution for assembling sheet metal ranges in collaboration with Ferro Umformtechnik GmbH & Co. KG.

Ferro Umformtechnik manufactures telescopic systems for cranes, lifting platforms and telescopic loaders, dumper bodies for vehicle construction as well as components for applications such as conveyor belts, bridge/wagon construction or renewable energy systems for its customers. For this purpose, the company procures raw sheets of different dimensions, steel grades and surfaces from its suppliers. This custom manufacturing is done in small batches, sometimes even with a batch size of one. However, the suppliers demand minimum order quantities that are often larger than required for the respective customer orders. The result: The company has a considerable stock of raw sheets.

For this reason, Ferro Umformtechnik and Fraunhofer IML have developed an AI-based solution to reduce the range. The basic idea: clustering similar metal sheets for different customer orders.

A practical example: The starting point is two customer orders with similar requirements for raw sheet metal. Here, similar means that the sheets have the same steel grade (e.g., S355J2+N), surface finish (hot-rolled and pickled) and thickness (e.g., 7 mm), and thus only differ in length and width. Let us assume that four sheets with a length of 10 meters and a width of 1.8 meters are used for one customer order and six sheets with dimensions of 10.5 x 1.6 meters are used for another order. Typical order quantities of these two raw sheets are 10 pieces. With order-specific raw sheet procurement, six sheets would therefore have to be stored for the first order and four for the second. However, it would be possible to procure an article of raw sheet metal with dimensions of 10.5 x 1.8 meters and to cut off the edge that is not required for the corresponding customer order. The resulting waste would be scrapped. However, this scrapping loss can become a profit if the warehousing costs (storage, handling and capital tie-up) are greater than the waste costs, for example.

If all possible combinations of sheet metal requirements were analyzed, it would be possible to optimize the sheet metal stocks. Other variables such as ordering costs or storage space requirements are also taken into account for the evaluation. However, the number of clusters to be evaluated increases very quickly with the number of similar sheets. While there are only five cluster possibilities for three similar sheets, the number of clusters to be evaluated for ten sheets increases to more than 100,000 combinations. It is not practical to "try out" all possible combinations. This is where the "AI-BOSS" solution (Artificial Intelligence Based Optimization of Sheet Sourcing) of Fraunhofer IML comes in. When AI processes are used, "smart" sheet clusters are created in just a few seconds. The researchers developed and applied the solution as part of a project with Ferro Umfomtechnik and a research project of the Dortmund High-Performance Center Logistics and IT.

Fraunhofer IML continues to work on AI-BOSS in order to use the solution for other companies and in related areas. For example, the range for steel bars can be created in a similar way. The same applies to procurement in wood and paper processing. The potential for smart procurement solutions compared to traditional methods is considerable and worthwhile, especially given the challenges in the "VUCA world."


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Doing nothing is not an Option

How sustainable and resilient is your logistics network? Answers to this question often remain vague. The indicators that have to be evaluated simultaneously and converted into reliable statements seem too complex. However, this is precisely what growing global uncertainties require. After all, logistics also has to contribute to overcoming economic upheavals and counteracting the effects of global climate change.

What do I care if a sack of rice falls over in China? Globalization should have shown the absurdity of such questions long ago. This is because even seemingly meaningless micro-events can develop an unforeseen dynamic that subsequently causes a global domino effect. The documented pandemic, supply bottlenecks, the war in Ukraine and protectionist tendencies all unequivocally document that it does matter what happens or originates on a local level in other places. If microchips are lacking, for example, entire industries come under pressure. However, weather extremes due to climate change also take their toll and endanger supply security. In addition, the problem of greenhouse gas emissions (GHG) caused by transport and logistics is still far from being solved.

Identifying vulnerabilities and uncovering potential for improvement

In light of this VUCA world characterized by many crises, it is high time or even overdue to make supply chains significantly more resilient and environmentally friendly. Transportation logistics experts at Fraunhofer IML have therefore been devoting themselves for some time to the question of how to make supply chains more robust and significantly reduce GHG emissions at the same time. Newly developed optimization processes also show how to achieve a largely balanced relationship between cost expenditure and impact success, even if this sounds ambitious – with the help of "sustainable network design" (SND). The project relies on classic logistics network planning and expands it to include sustainability and resilience. Transport emissions, general site emissions, emissions for article handling, and emissions that arise during the purchase of goods are recorded and evaluated. "This makes it possible to state for every warehouse site how many pollutants enter the environment during the procurement, handling and transport of goods," explains project manager Bernard van Bonn.

These results, which trading companies can also use for their scope calculations according to the "Greenhouse Gas Protocol," can also be used to derive the extent to which it is worthwhile to switch to electric fleets, whether the selected electricity mix is advantageous and/or whether there is a basic need to modernize the site. The resilience factor "failure costs of locations" was additionally integrated in the basic mathematical model. For example, it is simulated for each relevant node of the network what the effects are when only one of them does not fulfill its productive task to the usual extent. Neuralgic points are identified, and approaches are developed to prevent a complete supply chain from being dependent on a single production site; these include, for example, selective capacity limitations and the involvement of alternative suppliers – keyword: diversification.

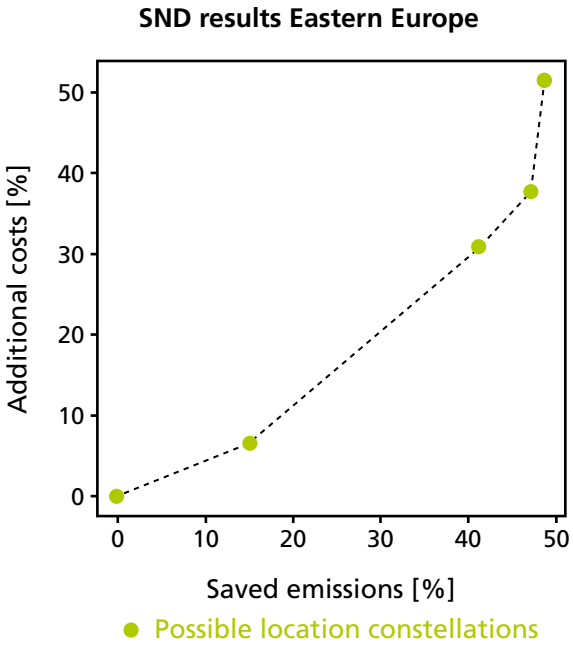
Costs vs. emissions – meaningful and reality-based results

Following the test phase, real data from project partners was implemented in the model for the first time. The observation was centered on an exemplary logistics network in Eastern Europe that consists of five potential warehouses and serves around 6,000 customers. It was assumed that all sites had identical characteristics in regard to capacity, emissions and costs for inbound and outbound activities that concern transport as well as operative internal goods handling. On the basis of this scenario, one thing soon became clear: If a package of measures exclusively aims to reduce GHG emissions as a mixture of transport-related and locally occurring greenhouse gases, savings of around 50 percent are possible. At the same time, such a one-sided concentration would incur a cost increase in the same amount.

Consequently, alternative logistics networks should be identified with the help of a simultaneous optimization of emissions and costs using various weightings. The scientists therefore concluded, among other things, that 15 percent of the emissions could be reduced with a cost increase of only 6.5 percent. This indicates a relative cost efficiency of the initial emission reduction. The model furthermore shows that a network with a reduced pollutant emission of 48.5 percent would cause additional expenses to the amount of 36 percent. This means that the reduction of the last 1.5 percent of emissions – measured relative to the original scenario with 50 percent – would require additional expenses of 14 percent. The researchers are currently working to further improve these ratios of costs to savings for GHG emissions. Potential can still be leveraged here especially on the cost side.

Examining the resilience of networks simultaneously

Network configurations in such formats are naturally very attractive from an economic and ecological perspective and are quickly added to the favorites list. For this reason,



the inclusion of resilience in the optimization ensures that decisions are not made at the expense of stability. Using the example of a network that has 6.5 percent higher costs and 15 percent lower emissions, it becomes clear that it could be disproportionately dependent on one location if the resilience factor is not taken into account. This in turn harbors the risk of a failure probability and high cancellation costs. "The simultaneous optimization of costs, emissions and resilience is decisively important for designing a balanced, sustainable and resilient logistics network," emphasizes Tim Kerkenhoff from the SND team. A one-sided consideration that only concentrates on one of these aspects can lead to suboptimum results and overlook important synergies. The integrated consideration of all three factors, on the other hand, enables companies to make more efficient and robust decisions that benefit not only their own organization but also society and the environment.

Resource efficiency and GHG emissions in focus

With GILA, a further project was launched in July 2020 to support the worldwide efforts to reduce GHG emissions caused by logistics. At the same time, the key figures developed here are also used in the "Sustainable Network Design" (SND) project. GILA stands for "German, Italian & Latin American consortium for resource efficient logistics hubs & transport." In this project, funded by the German Federal Ministry of Education and Research (BMBF), a consortium of ten partners led by Fraunhofer IML is working on new sustainability concepts.

"The definition of a uniform method for evaluating the environmental performance of logistics centers not only increases transparency but also creates a reliable basis for operative and strategic decisions," reports Kerstin Dobers, the project manager. This concerns both the reduction of GHG emissions as well as a more resource-efficient design of warehouses, fulfillment centers, hubs or terminals that have an interface function within transport chains. The goal of a "circular economy" is also relevant in this connection. "Determined average emission intensity values or other environmental indicators can be included in existing calculation tools and initiatives for environmentally friendly transport as default values in the 'EcoTransIt World' tool or as a benchmark, for example," Kerstin Dobers continues.

Preview of the findings of the 2023 GILA market study

The basis and driving force at the same time is an annual international market study that also gives insights into regional climate conditions and industrial preferences for specific technologies. A central instrument for evaluating resource consumption and emission efficiency is the so-called REff Tool® (Resource Efficiency at Logistics Sites). It enables participating companies to include the relevant resource consumption of a site in their carbon footprint. As a result, reliable KPIs are calculated for storage and handling, for example, GHG emissions per stored pallet. The systematic monitoring also has the advantage of enabling a quick identification of significant fields of action and the implementation of reduction measures in a targeted manner.

The results of the 2023 market study are expected to be officially presented together with the project partners in a webinar in October. After an initial analysis, the data from 2022 remains valid. According to this, 75 percent of the GHG emissions result from electricity consumption. Across the three activity clusters of handling, storage and warehousing, an average of 35 percent is accounted for by the cooling of goods, 28 percent by lighting and 28 percent by material transport. As expected, the operation of solely freezer or refrigerator warehouses accounts for the lion's share of electricity, with up to 78 percent. When asked how renewable the used electrical energy is, the surveyed companies stated that more than 70 percent of their total consumption is attributable to the respectively offered national electricity mix. According to their own

Research project GILA

- **Name:** German, Italian & Latin American consortium for resource efficient logistics hubs & transport
- **Goal:** Reduce environmental impacts of logistics sites and implement sustainability concepts
- **Consortium with ten partners:** Fraunhofer IML (Management), Arcadis Germany, P3 Logistic Parks, Politecnico di Milano (Technical University, Italy), Universidad de los Andres (Private university in Bogotá, Colombia), Green Router, Fercam, Prysmian Group, Conad, Flexilog
- **Duration:** July 2020 until July 2023

information, 32 percent of the sites use electricity that is "greener" than that available through the regular electricity mix. Seven percent produce their own electricity using solar panels, for example.

New ISO 14083 EU directive planned

The REff Tool® supports establishment of new standards such as, e.g., ISO 14083 for accounting and reporting the GHG emissions of transport processes. This orientation is also driven by the European Commission. Brussels, for example, is currently planning a directive that will define the ISO as an internationally uniform evaluation standard within the meaning of the "Green Deal." Among other things, users of the REff Tool® receive information on the carbon footprint of one or more sites and their average emission intensity values. They can compare their own results with the key figures depicted in the market study and use them as a benchmark. The current database of more than 900 sites worldwide can be considered a success of GILA. However, the continuation of the research work will help to achieve an even more solid key figure matrix for the emission intensity values of logistics sites. The REff Tool® will also be continued.

> **"The definition of a uniform method for evaluating the environmental performance of logistics centers not only increases transparency but also creates a reliable basis for operative and strategic decisions"**
>
> Dr.-Ing. Kerstin Dobers

Holistic change management in demand

Act or wait and see what happens? Considering that supply chains also have to function during turbulent times, this is more of a rhetorical question. The same holds true of the challenges that come with climate change. Dismissing sustainability as a mere buzzword does not do justice to the seriousness of the situation at all. Instead, massive efforts are required to ideally serve both aspects at the same time. Maintaining one's own competitiveness is one side of the coin, and companies' responsibility towards society and the environment is the other. Investing in the future naturally means having to spend money initially – and the willingness to forge new strategic paths using suitable technologies as well. Tools such as "Sustainable Network Design" (SND) and the REff Tool® show the way.

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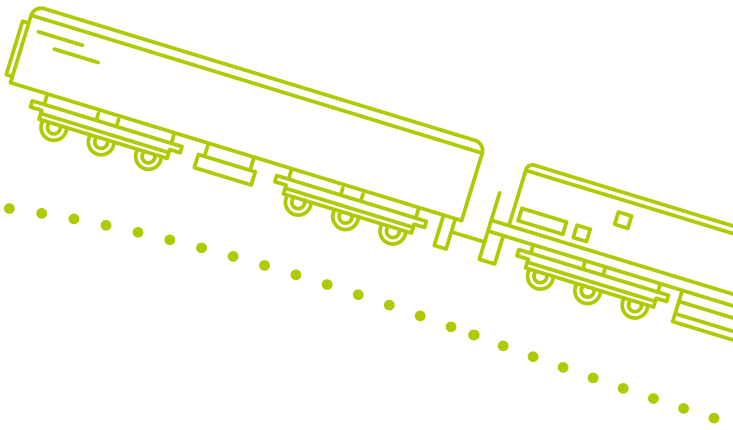

A small molecule on a long journey

Hydrogen is the smallest known molecule of our time, and it is precisely this small molecule that is to be the energy source of the future. Although it sounds very promising, it still presents many challenges – particularly in the area of logistics. This is where the research of Fraunhofer IML comes in. In the "H2LogisticsOnRail" project, our little H_2 molecule is sent on a long journey that is not only green but smart as well.

Hydrogen, especially when it is produced in a green manner, plays a major role in Germany's energy transition and beyond. Until now, our little molecule has been transported either in liquid form by rail, which is eco-friendly but very time-consuming, or in compressed-gas form by road. At this point, a comprehensive logistics solution is needed that meets the standards of intermodal transport and also fulfills the requirements for safe rail transport.

The solution: a smart hydrogen container that not only provides more safety but also reduces emissions in line with the energy transition. And it also allows a larger quantity of hydrogen to be transported per container unit. This goal is being pursued in the "H2LogisticsOnRail" project by Hexagon Purus, the world's leading manufacturer of high-pressure hydrogen containers and transport systems, Endress+Hauser, a specialist for measuring instruments, services and solutions for process automation, Infraserv Höchst, the operating company of Industriepark Höchst and a leading industrial service provider for the chemical and pharmaceutical industry, DB Cargo BTT, a European service provider for integrated chemicals, petroleum and hazardous goods logistics, and the experts of Fraunhofer IML.

"In order to meet the high expectations, we have bundled the best from the fields of hydrogen, logistics and industry together with our partners. Together we have taken on the challenge of developing the transport of the future and putting a smart hydrogen container on rails today," relates Moritz Tennhoff, research scientist at Fraunhofer IML.

To transport our little H_2 molecule from A to B in the safest and greenest way possible, the gaseous hydrogen is compressed up to 500 bar and put into specially manufactured hydrogen containers. The transport container, which comprises a large number of these hydrogen containers, can be transported safety and eco-friendly via freight train. Or, alternatively and in combination, by inland waterway vessel or truck. To ensure this safety, the container has been equipped with a variety of sensors. Our molecule is monitored very closely over the entire supply chain – whether in regard to location, temperature or pressure. In addition to the basic characteristics of the tank, the software concept developed by Fraunhofer IML and BTT also covers filling, removal and, fittingly, billing. All this information is transferred to a cloud and collected in real time. This allows possible disruptions or unexpected occurrences to be identified early on. In addition, predictions of possible critical cases or the need for maintenance should also be enabled, based on the data collected up to that point. Not only does all of this increase the transparency along the entire multimodal supply chain, but the advantages of ecologically generated hydrogen are fully exploited thanks to environmentally friendly transport.

"In comparison to diesel-powered truck trailers loaded with conventional pressure cylinders, we can reduce CO_2 emissions by up to 80 percent at considerably lower costs. There is also a still enormous potential to expand the technology further in the future. A next step could be to expand the container to a temporary fuel station in order to enable stationary deliveries," Tennhoff discusses further.

The project, which has been running since the end of 2022, is currently in a pilot phase in which the containers under development are exposed to all kinds of extremes, such as weather-related conditions and ramp tests. As soon as these tests have been completed, the molecule

of the future will be sent on its long journey in a smart container for the first time. The produced containers will be installed in another container that is equipped with any tested sensors and transported by DB Cargo BTT under real-world conditions. An initial test route will be the transport to Industriepark Höchst. Data will be generated and evaluated during this test, and adjustments will be made if necessary.

After this final test, the hydrogen containers will be mass-produced and then used throughout Germany – from simple transportation from A to B to further multimodal transports. In addition, operative software can be developed from the Fraunhofer IML concept and adapted to the individual needs of different industrial customers.

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"In long-distance transport, hydrogen trucks could stand a chance against electric vehicles"

Prof. Uwe Clausen

How important will hydrogen be as an energy carrier in the future?

We are currently observing a transformation process above all in Europe in which electricity and hydrogen will become much more important. Hydrogen is especially needed as an energy carrier for the decarbonization of basic industries, such as the steel industry. The long-term objective here is to replace the use of coal and coke with "green hydrogen." So far, hydrogen has also mainly been produced from the reforming of fossil fuels. Industry has promised a considerable increase in electrolyzer capacity, and the government has agreed to considerable direct and indirect subsidies in return. To recognize hydrogen as a renewable energy, the EU Commission has determined criteria in legal acts such as additionality (of renewable energy production) as well as its temporal and spatial correlation with electricity purchases of the electrolyzers. Special regulations to promote a "market ramp-up" are possible until the end of 2027. Whether this can be realized according to the ambitious schedule and in the desired scope will depend on the technical capacities of the manufacturers as well as the price development of CO_2 certificates and the achievable cost digression in hydrogen production. In any case, the required hydrogen will have to be imported to a – presumably larger – extent. For example, with an increase to 10 GW of electrolyzer capacity by 2030 in Germany, this could mean an additional demand of 30 GW of global electrolyzer capacity.

Hydrogen is also used for drive energy in transportation. For cars, the quantities have been negligible compared to combustion engines and battery-electric vehicles so far. In the case of trucks, the share is still also small, but high energy density could mean that hydrogen trucks stand a chance against battery-electric vehicles in long-distance transport. From practical experience at Mewa Textillogistik, for example, we are aware of the everyday usability, good feedback from the drivers and a satisfactory range of approx. 500 km. The purchasing costs are significantly higher compared to classic diesel vehicles, and diesel trucks are currently (still) more economical over their entire life cycle.

Hydrogen drives are being tested for shipping and aviation as well. Innovative niche suppliers already put four-seat passenger airplanes with hydrogen fuel cell technology on the market many years ago, and Airbus, MTU and other manufacturers are developing airplane models that should be operational with hydrogen drives by 2035. MSC Cruises intends to bring a cruise ship with a hydrogen drive to market in cooperation with the Italian shipyard Fincantieri and the energy specialist Snam.

Currently, many applications are not yet profitable. In the future, this will depend on how inexpensively "green hydrogen" can actually be produced and what conditions will arise in global markets for reducing greenhouse gases for companies.

What are the greatest challenges of this future technology from a logistics point of view?

In the future, hydrogen will have to be transported on a large scale and often over long distances. It can basically be transported in bulk by water, road and rail or in pipeline networks. The most economical option on land is pipeline-based transport. This will require considerable investments (as worked out for the "European hydrogen backbone") and then a good utilization for low transport prices per tkm. The use of natural gas pipelines has been discussed. Such a conversion, however, is only conceivable after retrofitting with other compressors as well as measurement and control devices.

Every pipeline-based infrastructure is capital-intensive and cannot (initially) reach many recipients dispersed over a wide area.

What solutions can Fraunhofer IML contribute for these challenges as a logistics institute?

For transport in individual containers, a high compression with pressures of 250 bar to 500 bar should be aimed for. Compression requires energy, and handling must be done with great care. At the IML, we deal with questions of infrastructure and transport chain planning as well as – e.g., in the H2LogisticsOnRail project – with container and handling solutions as a contribution to sustainable energy logistics.

Prof. Dr.-Ing. Uwe Clausen

Future supply chains are multimodal and digitally organized

Time pressure and competitive pressure are increasing rapidly in logistics. Artificial intelligence (AI) and the intelligent use of digitalization technologies support the industry very efficiently with planning and decision-making tasks. This is demonstrated by numerous research projects in which scientists from Fraunhofer IML are involved.

AI support along the complete supply chain offers a great potential for increasing efficiency, as shown by numerous projects along the supply chain. For example, in the AutoModal project, a software program was developed for loading and unloading that monitors the surroundings of the handling crane and detects people as well as vehicles. This is the basis for automatic operation of the crane when handling containers in the trimodal terminal. The politically desired competitiveness of inland water transport is provided by the OKTOPUS project (Optimization of the Logistics and Scheduling Processes in the Maritime-based Transport Chain through Machine Learning in Steel Logistics), in which a forecast system was developed on the basis of artificial intelligence (AI) methods. This project is to predict transport times on the water of the Rhine corridor between Rotterdam and the Ruhr region accurately to a few minutes and determine capacity requirements in the case of low water.

Accurate prediction of arrival times

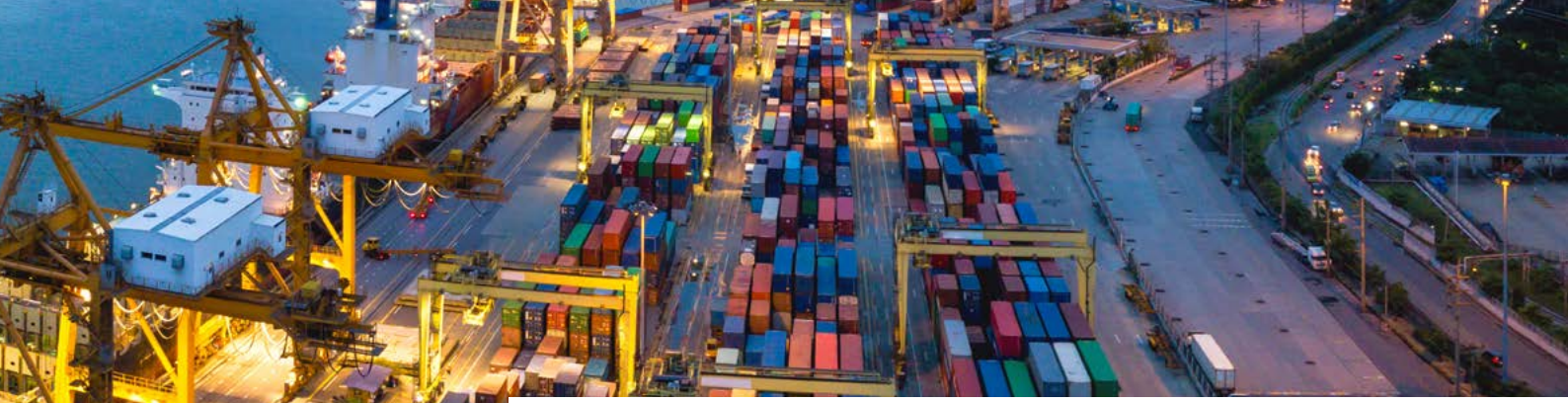
When shipments arrive at an inland port, they are loaded onto trucks for further transport to a distribution center (DC). Detailed planning of the resources within the DC requires accurate prediction of the arrival time. However, not every company has the means and prerequisites to implement and use corresponding technology. Within the BMVI-supported project "Silicon Economy," an open-source solution was developed for AI-based ETA (estimated time of arrival) prediction. This is based exclusively on open and freely accessible data sources and can also be used at less digitalized companies. To calculate the ETA, the AI uses, for example, weather forecasts that affect the driving speed, current and past traffic jam information, or, if necessary, legally required breaks, taking into account available parking spaces at truck stops.

Capacity planning through predictive analytics

As soon as a shipment arrives at a distribution center, it has to be handled and prepared for local transport. This requires corresponding resources at the warehouse as well as in local transport. The corresponding resource planning can be greatly simplified and more accurately forecast with predictive analytics, a sub-area of AI. This task, which is currently often done manually, can be almost completely automated and helps to make work easier and save costs. The result of this "predictive analytics" approach are predictions that show future volumes much more accurately.

Better transparency in local transport

When goods are on the last mile to the customer in a delivery vehicle, then the transparency and above all the punctuality of the delivery are what counts. Using AI methods, driving times and idle times can be learned from previous tours under a wide variety of conditions, which helps to increase the quality of tour planning. For this purpose, the geo-coordinates and the current speed are recorded in 30-second intervals on the driven tours. This data is used to develop a learning system that dynamically predicts the appropriate speed for individual road sections at specific times. For each journey segment, this results in corresponding time slices that predict the possible speed at the respective time. For optimum tour planning, the customer-specific idle times, in other words, the time from parking the vehicle to fulfilling the service and continuing the journey, are also of great interest. An AI-based expert system was therefore developed that predicts how long a driver will probably wait during a stop, depending on a multitude of different factors (e.g., number and weight of packages, season of the year and time of day, rural or urban region).



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Internet of Things makes logistics hubs more effective

Due to their function as transshipment points, logistics hubs play an important part in supply chains. Holistic digital solutions can be created here using the Internet of Things (IoT) and AI-based approaches. The I²PANEMA project, for example, uses nine demonstrators to show how processes at ports and thus in the supply chains can be made more efficient and secure. In particular, I²PANEMA aims to use the possibilities of the IoT to improve port operations, make them more sustainable and thus pave the way for networks of intelligent ports. One key focus area in the project is the topic of IT security.

The eCMR becomes compatible – finally!

In the future, mutually compatible shipping documents for international road freight transport (CMR) will also be created electronically and thus stabilize supply chains. For this purpose, the eCMR project was launched within the Open Logistics Foundation Community. The eCMR uses the results of the eCMR project that was carried out at Fraunhofer IML in the framework of the "Silicon Economy." The electronic consignment note is based on the creation, storage and transmission of digital consignment notes and machine-readable digital consignment notes, taking into account established templates and international standards. As a common data source, the eCMF also serves as an "enabler" for further digital processes, such as, e.g., automatic invoicing and payment. All developed components are made available to companies in the Open Logistics Foundation Repository.

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Future Logistics Congress – **41st Dortmund Talks**

The "Future Logistics Congress – 41st Dortmund Talks" has returned to the stage after three digital years. Under the motto "Logistics goes AI – Learning what we don't understand" everything revolved around artificial intelligence (AI) and its significance in logistics for the 450 participants at the traditional congress on September 12 and 13, 2023.

Artificial intelligence will radically change our everyday life and especially our world of work – this was something that the experts from science and business agreed upon. "AI is increasingly becoming an actively engaged partner of human beings," emphasized Prof. Michael ten Hompel, executive director of Fraunhofer IML, in his opening speech. This was followed by keynotes by Stefan Hohm (DACHSER) on artificial intelligence in the general cargo network and by Christa Koenen (DB Schenker) on artificial intelligence in global supply chain management.

In the subject area "Trade Ecosystem goes AI – via IoT," Prof. Michael Henke, institute director at Fraunhofer IML, subsequently discussed the potential of AI for the financial industry, together with representatives from T-Systems International and Commerzbank. In the afternoon, the focus was on "AI and sustainable, multimodal logistics" with Prof. Uwe Clausen, also an institute director at Fraunhofer IML.

On the second day of the congress, the Fraunhofer symposium started with an "AI plenary" for the first time. This was then followed by four parallel subject-specific sequences on the topics "Resilience and sustainability in supply chains," "Open source and open innovation," "Image processing with artificial intelligence" and "Digitalization of multimodal transport chains."

For the first time, the Lamarr Institute for Machine Learning and Artificial Intelligence and the Open Logistics Foundation were also event partners of the congress, in addition to the organizers Fraunhofer IML and Digital Hub Logistics.

Mansio wins 1st place at the Digital Logistics Award 2023

The Digital Logistics Award was presented for the sixth time in the framework of the "Future Logistics Congress – 41st Dortmund Talks." Seven finalists were able to present their diverse and innovative logistics solutions to the audience in a three-minute pitch. Afterwards, the audience and expert jury voted for their favorites. The festive award ceremony was held during the evening event of the City of Dortmund in the halls of the "Phoenix des Lumières" art exhibition.

The Aachen-based start-up Mansio secured the first prize, endowed with 15,000 euros, with its software-based transport system for road freight transport. The system of the start-up is based on the concept of swap transport: During a transport, a truck transfers its semitrailer to another truck. This allows a highly efficient use of resources and helps to optimize supply chains.

Prof. Michael ten Hompel receives the German Federal Cross of Merit on Ribbon

The outstanding scientific commitment of the executive director at Fraunhofer IML, Prof. Michael ten Hompel, has been honored with the Federal Cross of Merit by the German federal president. The award was presented by the mayor of Dortmund, Thomas Westphal, on March 23, 2023. Prof. ten Hompel has helped to consolidate logistics as one of seven areas of expertise in Dortmund and promoted the dialog between science and society in a unique way, according to Westphal.

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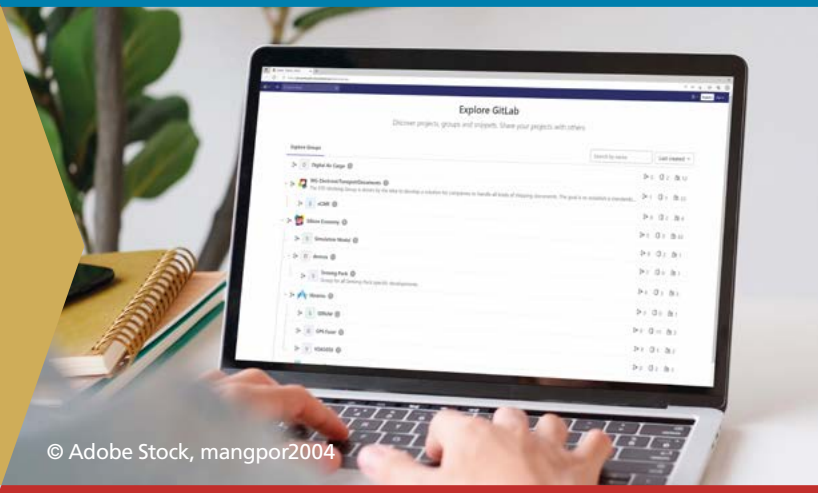
Fraunhofer IML at the transport logistic

Hardly any other area of logistics is affected so strongly by changes due to the sustainability concept as transport logistics. How we can keep pace during this transformation phase and even take on a leading role was presented by Fraunhofer IML at the "transport logistic" trade fair from May 9–12, 2023 in Munich. The institute presented innovative solutions and developments, from fleet and route planning to operational infrastructure.

Large-scale research project "Silicon Economy" enters the second funding phase

Since May 2023, Fraunhofer IML has been researching the latest technologies for the platform economy of the future together with the Fraunhofer Institute for Software and Systems Engineering ISST and various chairs of the Technical University of Dortmund. The second phase, funded by the German Federal Ministry for Digital and Transport (BMDV), will now increasingly deal the application of these technologies. The previously developed open source components will be taken to industry, tested and further developed.



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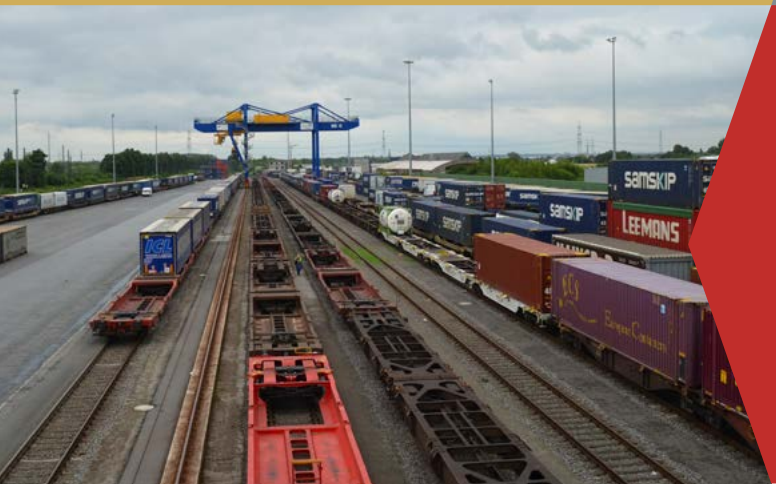

Fraunhofer Transport Alliance celebrates 20th anniversary

The Fraunhofer Transport Alliance has been pursuing the goal of realizing the "transport of tomorrow" since 2003. In the 20 years of successful collaboration, the involved institutes have been able to implement holistic technical and conceptional solutions through transport-relevant research and implement them with industrial partners. Their recipe for success is the close collaboration across the 23 involved Fraunhofer Institutes and research units and their wide range of expertise.

NE:ONE – The air freight of tomorrow

In June 2023, NE:ONE, an innovative open source ONE Record server software for the air freight community was launched as part of the ONE Record Hackathon. The software, developed in the framework of the Digital Testbed Air Cargo (DTAC) project funded by the German Federal Ministry for Digital and Transport (BMDV), will contribute to the introduction of the IATA One Record data exchange standard. As open-source software, NE:ONE not only helps to start using ONE Record technology but is also the starting point for the comprehensive digitalization of air freight.

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High-ranking visitors at the Lamarr Institute for Machine Learning and Artificial Intelligence

Not one but two state secretaries visited the Lamarr Institute for Machine Learning and Artificial Intelligence in July 2023. Mario Brandenburg, parliamentary state secretary of the German Federal Ministry of Education and Research (BMBF), paid a visit to the institute at the Dortmund location during his tour of the German AI competence centers. Together with State Secretary Gonca Türkeli-Dehnert from the Ministry for Culture and Science of the German state of North Rhine-Westphalia, he was able to see the various research and training projects for himself and experience the innovative AI technologies firsthand.

Climate targets? Only with combined transport!

A study of the Projektkonsortium für den Kombinierten Verkehr e. V. (Project Consortium for Combined Transportation) and LKZ Prien with the participation of Fraunhofer IML has investigated the potential of combined transport, focusing on the use of standard semitrailers. The study, funded by the German Federal Ministry for Digital and Transport (BMDV), has showed that strengthening combined transport or increasing the use of rail transport can significantly contribute to meeting the climate targets of the transport sector.


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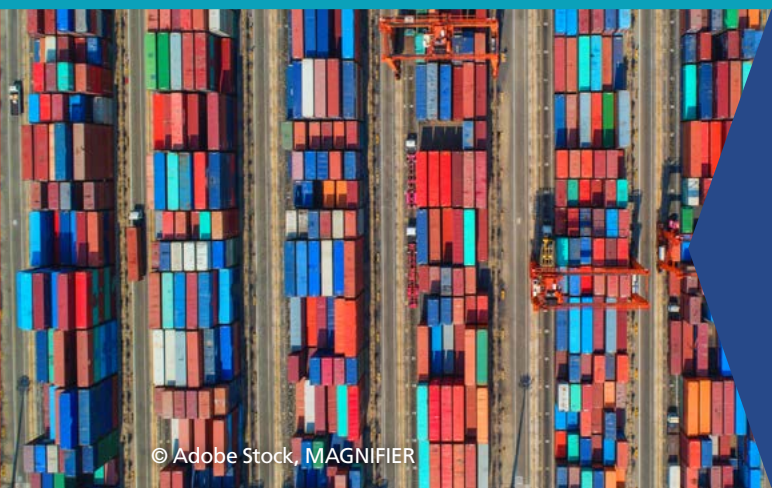
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Open Customs Blockchain Working Group

The Open Customs Blockchain Working Group, represented by the Open Logistics Foundation, ALS Customs Services and Fraunhofer IML, was selected as part of the first cohort of 20 use cases for the European Blockchain Regulatory Sandbox. This initiative, launched by the European Commission, is a decisive step towards improving the legal certainty in connection with blockchain and distributed ledger technology. It offers a structured approach to constructive regulation discussions between innovators and regulatory authorities extending across various industrial sectors.

Literature tips

Supply chain resilience and total cost of supply chain improvements with digital printing

War, a pause or a break in the march to Globalization and technology driving changes to customer buying behavior, leads brands and converters to rethink how they can improve responsiveness and agility in their packaging supply chains in an ever-changing world. Using quantitative modeling based on converter production data and known waste factors, this paper explores how digital printing can become a critical tool to enable greater resiliency, lower environmental impact, improved utilization of resources, and lower overall total supply chain costs for folding carton packaging production.

Open knowledge for the community

Under the title "Blockchain Navigator", "Blockchain Europe" publishes unique insights into the research results of the project for establishing the European Blockchain Institute in North Rhine-Westphalia, Germany. The aim of the publication series is to enable the introduction of blockchain technology in different industries and to already support companies when they are considering using it. In keeping with the spirit of the "Blockchain Europe" project and to create an open community, open-source software modules and concrete applications are provided.

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