WHITE PAPER

Digitale
Fabriek

Digital Factory of the Future

Towards more economic value from data

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Fabriek

Introduction

DIGITAL FACTORY OF THE FUTURE

Datafication is the creation of economic value from data. The manufacturing industry produces a lot of data, which potentially represents great economic value. The **"Digital Factory of the Future"** project (Digital Factory for short) aims to capitalise on the potential of the Brabant manufacturing industry. It is about improving the performance of existing companies, developing new services, and tackling societal challenges. In short, to turn data into a fully-fledged production factor.

The economic value of data can be cashed in by individual companies, in the collaboration between companies within value chains it becomes real gold. Collaboration can be strengthened by sharing data. This project is concerned mainly with the ways in which data is collected and stored, and how that data can then be exchanged and used in a smart way.

The project is a joint search for data-driven innovations. The aim is to realise an environment in which a Digital Factory could be demonstrated, showing how it could be implemented in your own situation.

TWO PHASES, TWO WHITE PAPERS

The project runs from 2020-2022 and has roughly two phases. During the first phase, until September 2021, the *Blueprint for the Digital Factory* and some relevant industrial use cases were elaborated. The main results of these can be found in this white paper. During the second phase, the blueprint and the use cases will be experimented with in a test and validation environment, and a number of themes will be further elaborated. These topics will be discussed in a second white paper.

INITIATORS

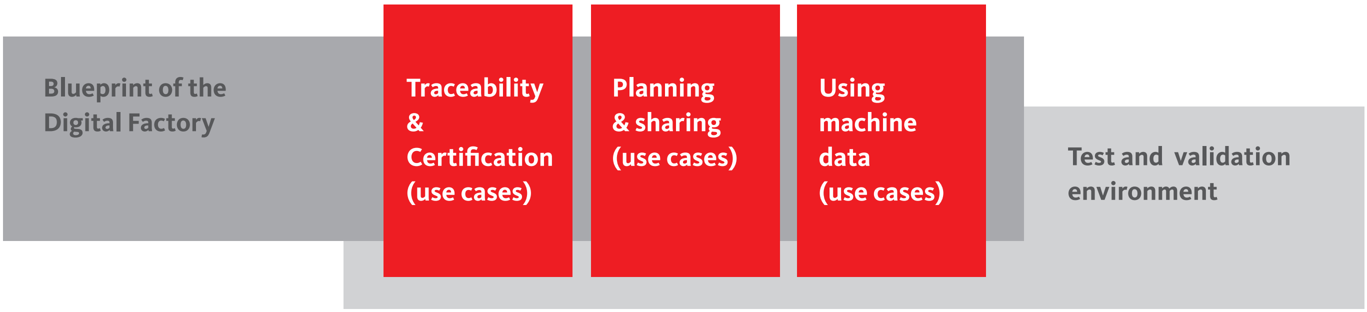
The Digital Factory project is an initiative by entrepreneurs and knowledge institutions in the manufacturing industry in the Brainport region, with Brainport Industries in Eindhoven as the coordinator. The project budget is approximately €3.7 million, of which approximately €1.5 million is a subsidy from the Province of Noord-Brabant.

WHAT YOU CAN DO

The Digital Factory invites parties to join the open innovative culture of the Factory of the Future, which offers companies the opportunity to meet new people and situations – an important key to innovation.

This invitation applies in particular to SME manufacturing companies. We hope this white paper inspires and activates them. The Digital Factory project will be successful if SMEs actually start digitising. The success will also be measured by the number of pilots and demo cases on the Brainport Industries Campus.

The Digital Factory project comprises three building blocks, as shown in the diagram below. A second white paper on the test and validation environment will be published upon completion of the project; the other components are the subject of this white paper.



Factory of the Future

FACTORY OF THE FUTURE

The Factory of the Future, of which the Digital Factory project is a part, is an innovation programme by Brainport Industries and the Province of Noord-Brabant, and it combines and coordinates developments in the field of datafication in the Brainport region. These developments relate to Industry 4.0, which in the Netherlands is also known as Smart Industry.

ROAD MAP 2021-2024

A roadmap has been drawn up for the realisation of the Factory of the Future. The goal is cost reduction, quality improvement and a shorter time-to-market by jointly developing smarter production processes and sharing facilities. The focus is on the industrialisation and production phases of high-tech products and systems (high mix, high complexity, low volume).

SMART INDUSTRY

The Dutch government is supporting the development of new ICT and production technology within the industry through its “Smart Industry Implementation Agenda 2018-2021”.

The innovation programme Factory of the Future benefits from this support with initiatives that are in line with the eight transformations that are being pursued within Smart Industry and that are visualised in the ‘Smart Industry wheel’ (figure 1).

FOUR INNOVATION DOMAINS

The eight transformations within the Smart Industry are positioned on the Roadmap 2021-2024 in four innovation domains.

Smart Manufacturing
Deployment of new production technologies; smart assembly and robotisation.

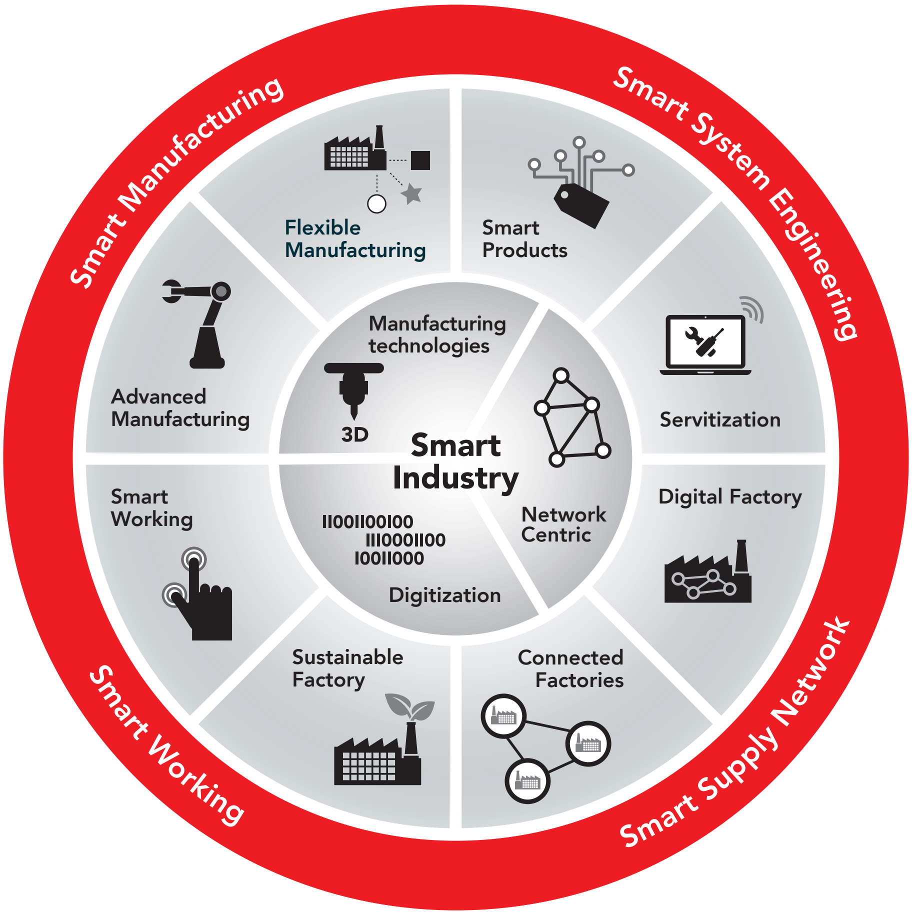
Smart Supply Network
Application of artificial intelligence; smart data sharing and smart logistics within the value chain.

Smart Working
Optimisation of processes through digitisation; training & education.

Smart System Engineering
Digitising and automating system development; deployment of flawless systems and software updates.

The Digital Factory has common ground with all four domains: it is the enabler of Smart Industry.

Figure 1
Smart Industry wheel



EIGHT TRANSFORMATIONS

The eight transformations within Smart Industry are explained briefly below.

Digital Factory

In digital factories, all information flows are digitally connected, seamlessly and securely, both internally and throughout the chain. This transformation is the enabler of the other transformations.

Smart Products

Products collect data and communicate with the environment, which provides feedback.

Servitization

Services are playing an increasingly important role in the business model of manufacturing companies, for example in maintenance.

Sustainable Factory

A sustainable factory works as economically as possible in respect to energy and material consumption.

Smart Working

In smart working, technology helps to make heavy, dirty and dangerous jobs lighter, cleaner and safer, or to carry out complex operations without errors.

Advanced Manufacturing

Smart production is error-free production because every production step is 100% controlled.

Flexible Manufacturing

With flexible production, a factory is able to realise different products with the shortest possible lead times.

Connected Factories

In a digital chain, companies in the entire value chain of suppliers, service providers and customers are connected digitally.

PROJECTS AND FIELD LABS

The transformations within the Smart Industry are shaped by the following projects and field labs within the framework of the Factory of the Future.

Digital Factory of the Future
This project integrates data-driven innovations that enable the sharing of data within the company’s own complex production environment and with the chain. Better use of data creates the preconditions that make the other transformations possible.

High Tech Software Cluster
This cluster develops software-driven innovations that drive the transformation to *Smart Products*.

Data Value Center Smart Industry
This Smart Industry Competence Center supports the transformation to *Servitization*, among other things.

Circular Economy in Smart Industry (CESI)
This is where the transformation to the *Sustainable Factory* takes place.

FutureTec
FutureTec (Education & Training) gives substance to innovative technical education in the Brainport region, which should contribute to the transformation to *Smart Working*.

Fieldlab K3D Addfab
his field lab takes the industrialisation of 3D metal printing, and with it *Advanced Manufacturing*, further.

Fieldlab Multi Material 3D
This field lab is committed to the development of multi-material additive manufacturing with plastics, a form of *Advanced Manufacturing*.

Fieldlab Advanced Manufacturing Logistics
This field lab focuses on faster delivery times and higher productivity in the supply chain, and therefore on *Flexible Manufacturing*.

Fieldlab Flexible Manufacturing
This field lab strives for flexible and high-quality small series production at mass production costs, and therefore for *Flexible Manufacturing*.

Smart Connected Supplier Network
By offering a new data standard and technical infrastructure, SCSN makes the sharing of data in chains much more efficient and facilitates the transformation to *Connected Factories*.

SMALL AND MEDIUM BUSINESS

The Factory of the Future promotes the eight transformations by involving the SME manufacturing industry in the Brainport region as much as possible.

CONTINUITY THROUGH A FOUNDATION

The Smart Connected Supplier Network Foundation was established to maintain and further develop the data standard and infrastructure. This foundation is financed by manufacturing companies (users) and service providers. Thus SCSN continually supports the exchange of order, logistics, administrative and technical data in customer-supplier situations. A possible development could be to add machine data to this.

Digital Factory of the Future

IT'S ALL ALREADY THERE!

A great deal is already available to Smart Industry. Robots are widely available and we have the Internet of Things, especially after the rollout of the 5G network. We have the software to get that technology up and running, and there are solutions for sharing data within chains. Practice, however is proverbially unruly, no less so in this area. For example, companies and consultants often have to spend a lot of time figuring out how to get valid data from machines and processes, and how you can use it in different places.

This is problematic even for larger companies, and certainly for many SME manufacturing companies. As a result, they forgo the use of smart technology or struggle enormously with testing and validating data, and connecting systems to each other. The promises of Smart Industry are not easily fulfilled in this manner.

DIGITAL FACTORY OF THE FUTURE

The Digital Factory of the Future project is taking steps to remove the barriers to data sharing. By using existing standards for data sharing in a convenient way, the digitisation of SMEs can be accelerated. The project delivers inspiring use cases and translates these into practical solutions that can be used by other companies. With the solutions, silos within organisations can be broken down and collaboration between organisations can be promoted.

Individual factories and chains blend into each other, for example where companies do maintenance on machines that are at other companies. To this end, systems work together via the cloud. At the Brainport Industries Campus, we see that companies are increasingly collaborating with each other and sharing data for this purpose. We see the same within the entire Brainport high-tech region.

Without data sharing, no collaboration; without collaboration, no competitiveness.

VOCABULARY OF THE DIGITAL FACTORY

- Architecture layers
- Cyber-Physical Production System
- Data Hierarchy
- Digital twin
- Industry 4.0
- Multi-agent System

Blueprint of the Digital Factory

The Digital Factory project focuses on the development of a blueprint for data sharing within complex production companies and in the chain. This blueprint includes (existing) standards, which are applied depending on the specific situation. The project is working on further agreements on the application of these standards, in particular with regard to the further standardisation of data exchange.

It is crucial for data sharing within one's own organisation that the departments and systems involved adhere to clear agreements about the structure and format of that data. The same applies to organisations in the chain.

These agreements have been laid down for the Digital Factory in a blueprint that focuses on:

a. Collecting and using data within one factory that as a result is becoming increasingly smarter, and in which devices and processes can work autonomously.
b. Controlled sharing of this data in the chain with customers, suppliers and providers of new services.

Since both things go hand in hand, there is actually one blueprint, one data infrastructure.

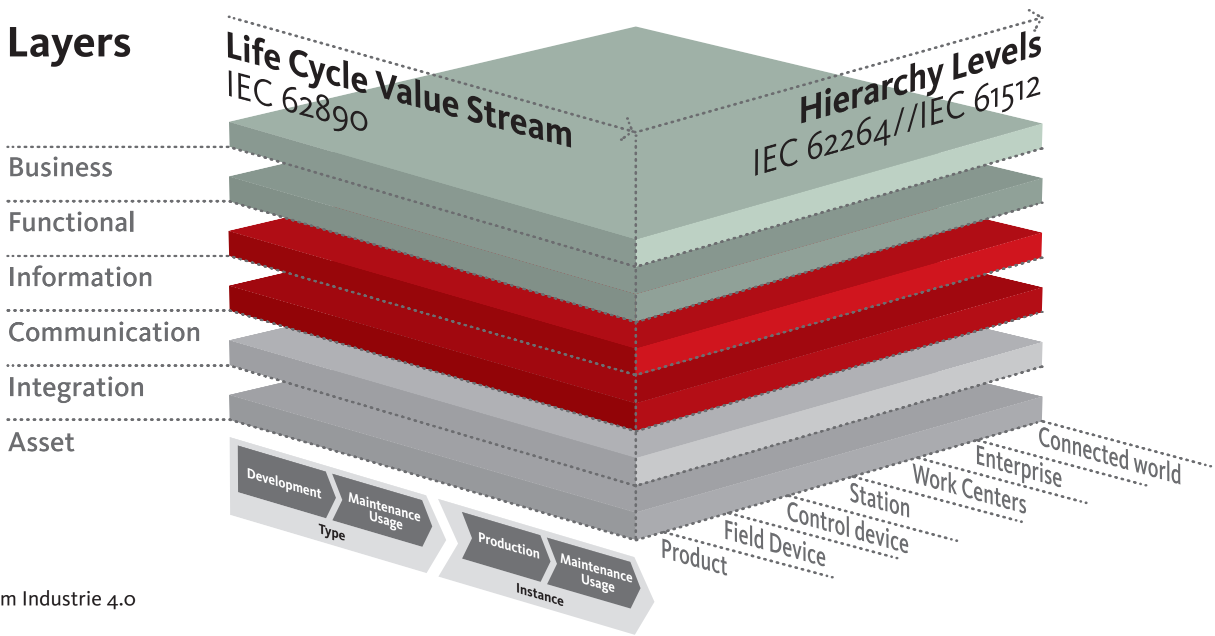
RAMI 4.0

To describe this blueprint, a general standard for data sharing within and between companies, namely **RAMI 4.0**, has been used.

RAMI 4.0 stands for Referenzarchitektur-Modell Industrie 4.0 (Reference Architectural Model for Industry 4.0) and was developed by the Plattform Industrie 4.0, an initiative of the German government. It is an overview of the most relevant aspects of Industry 4.0, laid down in the international standard IEC PAS 63088:2017 of the International Electrotechnical Commission.

The Digital Factory project is looking for open standards that can be applied widely by SMEs and that are future proof, so that they can also be used in the installation of new assets (machines), the development of new products, and the collaboration with new chain partners.

Figure 2
RAMI 4.0-model, Referenzarchitektur-Modell Industrie 4.0.



Source: Plattform Industrie 4.0

RAMI 4.0 is an ideal stepping stone for the Digital Factory to gain a good understanding of the relevant technologies, standards and use cases, and to subsequently record these in a blueprint. **RAMI 4.0 is a model that brings together open standards.**

The RAMI 4.0 model consists of three dimensions, namely (see figure 2):

- Life Cycle
- Architecture (*Layers*)
- Data Hierarchy.

LIFE CYCLE PRODUCT

RAMI 4.0 distinguishes two phases for the design of a product (machine) (*Type*, 'as designed') and for specific items (*Instances*, 'as built'):

- Type – Development
- Type – Maintenance Usage
- Instance – Production
- Instance – Maintenance Usage.

The design of a product (machine) usually consists of a 3D design and a STEP file (i.e. a 3D file format). A CAM program is often used in the production of the parts of that product, supplemented with measurement data and certificates that show that a specific item meets the quality requirements. In this way, a lot of data is generated during design, production and use of a product (machine).

A point of attention is the transfer from the developer of a machine (OEM) to the SME manufacturing company, which produces parts such as monoparts.

Another point of attention is how to keep the product 'as built' (and 'as maintained') in line with the product 'as designed'. This is because maintenance when using specific copies can lead to a change in the design (Type). Design changes may necessitate an upgrade of existing Instances.

The Digital Factory is mainly concerned with the 'Instance', i.e. the physical product (machine).

ARCHITECTURE (LAYERS)

RAMI 4.0 distinguishes the following aspects (Architecture Layers) aimed at open standards for communication and integration protocols:

- Business
- Functional
- Information
- Communication
- Integration
- Asset.

Business

This concerns the organisation and business processes, whereby the question is asked: what is it worth? A substantiated business case must show whether a company is competitive. The data you need for that business case must of course be available. Relevant to this aspect are the Generic Value Propositions, which are described below.

Functional

This concerns the functions of the product (machines), asking the question: what functionality is needed?

Information

This concerns the information needed for further application, asking the question: what data do I need to achieve the functional objectives?

DIKW HIERARCHY

The DIKW hierarchy provides insight into the relative value of data.

- Data
- Information
- Knowledge
- Wisdom.

Data includes all signals that can be captured. Information is a description of data – the semantic meaning – and can serve as a basis for decisions and actions. Knowledge is the entirety of insights, concepts, etc. that is formed on the basis of information.

Wisdom is an insight into using knowledge for a higher purpose. For the Digital Factory, Wisdom can also be read as artificial intelligence.

Communication
This concerns access to data, asking the question: how do I or my customer get access to data? RAMI 4.0 distinguishes different levels of communication, such as:

- Physical (wired/wireless)
- Data link (Ethernet, WiFi, GSM 4G)
- Network (IP, IPsec)
- Transport (UDP, TCP).

RAMI 4.0 follows the OSI model, a standardised reference model for data communication standards, Open Systems Interconnection (ISO X.200). It shows how RAMI 4.0 combines other standards.

Integration
This concerns the transition from the real to the digital world, asking the question: which parts of my product are available digitally in the network and which should be added to it? To achieve integration, Application Programming Interfaces (APIs) must be developed.

Asset
This concerns the 'physical' things in the real world (the other levels are digital), asking the question: how do I integrate my product with the process to place it in the 'virtual world'? In the RAMI model, Asset forms a broad concept; it could be a product, a process, a document or a person. In the Digital Factory it is often a machine.

DATA HIERARCHY

The third dimension of the RAMI 4.0 model is the Data Hierarchy and the systems deployed:

- Product
- Field device
- Control device
- Station
- Work centers
- Enterprise
- Connected world.

Product
This is the physical object to which the data relates, i.e. the machine being produced. This concerns static, semi-static and dynamic data. Static data relates to the nameplate information of a machine that in principle does not change, such as production capacity. Semi-static data can be found, for example, in periodic inspection reports, revisions and configurations. Dynamic data is about the use and maintenance of the machine, data that are constantly changing. This is related to the Life Cycle in the RAMI 4.0 model. The static data relates to the *Type*, the semi-static and dynamic data relate to the *Instance*. This means that two machines of the same *Type* (with the same static data) generate completely different dynamic data when used.

Field device
These are the components in a *Station* used for detecting and controlling, such as sensors, motors and robots. A *Field device* registers data and provides the data exchange. This concerns, for example, sensor data, analytical data and alarm data.

Control device
This is the brain of production, the devices that receive and provide input/output instructions. They control the *Field devices*.

Station
Operators actually carry out production using a *Station* by controlling and monitoring this process in real time.

Work centers
A collection of *Stations* jointly makes (a part of) a product. Typically, the *Stations* in a *Work center* perform various operations, such as drilling or milling. The Manufacturing Execution System (MES) helps decision makers to monitor and optimise the total production process in the *Work Centers*.

Enterprise
This concerns the Enterprise Resource Planning (the ERP system), with which other business processes, including the financial aspects, are managed in addition to production. Within the RAMI context, the management and coordination between different *Work Centers* is especially important, for example with regard to internal logistics and the planning of supplies and deliveries.

Connected world
In this category, the other levels come together and connections are made to suppliers, customers, service providers and other stakeholders in value chains and partnerships.

A higher level in the Data Hierarchy always includes the lower levels. The *Connected world* includes multiple *Enterprises* (the company itself, customers, suppliers), an *Enterprise* includes multiple *Work Centers*, a *Work Center* includes multiple *Stations*, and so on. Each level contributes to the creation of the *Product*.

From pyramid to network
Until recently, the ISA-95 pyramid was sufficient to describe the data in automated systems. This pyramid consists of five layers, with the typical systems for each layer (see the diagram below):

0. Instrumentation (sensors & actuators)
1. Process control (PLC)
2. Visualisation, user interfaces (SCADA/HMI)
3. Production management (MES)
4. Business management (ERP/PLM).

Figure 3
ISA-95 pyramid

Figure 4
The pyramid makes way for a network

This fairly rigid structure can be used perfectly for high production volumes. However, we are now seeing the arrival of more ICT on the factory floor, blurring the traditional data hierarchy and making more data available. We see machines becoming smarter and more connected, we see digital interfaces, sensors and applications of the Industrial Internet of Things. Data is collected in all kinds of ways, with sensors, *Control devices* or by an operator who enters data with a tablet. The pyramid makes way for a network, as visualised in the diagram above.

This development is important for the manufacturing industry (high mix, low volume, high complexity). The data lends itself to various purposes, in particular to providing insight into the current situation and optimisation. Via dashboards and by zooming in on specific steps in the production process, the same data provides insight into the specific machine as well as the overall production planning.

FRAMEWORK FOR STANDARDS

RAMI 4.0 is a framework that relates various standards to each other. Examples range from implementation standards such as OPC UA and AAS to a cloud standard such as GAIA-X. One or more standards apply to each position in the RAMI 4.0 cube. For example, different standards apply to the different Architecture Layers, such as GAIA-X for the *Communication* layer.

At the same time, a certain standard may apply to multiple positions in the cube. Data in the cloud can be used for certain performance indicators, such as Overall Equipment Effectiveness (OEE), one of the Generic Value Propositions (see below). Data from different positions within the cube can be included in the calculation.

Depending on how you look at the shared data, you can make a cross-section of the RAMI 4.0 model. In this way you can discover what the recommended standards are and how they are related.

UNIFORMITY OF STANDARDS

Specific standards are available for the consumer market. For example, there are standard plugs for TVs and there is an IP protection class for electrical equipment. For the manufacturing industry, the standards are less clearly defined, although progress is being made and market standards are slowly emerging. Some examples:

- Open Platform Communications (OPC UA): protocol for machine communication
- Asset Administration Shell (AAS): model for the way you can communicate with a thing, developed by the German Plattform Industrie 4.0
- GAIA-X: standard for secure European cloud facilities from the International Data Spaces Association.

GAIA-X

GAIA-X is one of the European initiatives designed to counter the dominance of the United States and China in the field of digitisation. GAIA-X serves data sovereignty, data availability and innovation. GAIA-X wants to avoid a unilateral dependence on large non-European platform providers. In addition, GAIA-X offers guarantees for the reliable, secure and transparent exchange of data. Furthermore, GAIA-X supports the digital business models of European industry.

When linking systems (for example between a machine and the cloud), it is essential that the same language is spoken. What are known as name-value paths function a bit like telephone numbers for data traffic: each data item (for example, power consumption) has its own name-value path. The standards do require the use of name-value paths, but leave each machine builder free in the exact naming.
Sometimes the machine builder can provide the name-value paths to the user. It would be better if all machine builders were using the same name-value path for a specific data item, then everybody would know which kind of data is being discussed, regardless of the machine builder. The Digital Factory aims to put all standard applications on the same footing, which could then be regarded as best practice. This is important, because if you do not clearly define the method of data sharing, you cannot, for example, build beautiful dashboards for different machines – at least not without laborious preparations to 'tie them together'. And without such a best practice standard, you are forced to update the dashboard every time a new machine is installed.

The Digital Factory is investigating the connection with developments in Germany, where UMATI (Universal Machine Technology Interface) is working on open, standardised interfaces.

The example of OPC UA, a protocol for data exchange between machines, shows that all this is by no means easy. In practice, each machine manufacturer has its own interpretation. In this pursuit of vendor lock, all kinds of 'dialects' of the protocol have arisen, which complicate data exchange between machines of different makes – OPC UA seems a new Tower of Babel. Assuming that going back to the default is impossible, a *wrapper* offers a workaround. This is a piece of software that enables data exchange between two dialects. The development of a universal wrapper is not part of the Digital Factory project; work is being done elsewhere on the OPC UA FX, a new standard for factory automation.

ALTERNATIVE REFERENCE MODELS

In addition to RAMI 4.0, there are other reference models that provide insight into the use of data in an industrial context. An example is the **IoT World Forum Reference Model**. This model corresponds broadly to the Data Hierarchy of RAMI 4.0 and the OSI model.

The international car industry has developed its own reference model, **Automotive SPICE**. Like the RAMI 4.0 model, this model has a predominantly German origin.
The **Autosar** architecture model is also known within the automotive industry, of which several variants can be found.

As a blueprint for the Digital Factory, RAMI 4.0 was preferred as it is more complete and generic.

INTERNATIONAL CONTEXT

Through the participation of Brainport Industries in a workgroup, the Digital Factory is involved in the further development of the RAMI 4.0 model by the Plattform Industrie 4.0. With this, the Plattform acknowledges that the Digital Factory is relatively advanced with the implementation of RAMI.

The Digital Factory is also involved in the development of the cloud standard GAIA X. Brainport Industries and TNO are in the lead in defining the International Data Space for Manufacturing.

The Digital Factory is also a showcase for DIMOFAC, an acronym for Digital Modular Factories. This is a Horizon 2020 project aimed at making manufacturing assembly lines more flexible in view of rapidly changing market demand.

In short, the Digital Factory also counts internationally.

Generic Value Propositions

The value of RAMI 4.0 as a theoretical model proves itself in practice. This proof is provided on the basis of the Generic Value Propositions. The Digital Factory offers nine **Generic Value Propositions**, nine promises of what the digitisation of the manufacturing industry can deliver (it is possible that this number will be expanded).

NINE GENERIC VALUE PROPOSITIONS

The nine Generic Value Propositions are grouped into themes, i.e. into business goals that can be achieved with them.

Collaboration with customers and partners in the chain	
1	Supply chain collaboration through increased transparency
2	Reduction of the administrative burden within the purchase-to-pay process
3	Collaborative design and engineering using model-based design
Modular manufacturing	
4	Analysis of Overall Equipment Effectiveness (OEE)
5	Automated programming of flexible manufacturing lines
6	Smart Production Planning: from customer order to operation
Improving quality & reducing maintenance costs	
7	Predictive Maintenance and preventing downtime
8	Zero-defect manufacturing
9	Certification of products or process outcomes based on measurement data

IMPORTANCE OF GENERIC VALUE PROPOSITIONS

The importance of the Generic Value Proposition is explained briefly below.

Supply chain collaboration through increased transparency
Machine builders are increasingly dependent on just-in-time parts delivery. Optimisation is possible if a company has insight into the planning and progress with regard to, among other things, production and stocks of suppliers or customers. This insight can be gained by exchanging data in a secure manner.

Reduction of the administrative burden in the purchase-to-pay process
SMEs play a crucial role in supply chains, but data exchange and processing often still has to be done manually. However, this can also be automated.

Collaborative design and engineering using model-based design
The exchange of traditional 2D designs, including documentation, between customer and supplier can be replaced by 3D designs, which contain all necessary information.

Analysis of Overall Equipment Effectiveness (OEE)
Production resources require large investments and must therefore be used efficiently. This usage can be analysed with measurements of availability, performance and quality. Machines can provide the necessary data for that purpose.

Automated programming of flexible manufacturing lines
An assembly line must be reconfigured for each production batch, which involves a lot of programming. It is possible to speed up configuration using digitisation.

Smart Production Planning: from customer order to operation
The translation of an order to production includes the required resources and the availability of machines. Drawing up a plan often requires a lot of manual work. It is possible to arrive at an overall production planning through automation and to respond flexibly to changes.

Predictive Maintenance and preventing downtime
Machine builders use all kinds of complex machines. Based on the data generated by these machines, it is possible to gain insight into their wear and to prevent malfunctions through timely maintenance. This can be addressed during maintenance.

Zero-defect manufacturing
Machine builders are faced with increasingly higher requirements, on the one hand with regard to complexity and reliability of delivery, and on the other hand with regard to waste reduction. It is therefore important to manufacture without error. Digitisation makes it possible to quickly detect errors in production and take corrective measures.

Certification of products or processes outcomes based on measurement data
In a production process, a lot of data is often collected and analysed. Data on process conditions makes it possible to predict the quality of the output. This allows the output to be released for delivery without additional testing. In the same way, certification can then take place.

GENERIC VALUE PROPOSITIONS AND RAMI 4.0

On the basis of the RAMI 4.0 cube, existing standards that can be applied to each of the Generic Value Propositions can be inventoried. If we look at the Architecture (Layers), the Generic Value Propositions differ mainly in the *Information* and *Functional* layers. We see many similarities in the *Integration* and *Communication* layers. The Generic Value Propositions are located in the *Business* layer, as indicated above.

DATA SCIENCE

A data scientist deals with three things:
- Domain knowledge (structure)
- Mathematics (statistics)
- Programming (software).

The importance of Data Science is increasing due to the impact of information technology and the abundance of data. The Digital Factory is a pre-eminent research object for the data scientist.

USE CASES

The RAMI 4.0 model provided a handle for a number of use cases around three themes, namely:
- Traceability & Certification
- Planning & Sharing
- Collecting and using machine data.

The use cases prove the practical value of RAMI 4.0 as a theoretical model. The table below lists the use cases, stating (potentially) relevant Generic Value Propositions.

In the following chapters, the use cases are discussed by theme.

COMPANY	USE CASE	RELEVANT GENERIC VALUE PROPOSITIONS
TRACEABILITY & CERTIFICATION		
Additive Industries	Certification of metal-printed parts	8. Zero-defect manufacturing 9. Certification
ENGIE	Dynamic certification of utilities	9. Certification
PLANNING & SHARING		
KMWE	Planning in a high-mix, low-volume environment	1. Collaboration in the supply chain 2. Reduction of administrative burden 5. Automated programming 6. Smart production planning 7. Predictive maintenance.
COLLECTING AND USING MACHINE DATA		
De Cromvoirtse	Digital Twin for production line simulations	3. Joint design and engineering 4. Analysis of OEE 5. Automated programming 6. Smart production planning 7. Predictive maintenance 8. Zero-defect manufacturing (potentially).
Neways	Easy MES: plug & play integration of machines in production parks	3. Joint design and engineering (potentially) 4. Analysis of OEE (potentially).
Omron	Data Science for optimal machine efficiency	4. Analysis of OEE 5. Automated programming 6. Smart production planning 7. Predictive maintenance.
IJssel Technologie	Digital Shadow	4. Analysis of OEE 5. Automated programming 6. Smart production planning 7. Predictive maintenance.

Traceability & Certification

In the Digital Factory, it is possible to determine the quality of products during the production process, so that products can be released without additional testing. Products that do not meet the specifications can be detected and sorted out early. This possibility of guaranteeing the quality of products enables the Digital Factory to carry out validated product certification. At the same time, the production process can be optimised, based on parameters such as material use and speed. In this way, the Digital Factory saves on production costs by limiting waste and superfluous process steps. It also reduces consequential damage to customers due to the contamination of equipment or recalls. In addition, administrative costs can be saved by automating the so-called *chain of custody*. This concerns the chronological (digital) recording of the quality documents.

The Digital Factory can automatically generate certificates for delivered products, based on predictions of the quality of the processes. This requires an algorithm that clarifies how production parameters, processes and environmental factors, and their interaction influence the quality of the products. Such an algorithm is in fact a digital twin of the factory.

Use cases

In the Digital Factory project, methods were developed to collect and merge data from different sources in real time. Work has also been done on building a digital twin. Practical experience was gained with traceability and automatic certification of products and services through two use cases. This concerns **Additive Industries** and **ENGIE**. The next step is the elaboration of these use cases in a form that is applicable to other SME manufacturing companies.

USE CASE ADDITIVE INDUSTRIES / CERTIFICATION OF METAL-PRINTED PARTS

Additive Industries is a supplier of high-quality 3D metal printers that are used for aircraft and car construction, medical technology, and high-tech devices. The quality of the 3D-printed products is critical, as for example an aircraft part must not fail. The company is developing, among other things, an online data platform for the 3D printers.

Ambition

Additive Industries' long-term goal is to be able to predict the quality of its printed products, in order to determine whether the product meets the specifications. In the short term, the company wants to move towards predictive maintenance.

Developments

The use case of Additive Industries relates to the industrial 3D metal printer MetalFAB1, a laser powder-bed fusion printer, suitable for larger construction volumes. The recoater is the component that applies layers of metal powder to the process surface of the machine in a reciprocating motion. For each layer, a part of the metal powder is fused together in the shape of the cross section of the product to be made. Sometimes artifacts arise in the build-up of the product, which grow layer by layer until they protrude above the height of the powder bed (typically 20 to 100 microns). As a result, these artifacts obstruct the back-and-forth motion of that recoater, which can cause it to jam. Such a failure requires maintenance and has an impact on the quality of the end product.

The machine generates a large amount of data during printing. In the use case, Additive Industries checked whether that data could be processed into a prediction. An algorithm for the recoater was defined based on the relationship between motion sensor data and a malfunction. A deviation in the torque of the servomotor driving the recoater appears to be a possible predictive factor for blocking the recoater. The algorithm for the recoater is basically a digital twin. A digital twin does not necessarily have to relate to an entire factory or a whole machine, it can just as easily be the digital representation of one component, as in this use case.

› Continuation use case Additive Industries

It has been shown that the algorithm can predict a failure of the recoater, so that action can be taken before the recoater crashes (predictive maintenance).
Ultimately, the vision of Additive Industries is to extend the algorithm with information from other system components to predict the quality of the final product, enabling automatic certification.

Outlook
Until now, the focus has been on detection and prediction of failures on a limited data set. It is now a matter of applying the algorithm to other materials (alloys) and configurations. When detection functions robustly under different operating conditions, a solution can be offered based on that algorithm. In addition, a development in the degree of autonomy will occur, meaning the extent to which a machine can take an action itself without human intervention. The simplest form would be a notification to the operator before the problem occurs. They can then pause the print job and remove from the batch the one product that threatens to cause the failure, after which the rest of the batch is completed. A more advanced mitigation would be for the system to do this itself without operator intervention.

Additive Industries aims to make the implementation of the detection algorithm as generic as possible, so that it is easy to add use cases for other machine components in the future. An important source of information here is the online data platform that the company offers and is constantly developing. As a large part of the installed base of 3D metal printers is connected to this, relevant machine data from various components can be used to train and validate algorithms. All of this is the subject of follow-up research by JADS students.

A 3D metal printer from Additive Industries has been installed on the Brainport Industries Campus and it is intended to be included in the test and validation environment of the Digital Factory project.

USE CASE ENGIE / DYNAMIC CERTIFICATION OF UTILITIES

ENGIE is the Dutch market leader in technical services, among other things. This use case concerns utilities that are delivered to Brainport Industries Campus, more specifically to the tenants on that campus. ENGIE guarantees the condition of the rooms in terms of light, heat and cooling.

Ambition
ENGIE wants to achieve more efficiency and transparency in monitoring the condition of rooms. The automatic generation of certificates is part of this development. The agreed quality is delivered if certain parameters are reached, after which the certificate for that delivery can be issued. It is no longer necessary to determine the quality on a random basis.

Developments
The use case shows that significant steps must first be taken in the field of traceability (transparency) of data before it is possible to switch to automatic certification. That starts with facing the problems associated with sensors. Sensors provide the data that determines whether the guaranteed condition has actually been achieved, for example, whether the temperature was indeed between 20 and 22 degrees.

The first problem concerns the presence of sensors in the existing buildings. There is rarely a business case for adding sensors because of the costs associated with the installation.

› Continuation use case ENGIE

Wired sensors are preferred for (semi-) continuous condition measurements, on the basis of which installations are controlled, meaning that wireless systems such as LoRa and 5G are less suitable.

The second problem concerns the continuous monitoring of sensor operation. Often this is an incremental measurement and the measurements are passed on based on *change of value*. If there is no signal, does that mean there is no change or rather a faulty sensor? This can only be determined by revalidating the sensor.

Moreover, the *change of value* is a design choice: how often a measurement is passed on (how many seconds or minutes), and for which change (for example, how many degrees).

A third problem is the sheer amount of data generated by measuring the conditions in a building complex. It requires a modern, secure IT environment. Added to this is the complexity of the situation. Think of the diversity of buildings, where changes are poorly documented. This applies certainly to old buildings, but in practice even a new building '*as built*' no longer corresponds to its design. This requires discipline with regard to Management of Change. Sensor management is therefore a multidisciplinary activity, which should lead to sensors taking valid measurements in a reliable manner.

The collected sensor information must be presented to customers via dashboards after processing. The use case focuses on the quality of the data flow and data processing. Only 'calibrated' algorithms are suitable for charging for 'consumption'. So there must be *algorithm compliance*.

Outlook

The transparency of data has not yet been fully realised. It is important to have the reporting in order to gain customers' trust. Only then can the automatic certification process begin.

THE USE CASES AND THE BLUEPRINT OF THE DIGITAL FACTORY

Additive Industries wants to test its own algorithm for the recoater in the test and validation environment of the Digital Factory project. The RAMI 4.0 model offers handles for the use case that mainly relate to the Life Cycle phase *Instance – Maintenance Usage* and to the Architecture Layer Asset. Frequent crashes of the recoater can provide feedback to the *Type – Maintenance Usage* phase.

With regard to the RAMI 4.0 model, the ENGIE use case focuses mainly on the Architecture Layers *Asset* and *Information*, as it is about obtaining the correct (valid) data about consumption from the system. It should be taken into account that certification has yet to be developed, as other Architecture Layers are coming into the picture.

Planning & Sharing

In the Digital Factory, it is possible to absorb fluctuations in the order book, shorten lead times and reduce inventory costs by synchronising production schedules across the chain and dividing logistics and production capacity across the chain. To this end, the Digital Factory integrates the planning for materials, tools, personnel, production and stocks into one model. This model also derives its strength from sharing data from multiple companies. This data can be integrated into one master plan and used for simulation and optimisation.

In the Digital Factory, a dashboard shows the impact of the master planning on KPIs, such as machine utilisation, stocks, work in progress and lead times.

To achieve this, new technologies must be developed and applied in two related systems. The first is the **multi-agent system**. Any entity in the factory can be reproduced by means of an *agent*, an autonomous piece of software. Examples are a machine, automated guided vehicle (AGV), inspection station, or preparation station. In terms of the RAMI 4.0 model, the multi-agent system represents the collective of Asset in combination with the *Integration* layer.

The second is the **Cyber-Physical Production System**, in which the factory (the Asset) is combined with its digital twin. This system has two dimensions: machines communicate *horizontally*; while *vertically*, the system includes production planning in all its aspects. Multi-agent and Cyber-Physical Production Systems form Siamese twins.

The cyber-physical system assigns tasks to the agents on the basis of an algorithm. By applying machine learning and artificial intelligence in this algorithm, the production process can become more efficient. In this way, understaffing can be better utilised. The system also provides reports, for example on OEE and quality, and can provide input for Root Cause Analyses. Poorer performance can predict a need for maintenance. By using machine data in the Cyber-Physical Production System, a new way of production planning is possible. For example, the system should be able to respond adequately to failures by learning from the past how it could manage better in the future. It makes the system self-learning and more autonomous. This creates the next innovation from the Digital Factory: an Autonomous Factory. This is an innovation that could boost the entire manufacturing industry.

This image of the Digital Factory is still for the future. For the time being, the development of the system still requires the necessary attention from the Digital Factory project (and for the time being, factories will need people). After all, there is still a lot of manual input in practice and it is not always clear why certain planning choices are made. Although a lot of data is already collected during order processing and production, in many cases it is linked poorly or even not at all. What also plays a role is that a Cyber-Physical Production System is not ready-made on the shelf; each algorithm to control production automatically must be programmed separately. Furthermore, the agents must be made suitable for coupling to the digital twin.

At Eindhoven University of Technology, a Cyber-Physical Production System is being developed as a generic concept, not just for the use case (see below). It is a form of precompetitive research. The RAMI 4.0 model provides structure for realising this concept. The university is doing pioneering work, because as far as we know, the Digital Factory is not being developed in this way anywhere else.

CYBER-PHYSICAL PRODUCTION SYSTEM

Within the Cyber-Physical Production System, data exchange takes place on three levels:

- *Shop Floor Control*: controls the agent (execution of tasks)
- *Global Control Unit*: controls the factory (planning of tasks)
- *ERP-system*: controls the entire company; is not part of the digital twin.

At the *Shop Floor Control* level, the system (see box) works optimally if a certain task is assigned automatically to the machine that is actually available for it. Auction theory is therefore applied in the development of the algorithm: the system 'writes out a task', the various machines in the multi-agent system 'make a bid', after which the task is assigned to the 'highest bidder'. The algorithm is generic in the sense that it is fairly easy to add an extra machine (agent) and the algorithm can be applied – with some adjustments – to different companies.

At the level of the *Global Control Unit*, the system works optimally if tasks can be scheduled automatically over a longer period, taking changeover times, among other things, into account.

The concept of the Cyber-Physical Production System will be built, tested and validated in the test and validation environment of the Digital Factory.

Use case
Developing the Cyber-Physical Production System needs to be done in small steps, something that is even truer when demonstrating it. The Digital Factory project examined which data is available in which form and how this data can be integrated. Dashboards were also examined. Practical experience was gained with planning & sharing through a use case, namely at **KMWE**. The next step is elaborating this use case in a form that is applicable to other SME manufacturing companies.

USE CASE KMWE / PLANNING IN A HIGH-MIX, LOW-VOLUME ENVIRONMENT

KMWE supplies complex, functionally critical components and high-quality (clean room) assembled mechatronic modules to the medical sector, the semiconductor industry, industrial automation, and the aviation industry.

Ambition
The high complexity of the products means that increasingly higher demands are placed on production planning. This use case aims to contribute to integrated supply chain systems so that multiple aspects can be included in planning. Initially, the processing of the internal status of orders and stocks is examined.

The use case relates to the planning of the KMWE shop floor on the Brainport Industries Campus, where operations such as milling and assembly take place. The planning includes what is called the 5Ms: man, machine, method, material and management. For integrated planning, it is necessary to link different applications. KWME uses the ERP system Glovia from Fujitsu Glovia and the planning program ISTOS from DMG Mori.

Development
KMWE is not ready to apply Cyber-Physical Production Systems yet. Attention first had to be focused on the interface between the shop floor planning method and the overall planning tool. That in itself turned out to be a complicated

› *Continuation use case KMWE*

task, due to a difference in planning methodology. ISTOS plans forwards, while the shop floor requires planning backwards. Forward planning starts when the order is received and the first possible delivery date is calculated; backward scheduling schedules the last activity first and calculates when an order should start.

In addition, the fact that KMWE uses both old and new DMG machines also plays a role, as good data exchange requires the latest software (which is ideally also suitable for non-DMG machines). As that linking is already proving difficult, KMWE is still a long way from automatically distributing tasks across machines.

Based on research by students from Eindhoven University of Technology and Fontys, it can be concluded that it is easier to (automatically) allocate tasks when the production volume fluctuates less. KMWE's planners therefore strive for a flat schedule, but this is rarely feasible in this dynamic environment. In theory, large safety stocks are necessary for this, but this is not an option due to the KMWE's complex end products.

As by-product of the project, KMWE now has the 'OEE PowerBI Dashboard', in which data from various sources is brought together, initially in an Excel file, then in a more robust format. The dashboard shows information about the malfunctions and availability of machines. This dashboard is a digital representation of the physical Asset, and the beauty of it is that you can perform simulations by introducing malfunctions into a well-run production process.

Outlook

KMWE has gained many new insights into the possibilities of the Digital Factory. Still, there is work to be done before algorithms are developed to automate shopfloor planning. KMWE is therefore looking to cooperate with Fujitu Glovia and DMG Mori. A Cyber-Physical Production System remains something for the future, but it is promising enough to continue the effort. In addition, KMWE will continue to appeal to students for assistance.

At the moment, KMWE is the only large manufacturing company located on Brainport Industries Campus. From a planning & sharing point of view, it is interesting that Brainport will expand into a multi-company campus where resources such as AGVs and machines are shared. By connecting digital twins, the overall planning of these resources can be optimised.

THE USE CASE AND THE BLUEPRINT OF THE DIGITAL FACTORY

The RAMI 4.0 model helps to structure and standardise the problems that KMWE is facing. However, it is still a challenge to relate this model to all aspects of individual situations.

Collecting and using machine data

In the Digital Factory, it is possible to produce smaller series at lower capital costs by optimising the configuration of production lines by using simulations. The deployability and manageability of entire machine parks can be improved by combining machine data.

It is important then that data is standardised or that a method is found with which data can be extracted from machines in a standardised manner. The configuration of machines is described using static, semi-static and dynamic data. Standardisation is important because of the different phases in which data applies:

- Before purchase: to determine the required capacity and configure the production line optimally
- On commissioning: to integrate new machines quickly
- During production: to manage the production process
- In maintenance: to optimise maintenance and reduce unplanned downtime.

By using machine data it is possible to reduce the share of capital costs in production costs.

The RAMI 4.0 model is helpful in data exchange, especially the Architecture Layers. This concerns *Asset, Integration, Communication* and *Information*. The use cases add their *Business* layer to this. The *Communication* layer in particular poses problems for companies, because there is a range of technologies (the problems surrounding standardisation of protocols have been discussed above).

Use cases

Practical experience was gained by collecting and using machine data from four use cases. These are **De Cromvoirtse, Neways, Omron** and **IJssel Technologie**. The next step is elaborating these use cases in a form that is applicable to other SME manufacturing companies.

USE CASE DE CROMVOIRTSE / DIGITAL TWIN FOR PRODUCTION LINE SIMULATIONS

De Cromvoirtse is a leading metal worker, which offers a wide range of operations such as cutting, sawing and bending of sheet metal.

Ambition

De Cromvoirtse's strength lies in lightning-fast delivery, but even this is not fast enough, as frustrations surround the fact that a product with a *touch time* of just five minutes requires a delivery time of two days. The goal is to halve delivery time through better insights into the processes. This requires optimal planning of the machines.

The company wants to develop a system to simulate an order, so as to provide insight into lead times and the moment that the product is ready. In addition, the system could be used to determine what it means when a machine is replaced or added – that is, an investment planning tool. This insight should bring the goal of halving delivery times within reach.

Development

De Cromvoirtse has about 30 machines of different types and brands, about half of which are CNC machines. Some provide usable data, others provide unusable or unreliable data. Still other machines do not supply any data at all; the notification of completion has to be done manually. Naturally, manual registration is not always flawless, which alone is reason enough to automate registrations. The effect of this is that fewer high-level training requirements can be set for new staff. The order simulation tool is in fact a digital twin of the production line. A design is being made for this.

› *Continuation use case De Cromvoirtse*

Meanwhile, two other developments are taking place at De Cromvoirtse, namely chain integration and tagging. With regard to chain integration, the company is working on the implementation of the standard solution developed in the Smart Connected Supplier Network for optimising the data exchange between suppliers and customers. Secondly, an intern carried out a feasibility study into tagging, for the automatic transmission of notifications of completion, finding that it still involves a lot of paperwork. Initially, Ultra-Wide Band (UWB) was considered as a solution, but 5G came into the picture after consultation with the High Tech Software Cluster.

In addition, De Cromvoirtse had students carry out research into the robotisation of a press brake and the logistic layout of the production hall. The company was able to gain experience with robotisation in the Flexible Manufacturing Fieldlab. From this the company developed the ambition to program a robot at lightning speed, in zero minutes instead of four hours – a lot more ambitious than halving delivery times.

Outlook

De Cromvoirtse would be helped greatly by having a partner that could help build the digital twin. The company realises that one of its own employees must be responsible subsequently for maintenance.

USE CASE NEWAYS / EASY MES: PLUG & PLAY INTEGRATION OF MACHINES IN PRODUCTION PARKS

Neways Electronics International in Son has about 20 production lines at various locations in Europe, each with six to 10 machines, for the automatic serial production of electronic printed circuit boards. The machines are of different makes and ages. The data input concerns recipes and instructions; the output relates to the execution. The lines are similar, which is why the use case concerns only one of them, with five machines.

Ambition

Neways aims to use the collected machine data in three ways:

1. Traceability: recording the relationship between a produced printed circuit board and the components from which it is built
2. Analysis of the products, especially relating to quality problems
3. Statistical process control, to be able to intervene in the production process before things go wrong.

Preferably, it would be possible to connect new machines to the data warehouse and integrate them into the Manufacturing Execution System quickly; currently this can take months.

Development

The problem is that the machines deliver data in different formats. Before that data can be used, it needs to be collected, translated and normalised into one format. There is no universal method for this.

Students from Fontys built a simulator, a rudimentary digital twin, that represents the data production of two brands of machines. This simulator is able to collect, translate and normalise the data. The repeated development of translation software per individual machine is quite expensive, which is why Neways would like a software-supported translation.

Outlook

Neways does not want to be dependent on a single machine builder, so the problem of uniform data remains unresolved. Neways intends to commission a new group of Fontys students to develop a semi-automatic translation machine. In doing so, the company is looking towards the possibilities offered by machine learning and artificial intelligence.

USE CASE OMRON / DATA SCIENCE FOR OPTIMAL MACHINE EFFICIENCY

Omron fulfils a double role in the Digital Factory project. On the one hand, it is a developer of electronic components, from sensors, industrial PCs (edge controllers) to robots, which can be used to digitise factories. On the other hand, the company in 's Hertogenbosch has about 30 assembly lines that are potentially eligible for digitisation. Omron thus develops components for digitising its own machines (and those of other companies).

Ambition

Omron wants to fully digitise an assembly line on which electronic components are produced, partly manually. This should lead to insight into the performance of the line, automatic process and quality control, and predictive maintenance, and ultimately to a greater efficiency of the line. Omron also wants to develop a blueprint for the digitisation of all assembly lines.

Development

Even before the project started, a change had been made with one of the machines in the assembly line, namely the *pin stitcher*, which assembles a part of the product fully automatically. This machine was already delivering 58 signals that remained unused. Omron placed a self-developed device, the Omron AI Controller, in this machine. This component is able to log the signals every millisecond and recognise real-time patterns. A built-in algorithm compares the measurements (*features*) with certain limit values. If the limit is exceeded, a bad product will be set aside or a maintenance employee will receive a warning message by e-mail. The e-mail has already proven itself in practice. However, it has not yet been possible to distinguish the bad from the good parts; the 58 signals turned out to be insufficiently relevant for this.

In the project, Omron focused on machine data to improve OEE (Operational Equipment Efficiency) based on anomaly detection in production. To do justice to the influence of the operators on efficiency, the ratio was adjusted to ORE: Operational Resource Efficiency.

Omron realises that solutions for digitising one machine cannot simply be copied to another. To make that easier, the company is turning to the Asset Administration Shell (AAS), the data sharing framework that aligns with the RAMI 4.0 model, specifically the *Integration* layer. This means that an AAS acts as a standardisation layer to centralise all data and make it possible to change it into one format. An AAS model is currently being developed for Omron's demo machine on the Brainport Industries Campus; a time-consuming job, partly because Omron has proven to be one of the pioneers in this field.

Outlook

To enable automatic quality control for the pin stitcher, a redesign of that machine is required so that relevant measurements can be made. This may require replacing the pneumatic drive with servo motors. The fact that automatic quality control at the Omron location in Italy does appear to work for the existing production of relays gives confidence.

Omron expects to be able eventually to apply the AAS model to the machine on the BIC to other machines and scale it up to the assembly lines. The aim is for machines to 'know' what is going on based on the machine data and then take the correct action. In this way, the performance of machines can be improved and the next step is taken in the field of Flexible Manufacturing. This is where AAS and ORE come together again.

Omron has learned to start with the basics (the machine) before thinking about digitising an assembly line and eventually an entire factory. Omron also learned that it is important that smart technology, such as the Omron AI Controller, is built into or added to the (existing) machine, so that the data is processed there. Ideally, AAS will be built in directly. Designing a new machine offers opportunities to obtain relevant machine data.

Omron advises to start small, with a clear problem statement and a defined goal. That alone is difficult enough in practice.

USE CASE IJSSEL TECHNOLOGIE / DIGITAL SHADOW

IJssel Technologie supplies smart, innovative maintenance solutions for industrial factories and manufacturing networks. This use case relates to the maintenance work that the company performs for Tata Steel. This concerns the on-site inspection and repair of conveyor rollers of the steel producer's production installations. IJssel carries out part of the overhaul work itself, while the rest is outsourced. This concerns approximately 3,000 rolls per year.

Ambition

IJssel wants to develop a digital twin for each conveyor roll they have in maintenance. This would describe the roll completely: type, usage, maintenance history, etc. In other words, all conceivable static, semi-static and dynamic information about purchase, assembly, use and maintenance – a 360-degree view of the *Asset*. With the help of those digital twins, future maintenance can be planned optimally, working towards condition-based maintenance. As well as maintenance, the steel production process can also be better controlled using data from those digital twins. Data from Tata Steel and its contractors is needed to 'fill' the digital twins; gone are the days when that information could be provided by e-mail.

Development

IJssel uses an Asset Administration Shell (AAS) to develop unique digital twins per roll. As data from IJssel, Tata Steel and the contractors must be included in this AAS system, there are some challenges involved.

Firstly, the data exchange between the parties concerned (via the cloud) must be set up. As it concerns competition-sensitive data, the data exchange must be secure, which places demands on the cloud environment in which this takes place.

Secondly, the issue is that the data is held by different parties. In concrete terms, part of the data about the rolls is contained in the digital twin of the relevant rolling machine. The digital twins of the rolls therefore work with copies of some of the data in other digital twins. IJssel calls this hybrid system a *digital shadow*, hence the title of this use case.

A third complication is that some contractors are not allowed access to all (confidential) data. In the digital twin, that access is thus strictly defined using settings in the AAS framework.

Outlook

IJssel is at an experimental stage (the duct tape phase), where TNO is being called upon for support. For example, the company is working on a digital twin for the rolls in a machine that has yet to be put into use at Tata Steel.
IJssel has a pioneering role here. IJssel is convinced that the *Blueprint of the Digital Factory* can be applied and that the digital shadows have added value. Or as Frank Sinatra once sang: “Here comes the party for my shadow and me”.

CYBER SECURITY

During the Digital Factory project, the international business community was shaken by attacks with ransomware, which appeared to originate mainly from the Russian organisation REvil. It is a warning for the Digital Factory.

In this regard, Fontys Hogescholen recently conducted a study into the vulnerabilities of the Asset Administration Shell. This has been applied to a realistic *toy example*: a drawbridge was defined using the AAS framework. Fontys subjected the bridge to an attack by ethical hackers.

The conclusion was that AAS presents a **medium risk**. This means that AAS must be set up carefully when used in the Digital Factory (and that a follow-up investigation is desirable).

Beware – in addition to ransomware, there are other digital threats, such as viruses.

THE USE CASES AND THE BLUEPRINT OF THE DIGITAL FACTORY

It appears that the application of the RAMI 4.0 model for the collection and use of machine data at the companies concerned is a step-by-step process. It requires an investment in the study, interpretation, elaboration and use of open standards. Those who are really interested have already come a long way. Others have been helped by experts. Once the system is set up, there must be someone in every company who maintains it – a digital twin is never finished. Furthermore, a machine builder could make a valuable contribution to the Digital Factory.

TESTING, DEVELOPING AND VALIDATING

A test and validation environment (TVE) is being set up on the Brainport Industries Campus. This is where theory and practice come together. In the TVE, the RAMI 4.0 model is used concretely in the digitisation of production processes. Some of the use cases are further elaborated in the TVE.

The TVE functions ultimately as a demonstration of the Digital Factory for other companies. The aim is to prove the value of the Digital Factory by proving its impact on the nine Generic Value Propositions (GVPs).

Within the Digital Factory project, three themes are further elaborated for the benefit of the TVE, namely:
- Factory Planning Dashboard
- OEE Dashboard
- Data-enabling (AAS).

The TVE, the GVPs and the three themes are the subjects of a second white paper on the Digital Factory, which will be published at the end of 2022.

Involved parties

DIGITAL FACTORY OF THE FUTURE

The Digital Factory is a project by entrepreneurs and knowledge institutes in the manufacturing industry in the Brainport region, with Brainport Industries in Eindhoven as lead party. It is subsidised by the Province of Noord-Brabant.

Blueprint for the Digital Factory

The 'Blueprint for the chain and the factory' work packages are mainly executed by TNO.

Traceability & Certification

The following parties were involved in the Traceability & Certification work package:

- Jheronimus Academy of Data Science JADS
- ENGIE
- Additive Industries.

Planning & Sharing

The following parties were involved in the Planning & Sharing work package:

- Technische Universiteit Eindhoven
- KMWE
- Fujitsu Glovia
- DGM Mori.

Collecting and using machine data

The following parties were involved in the Collecting and Using Machine Data work package:

- PDM
- Fontys
- De Cromvoirtse
- Omron
- Neways Electronics International
- IJssel Technologie
- Itility.

Affiliated partner organisations

The following parties were also involved in the Digital Factory project:

- Data Value Center Smart Industry
- Brabantse Ontwikkelings Maatschappij
- Cyber Weerbaarheid Centrum.

PARTNERS

Below are brief introductions, in alphabetical order, of the parties in the Digital Factory project.

Additive Industries

Additive Industries is a manufacturer of 3D metal printers for high-quality metal parts. The metal printing systems are aimed specifically at high-end and demanding markets, such as aerospace, automotive, energy, and high-tech equipment. The systems are characterised by large construction volumes, robustness and productivity.

Brainport Industries

Brainport Industries is a cooperative of high-tech suppliers involved in projects in the fields of technology, market and people to strengthen the innovative power of its members. The aim is to increase professionalism and competitiveness, especially in the high-mix, low-volume, high-complexity domain. The Digital Factory is facilitated on Brainport Industries Campus.

De Cromvoirtse

De Cromvoirtse is an industry leader in the supply of top-quality sheet metal. The company offers a wide range of operations, including cutting, sawing and bending. Its strength lies in fast delivery and high quality. Its ultimate goal is an extremely effective production process, so that customers can focus on their own production.

DMG Mori

As part of a worldwide sales and service network, DMG Mori in the Netherlands offers comprehensive solutions for the individual needs of customers. DMG MORI unites German and Japanese tradition, precision and technological leadership in machine tool construction.

ENGIE
ENGIE Netherlands is the market leader in technical services, among other things. It has more than 5,700 employees working on technical, innovative and digital solutions for projects ranging from integrated sustainable area development to energy-efficient, smart buildings, and from reliable generation and supply of geothermal heat or hydrogen to innovative solutions for electric driving.

Fontys University of Applied Sciences
Fontys is an educational institution with an offer in almost all sectors. In addition to education, practice-oriented research is important within Fontys in realising its ambitions. For the Digital Factory, the research groups Operational Excellence, Robotics & Mechatronics, Big Data and High Tech Embedded Software are working together.

Fujitsu Glovia
Fujitsu GLOVIA is a leading innovator of ERP solutions in the manufacturing industry. The company supports manufacturers and assemblers to manage and optimise their business processes. The company provides scalable solutions to single-location manufacturers and multinational, multilingual, multi-currency companies.

IJssel Technologie
IJssel is a specialist in Smart Industry: smart, innovative solutions for industry. IJssel is a discussion partner at all levels, from business administrator to engineer and mechanic. Based on the IJssel model, organisations are set up in such a way that continuous improvement becomes the basis for all business processes.

Itility
Itility makes companies digital and ensures that IT is fast, standard and scalable, and makes companies smarter. Itility is close to its customers in order to be able to define and implement the smart functionality they are looking for. Everything is based on the idea that systems should be professional, scalable and available.

JADS
The Jheronimus Academy of Data Science (JADS) is a partner of Eindhoven University of Technology and Tilburg University. JADS is engaged in education and research in the field of data science, involving the business community.

KMWE
KMWE Group is an international supplier to the medical sector, the semiconductor industry, industrial automation, and the aerospace industry. KMWE has approximately 600 employees and supplies complex, functionally critical components and high-quality (clean room) assembled mechatronic modules.

Neways Electronics International
Neways offers its customers customised solutions for the entire product life cycle of both electronic components and complete (box-build) electronic control systems, from idea to development, production, repair and service. Neways products are used in the semiconductor, medical, automotive, and industrial sectors, among others.

Omron
Omron Netherlands is a technology supplier in industrial automation, healthcare and electronic components.

PDM

PDM is an expertise bureau that innovates and optimises products and production environments. PDM is a product, design and industrialisation partner for the high-tech industry. In addition, maintenance, turnarounds, production and operations, and performance optimisation are the most important areas of knowledge and experience in the process industry.

Eindhoven University of Technology

Eindhoven University of Technology (TU/e) is a technical university that focuses on education, research and valorisation. In the High Tech Systems Center (HTSC), TU/e brings together multidisciplinary research activities in the field of complex high-tech mechatronic systems.

TNO

The Netherlands Organisation for Applied Scientific Research (TNO) is an independent research organisation. TNO's mission is to connect people and knowledge to create innovations that enhance sustainably the competitiveness of companies and the well-being of society. TNO works together with partners and focuses, among other things, on industry and ICT.

Sources

More information about the Digital Factory and related themes is available online.

Smart Industry
www.smartindustry.nl
Information related to the whole of the Netherlands.

Fabriek van de Toekomst
www.fabriekvandetoekomst.com
Programme information from Brainport Industries.

Smart Connected Supplier Network SCSN
https://smart-connected.nl
Standard and infrastructure for data exchange.

Data Value Center Smart Industry
https://smartindustry.nl/competence-centers/data-value-center-smart-industry-dvc-si
Competence Center for Smart Industry.

Plattform Industrie 4.0
www.plattform-i40.de
Information about RAMI 4.0 and AAS.

The International Operability Standard
www.opcfoundation.org
Information about OPC UA.

DIMOFAC, Digital Modular Factories
www.dimofac.eu
Flexible assembly lines in the manufacturing industry.

Brainport Industries

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Brainport Industries
Digitale Fabriek van de Toekomst
www.brainportindustries.nl

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