Successful Collaboration in Global Production Networks

fair, secured, connected

Imprint

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Preface

In today's world, manufacturing companies face many challenges due to the uncertainty and complexity of environmental influences as well as increasing competitive pressures. The pandemic has clearly illustrated how volatile and fragile our supply chains have become. One way to overcome these challenges together is to collaborate with other companies in the value network.

Collaborations, i.e. successful cooperation with strategic partners and customers to achieve common goals, will continue to gain in importance. Instead of individual companies, entire value chains and networks will therefore compete with each other in the future. This will require a shift toward fast and seamless data exchange between the players in the value network.

Advancing digitization and thus a generally increasingly networked world are increasingly supporting such collaborations, as the sharing and collaborative use of data is becoming much simpler. At the same time, the right handling of data will be decisive for competition. Digitization is moving from being a driver of change to an enabler of change. Innovative business models and the exploitation of the potential hidden in data will make it possible to realize reliable, flexible and, at the same time, resource-conserving value creation.

The number of existing cloud-based collaboration platforms is growing steadily. Small and medium-sized enterprises in particular have to serve many different customer platforms at the same time, while they themselves are still struggling with internal digitization challenges. Standardization initiatives for secure data rooms in the industry, such as GAIA-X, therefore hold great potential.

In addition to these fundamental infrastructural issues, there are further challenges with regard to collaboration projects. Particular importance is attached to the competent handling of data protection and data security. There are often reservations that the disclosure of data and information will result in the loss of hard-earned expertise and competitive advantages that have been built up over time. At the same time, however, users from an engineering environment are only able to assess the risks of digital collaboration to a limited extent. In order to secure one's own competitive position in the long term, digital competencies must therefore be built up and barriers to collaboration overcome.

Success stories and clear recommendations for action can provide an important impetus for the implementation of successful collaboration projects, showing how collaborations can be approached in practice and what added value they generate. That is why we would like to provide manufacturing companies with such guidance in the form of this action guide. The collaboration projects explained below and the best practices derived from them are intended to help companies find their own strategies on the path to more collaboration. We hope you enjoy reading this guide and are always available for questions and discussions.

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Greetings from the Programme Management Agencies

An increasing share of value creation in the manufacturing industry is distributed in production networks. In parallel, the demands on the product quality are increasing. Delivery times and reactions to customer change requests are becoming ever shorter. To en-sure the competitiveness of our companies, greater collaboration between partners in their supply relationships is therefore neces-sary. The use of digital technologies offers great potential for this. However, until now there has been a lack of a holistic approach to using them for collaboration in networks. Until now, the use of digital technologies has only allowed locally available data to be ex-changed in a targeted and secure manner.

The aim of the ReKoNeT / SmartCoNeT projects was to develop methods, IoT solutions and business models that promote more intensive collaboration in production net-works. These can now be used to increase quality, delivery capability and flexibility in supply relationships. In the German ReKoNeT project, the work was carried out using the example of three use cases in the mechani-cal and plant engineering and automotive supply industries. Here, the methods for collaboration in the case of high variant di-versity and short delivery times, cross-location quality control loops for cross-network component pairing, and for the de-velopment of digital business models were considered.

Based on the considered use cases, the project showed how intensive data exchange and intelligent analysis methods in collabora-tion can improve the quality of the created products, shorten delivery times and react flexibly to dynamic order changes. The methods could be transferred to other sec-tors, such as the consumer goods industry, and in particular to growth markets in Asia, as part of the EUREKA SMART cluster pro-gram on Advanced Manufacturing with inter-national partners from Spain and South Ko-rea.

The work on which this report is based was funded for German partners by the Federal Ministry of Education and Research (BMBF) within the “Innovations for Tomorrow’s Production, Services, and Work” Program, for the Spanish partner by the Center for the Development of Industrial Technology (CDTI), and for the Korean partners by the Ministry of Trade, Industry & Energy (MOTIE). The international cooperation took place within SmartCoNeT, a project funded under the SMART EUREKA CLUSTER on Advanced Manufacturing programme. We would like to take this opportunity to thank everyone who contributed to this pioneering research and development work with their knowledge, commitment and experience.

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Introduction to the World of Collaboration

Nowadays, competition no longer takes place only between companies, but often also between entire value-adding networks [1, 2]. In order to position oneself competitively as a value-adding network, the collaboration of all network partners is necessary to achieve a common, overriding goal [1]. Due to the seemingly limitless possibilities in the exchange of information, companies are moving closer together. Advancing digitization serves as a key enabler of data-based collaboration projects [3]. At the same time, there are numerous challenges in the implementation of such projects that should be given some attention [1].

Requirements for interoperability, data protection and data security resulting from cross-company data exchange present companies with major obstacles. However, the challenges are not solely of technological nature. Particularly noteworthy is the challenge of evenly sharing the resulting collaboration benefits according to the contributions made by the partners. This operational guideline is intended to help companies overcome these challenges in order to successfully implement fair, secure and cross-linked collaboration.

In order to introduce to the world of collaboration, a common understanding of collaboration is created in the following and the possible types and forms of collaboration are outlined. In addition, added values and new business models resulting from collaboration are described, as well as the obstacles they face.

Collaboration – a change of paradigm

Collaboration enables e.g. the coordination of material and information flows throughout the value-adding network by sharing knowledge and resources from suppliers and customers. Effective collaboration is therefore essential for manufacturing companies. [4]

But what does collaboration actually mean? The literature provides many different definitions [5, 6]. Summarized, the following definition is probably the best:

Collaboration is a temporary, negotiated partnership between two or more independent parties to achieve common goals through the collective use of resources and information [7, 8].

It is particularly important to emphasize that it is a partnership of independent parties. To make this more precise, Figure 1shows which forms of collaboration exist and how they differ from other forms of cooperative work [9, 10]

As a partnership of multiple parties in pursuit of a common goal, collaboration is strongly distinguished from traditional, purely transactional business relationships (arm's length relationships), in which the individual parties interact very little and are solely concerned with their own direct goals and benefits. Joint ventures and integration on the other hand, go beyond collaboration, as the cooperation is based partly or even entirely on joint ownership and the parties are thus no longer legally independent of each other. [10]

The first stage of collaboration is (intensive) communication, which is characterized by the sharing of information, e.g., to jointly increase productivity [9]. When the two parties synchronize their production processes and decisions, it is called coordination. The third stage is intensive collaboration, where the actors increasingly decide together on strategic issues. The last stage of collaboration is partnership. The partners are closely linked financially and share profits and losses. The goal here can be e.g. to reduce development times and share as much knowledge as possible. [9]

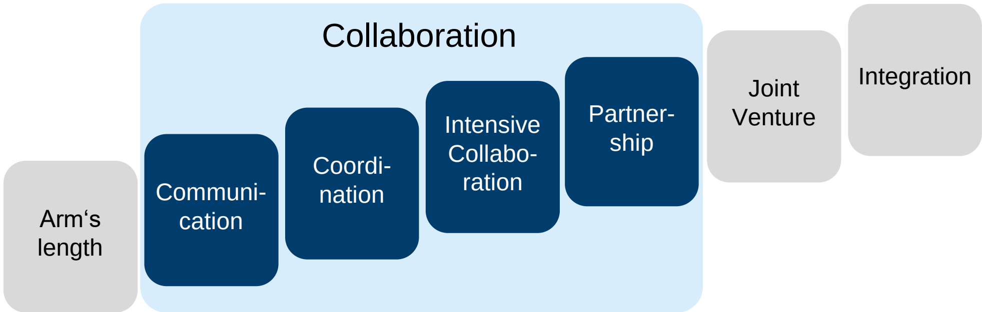


Figure 1: Collaboration according to the intensity of cooperation (based on [10, 11])

Another way of characterizing a collaboration is to distinguish it into horizontal and vertical collaboration (see Figure 2) [11].

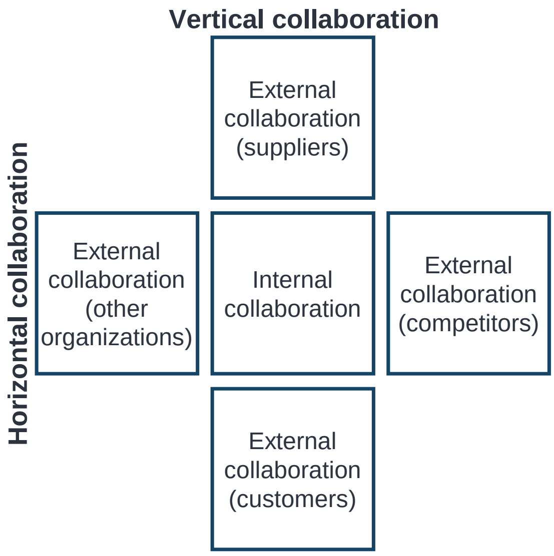


Figure 2: Vertical and Horizontal Collaboration (based on [12])

Collaboration with upstream or downstream players in the value-adding chain is referred to as "vertical" [11]. While the partners concentrate on their core competencies in the value creation process, as in a traditional business relationship, in a collaboration joint services can be offered at the same time or product quality can be increased by exchanging measurement and process data [5, 12–16].

Horizontal collaboration on the other hand refers to cooperation with parties on the same level of the value-adding chain, i.e. with competitors or other organizations [11]. Horizontal collaboration can improve the position of smaller companies compared to large competitors, suppliers or customers [17]. Specifically, horizontally collaborating companies can e.g. share manufacturing or development resources [11]. Collaboration with independent third parties such as insurance companies and start-ups can also be assigned to this form of collaboration.

All well and good, but what's the point of such a collaboration anyway?

The implementation of a collaboration between companies always pursues the goal of realizing a collaboration benefit. Collaboration benefits are achieved cross-company and exist only through the relationship between the collaboration partners [6]. Empirical studies have shown that collaboration has beneficial effects on process efficiency, supply flexibility, competitiveness, quality, and innovation [6]. The best-known example of successful collaboration may be the reduction of the Bull-Whip effect through collaborative order management. But collaboration benefits go far beyond this. By collaborating with e.g. an insurance company, completely new business models such as pay-per-part or machine leasing contracts can be realized [3, 18].

Despite these positive effects, there are a large number of different obstacles and risks that often prevent the successful implementation of collaboration projects in practice (see Figure 3) [11, 18, 19]. Projects might even fail before the actual start due to e.g. the fear of revealing data and the uncertainty or rather the lack of knowledge of who owns the data.

There is a lack of concrete recommendations for operation to accompany users on their way to collaboration [20]. This user guide is intended to close this gap.

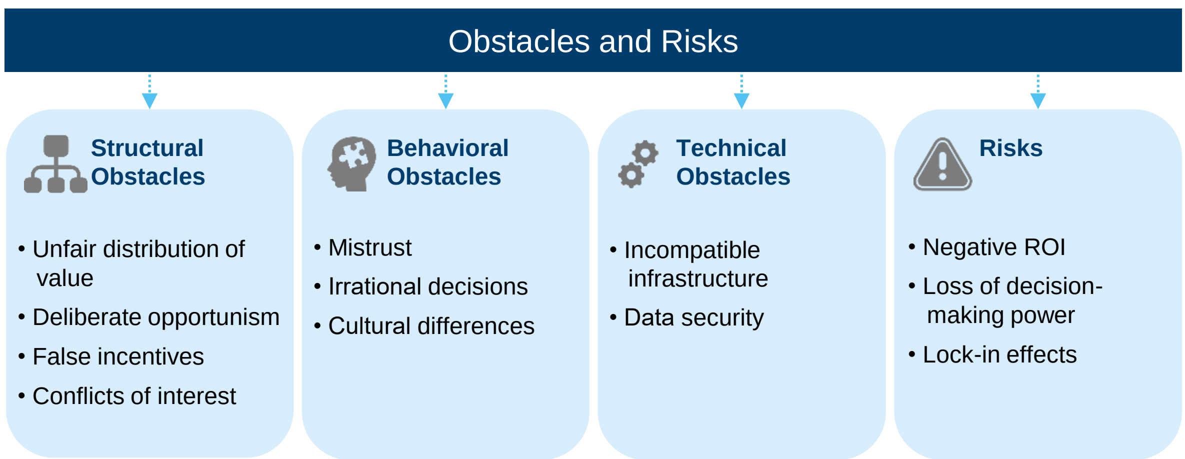


Figure 3: Obstacles and Risks of Collaborations (based on [11, 18, 19])

Procedure for the Successful Implementation of Collaboration in Production Networks

In line with the wide range of collaboration options and benefits mentioned above, there are numerous possible collaboration projects. This will also be illustrated in the further course of the guideline on the basis of the presented Use-Cases. Despite their heterogeneity with regard to the context and the objective of collaboration, most projects for implementing data-based collaboration in value networks can be standardized in three basic phases (see Figure 4): concept phase, concretization phase and implementation phase.

However, the phases are by no means to be understood sequentially. Rather, it is advisable to design projects, especially those with a high proportion of software development, in an agile manner and to continuously implement, validate and adapt individual functional increments from a certain planning development status. As the procedure is iterated through, the result space is narrowed down more and more, so that in the end a solution is developed for the implementation of successful collaboration.

Initiation of the Collaboration

Initially, the collaboration starts with ideas for the collaboration and the selection of suitable and necessary partners. Suitable collaboration partners are first and foremost companies with pre-existent long-term supply or business relationships. However, collaboration with

Experience has shown that small and medium-sized enterprises (SMEs) in particular are willing to enter into deeper customer-supplier relationships

previously unknown companies (especially start-ups) should not be ruled out from the outset and can be crucial, especially for innovative projects such as the introduction of new business models.

Concept Phase

If the joint decision to implement a collaboration project has been made, the formal foundations for projecting the collaboration (collaboration models, NDAs, etc.) should be created and joint goals formulated in the concept phase. The goals can be formulated e.g. through a ***Collaboration Vision*** (see p. 44). This represents an initially abstract solution to the common problem and serves to continuously synchronize the understanding of the goals between the partners.

A collaboration project should be accompanied by a cross-functional and cross-company project team. Interdisciplinary teams of experts concretize the collaboration vision within their area of expertise. They develop solutions and provide access to a heterogeneous body of knowledge. Based on the collaboration vision, specific solutions can be proposed and elaborated.

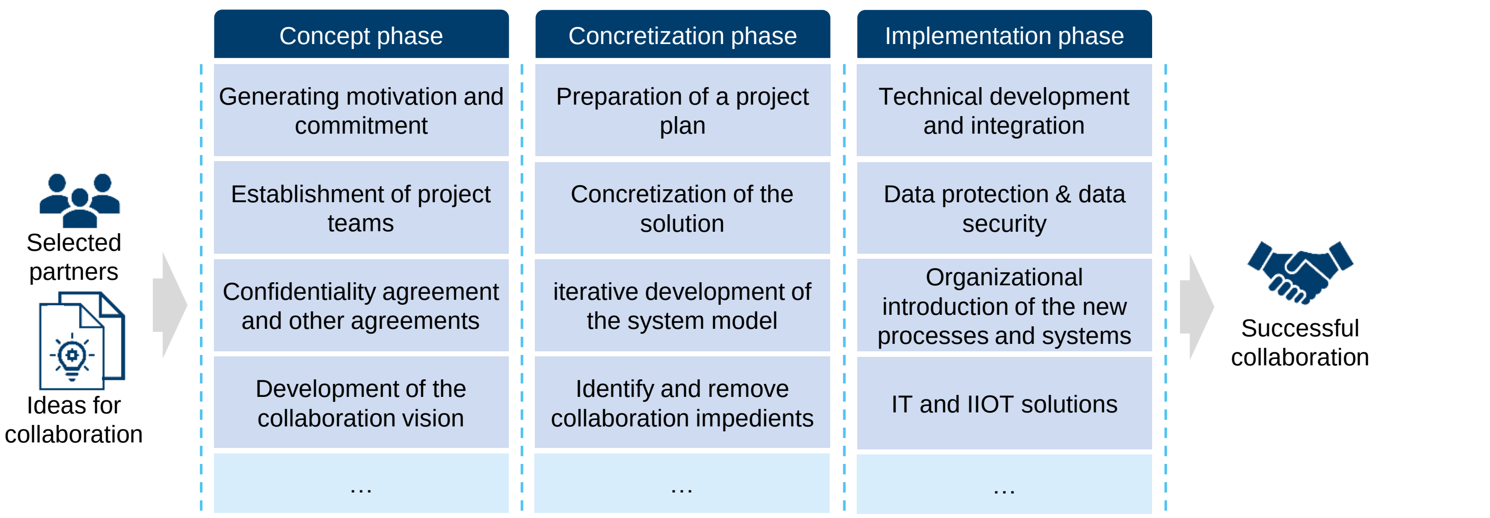


Figure 4: Integrated Process to achieve successful Collaboration

Concretization Phase

In the subsequent concretization phase, the aspects relevant for collaboration within the value network are analysed and formalized. The central element of the concretization phase is the ***System Model*** (see p. 45). In this model, the ideas of the collaboration vision are continuously concretized. The system model serves both as a planning and communication tool between the partners. It visualizes the material, information and financial flows between the partners involved and depicts the interdependencies. In this phase, it is also important to systematically identify possible ***Obstacles to Collaboration*** (see p. 46f) and to develop solutions for overcoming them.

Implementation Phase

In the implementation phase, the concretized concepts are finally put into practice. The choice of the right ***technologies*** (see p. 52ff) or enabled in the first place with the aid of modern IT technologies and IIoT solutions (Industrial Internet of Things). It is also important to consider appropriate ***Standards und Reference Architectures*** (see p. 46). Since collaboration between partners from different companies inevitably involves the exchange of data across company boundaries, ***Data Security*** (see p. 49) and ***Data Privacy*** (see p. 50 f) often pose enormous obstacles to collaboration. It is therefore crucial for the success of a project to involve the relevant experts from the respective partners and to reach concrete agreements at the right time.

To realize a successful collaboration, many different aspects must be considered, which are planned and developed in the concept and concretization phase and implemented and validated in the implementation phase. Numerous tools are available to support the procedure, which are provided and explained in detail in a ***GitHub Repository***.

The following chapters present exemplary collaboration projects that were worked on as part of the publicly funded joint projects ReKoNeT and SmartCoNeT. Based on these projects, best practices were identified that can be used in the implementation of own collaboration projects.

Collaboration Projects in the User Guide

This user guide is based on the results of the project "***ReKoNeT*** - *Data-based Control of Collaborative Value-Adding Networks with Secured Transparency*" and its international counterpart, the EUREKA SMART project "***SmartCoNeT*** - *Smart Control of Customer-Based Collaborative Manufacturing Networks with Secured Transparency*".

In the German ReKoNeT project, 8 industrial companies and 2 institutes have collaborated to test the implementation of collaborations in dynamic value-adding networks based on concrete industrial examples, and to develop corresponding organizational and information technology guidelines and general recommendations for implementing collaborative value creation. ReKoNeT has been one out of 11 collaborative research projects within the national funding framework "Industrie 4.0 - Collaborations in Dynamic Value-Adding Networks (InKoWe)" – as part of the “Innovations for Tomorrow’s Production, Services, and Work” program – of the German Federal Ministry of Education and Research (BMBF).

In the international SmartCoNeT project, 3 partners from the ReKoNeT consortium have collaborated with 3 partners from Spain and South Korea in the framework of the SMART EUREKA CLUSTER on Advanced Manufacturing programme with the aim to jointly validate the findings on implementing customer-based collaborative value creation processes in diverse settings of customer-based manufacturing networks.

In total, five industrial use cases – three from the German ReKoNeT consortium and two from the international SmartCoNeT project – are presented below as examples for successfully implementing collaborative value creation in different manufacturing networks.

The described use cases represent a cross-section of the wide range of possible collaboration projects in the various industrial sectors (from textile industry to mechanical engineering) with different collaboration visions and objectives of the individual partners (from acceleration of production processes to development of new business fields). Figure 5 depicts the consortia and shows how the use cases differ in type and direction.

In all of the use cases, the three phases of the integrated procedure described above were jointly implemented and validated - despite all the differences in the content and technical details of the respective issues. Accordingly, the following description of the use cases is structured according to the three phases:

- Concept Phase
- Concretization Phase
- Implementation Phase

After the description of the five use cases, the key findings are summarized in various "best practices" and useful tips and tricks for successfully implementing collaborations in value networks.

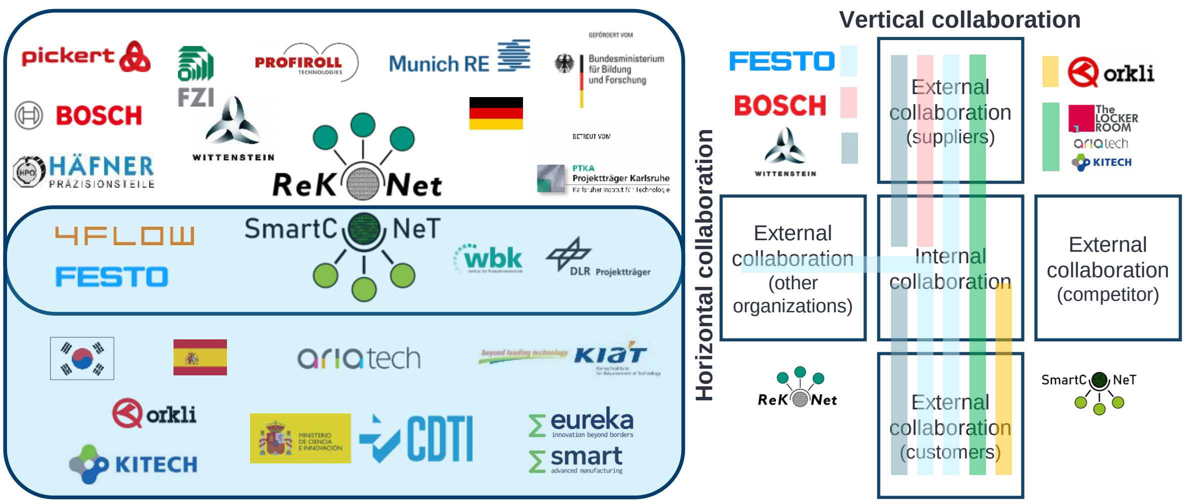
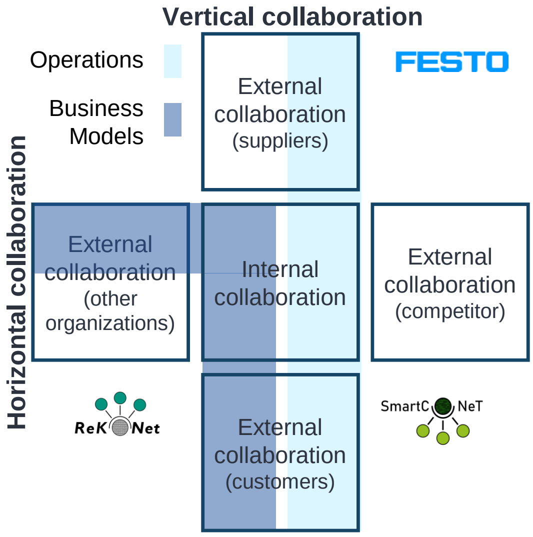


Figure 5: Partners of the ReKoNeT/SmartCoNeT-Consortium displayed in the Collaboration Matrix

Collaborative Capacity Management

Application at Festo SE & Co. KG



Use Case Introduction

Festo operates a global production network with 11 Global Production Centres (GPCs) to ensure supply to customers worldwide. In Festo's value network (see Figure 6), lead plants develop production technologies for defined product groups. The knowledge about the processes is transferred to other plants in the network as required.

Within this network, Festo manufactures industrial automation products in large series through to customer-specific special solutions. Festo has built up a heterogeneous, specialized machine park in order to map the high diversity of variants, particularly in machining production. Production concepts are often set up and operated site-specifically and for a defined range of products

Since it is not possible to achieve uniform utilization of equipment across products and locations, situations can arise in which equipment in the network is underutilized that could theoretically support the production of a heavily utilized product. Until now, short-term levelling of capacity utilization has only been possible with a great deal of manual effort and experience, since not all machines are mapped uniformly in the information systems. In the collaboration project, new solution approaches are to be created for the cross-location and cross-company allocation of customer orders in the network.

Phase I Conceptual Design

In the concept phase, it was crucial to establish a common understanding of the overall problems with the project partners involved at Festo. In an explorative, workshop-based procedure, three applications were defined. Each application focuses on a different section of the production network (see Figure 7).

In the first application, the focus is on Festo's internal production network. The goal is to build an automated decision support system for effective, cross-functional collaboration between different departments when introducing new products into Festo's production network. The decision support is based on a recommender system [21]. In the future, this system

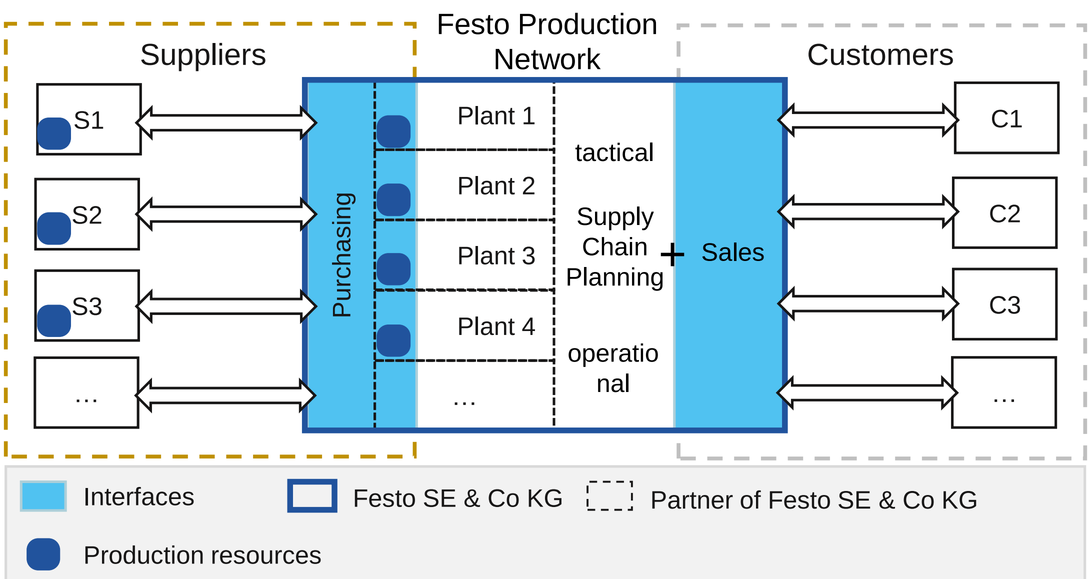


Figure 6: Collaborative Production Network at Festo

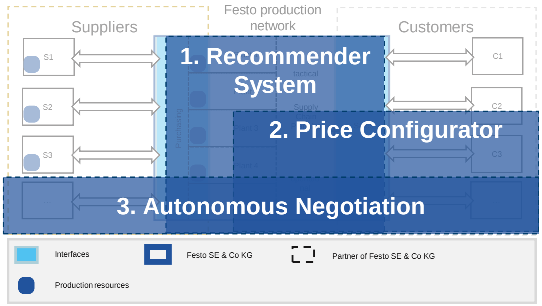


Figure 7: Scope of the Applications

will automatically suggest production scenarios for new semi-finished parts based on capacities, capabilities and costs. This will simplify and support time-consuming manual coordination between supply chain management and the factory. Additionally, it identifies production resources that would not currently be considered due to existing constraints [21].

In the second application, the dynamic quotation generation using a price configurator, the aim is to achieve efficient, automated coordination with the customer considering the capabilities and availability of the production network. The customer is offered price incentives to align his delivery time preferences with the current capacity utilization situation of the value network. Methods from revenue management in combination with reinforcement learning provide solutions for this. This integrative approach makes it possible to ideally map the customer's preferences in terms of price and delivery time. At the same time, the utilization status of the production network is reflected in the price. Thus, the product price can be used to influence bottleneck situations in the network.

In the third application, automated negotiation in decentralized production marketplaces is investigated. Participants can be machines, production lines, or companies in the network. The price for the production of orders is determined by the production resources via auction mechanisms and passed on to the customer. In order to be able to make realistic statements about these network and market effects, data from a 3D printer park at Festo are used as a basis. Here, the ordering behaviour on the customer side is approximated by historical data and used as input for the decentralized network of production resources. The findings help to assess how flexibly value networks can be extended to include participants.

The applications described are summarized in the collaboration vision (see Figure 8). This has proven to be extremely helpful. Based on this representation, it was possible to communicate an overview of the required services and network entities to all participants in the applications.

Phase II Concretization Phase

In the concretization phase, the described applications were further elaborated with the help of the system model. In the further description, the Recommender System is dealt with in more detail. The description of the other two applications will be limited to the results.

Application 1: Recommender System for Generating Supply Chain Scenarios

During the introduction of new products into the Festo production network, several supply chain scenarios are generated. They are used to select suitable locations and production processes and form a decision basis for make-or-buy questions. Several locations are usually involved in this process to create the local production concepts, which are then expanded by a central department to include logistical factors and combined into scenarios. Because of the high personnel coordination effort and the combinatorial complexity involved in machine selection, cross-site and regional concepts are not always considered. Also, existing equipment from Festo's entire machine fleet cannot be fully included in the considerations. The Recommender System aims to solve this coordination problem. Limitations in responsibilities, due to competing

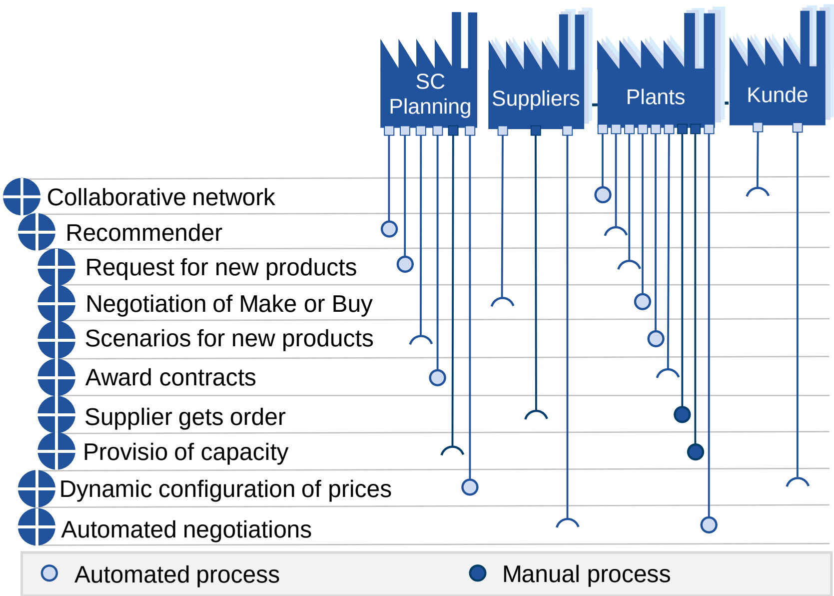


Figure 8: Collaboration Vision of the Festo Use Case

objectives or limited knowledge about manufacturing options are reduced by the data-based approach.

With the help of the system model (see Figure 9), existing processes could be analysed and sub-functions of the Recommender System defined, which will be explained in the following. The focus is on the machining production of four production sites with several hundred machines.

Recommendation Engine for the Identification of Production Resources

The large number and varying ages of the machines in Festo's machine park mean that there is no uniform digital description of the production resources. Consistent modelling of all machines with their production capabilities is not available and would involve a great deal of manual effort. Therefore, machines for a product to be manufactured should be suggested by means of a "recommendation engine" [21]. This class of algorithms is common in the consumer environment and is often used by digital platforms to suggest relevant content to users based on their user behaviour. Transferred to the industrial problem, this results in the possibility to assign parts to a machine based on past orders instead of based on machine capabilities. The database used consists of historical production data available in the ERP over a long period of time (including ID of the material, ID of the machine, production time and production technology). The algorithm can be trained with the historical data and calculate suggestions for machine-part number combinations. The restriction of the time period, the location or the production technologies in the training data determines which statements can be generated by the system. A web-based prototype outputs potentially matching suggestions on request of part or machine number.

Introduction of new Parts to be manufactured

A limitation of the Recommendation Engine is that only learned interactions between parts and machines are considered in the recommendations. Since a new product has not yet been produced on an existing line, the system cannot make recommendations about it. However, at the core of the new product introduction process is this very issue.

To address this limitation, in addition to manually entering similar part numbers, a learning process can also be used. In this process, the

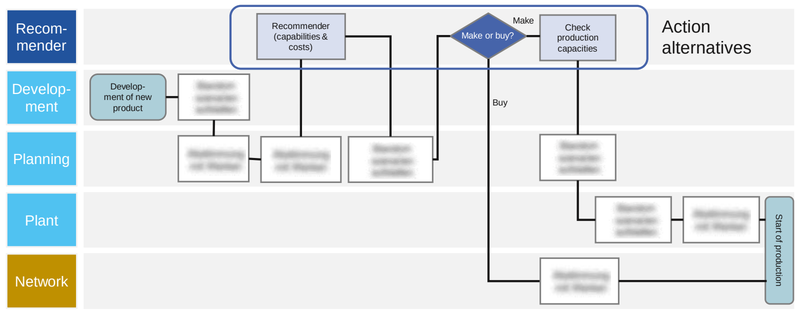


Figure 9: Section of the System Model of the First Application

CAD files of existing part numbers are clustered using an autoencoder procedure (see Figure 10) [22]. New parts can then be assigned to a cluster and corresponding suggestions for plants can be generated [22].

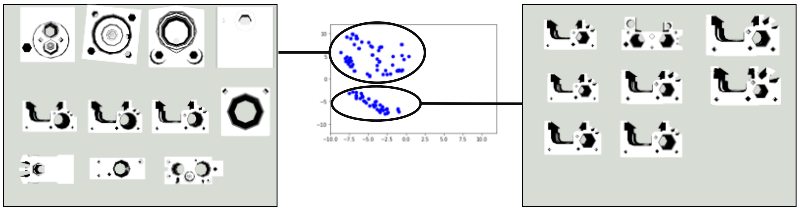


Figure 10: Determination of Similar Parts by Clustering of CAD Models

Generating Supply Chain Scenarios

To arrive at the supply chain scenarios in the final step, cost and availability data are merged with the results of the recommendation engine. In a web-based prototype, additional filtering options are implemented to allow for different site and network configurations, as well as to integrate make-or-buy decisions. In addition to scenarios that map only one location, it is now possible to allocate resources across locations. The Recommender System can also be used to identify alternatives for short-term bottlenecks.

Application 2: Automated Price Configuration in the Production Network

The Recommender System aims at optimizing the state of the value-adding network. However, the influence on the demand side is also a lever to achieve levelling effects in the production network. Changes in the price of services, considering the current situation on the supply side, are already a reality in the tourism industry, for example. Prices are adjusted upwards or downwards to the customer's expected willingness to buy with the help of behavioural information. This so-called revenue management is more difficult to implement in the industrial environment. On the one hand, the buying behaviour of professional buyers differs from that of consumers. On the other hand, a disproportionately more complex resource situation must be considered in a collaborative production network.

However, simulation studies carried out indicate that a transfer to the industrial environment is possible with further testing. For this purpose, a simulation of the production network and the purchasing behaviour of customers is set up as a training environment for a reinforcement learning agent. On this basis, price adjustment strategies can be investigated without negatively affecting the customer relationship.

The simulation result shows that earnings and delivery reliability can be positively influenced. In the current version, the approach leads to a non-negligible number of rejected orders. This argues for further evaluation with e.g. more detailed simulation and behavioural models of the promising approach.

Application 3: Autonomous Negotiation in Decentralized Manufacturing Marketplaces

In the third application, the view is extended to the entire value-adding network. In particular, the flexible expansion or reduction of physical production resources becomes interesting to deal with volatile order loads.

The data that ensures the efficient use of a global production network is collected, processed and stored decentrally along the entire value chain. In most cases, however, they are not visible to all participants in a value-adding network. Much of this data is subject to organizational, technical or legal restrictions. One way to deal with these hurdles is to model the value-adding network according to concepts of decentralized, agent-based marketplaces.

Markets are very efficient at aggregating information from many sources and reflecting it through price. Using a transparent market mechanism, orders can be placed in the production network, with attention paid to compliance with soft constraints by the producing units. The units take orders from the market at self-defined minimum conditions and trade at their own risk. For such a system to work together reliably and cost-effectively, it is necessary that the producing units and customers benefit from each transaction (individual rationality) and disclose their true costs or willingness to pay to the mechanism (incentive compatibility). It should also be ensured that the network operator does not have to subsidize the market (budget balance).

In order to work out the options for action for the flexibilization of value networks, a simulation is built based on real order data of a 3D printer park at Festo. The coordination of orders and agents is implemented with a second price auction and the approximate compliance with the aforementioned conditions is shown under suitable assumptions. The results are used to derive rules for pricing via auction and budgeting for individual agents. However, a refinement is necessary for the modelling of the agents' bidding behaviour, since rational assumptions have been used so far. Here, risks from the behaviour of agents are to be expected, which can have an influence on the budget balance.

Phase III Implementation

The Recommender System could create direct operational added value with low implementation hurdles and was therefore transferred to Festo's IT infrastructure. The Recommender System is also available via the ***GitHub Repository***.

The studies from applications two and three are used as a basis for further developments, so they are still in the concretization phase. In addition, new business models in the collaborative environment were evaluated.

Operational Deployment of the Recommender Systems

The Recommender System is not limited to decision support for the strategic and operational allocation of resources. After the evaluation with the departments at Festo, further fields of application were identified. These include standardization and benchmarking of production equipment as well as support for general changes in production concepts.

However, the evaluation also reveals limitations. The procedure is accompanied by a lack of clarity in the suggestions, which reduces acceptance among experts. It is obvious to complement the purely data-based approach with feedback functions and more detailed capability modelling of machines. This can optimally support the advantage of making decisions considering Festo's entire machine fleet.

Designing prototypes as services has proven to be a successful recipe for integration into the flexible IT architecture at Festo (Figure 11). Interfaces and runtime environments should already be designed during prototyping so that they can be connected to the productive IT systems. Future expandability to include network participants outside of Festo and the integration of IoT data can also be technologically mapped in this way.

Development of products and evaluation of new business models

In addition to supporting production activities, the Festo use case also evaluated new business models for hedging risks for active production assets based on increasing transparency through IoT technologies.

A risk analysis was conducted as part of the Recommender System. Among other things, risks such as data availability from secure data sources and volatile availabilities in the network were identified. These risks can be reduced by expanding product and service offerings, including through horizontal collaboration with organizations outside the traditional manufacturing ecosystem. In particular, the use of IIoT technologies and risk transfer solutions represent mechanisms for reducing risks for participants in the plant creation network.

Based on the insights gained, it was possible to derive requirements for a prototype for the collection of operational machine data. The developed IIoT sensor kit can be easily installed and programmed in a production environment. It can be used to quickly aggregate and transmit characteristic values of machines in a decentralized manner. The feasibility of production-related AI applications can also be implemented and assessed at low risk.

Second, risk transfer solutions based on IIoT data represent another interesting area for technology-based service offerings. Business models here not only serve collaboration in existing supply chains, but are also offered collaboratively by multiple partners with complementary competencies. Munich Re and Festo have evaluated a collaborative business model in a pilot application at Festo's Scharnhausen technology factory. Combining maintenance information and financial data, it was possible to derive offers for data-based risk transfer during the operation of machines. Together with plant manufacturers, maintenance-as-a-service concepts and other performance guarantees can be offered, for example. Plant operators benefit from better planning of maintenance costs and increased plant availability.

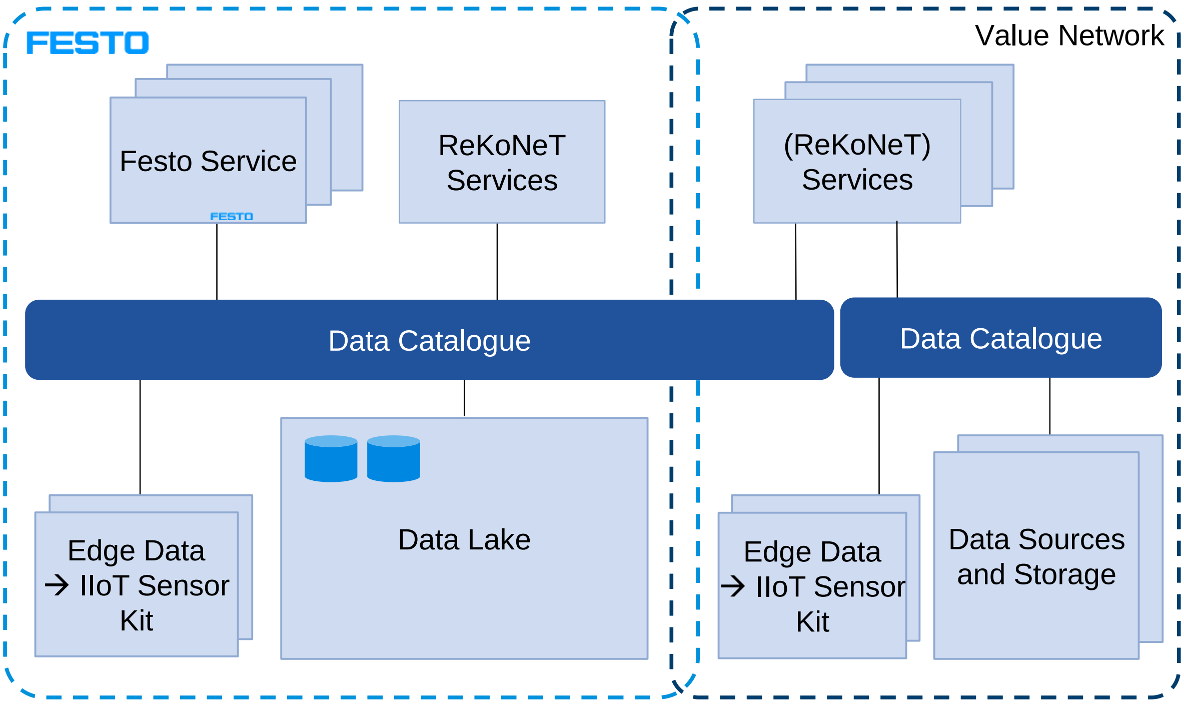
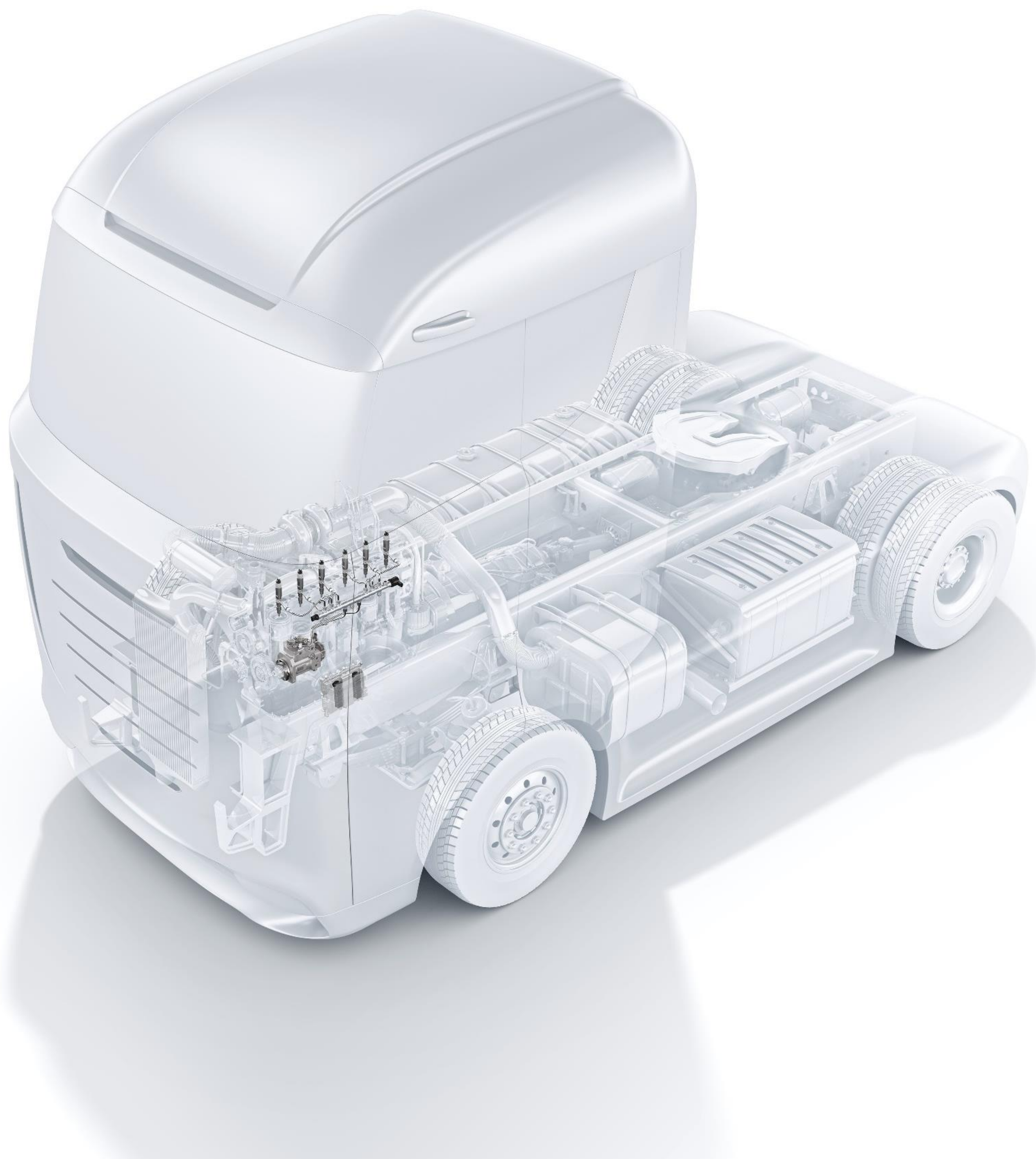
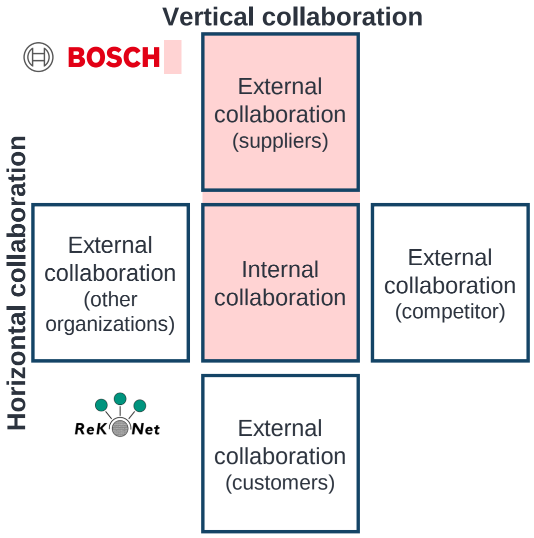


Figure 11: IT Architecture of the Recommender System



Collaborative Quality Control

Application at the Robert Bosch GmbH



Use Case Introduction

Due to the increasing demands on quality and the simultaneous cost pressure in production, manufacturers of high-precision components are facing great challenges. The necessary quality requirements can usually only be realized through very tight tolerances for individual components and preliminary products. Despite these tight tolerances, even conforming components that are close to their tolerance limits can lead to non-conforming products. For example, if they are combined with components that are also close to a tolerance limit. Through targeted component pairing or similar data-based quality control strategies, such unfavourable combinations can be avoided.

In global production networks, responsibility for the production of high-precision components is also passed on to suppliers. However, this often lacks transparency and traceability due to a lack of data and information exchange between the supplier and the focal company. Due to the lack of data exchange, quality control strategies often cannot be applied across companies. Accordingly, the tolerances of supplied components must be defined even more tightly to ensure the functionality of the final product. In this example, data-based collaboration could prevent inefficiencies in the value network caused by excessively tight tolerances and excessively high production costs at the supplier (see Figure 12).

In the use case of Robert Bosch GmbH, the data exchange of quality data for the application of data-based cross-company quality control strategies is demonstrated. The international production network (IPN) for the manufacture of common rail diesel injectors for commercial vehicles serves as the basis for the investigations.

In the remainder of the chapter, the use case is described using the previously described procedure for implementing successful collaboration projects.

Phase I Conceptual Design

The function-oriented quality control of high-precision components in value networks is a very complex problem. In the conceptual phase, it was therefore crucial to first develop a common understanding of the technical issues among the project partners involved. In order to make this comprehensible, the paradigms of function-oriented quality control as

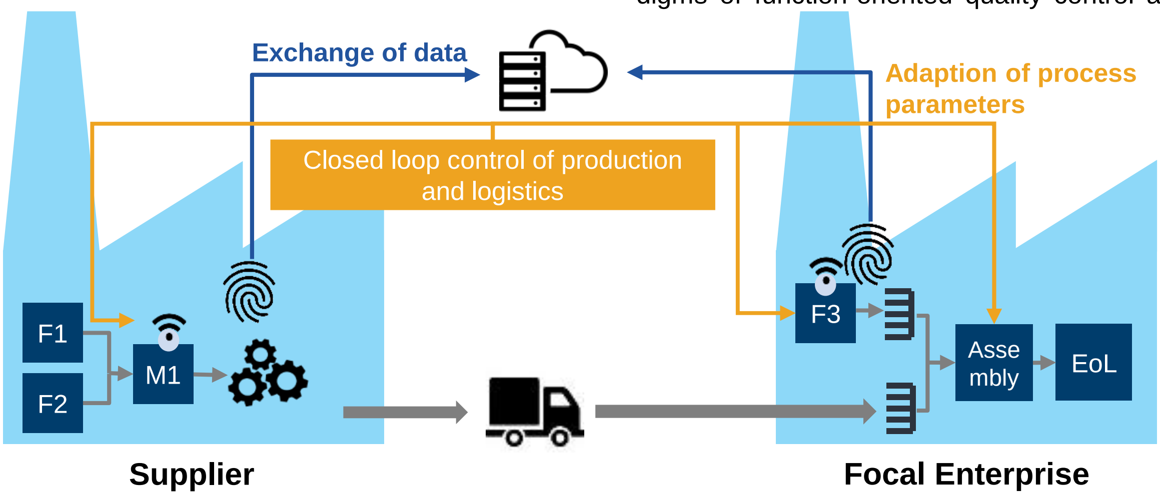


Figure 12: Target Vision of Cross-Company Quality Control ([15, 16])

well as the motivation and objective of the use case are explained in the following. Based on this, the resulting collaboration vision is derived.

Function-Oriented Quality Control in Production Networks

As mentioned earlier, function-oriented quality control enables the production of high-precision products from less precise components. The most widespread strategy is selective assembly. Here, the pairing of two components is done based on previously defined classes. In addition, there are many other different quality control strategies (see Figure 13). The core component of the approach is a cross-process quality controller, which adjusts and optimizes the control parameters using the acquired data from the inline measurement based on a functional model for predicting the product's function in the end of line (EoL) functional test. [23]

In assembly, the pairing of components can also be done individually based on the respective measured data instead of selectively (individual assembly). If the control loop is extended into the manufacturing of the components, better pairing can be achieved by parameter adjustment. On the one hand, this can be done individually by manufacturing the matching opposite for each component, or by adapting nominal values (stat. adaptive manufacturing) for individual batches. Finally, if the aforementioned strategies are mastered, the tolerances of the components can be widened. [23]

Motivation & Objectives

Injectors are subject to high functional requirements resulting from increasing market demands (low fuel consumption) and regulatory requirements (low emission values). These functional requirements are reflected in the required fits in the submicrometer range and correspondingly tight tolerances for the individual components. In order to meet functional requirements cost-effectively, the components can be paired with respect to their functional parameters. As a result, high-precision products can also be produced from less precise subcomponents. There are a large number of parameters that are simultaneously relevant for the pairing, some of which also occur in supplied components

The goal of the use case is to demonstrate network-wide pairing of components with collaborative real-time production control. By using individual component data from the manufacturing processes at the supplier plant and by the model-based, individually calculated selection of the ideal pairing component, the goal is to reduce the reject rate and ideally to expand the specification of the upstream processes. This can be expected to result in a significant increase in production efficiency as well as decreasing quality assurance efforts in the supply chain. In order to simplify data integration and initially focus on illustrating the great potential of value network-wide pairing, a Bosch-internal plant was chosen as the supplier plant.

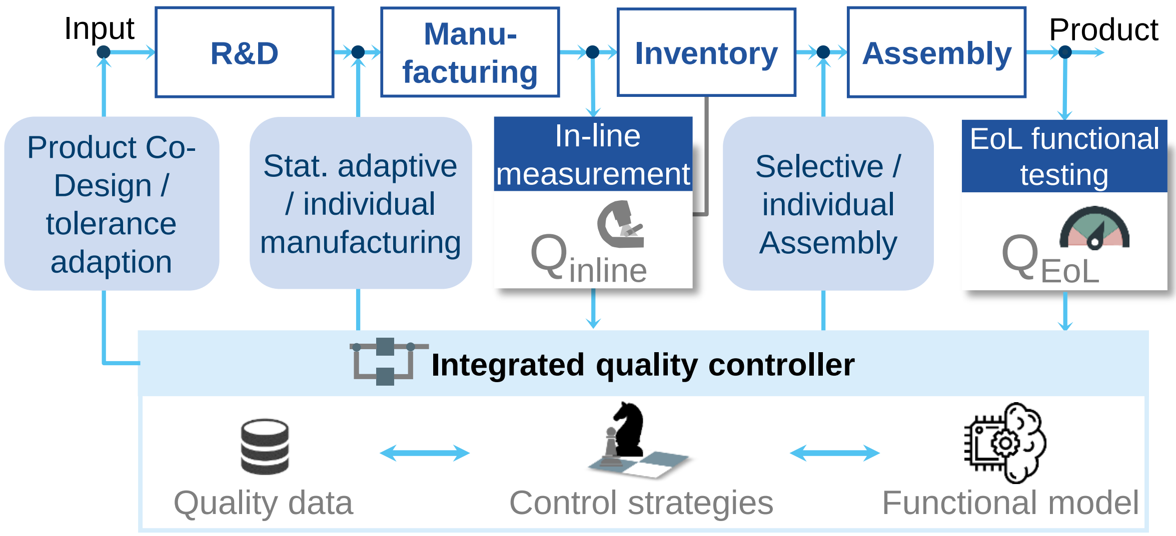


Figure 13: Function-Oriented Quality Control (see [23])

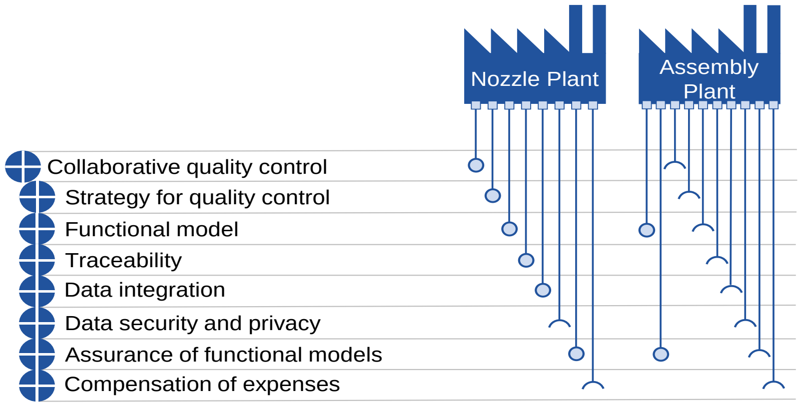


Figure 14: Collaboration Vision Collaborative Quality Control

Collaboration Vision

In the use case, cross-company quality control between the nozzle plant (here: nozzle = supplier part) and the residual injector is to be demonstrated. For the implementation of an efficient strategy, a component-specific allocation of the measured components and a continuous component traceability in the assembly plant are required. In addition, the concrete control strategy and the functional model must be developed and validated.

The goal of such collaboration is to work out the global optimum, i.e. to optimize quality costs throughout the entire value network. Often, such an optimum can only be achieved by one partner having higher expenses than before (e.g. due to additional infrastructure costs). These supposed additional efforts, as well as the resulting savings, must be fairly distributed in the value network. Figure 14 depicts the collaboration vision.

Phase II Concretization

In the concretization phase, a refined understanding of the process was created with the help of the system model. Using the system model, it was possible to simulatively assess possible quality control strategies and identify concrete collaboration obstacles and design solutions for them.

With the help of the system model, a component diagram (Figure 15) and an activity diagram were modelled based on the current state. In the component diagram, the interactions and data flows between the relevant components were depicted. A distinction was made between physical components (plants, product modules and stations) and IT infrastructure components. In the end, it was possible to clearly understand which product module receives its characteristics at which station in which plant and how the information on these characteristics interacts with the control system. For this purpose, it was very helpful to start at the plant level and successively increase the level of detail.

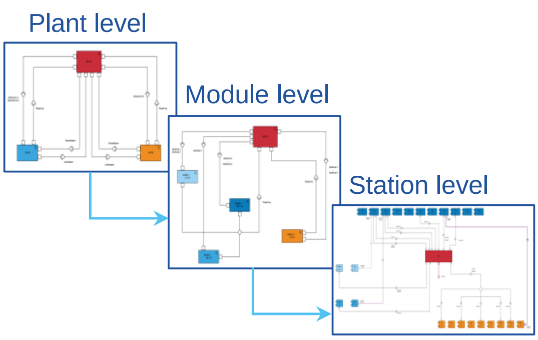


Figure 15: Concretization of the Component Diagram

Starting from the component diagram, the concrete material and information flow was represented in an activity diagram. For the design of such diagrams, it is useful to refer to existing documents in the company, such as value stream diagrams. As a result, for each cross-company quality control strategy considered, it was possible to show exactly which data must be shared under which conditions in order to implement the strategy.

For example, Figure 16 depicts an activity diagram of a collaborative quality control strategy for implicitly widening tolerances in real time. Here, the supplier is made an offer for out-of-tolerance parts (B-goods) that could still be utilized through individual assembly based on the data it submits for all parts. These and other visionary quality control strategies were examined in workshops during the project with regard to possible challenges and collaboration obstacles that might arise. The system model helped to make the discussions as concrete as possible

Based on the system model, a discrete-event simulation was developed for the technical and economic evaluation of the quality control strategies. It is crucial to compare the

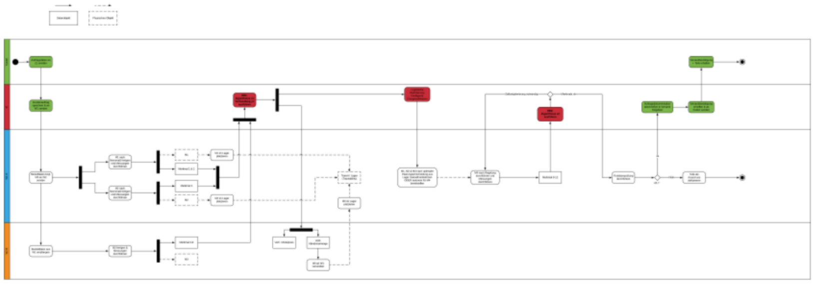


Figure 16: Activity Diagram Real-Time Tolerance Adaption

supposed saved quality costs with the additional costs for the organizational implementation of the control strategy and to evaluate the strategies not only from a technical point of view (improvement of the product function) with the help such decision support systems.

Phase III Implementation

In the implementation phase, a data-driven functional model and a decision support system were developed that evaluates the batches of supplied parts based on their impact on the product function. The collaboration system could be validated prototypically in a running production environment. Implications for the technical implementation of the models are also discussed in this chapter.

The quality control strategies considered are based on function models which predict the product function of both the individual components and the complete injector on the basis of component-specific data. These models map the product function in the sense of a digital twin of the product and, by means of sensitivity analyses, reveal which parameters have an influence on the function of the end product. All kinds of machine learning methods can be used to create such models. Figure 17 shows a general procedure for training functional models.

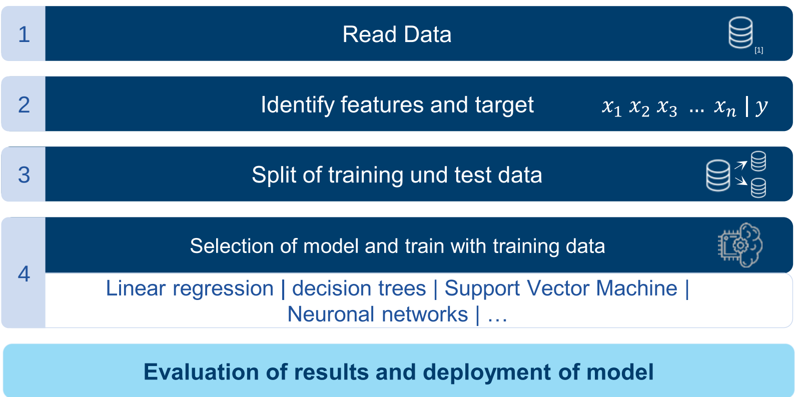


Figure 17: General Process for Deriving Functional Models

The data for training the models can originate both from a multi-physical development model (digital master) and from historical measurement and process data from series operation (digital shadow). When using the models in a real production environment, however, the performance of the overall system should always be kept in mind so that production processes and the cycle time are not interrupted by waiting times for database queries or calculation processes.

With the aid of the discrete-event simulation described above, an individual assembly strategy of the nozzle module in combination with batch allocation was identified as the best quality control strategy. Batch allocation is a novel logistic quality control strategy for inter-company quality control. The idea is to reorder the sequence of batches of components to be assembled before entering assembly based on the batch-specific dispersion of components. In this way, assembly is supplied with the most appropriate of the available batches in each case to compensate for counteracting effects. [16]

A prototype collaboration platform was developed to implement batch allocation. This decision support system evaluates the influence of the respective batch on the quality costs on the basis of the transmitted batch-specific data of the supplier depending on the available parts in the assembly line. For this purpose, the functional model is used to predict the performance of the product in the end-of-line test bench and to calculate the expected scrap.

The supplier is provided with its own interface to the platform. Using an interface specially adapted for him, he has the option of uploading his batch-specific data. He can then see for each batch how it affects the quality costs compared to a standard batch (see Figure 18). The costs shown are based on a sample data set and do not correspond to the real costs and functional tolerances.

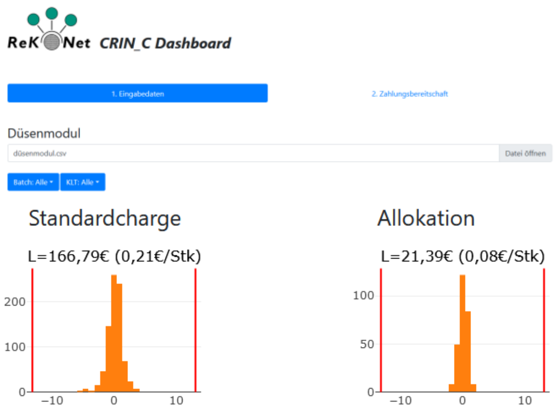


Figure 18: Collaboration Platform Supplier View (Figure shows fictional values)

In order to better estimate the quality costs, they are calculated using Taguchi's loss function. Here, the quality cost increases with increasing distance of the predicted deviation of the component from the nominal value of the EoL test bench. Multiplied by the distribution of components in a batch, the resulting costs are obtained (cf. Figure 19). By creating transparency of the effect of different batches on the product function, incentives could be set in a next step to adjust the distribution in the best possible way.

From the focal enterprise's point of view, the platform serves as a decision support system for logistics control. Based on the transmitted supplier data and the data on the available in-house manufactured parts, the ideal sequence of batches of the nozzle module is specified for batch allocation. Subsequently, the data is provided accordingly in the MES for the individual real-time pairing of the nozzle module to the residual injector at the assembly station.

The collaboration system was tested in a prototype trial under real production conditions. In the process, the scatter in the test point under consideration was significantly reduced by up to 20% within the tolerance, which once again exceeded the expectations of the system. The results clearly show that a significant improvement in product quality can be achieved by exchanging quality data within the collaborative production network.

In the use case, the quality of the concretely considered end product is already very high due to the very tight tolerances and the high process reliability of the preliminary products. This means that there are only isolated cases of scrap or rework. Conversely, this means that the collaboration system presented here could be used to widen the tolerances of individual components, including those supplied externally, where the scrap rate on the supplier side is uneconomically high, while maintaining or improving the quality of the end product.

However, since the collaboration system has so far only been developed as a prototype, there are still numerous hurdles to overcome before it can be used under series production conditions. For example, the development effort and investment costs of a stable solution must first be compared with the expected cost savings. Furthermore, it must be ensured that the functional model also makes reliable predictions under changing conditions.

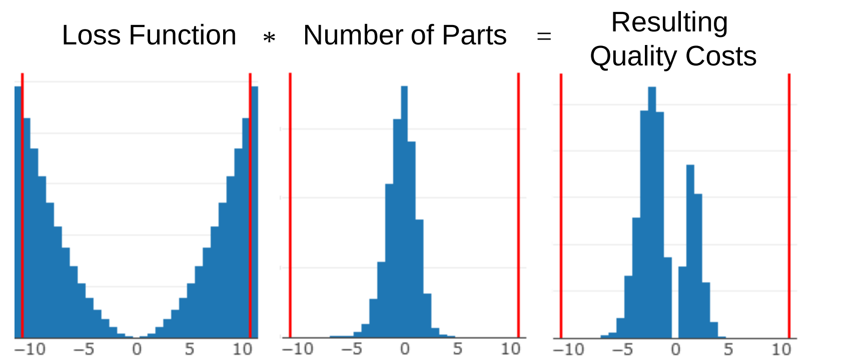
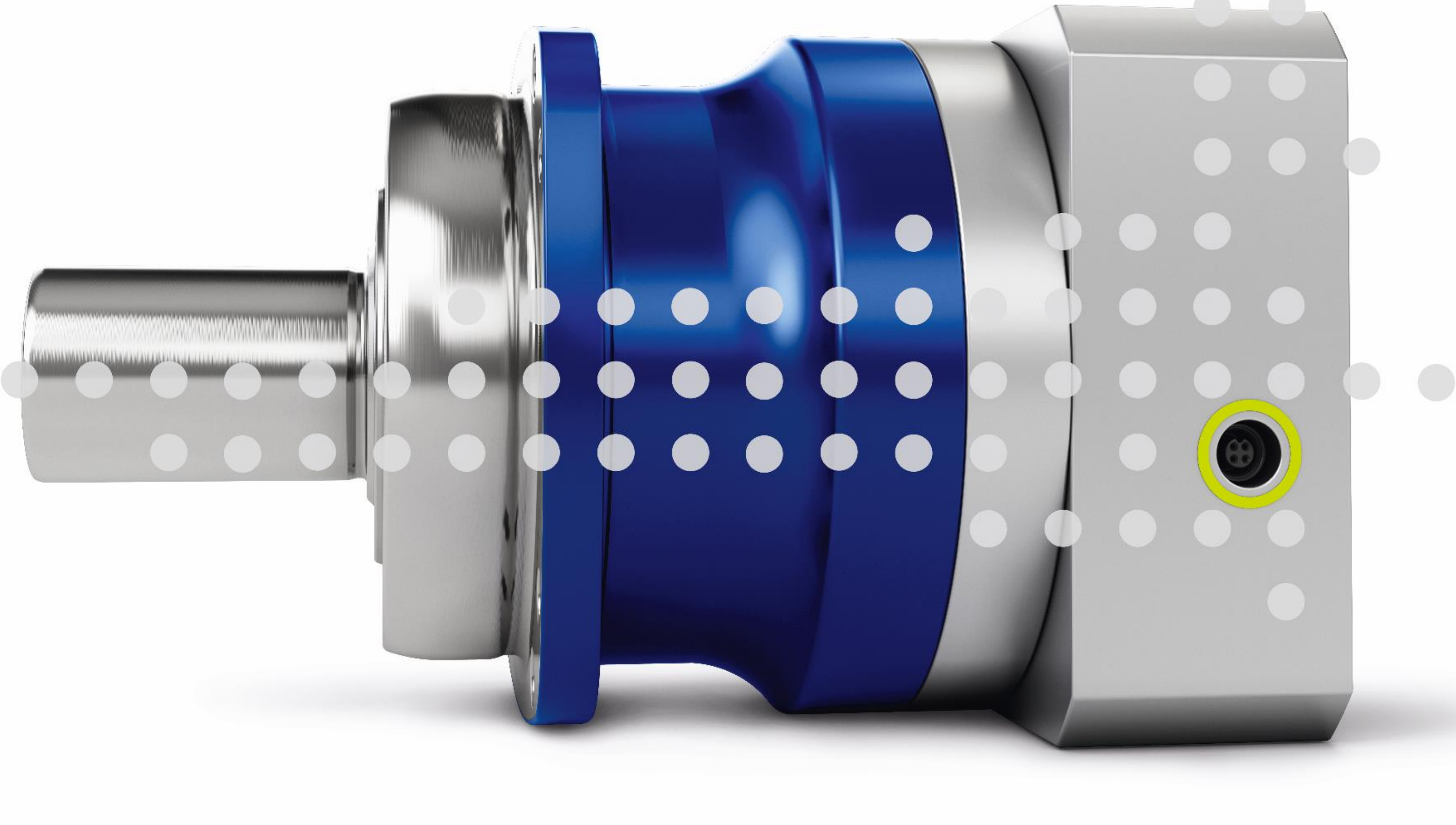


Figure 19: Derivation of Quality Costs ([15, 16])

Nevertheless, the use case and the methods and paradigms demonstrated in it serve as a flagship project for future collaboration projects with external suppliers. The unique feature is that by linking the data to the product function via the functional model, the value of the data becomes clearly quantifiable. On the one hand, the mere existence of the data and its importance to the functional model can be directly represented as a monetary equivalent (e.g., through avoided scrap). This expected added value can then be compared to the expenses for measurement technology and IT infrastructure for data exchange at the supplier. Furthermore, even the optimal data quality (e.g. through more precise measurement technology) can be weighed against the improved forecast quality and the associated saved quality costs.

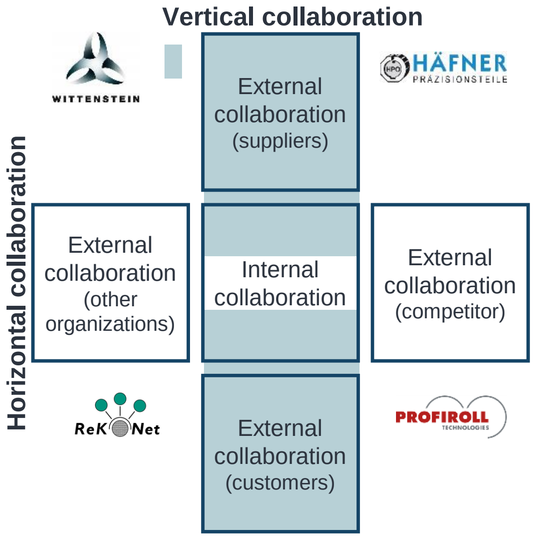
However, implementing the collaboration system with external partners requires far-reaching considerations and coordination in advance. On the one hand, this includes contractual issues, but also coordination on the technical requirements of data transmission and networking, especially with regard to guaranteeing data protection, ensuring individual know-how and protecting data from internal and external manipulation.

What needs to be considered with regard to these topics can be read in the Best Practice section. The decision support system will also be made available in the aforementioned ***GitHub Repository*** after the end of the project.



Collaborative Development of Digital Business Models

Application at WITTENSTEIN SE



Use Case Introduction

Digitalization enables ever higher degrees of networking between components and production systems - from suppliers to customers. Nevertheless, communication and data exchange are often characterized by manual activities and numerous media discontinuities. There is no data integrity end-to-end, from customer to customer in the value chain.

On the other hand, WITTENSTEIN SE has a robust system landscape with many design options and usable standards at its disposal, the full potential of which has not been tapped. In 2016, a dedicated department was established, the Digitization Centre, which handles challenges in Smart Products, Data Driven Services, Smart Factory and Smart Operations. This is flanked by specialist departments that are excellently positioned in individual domains, e.g. plant engineering and IT. Along the value chain of the Galaxie® drive system, the theoretical findings of the project were tested on two applications at WITTENSTEIN SE.

Phase I Conceptual Design

The first phase deals with the company's initial situation and the motivation to address the issue of collaboration. A collaboration vision and initial objectives were derived from the corporate strategy.

Motivation

In order to expand one's own service offerings and to offer existing services at ever lower costs, an increasing integration of partners is necessary. In relation to smart products, this is also confirmed by a study conducted by Fraunhofer IPK [24]. 71% of companies expect an increase in collaboration partners as a result of smart products. In order to ensure the controllability and stability of the overall system, existing integration concepts must be rethought and expanded.

Objective

The objective is twofold. First, the classic product value chain must be enriched with smart products, data- and service-based value creation processes, and new offerings must be developed with the aim of increasing productivity and conserving resources. Secondly, data already available locally in the value network should be made available to all partners and the resulting local added value distributed evenly.

A key success factor for successful collaboration is the creation of shared added value through collaboration. In this case, the bidirectional exchange of data (from the perspective of each partner) is intended to generate added value at various points in the value network (see Figure 20).

Phase II Concretization

In the concretization phase, two applications were developed and modelled based on the collaboration vision. These are explained below

Application 1 – Distributed Added Value Through Locally Available Data

The first application is again divided into two parts. On the one hand, the focus is on eliminating duplicate quality checks of the same components in value networks. On the other hand, changes in delivery status are to be communicated in real time within the network to increase the response time of all partners. This is demonstrated in concrete terms between the WITTENSTEIN production plant at the Fellbach site and the supplier Häfner Präzisionsteile Oberrot (HPO). HPO records measurement data during the production of pre-turned parts and during the outgoing goods inspection, but this data is only available locally. There is no direct communication to the outside.

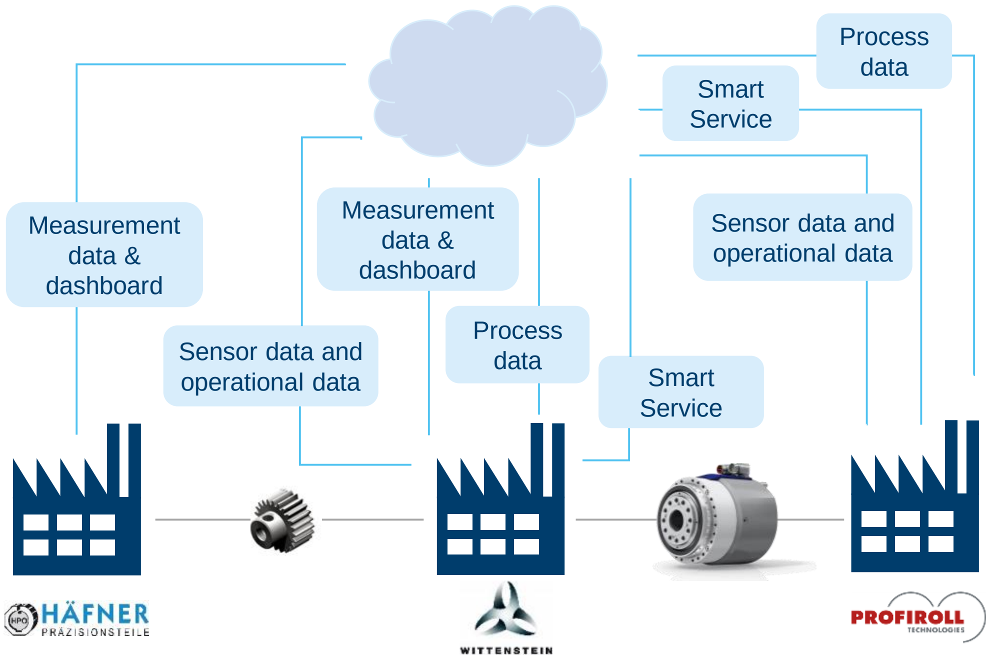


Figure 20: Big Picture Collaboration shows which data to be exchanged. Data can also be transferred from one partner to another without going via third parties. (WITTENSTEIN SE)

In many companies, quality assurance processes are associated with high costs and also represent a bottleneck. In the initiation phase of the project, the incoming goods inspection at WITTENSTEIN proved to be a particularly attractive area for digitization. Particularly in the case of the Fellbach site, where pinions for the drive systems are manufactured, potential for optimization was identified. Together with the company HPO, the processes for incoming goods inspection are to be streamlined here by exchanging relevant data. The aim is to use quality data recorded by HPO during outgoing goods inspection for incoming goods inspection by WITTENSTEIN. This will relieve the bottleneck area of quality assurance and reduce machine costs

On the one hand, platform technologies are to be used to exchange quality data so that WITTENSTEIN can use them for incoming goods inspection. On the other hand, the same technology is to be used to inform the right contact person directly in the event of adjustments to the delivery conditions. No manual effort is required; WITTENSTEIN can then decide whether to contact HPO to find a solution.

Benefits for the Partners

The exchange of quality data results in a number of benefits for the parties HPO and WITTENSTEIN. First of all, the digitalization of test reports, for example, simplifies documentation and cross-company availability. In the event of a supplier audit of HPO by WITTENSTEIN, these can be retrieved in advance and statistics on committees and documented measures can be included. In this way, audits can be accelerated in the future and fewer improvement measures have to be implemented at short notice. It also lays the foundation for further integration of data into master systems at WITTENSTEIN. The documents previously available as PDFs or in printed form can only be entered with a great deal of manual effort, and transferring them by hand is prone to errors. HPO is therefore able to offer an attractive digital feature that brings direct and perspective benefits to customers like WITTENSTEIN. Given the strong focus on digital documentation in companies, this feature can also become a prerequisite when selecting suppliers. As a technical basis, the transfer can also be used for further documentation and information, and the bond between supplier and customer can be intensified in further projects.

The greatest added value arises on WITTENSTEIN's side as a customer. On the one hand, the early provision of information means that parts can be released more quickly and used in production. On the other hand, the WITTENSTEIN company saves itself the double measurement during the incoming goods inspection. Since this is a bottleneck area, this advantage of closer collaboration with HPO should be weighted very heavily.

With regard to the existing problem of delivery date changes, the digital provision of the necessary information helps to reduce time losses in communication. For example, delivery delays can be processed earlier and the available response time increases, also due to the automatic provision of the right contact person. The connection to the master systems at HPO ensures that decisions are always made based on the most up-to-date information. This creates a feeling of security among employees, also because they are sure to be informed if serious problems occur. For HPO, this means a reduction in workload, as the customer becomes active should a problem be relevant enough. In the event of a slight delay in the delivery date, for example, this can be confirmed by WITTENSTEIN without much effort. However, if the responsible scheduler receives a high delay message, he can contact HPO directly to work out a solution together.

System Model

Based on the collaboration vision, the application was concretized with the help of a functional diagram. A section of this is shown in Figure 21.

The starting point of the data transfer is always HPO's ERP system. The master data for customer orders, production orders, parts, etc. are created in this system. These are regularly transferred automatically into a CAQ system, the RQM of the company Pickert. This ensures that the information between ERP and CAQ is congruent.

As soon as a new customer order is received by HPO, a new production order is created. Via a scheduler this data is written into an intermediate table. RQM reads the new data cyclically from this intermediate table and creates the corresponding entities in its own databases.

This triggers a WFCL script that sends the new production orders to the REST interfaces of an Integration Hub. The Integration Hub transforms the data and sends it on to the ZERO defects system portal, which is also hosted by Pickert. Here the data is transferred to the various ZERO defects core services. The customer, in this case WITTENSTEIN, now has access to the ZERO defects portal via password-protected access. To display a production order, parts, parts lists, product diagrams, etc. are generated in the HPO client at ZERO defects. Using a release

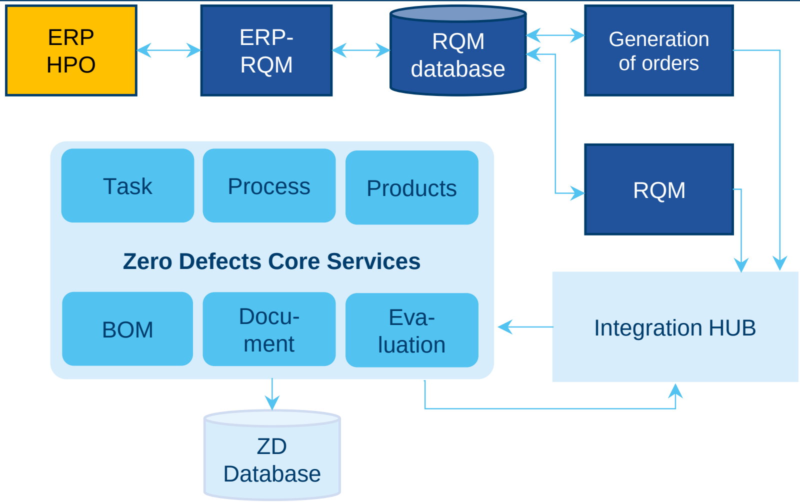


Figure 21: Architecture and Data Flow WITTENSTEIN / HPO

mechanism, HPO can decide which of these data sets should be visible in the WITTENSTEIN client and which should not.

Whenever HPO parts are manufactured from the split orders, the data generated during quality inspection is sent to the ZERO core via the above-mentioned WFCL scripts. There, they are then available for HPO and WITTENSTEIN to view and further analyse. Information can be individually configured by the respective viewer via dashboards and widgets.

Application 2 – Collaboration through Smart Services

The starting point at WITTENSTEIN is a smart transmission (transmission with cynapse®) that can independently record, process and communicate information. The digital value-added services (Smart Services) based on this have so far been used by WITTENSTEIN as stand-alone software services in customer applications and platforms. The reason for the lack of integration with other services or in a machine platform is not the lack of technical interoperability, but the lack of dovetailing of business models between component and machine manufacturers. Only with this interlocking does a resource-saving, scalable and added-value I4.0 solution become possible for machine operators.

In the course of the application, bidirectional data streaming will be established between WITTENSTEIN SE and Profiroll Technologies GmbH. This makes it possible to receive drive system operating data from the real operating environment in the field and to provide and consume services based in part on this data.

In this case, an edge component was selected that receives data from the IO Link Master and makes it available to WITTENSTEIN via the Azure IoT Hub. This operating data can then be evaluated using statistical methods or higher algorithms. With the installation of the Edge component provided by WITTENSTEIN, Profiroll gains direct access to pre-installed and offline-capable services, such as threshold monitoring. In addition to pure data streaming and the provision of standard services, the aim is to use the established infrastructure for the joint development of new services tailored to the customer. The collaboration will be sustained by new business models from which component manufacturers, OEMs and operators will all benefit. A characteristic feature of the new collaborative business models is that the previous product-related value flow is supplemented by the value flow of data and smart services (see Figure 22).

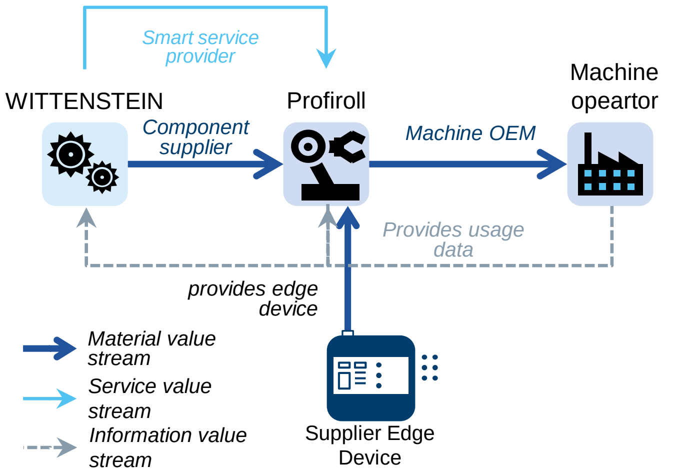


Figure 22: Value Creation Enabled by Smart Services (WSE)

Benefits for the Partners

In this application, too, added value is created for the partners at various points. For example, the machine operator benefits from reduced downtime, optimized processes and improved quality. The purchase and use of the services are designed to be flexible and easy for the operator. Another objective for WITTENSTEIN and Profiroll was to share the required IT infrastructure and leverage scaling effects. In further iterations, the aim is to extend end-to-end information transparency to other partners in the value network.

The vision of the "digital twin" of the product is obvious here. This contains not only physical information about an object, e.g., dimensions and specifications. But also, information that is recorded during the creation process, e.g. quality data. Cynapse® as a "connectivity building block" has become the gateway to a service-oriented business field and supports the use of the digital twin from the creation to the operation and recycling of a product.

Phase III Implementation

The basic building block of the business models is the continuous data flow from the component in the field to the digital service, which can be localized within the plant or in a cloud. For machine-to-cloud and cloud-to-cloud communication, it was possible to build on the work of DIN SPEC 92222 "Reference Model for Industrial Cloud Federation". The specification provides for assigning the devices in the field to an edge gateway and establishing one or more cloud connections via it.

Within the Profiroll machine, the drive systems were therefore connected with cynapse® via an IO-Link master to both the programmable logic controller (PLC) and an industrial PC (see Figure 23). A connection to the cloud platform is then established via the industrial PC.

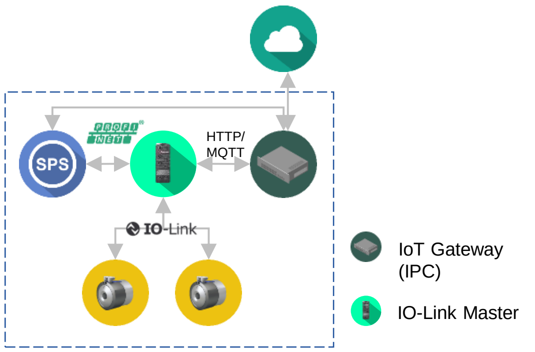


Figure 23: Integration of Smart Drive Components

In order to enable both the commissioning engineer and the user to easily interact with the services, a Smart Service Management Front End (see Figure 24) was developed. The front end lists the individual components within the machine and displays the digital nameplate of the selected component. Below the product information, the available and already installed services for the individual component are displayed.

Another basic building block within the architecture is the data gateway, which controls the communication flows within the machine to the smart services, but also maintains the connection to cloud systems (see Figure 25). The data gateway makes future expansions or

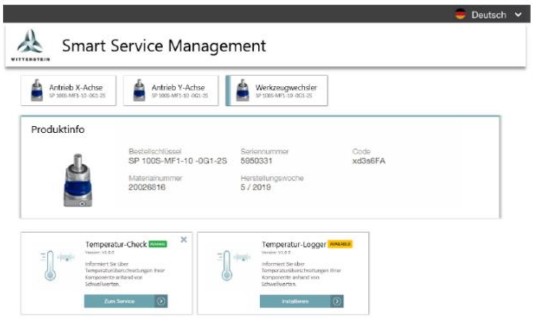


Figure 24: Smart Service Management Front End

step-by-step update scenarios of individual services and smart products conceivable, since they can now be operated decoupled from one another. The project was able to identify three types of alternative, collaborative business models for component manufacturers, which were validated in the use case: Smart Component Provider, Smart Service Provider and Data Driven Solutions for individual problems. The concepts are similar to those shown in Figure 26 - Figure 28.

The first alternative is very close to the existing business model of component sales. However, additional competencies are necessary since drive systems do not usually contain firmware.

In the case of the second alternative, there are special requirements for collaboration in the value network. More trust related to data exchange and understanding of the customer application is necessary. Nevertheless, WITTENSTEIN SE has already been able to serve its first customers in this business model.

The third alternative has not yet been tested, but is similar to WITTENSTEIN SE's solutions business. However, since the solutions relate less to hardware, this model also requires the greatest change, which will run through all corporate processes.

In the course of implementation, a modular architecture was created that can be implemented with the appropriate business model for the individual situation of the users.

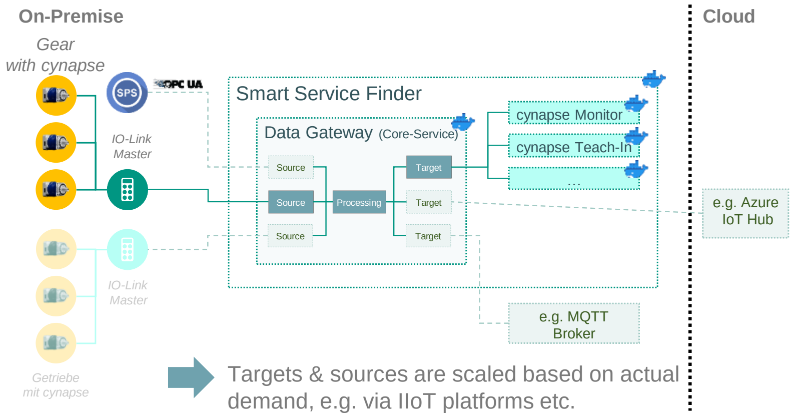


Figure 25: Architecture smart Service Finder

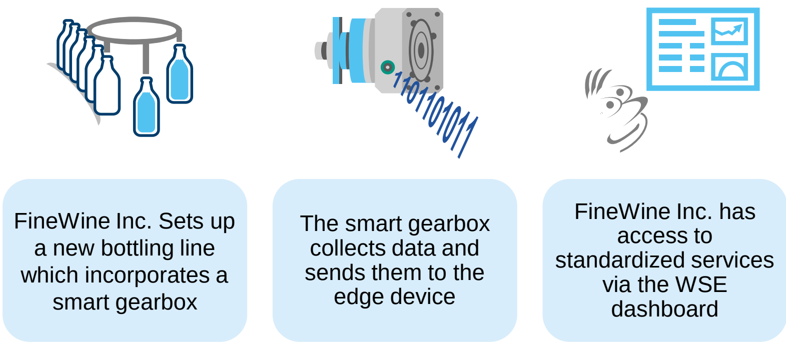


Figure 26: Smart Component Provider

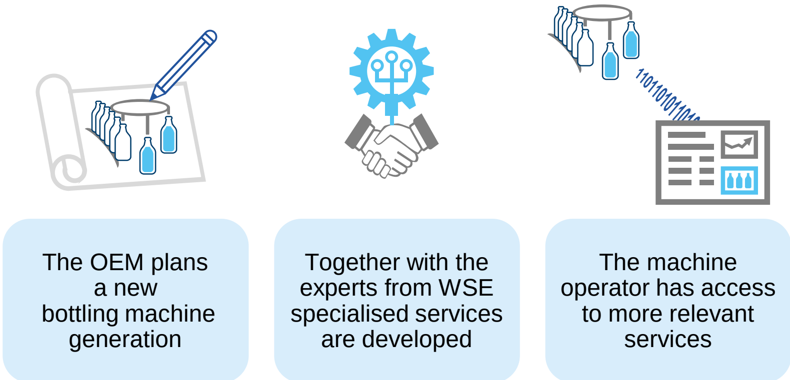


Figure 27: Smart Service Provider

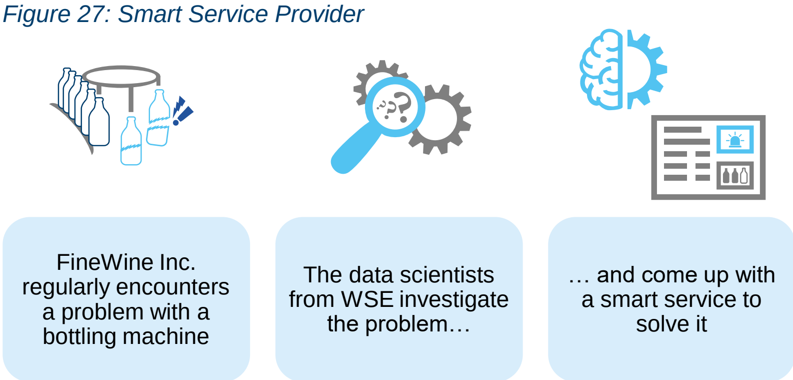


Figure 28:Data-Driven Solutions for Individual Problems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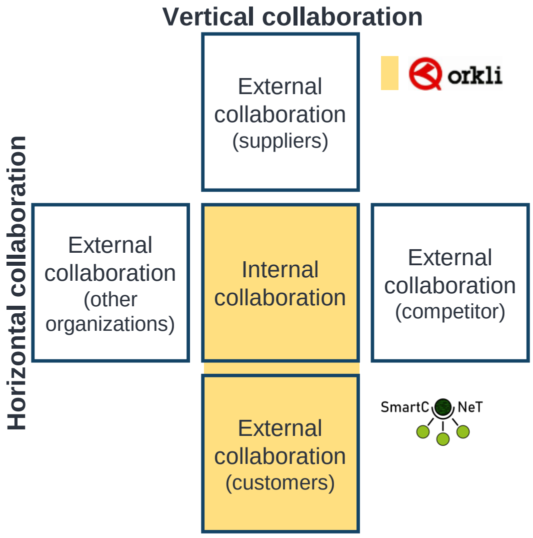
Intelligent Logistics Through Collaborative Data Exchange

Application at ORKLI S. COOP



Use Case Introduction

Orkli, S. Coop - part of the Mondragon Corporation Group - is a company founded in 1982 with approximately 1,000 employees. The company manufactures and distributes components for heating and gas appliances worldwide and is a leader in the field of gas safety. 80% of the production of the company, headquartered in Ordizia, Spain is exported. Orkli has stakes in two Italian companies and owns two other production facilities in China and Brazil.

Orkli's use case relates to the area of procurement logistics in the capital goods sector, where, as in many other industries, there is still very often a lack of data and transparency in logistics processes. A lack of data hinders process optimization and leads, for example, to overload management in warehousing. This is reinforced by growing and increasingly complex supply chains

Phase I Conceptual Design

With an in-house development, the Ekanban system, Orkli wanted to improve the situation for its customers. Data should be generated and shared to redefine the logistics process, reduce costs and establish a direct exchange of information between customers and ORKLI.

The primary goal of the use case was to install a comprehensive solution for supply chain optimization through Ekanban. This solution was to include simple add-on devices with artificial intelligence capable of managing consumption, orders and inventory levels, actively reducing them and eliminating fixed and operational management costs. The KPIs for this project therefore included reducing inventory by at least 20%, reducing delivery times by 5%, improving collaboration between the various players in the supply chain, automating component provisioning, and ensuring smooth production.

SmartCoNeT's practical work has shown that thinking in terms of service-oriented, changing business models helps to discuss specific value propositions for the stakeholders involved.

Orkli's motivation for this use case was to change its business model from a component supplier to a value-added service provider in the area of production logistics.

Orkli's strategy was focused on the scalability and extensibility of Ekanban. Implementing Ekanban in relevant companies means also gaining access to their customers and suppliers. Capturing more consumption events also means that Ekanban can be extended to include a forecasting module as an additional functionality.

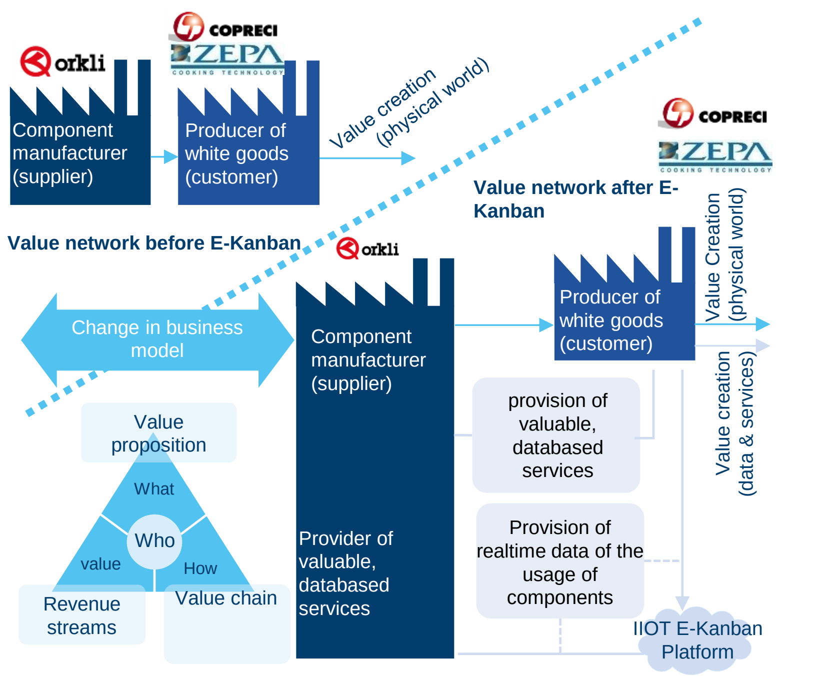


Figure 29: Business Innovation at Orkli

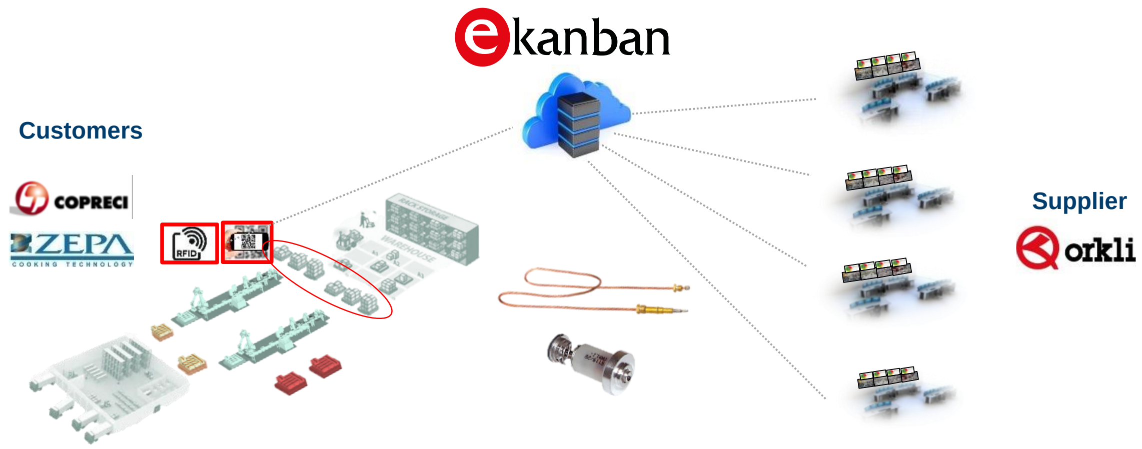


Figure 30: Use Case Scenario for Intelligent Logistics through collaborative Data Exchange

Orkli started the development of the use case with an analysis of the stakeholders involved and their respective roles and needs, in order to develop a solution that would best meet the needs and expectations of the stakeholders.

As a first step, workshops and meetings with the different stakeholders were organized to develop a common collaboration vision or a corresponding use case scenario.

Phase II Concretization

Based on the jointly developed application scenario, Orkli began developing the system model. Excerpts of the diagrams developed in the process are shown and explained below.

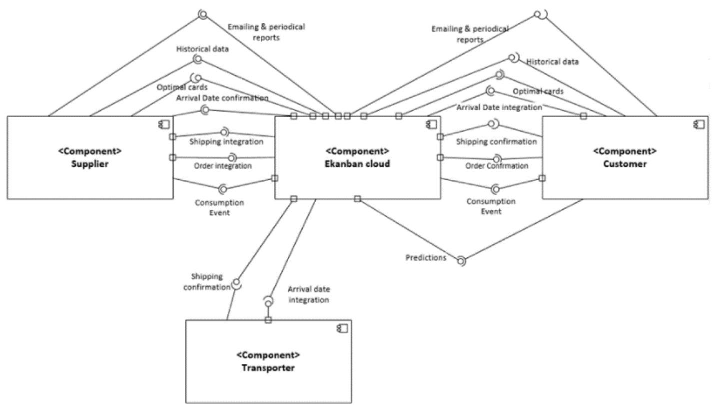


Figure 31: Component Diagram Ekanban

As the **component diagram** shows, there are two main actors in the use case (supplier and customer) and two other important "components" (Ekanban cloud and transporter). Using IoT devices, the customer's consumptions should be captured in real time and shared in the Ekanban Cloud so that both the supplier and the customer can visualize the consumptions in real time. Once the consumptions are recorded and a direct communication and information flow is established between the supplier, the customer and the transporter, the product can be tracked in real time continuously through the Ekanban platform. Thanks to the platform, it is possible to visualize the status of a product (consumed, in production, in transport, in stock) in real time

Moreover, the Ekanban platform offers other additional information and functions, such as historical consumption data, personalized reports, emailing, and an alert system for products that are in an alarm state (e.g. out of stock), as well as the proposal of Ekanban optimization charts.

Through the **communication diagram**, the relevant communication and information flows between the actors of the supply chain (customers, suppliers, transporter) could be represented. The Ekanban cloud is at the centre of communication and data processing.

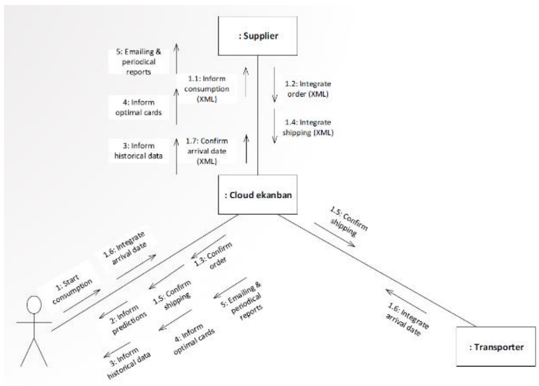


Figure 32: Communication Diagram Ekanban

The **activity diagram** identified the required interactions between the central components.

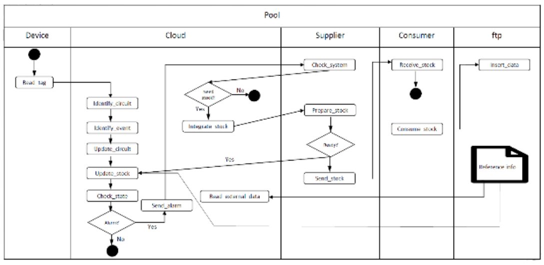


Figure 33: Activity Diagram

Using the IoT devices, the customer is able to share the real-time consumption data with the Ekanban Cloud. The cloud receives and processes the data, providing the supplier and the customer with the necessary information to make the best decision in any situation. For example, the cloud sends an alert email to the supplier when there are signs of inventory shortages. Thanks to this warning, the supplier can react in time and make the necessary decisions to solve the problem, making a new delivery to the customer in this case.

In the **class diagram**, all the necessary data to implement the application scenario were classified (organization, user, circuit, stock_state, card_state, and device), assigned the appropriate characteristics, and related to each other.

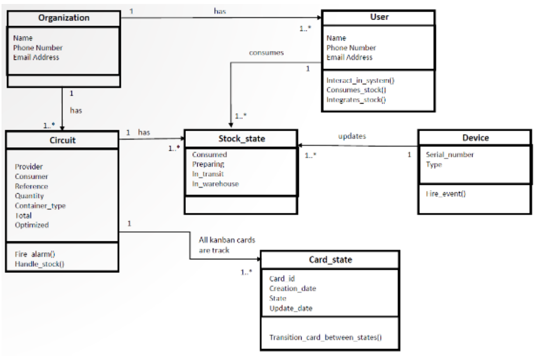


Figure 35: Class Diagram Ekanban

After developing the system model with its four diagrams, the relevant **IT architecture and infrastructure** were analysed.

In the implementation of the Spanish use case, consumption data should be collected in the customer's and supplier's store floor via QR codes or RFID tags and transmitted to the Ekanban database via an IoT gateway. In addition, the carrier communicates to the database via shipping information (in this case, the communication between the carrier and the Ekanban cloud is direct). XML should be used for information from third party systems (MES,

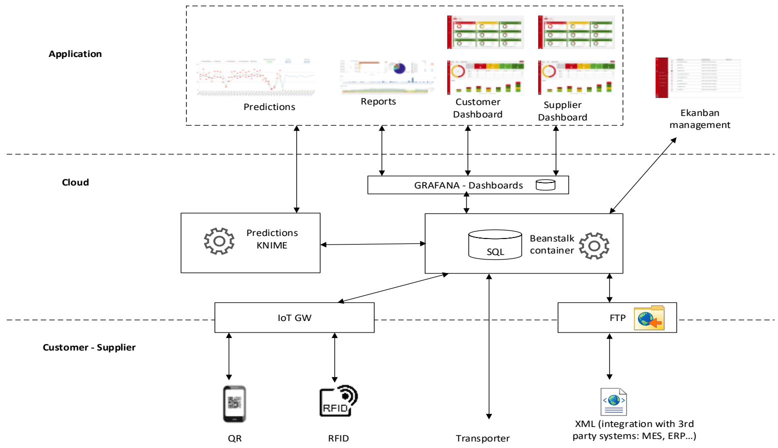


Figure 34: IT Architecture Ekanban

ERP...). Information exchange should be done via FTP or file transfer protocol.

In the cloud-based Ekanban database (Beanstalk container) all data from the customer and the supplier are stored and processed. Once the data is processed and the information is generated, Grafana software is used to visualize useful in information in graphs or dashboards. Using Knime, consumption forecasts are calculated and displayed graphically by applying digital algorithms to the customer's real-time consumption data.

On the application side, various dashboards are used for both the customer and the supplier to present real-time product traceability, periodic reports, and various forecasts, among others. Also, in the management area, users can define and manage the organizations, users, IoT devices, etc. in the system itself.

Based on the identified practical requirements for the implementation of this application scenario, the following tasks were identified:

- Capture consumption data with **simple, remotely controllable IoT devices** using RFID technologies, jointly developed with technological cooperation partner Embeblue.
- Capturing consumption data with the **Ekanban mobile app**, jointly developed and improved with the partner Batura Mobile Solutions
- Development of a new **visualization platform** including a new **security and data encryption system** together with Magnet.
- Analysis of consumption data with new **predictive algorithms**, co-

developed with technology partner Lis Solutions.

- **Testing and implementing** value-added services with two customers, Copreci and Zepa

Good collaboration and communication with technology partners was a recipe for success to ensure proper development of the desired results. Before starting the technical developments, the first step was to specify the needs, expectations and goals of the partners. Using shared Gantt charts and regular meetings, Orkli managed the joint projects. Collaboration, communication and partnership were the most important prerequisites for the successful implementation of the technical achievements.

Phase III Implementation

As part of the project, the Ekanban system was successfully developed and implemented at no less than two customers. This enabled Orkli to successfully change its business model from a component supplier to a value-added service provider in the field of production logistics.

Both pilot customers appreciate Ekanban's intelligent service offerings to optimize the supply chain by controlling consumption in real time and optimizing the flow of information and materials between customers and suppliers in the production network. Initial figures on targeted KPIs show that the Ekanban system is making a significant contribution to supply chain optimization in collaborative manufacturing networks: 30% inventory reduction (originally targeted 20%) has already been demonstrated. The potential is even higher. Another impressive figure is the 75% reduction in urgent material shipments.

The first successful implementations and experiences have aroused the interest of other companies, also from other industries. Thus, several more implementations will follow in the near future. In conclusion, the SmartCoNeT approach has also contributed to Orkli's longer-term goal of targeting customers outside the home appliance industry and generating additional revenue in new markets.

The following is a brief description of some of the technical solutions implemented in the Ekanban system during the project.

Non-Intrusive RFID Device

Orkli worked with Embeblue to develop a self-sufficient, easy-to-implement RFID device that captures 100% of customers' consumption transactions. Since customers often do not want to integrate third-party devices into their infrastructure, it is important that the devices have their own communication network. This allows the devices to warn of malfunctions, and Orkli can remotely communicate with these devices and perform predictive maintenance tasks.

Figure 36: Non-Intrusive RFID Device

Visualization platform with safety system

A dynamic and easy-to-use Ekanban display platform was developed in collaboration with Magnet. Through the platform, customers can self-report issues and have the ability to make changes to their business logic. A panel control makes it easy to make changes or manage Ekanban without having to directly access the database. The platform is hosted in the cloud (Amazon AWS). As a result, customers can keep an eye on their warehouse's key KPIs at all times and from anywhere via the Ekanban platform's business intelligence module (see Figure 37)

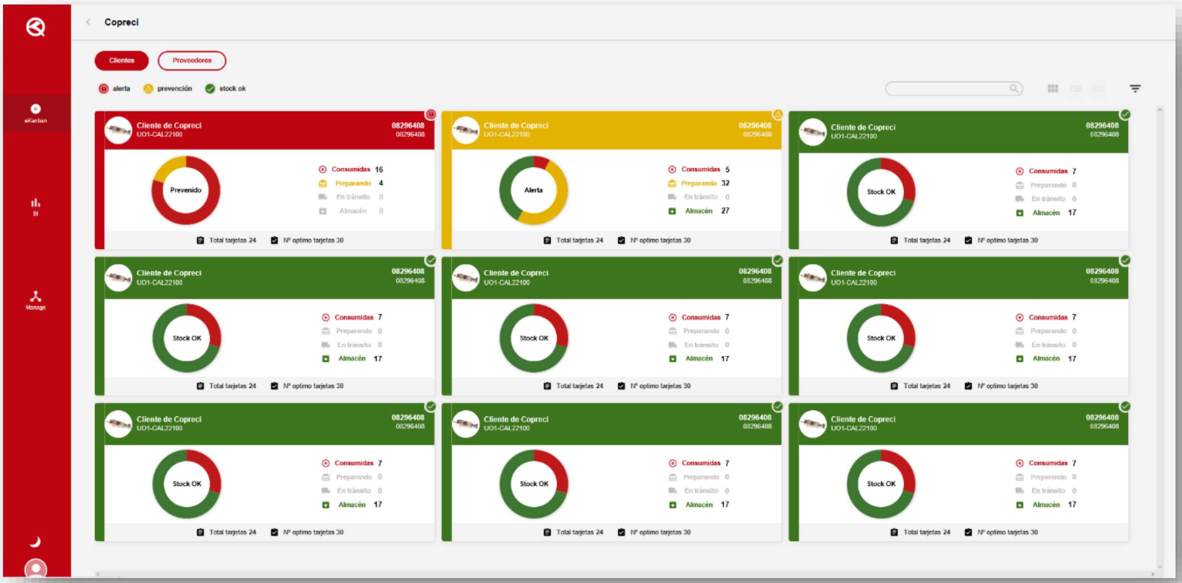


Figure 37: Business Intelligence Module of the Ekanban Platform

Predictive algorithms for consumption

The main objective of the use case was to develop advanced forecasting algorithms to predict customers' future consumption with the highest possible reliability. This gives the company more flexibility and response time. In addition, production planning and raw material purchasing can be optimized, resulting in shorter lead times and higher customer satisfaction.

To develop the prediction algorithms, various classical and novel prediction techniques from time series analysis were considered (Arima, Deep Long-Short-Term-Memory (LSTM), ...). The module was extended in such a way that for each specific use case and customer, the best algorithm to calculate the top prediction is selected, based on the consumption trend that follows each specific item.

After successful testing, the algorithms were integrated into the Ekanban system to store all data and information in a single platform.

Figure 38: Predicting Consumptions in the Ekanban Platform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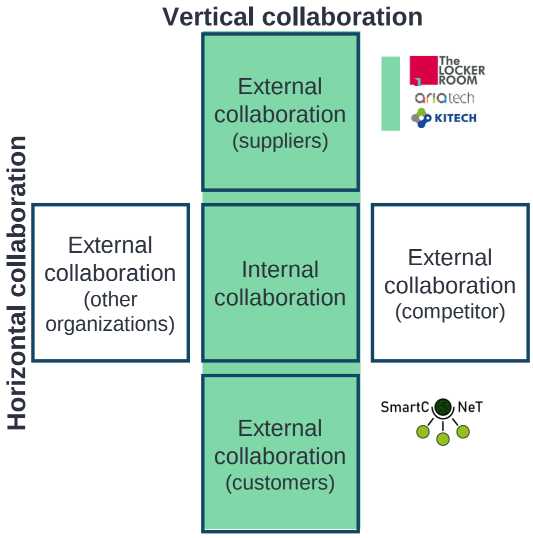
Collaborative Manufacturing of Personalised Sportswear

Application at ariatech Inc.& KITECH



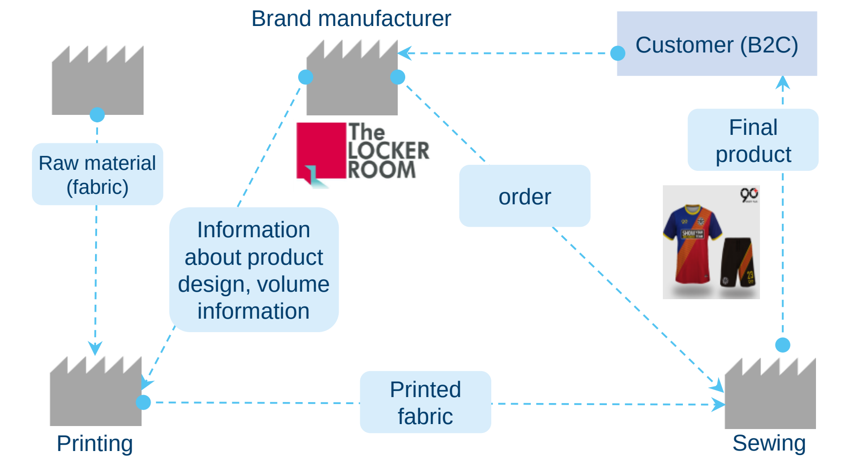


Figure 39: Overview Use Case Personalised Sportswear

Use Case Introduction

The South Korean use case addresses a collaborative value chain in the sportswear industry with a particular focus on product design, material supply, printing and sewing processes. A real challenge in such supply chains is the sharing of production orders and design information created by brand manufacturers in real time. It is extremely rare for process information to be shared between the raw material, printing and sewing trades in real time, making it difficult to accurately control production. As a result, it is difficult for brand manufacturers to expand orders and respond to customers with fluctuating production schedules.

To address such issues, the use case focused on building a cloud platform that collects and shares data across the value chain. The use case aimed to support the integration of product development in the value chain by developing a system for an integrated production system (machine-IoT-MES cloud). The goal was to develop an integrated platform that can be used as a collaboration system for different stakeholders related to the value chain from product development to delivery to the customer (engineer-to-order).

Phase I Conceptual Design

The overall goal of the Korean use case was to improve the overall efficiency of collaborative value creation around the brand manufacturer (The Locker Room), focusing on the value chain for manufacturing personalized sportswear. The brand manufacturer is a company that performs product design with an online shopping mall specializing in customizable sportswear that does not have its own production system.

The collaboration system should therefore include four companies (brand manufacturer, fabric supplier, fabric printer, and sewer) and involve the customers who purchase the final product (e.g., a personalized sports shirt). The collaboration system around the brand manufacturer was to include smart services such as real-time process management and quality management in the sewing industry. Targeted KPIs included line throughput, lead time and capacity utilization, which can be used to evaluate the impact of improved line management. The collaboration vision is shown in Figure 41.

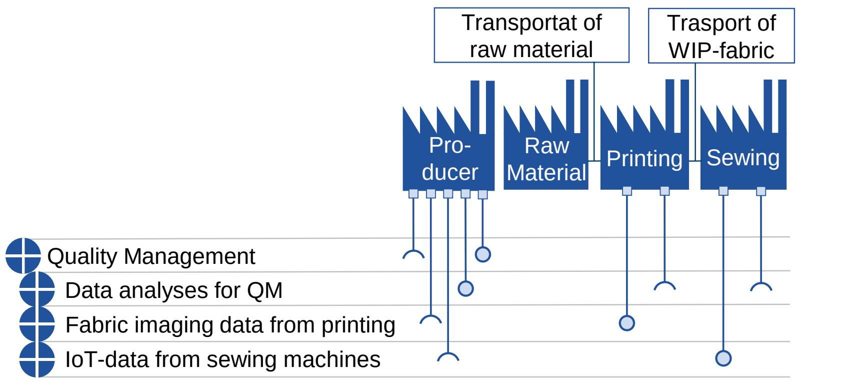


Figure 40: Collaboration Vision Cloud-based Production Control for Personalised Sportswear

Korean partners KITECH and ariatech began development of the use case with an analysis of the stakeholders involved and their respective roles and needs. Production managers and employees of the four companies in the production network were identified as relevant stakeholder groups for the collaboration scenario. Real-time process information (order information) and information on quality issues (especially for the printing and sewing companies) were identified as the main needs of these stakeholders.

Phase II Concretization

Based on the jointly developed collaboration scenario, the Korean partners began developing the system model. Excerpts of the diagrams developed in the process are presented and explained below

"We had no previous experience in creating such system models. Therefore, it took us some time to understand and familiarize ourselves with the model in the beginning. [...] However, after seeing some examples, we realized that the basic system model is quite intuitive and it helps to better understand and visualize the use cases. After creating our own system model, we also found that thanks to this model, we are able to better visualize some of the basics of our case. So we think it's worth spending time on, and it could be useful in other circumstances in the future."

As the **component diagram** illustrates, a total of 6 components are included with the cloud platform as the focal component:

- Cloud - Central Repository Actor where all information about the production process is stored.
- Customer (individuals) - user of the web store who orders products.
- Customer (brand manufacturer) - Actor that instructs the production by confirming the customer order.
- Supplier (raw material) - actor who supplies fabrics.
- Manufacturer (printing) - thermal transfer printing company - actor who receives and prints the fabric.
- Manufacturer (assembly) - actor of the company that performs sewing works after receiving the printed fabric.

Important information exchanged in this collaboration scenario includes raw material information (RMI) of the garment fabric, work-in-progress (WIP) e.g. for garments with sublimation printing or finished goods inventory

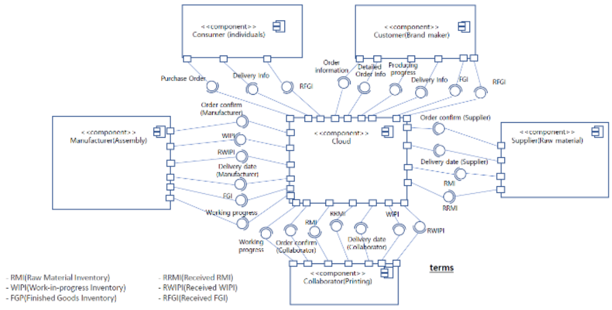


Figure 41: Component Diagram Personalised Sportswear

(FGP) for the garment to be delivered to the customer.

When a brand manufacturer receives an order through the web store, it not only provides a set of information to process the order, but also receives information about the status of goods in and out from material order to production process through the dashboard in real time. In doing so, it is possible to create efficient and flexible production schedules by ensuring the flow of information between companies via the cloud and building a system that can actively respond to disruptions.

In the **communication diagram**, the main information flows were captured. The main communication flow represents the interaction from customer order (individuals) to process-specific production information to delivery.

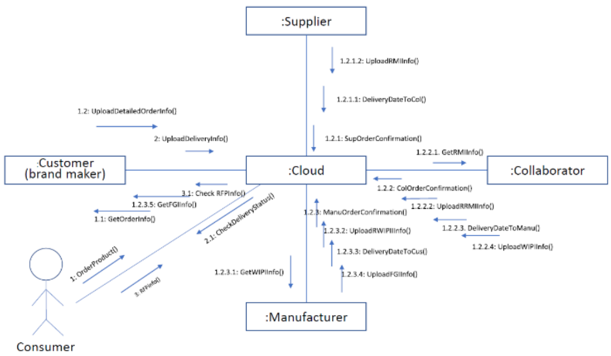


Figure 42: Communication Diagram Personalised Sportswear

The main communication flow of each object is as follows:

1) The customer places an order for a product. Based on this order, the brand manufacturer creates a design proposal and generates order and design information and work orders that go to the collaborating companies.

2) Through the cloud, the fabric supplier checks the fabric order information and completes the fabric delivery

information. The print shop documents the amount of fabric used (including WIP). The sewing plant queries the WIP information and adds its own information on fabric consumption (incl. WIP) and product delivery via the cloud.

3) The brand manufacturer checks the order processing status of each cooperating company via the cloud, checks the product delivery information, and the customer receives the finished product.

An **activity diagram** was used to identify the required interactions between the central components. The data generated by the barcode systems, sensors, and various IoT devices are collected by the cloud system, and the required information is provided to the cooperating companies (see Figure 43).

Through this information exchange, the cooperating companies can easily create and man-

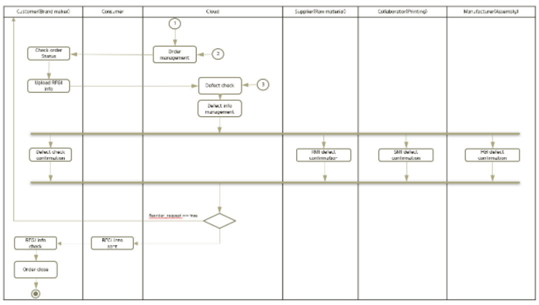


Figure 43: Activity Diagram Personalised Sportswear

age intelligent production schedules. For each order, a status query can be made on the exchanged order, design and process information. Due to the continuous recording of production defects throughout the entire production process, all defects can be corrected by the time the customer orders are completed.

The **class diagram** represents the actors defined in the component diagram as independent classes. In addition, there are classes for order management, classes for defect management, and classes for RMI & WIP defect checking. The diagram was composed by defining exchange data and interfaces between all classes (see Figure 43).

After developing the system model, the required **IT architecture and infrastructure** was analysed.

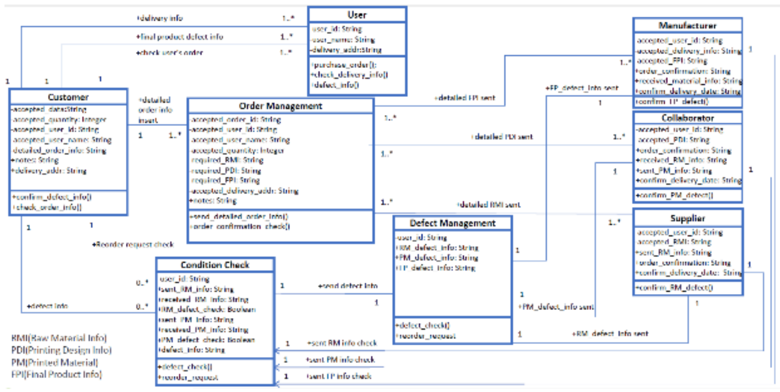


Figure 44: Class Diagram Personalised Sportswear

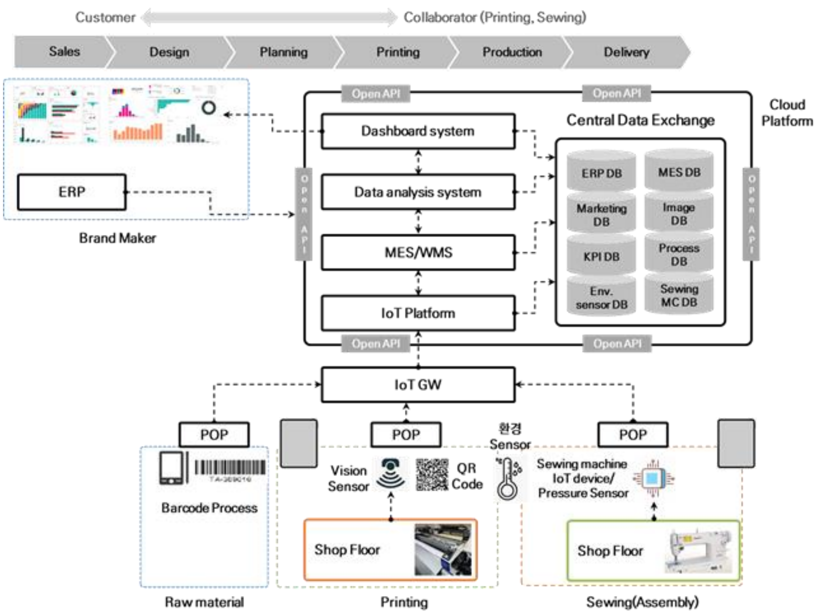


Figure 45: IT Architecture and Infrastructure Personalised Sportswear

To implement the use case, each company needed a traceability system to provide material flow data to the MES system. Information on work performance was to be generated via an IoT device on the sewing machine, information on the status of order processing via the vision sensor (QR code recognition), and information on measurement data via the temperature and humidity sensor, and stored in the database via the IoT gateway. In this process, the MES system must be networked with the ERP system to store customer order information and manage design information and work order information.

A Big Data engine shall provide machine learning-based analytics data, using various manufacturing data collected from IoT platforms. A user interface is to be created for each collaboration partner via the cloud, enabling role-based data processing and management. In doing so, there will be a separation of shared and non-shared information.

The analysis identified the following gaps and practical requirements for implementing the collaboration scenario:

- Integration of order, customer, and product information, as well as information about work orders and quality issues.
- Integration of batch information (QR, barcode, etc.), IoT data from sewing machines, image processing data from printing machines, data from environmental sensors
- Resolving the issue of data ownership (order-customer information management under the Personal Information Protection Act).
- Application-specific solutions for the realization of IoT system, with special focus on sensor integration, barcode system, IoT gateway, IoT platform, MES/WMS, ERP integration, cloud technologies, data analysis engine, etc. (including IT security issues such as channel and data encryption and access control management)

Therefore, the main technical tasks of the roadmap for the implementation of the scenario included:

- Development of a cloud-based MES to support value chain collaboration with Fonetech Inc.
- Development of a sewing machine IoT device for data collection with Ari Info Tech Inc.
- Development of a role-based visualization system with integrated IT security.
- Testing and implementation of collaboration system with The Locker Room Inc.

Phase III Implementation

With the implementation of the collaborative system for efficient production in the textile production network around the brand manufacturer "The Locker Room", the intended goals were achieved: A service for tracking order status was provided to customers. All collaboration partners can now call up the status of the manufacturing process in real time, and order management in the sewing room has been significantly improved.

Initial tests of the developed and implemented collaboration system at the four collaboration partners (design, fabric, print, sewing) have shown that the system fundamentally increases the level of process automation (7 out of 13 product development processes could already be automated). Thus, the efficiency and quality of the process could be increased and the delivery time of the final product could be reduced.

Other companies (one printing plant and two sewing plants) have already connected to the system. It is expected that the number of new cooperation partners will continue to increase. In the future, the developed platform solution could also be used in other industries for more efficient manufacturing in production networks. Some of the technical solutions implemented as part of the project are briefly described below.

Cloud-based MES and mobile work order management system

The cloud-based MES system developed to integrate the "design-fabric-print-sew" value chain consists of system management, standard information, work order management, inventory management and reporting functions. In addition to this MES system, a mobile system with work order management function was developed. This mobile system helps workers in the sewing shop to manage their work orders more easily.

Figure 46: Cloud-Based MES and Mobile Work Order Management System

Data Acquisition System

A data acquisition system was developed to meet the specific requirements in the textile production network. The developed sewing machine IoT device as well as other sensors in the production send data periodically (via MQTT / http) to the IoT gateway, which in turn passes the necessary data to the IoT platform.

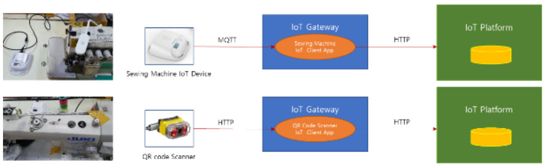


Figure 47:Vertical Sensor Integration into IOT Platform

The data acquisition system is vertically integrated into an IoT platform via an IoT gateway. The server nodes of the IoT platform use Apache zookeeper to coordinate services. The IoT platform cluster requires MongoDB and MariaDB database instances to store the endpoint data.

Figure 48: IOT Platform Based Data Collection System

Role-Based Visualisation System

A role-based visualization system was implemented for the various partners in the collaborative value chain. The role-based visualization system manages the RBAC (Role-Based Access Control) engine, which provides a list of allowed menus based on the specific user role. For example, monthly sales information by product is displayed only for the CEO and brand manager.

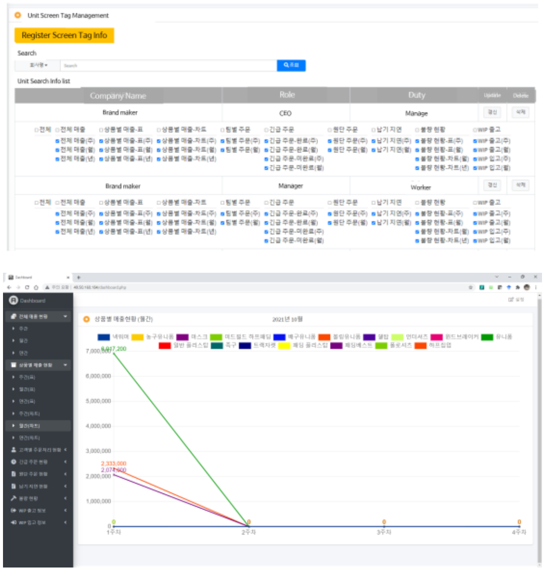


Figure 49: Role-Based Visualisation System

Best Practices – What Makes the Collaboration Successful

The five use cases described represent a cross-section of the broad spectrum of collaborative use cases in various industrial sectors (from the textile industry to mechanical engineering) with different collaboration visions and objectives of the individual partners (from acceleration of production processes to the development of new business models).

A large proportion of the use cases described can be assigned to vertical collaboration between partners along the value chain (see Figure 50), which also corresponds to the current prevalence of collaboration in general practice. Nevertheless, there are also increasing tendencies toward horizontal collaboration between partners, as is also described in the Festo and Munich Re use case. In the case of collaborations with competitors, particular attention should be paid to antitrust law.

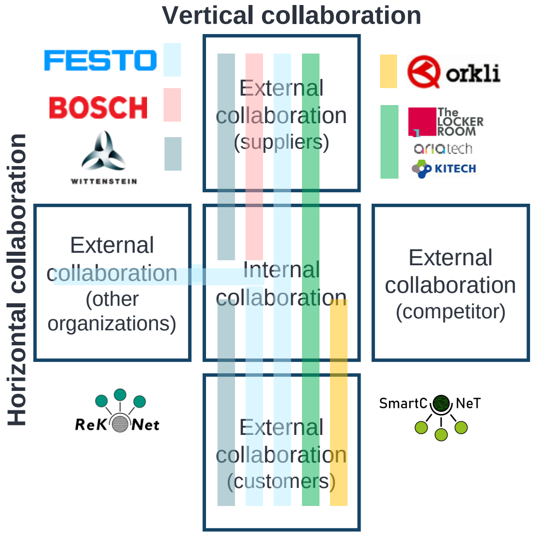


Figure 50: Classification of the Use Cases

Regardless of the type of collaboration, some success factors and best practices for initiating and implementing successful collaborations in production networks can be identified (see Figure 51) [25]:

Trust and goal congruence are the basis for successful inter-company collaboration. It is important from the outset to avoid or reduce information and power asymmetries.

The successful establishment of **long-term collaboration** requires time and a **step-by-step, iterative approach**. Initial small successes - e.g. in a selected area/segment where the added value of collaboration is immediately apparent to all stakeholders - pave the way for more extensive collaboration. This can be seen, for example, in the presented use cases.

Focusing on a few, **carefully selected partners** whose strategic orientation and **corporate culture** match your own company helps to quickly identify collaboration potential and achieve initial success together. Initial projects should be carried out with partners who are well known. Once a collaboration has been successfully implemented, the methods can be extended to other partnerships.

Long-term commitment or the lasting achievement of joint benefits should always be at the forefront of collaboration. Opportunistic behaviour by individual actors should thus be avoided.

Successful collaboration with external partners is based on an **open collaboration culture within the company** (no "silo mentality"). Without transparency, communication and cooperation within the own companies there is no successful collaboration between the companies.

Successful collaboration builds upon the **existing strengths** of the individual partners, which ideally **complement each other**. In this context, it is important to know the needs of the respective partners precisely in order to be able to use the existing competencies in a targeted and effective manner.

Continuous, flexible and transparent **communication with all partners** prevents misunderstandings and mistakes. Joint project teams or auxiliary tools such as the **system model** for the joint concretization of the **collaboration vision** or the required specifications are suitable for discussing and communicating with each other in a targeted manner.

The success of collaborations is a work of many hands and depends on the personal commitment of the people involved. That is why the development of a **shared culture of trust and openness** between the organizations and individuals involved is a key driver of problem-solving and innovation capability in the context of collaboration.

In the following chapter, some of these topics are further explored and concrete tips and tricks for implementing collaborations in value networks are presented.

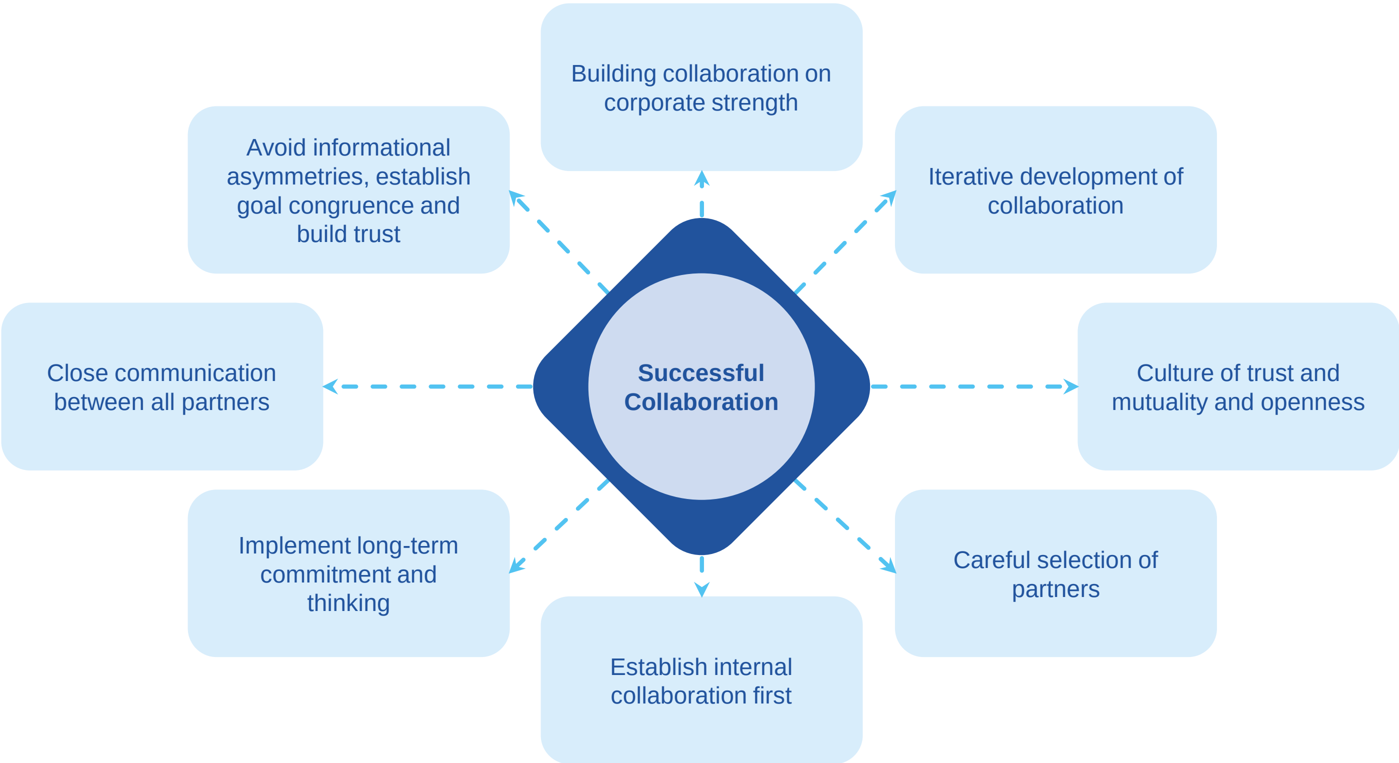


Figure 51: Determinants of Successful Collaboration (see [25])

Best Practices – Collaboration Champions Love These Simple Tricks

Based on the lurid titles from the digital media, we want to share with you, completely without paywall, the most important tips and tricks that you should consider when successfully implementing your own collaboration project. The tips are intended to provide a brief impetus in each case. More information on the respective content can also be found in the linked ***GitHub Repository***, for example, a comprehensive analysis of data privacy in collaborative production networks.

The Collaboration Vision is the First Step

Due to the many areas that a collaboration usually touches, such as purchasing, sales, engineering, IT, a team behind it is equally diverse. Consequently, a central task is to establish a **common understanding of goals** between all participants, which provides the necessary foundation. This is the purpose of the **collaboration vision**. It is important to note that planning a collaboration project according to the waterfall model cannot succeed. The final interaction at the beginning of the endeavour is too uncertain. Consequently, the collaboration vision is not a one-time thing, but a living document that needs to be constantly updated as the project progresses. This ensures that all partners remain synchronized on the essential points. The collaboration vision can also serve as a basis for discussion in order to critically question and adjust various aspects of a collaboration project [26].

The format of a collaboration vision can take many shapes. In the context of the ReKoNeT research project, one form of representation was elaborated, an example of which is explained below [26]. Two basic ideas were central in the development of the representation form: First, it should be based on known modelling forms, as far as this is helpful. However, in doing so, a certain degree of clarity should also be provided. An example for a descriptive symbol is the factory symbol. The second basic guiding principle was to choose the representation form in such a way that an organic growth of the collaboration vision is possible.

It should be noted, however, that too extensive a representation within the collaboration vision can also be a hindrance.

Figure 52 shows the result of the considerations [26]. This is an abstract example. The collaboration vision starts at the top of the figure with the high-level representation of the value chain. The central actors are represented by factory symbols and named. Below that is the interaction logic. The first path of the interaction logic is the collaboration target. All further paths are subordinated to the collaboration target. Each path represents a building block for implementing the collaboration goal. With the help of the continuous sub-ordering of paths, an arbitrary splitting and concretization of the individual interaction modules can be formed. It is up to the collaboration team to find a suitable subdivision. However, as already mentioned, the scope can also become too large. One suggestion is to use differently detailed sections of the collaboration vision for different levels of discussion.

In addition to the trajectories, it also shows who takes a taker role and who takes a giver role. This explicit representation forces the team to discuss who benefits directly from individual building blocks and who mainly has efforts. It is possible to leave the first lane, the collaboration goal, free of roles.

In addition to the overall representation, it may be helpful to create a fact sheet for each lane to support further elaboration.

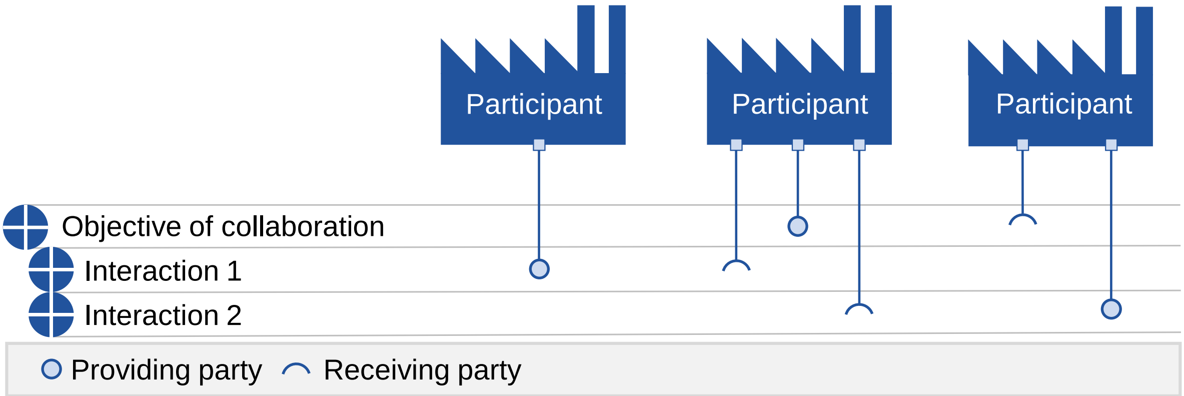


Figure 52: Schematic Structure of the Collaboration Vision (see. [26])

Models for Collaboration Create Structure and Improve Communication

As vividly explained in the use cases, the **system model** as a central planning tool is the **heart of the concretization phase**. The abstract representation of processes, data and responsibilities creates **transparency**, a **common understanding** and **commitment** about the collaboration use case among all partners involved. In addition, the system model enables people from outside the field to understand important issues and discuss them during the concretization and implementation phase. For this reason, it is advisable for a consortium willing to collaborate to convert the collaboration vision into a first draft of the system model right at the beginning of the concretization phase [26].

By illustrating the details of related processes in a simplified form, the system model not only creates a common understanding between the partners, but also supports the **design and documentation of the ideas**. The system model shows the nature and interrelationships of the processes by describing all collaboration-relevant components, such as companies, machines or IT infrastructure elements, in sufficient detail. On the other hand, it visualizes the mutual interactions of these components, which take place in the form of transferred data and/or materials.

The system model supports the later phases of the project with further submodels specialized on the relevant issues. In this way, the system model continues to develop and, in an iterative procedure, captures more and more sub-aspects that, taken together, abstract the system as a whole. The focus throughout is on highlighting use case-related data. This means that all submodels united make visible which data is shared at which points in time, how it is used, for whom it can be viewed, and which decisions can be derived from it.

The properties of different views of the system model are explained below (see Figure 53) [26]. It makes sense to model the system model with UML. Thus, an appropriate diagram type is given for each view.

The **structure view** shows all components including their relations among each other. Components are parts of the entire system that make a relevant contribution to the collaboration. This includes, for example, acting actors, companies, machines or even cloud systems. The structure view is visualized with a **component diagram**.

The **behaviour view** represents the sequential communication among the components already described in the structure view. It highlights the initiators of a communication and shows all possible decision paths in the communication process in the further course. The behaviour view is visualized with a **communication diagram**.

The **process view** describes the internal behaviour of a single component or a group of components. It represents an essential extension to the structure and behaviour view, since it shows in detail the course as well as the causalities of the collaboration-relevant processes. Important elements of this view are decision paths, termination criteria, bifurcations and mergers. The process view is visualized with an **activity diagram**.

The **class view** is a concretization of the structure view and describes the data used for collaboration. It includes the classes of data necessary for collaboration, their characteristics, and the relationships between them. In principle, the class view can be used to discuss various issues, for example, to clarify data protection issues. The class view is visualized with a **class diagram**.

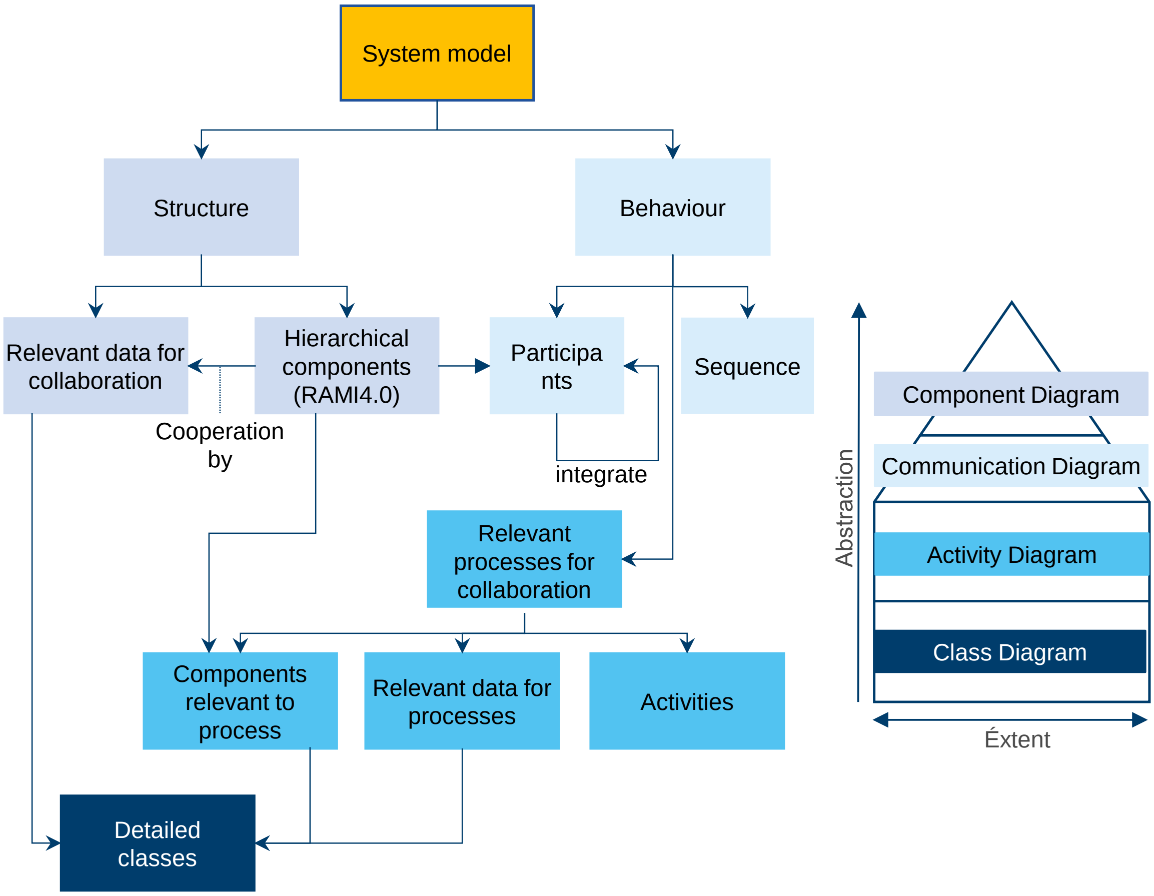


Figure 53: Representation of the Different Views of the System Model to Illustrate the Interaction Between the Different Diagrams (see. [26]).

These Standards are a Must-Have for Collaboration

Standards create a common basic understanding and provide a stable core for innovations. The Reference Architecture Model Industry 4.0 (RAMI 4.0) is a three-dimensional map that describes a structured approach to the topic of "Industry 4.0". It ensures that all industry 4.0 participants understand each other and can communicate efficiently in this way.

Within the RAMI4.0 cube, "preferred standards" are located that have proven themselves in both the German and international context. Not only data formats and communication protocols are considered, but also, for example, legal aspects or system and role understandings of individual actors. Collaboration on the basis of this regulatory framework thus frees up resources for actual value creation and innovation.

Must-haves from this research project are:

- The separation of field devices, edge devices and cloud or IT.
- The management shell as a standardized digital twin
- OPC UA as the information carrier for communication during the usage phase of a smart device. Both as client/server and pub/sub via MQTT architecture.
- DIN SPEC 92222 "Reference architecture for industrial cloud federation"

Identify Collaboration Obstacles at the Right Time

Actively addressing collaboration obstacles and overcoming them is crucial for the successful implementation of a collaboration project. This chapter therefore presents a workshop concept that has been tested in the project. This workshop concept is intended to help you identify the potential obstacles and risks of your own collaboration project so that you can subsequently eliminate or at least minimize them. The workshop concept is shown in Figure 54.

First, known collaboration obstacles and risks are presented in a keynote speech. To create a general awareness, these should be explained in detail at the beginning of the workshop. Also, the background and interrelations should be addressed. This is followed by a repeated discussion and collection of possible collaboration barriers and risks that need to be overcome in one's own collaboration project. In the process, the focus is sharpened more and more. In order to remain as open-ended as possible, everything that comes to mind should first be mentioned in the sense of brainstorming.

In a first step, general obstacles and risks that apply to the **type of collaboration** project should be discussed. In a joint product development project, for example, aspects of trade secrets protection will be more important than in the exchange of order-related data. In the latter, on the other hand, there may be reservations about shared information being opportunistically misused for subsequent price negotiations.

The next step is to sharpen the focus and change perspective from the general nature of the collaboration project to the **specific business relationship**. Based on the joint **collaboration vision**, there should be an intensive discussion of the specific obstacles and risks that could arise in the collaboration project.

The final step is to further **specify and localize the potential problems**. The **system model** is used as a tool for this purpose. On the basis of the concrete information flow and material flow the obstacles and risks identified so far are localized concretely and assigned to the respective components. In addition, this step can also identify other potential problems that have not yet been identified in the higher flow levels.

Subsequently, the collected obstacles and risks are summarized in a list and evaluated with regard to **relevance, criticality and probability of occurrence**. Based on the prioritized list of collaboration obstacles, targeted solutions can be developed in the further course of the collaboration project.

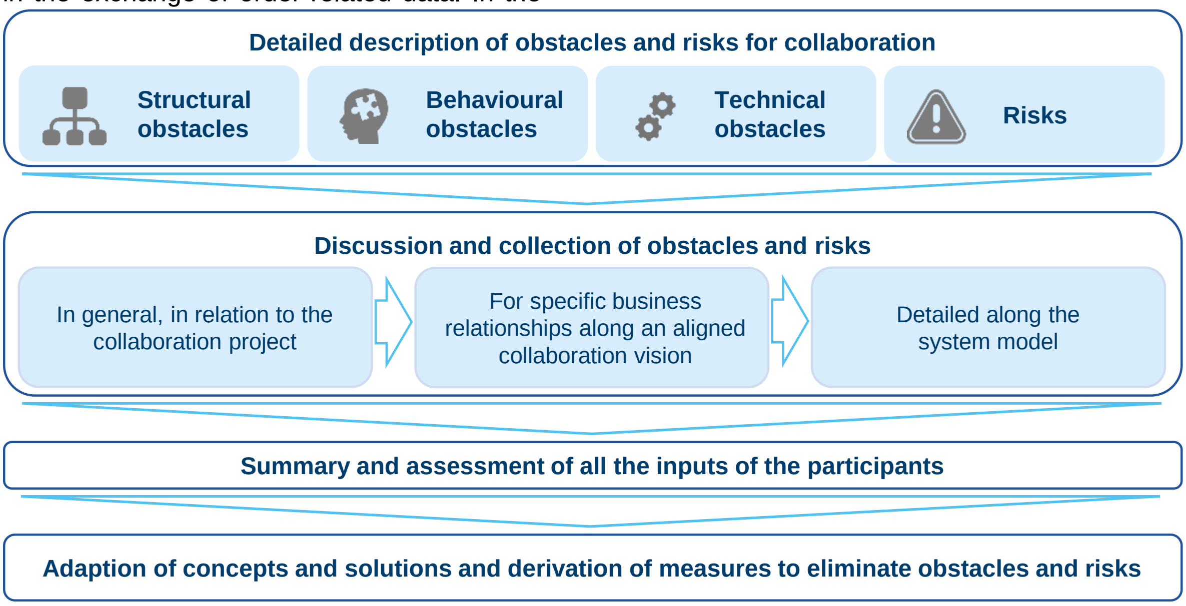


Figure 54: Workshop Concept to Identify, Localise an Prioritise Obstacles and Risks of a Collaboration Project

Trust Issues can be Resolved

Having systematically identified the potential obstacles to collaboration, it is of course even more important to solve them. An important point in collaboration projects is the creation of trust and goal congruence in order to prevent opportunistic behaviour.

There are many ways to do this. An important success factor is open communication. However, many reservations and concerns can and should be addressed, especially with clear contractual provisions. On the one hand, this includes confidentiality agreements to ensure the protection of trade secrets. On the other hand, incentive systems or bonus systems should also be laid down, for example for the sharing of effort and compensation payment of collaboration profits. For these topics, it is advisable to involve the relevant legal departments and specialists at the right time during the concept phase.

In addition to these trust-promoting measures, in this tip we would like to additionally discuss other solutions that can be used to secure trust issues technologically or by third parties.

Risk Management Solutions for AI Models

Through digitalization in general and data acquisition through sensor technology in particular, relevant process steps in production and collaboration projects are being taken over by artificial intelligence (AI) and machine learning. These applications hold enormous potential for accelerated processes, cost savings or increased result quality. However, the risk of error posed by AI also creates new risks that require targeted risk management.

In operational risk management, the decision must be made to develop an AI model in-house or to purchase it. In-house development offers full control and transparency - but requires the necessary expertise. Risks of external models can be reduced by detailed examination and test phases. However, as explained, the risk of errors through AI cannot be completely eliminated.

AI providers usually pass on the risk of a high error rate to their customers because they contractually exclude liability for errors made by the AI. However, more and more companies are offering a targeted performance guarantee in addition to their product: This involves making a promise about the accuracy of the model. If the promise is not kept, the AI user receives a contractually defined financial compensation for the damage. The AI provider can insure such guarantees in the background in order to be able to provide sufficient capital in the event of a claim.

This constellation combines the AI service with a risk transfer. It provides financial security for the AI user. This security can be used by the AI provider as an additional selling point for its AI product, as it represents a hedge of the investment for the AI user. For the AI provider, the promise offers the advantage of an accelerated rollout through shorter test phases.

For the risk analysis, some information is needed: Detailed insight into the AI development, monitoring and update processes. For example, how representative the training data is and how its quality is ensured is crucial. Another criterion is previous empirical values, e.g. performance figures from models rolled out in the past.

Insured performance guarantees specifically for AI models can be applied in almost all industries and AI processes. For a successful risk analysis and economically viable deployment, the AI model should already demonstrate a certain robustness, be used in an application with frequent use, and pose a financial risk to the user in case of underperformance. If this is given, the decision for the appropriate AI provider can be simplified by an insured performance guarantee and the expected financial benefit of the use of AI can be protected.

Data Security – Your Constant Companion

When opening up IT systems as part of a collaboration project, you open yourself up not only to trusted actors, but potentially to untrusted ones as well. New interfaces to the outside world are opened and systems that previously ran purely internally now also communicate with external systems.

With these changes, it is important to recognize the impact on IT security and use appropriate measures to ensure that the system can maintain the security level. The concepts and technologies presented are continuously updated and secured against new types of attacks, for example. Once a data security concept has been created, it should therefore be re-evaluated at regular intervals and adapted if necessary. This applies in particular to specific technologies and products,

For the practical realization of a secure, i.e. integrity-protected as well as confidential, exchange of data, it is crucial to weigh the costs and benefits of a measure against each other. In a separate guide, which is provided on the ***GitHub Repository***, various methods are explained that make it possible to list threats and categorize them according to their severity.

To begin with, the threats need to be listed. It is important here that an enumeration of the assets worth protecting exists as a result. These may include production output, corporate reputation and intellectual property. Initial possible attacks on these assets worth protecting should also be identified. These include denial of service attacks, data tampering, data spying and other attack targets.

If threats and the architecture of the system are known, so-called attack trees can be created in order to visualize various attacks and determine their probability of occurrence, as well as to define countermeasures if necessary. The goal of attack trees is also to describe in more detail the still rough attack ideas from a more unstructured point of view. This also implies a detailed overview of the techniques used in an attack. Only on this basis can suitable protective measures be recommended or implemented.

Different attacker models can be distinguished. An attacker model is an abstract definition of an attacker type, on the basis of which attacks can be identified and modelled in detail, and corresponding protective measures can be evaluated. Archetypal attacker models can be attackers from the Internet, attackers from partner companies, attackers from your own company or state attackers.

These different attacker models in particular make it difficult to make blanket statements. For example, for the secure exchange of data between two companies via the server of a cloud storage company, all data does not necessarily have to be encrypted end-to-end, provided the storage provider is trusted with regard to its own organizational capability for data security. However, if the provider is classified as untrustworthy or if the company wants to protect itself against an attacker compromising the cloud storage provider, end-to-end encryption cannot be dispensed with.

In the context of collaboration, it may be necessary to make calculations based on data from several participants. However, some of this data is not intended to be shared. Here, there are two ways to compute functions without the other participants gaining knowledge of the data. Multi-Party Computation (MPC) is a cryptographic paradigm whose protocols ensure just that. However, implementations of MPC protocols are not yet practical in many cases, which is why we want to present here another possibility based on Trusted Execution Environments (TEEs). The use of TEEs makes it possible to create isolated sections, called enclaves, within the computer. The identity and integrity of the code in these enclaves can be verified, but the processed data cannot be read. Examples of TEEs in modern processor architectures include Arm TrustZone and Intel SGX.

Data Privacy is not an Obstacle to Successful Collaboration Projects

Understanding data protection aspects as non-functional requirements that must be considered from the outset when developing a system is an important first step toward meeting the complex requirements for implementing data protection obligations in a targeted manner. If one considers that the general data protection requirements to be met in an industrial company have already presented many companies with major challenges in some cases since the General Data Protection Regulation (GDPR) came into force, it is easy to imagine that these challenges will only become greater as a result of the increased use of IT in the course of current digitization efforts. Recognizing that data protection need not be an obstacle or an impediment to adopting novel approaches and using technologies previously unheard of in these areas is elementary.

Processing personal data in a corporate context when planning, developing and implementing a collaboration project is possible and requires prudent and forward-looking planning. Like any other introduction of processing with personal data, a certain lead time and the involvement of central departments as well as the respective functional managers is required. This ultimately ensures that a system that has been developed and put into operation can ultimately be operated in compliance with data protection law and that time-consuming and cost-intensive rework can be avoided in later use.

Before starting to plan the implementation of data protection requirements, it is first necessary to obtain an overview of the type of data that is to be processed and the planned data flows. What initially sounds like a trivial requirement turns out to be a complex undertaking upon closer examination, because this initial inventory serves as the starting point and foundation for all further measures to be initiated.

In any collaborative exchange of personal data, the question of necessity must also be asked. This follows from the principle of data minimization. Already in the design of technical systems, the processing of personal data should be limited or avoided altogether. Technical options such as anonymization could help to optimize processes with operational data without running the risk of endangering the rights and freedoms of employees by processing personal data. In addition, data protection law is not applicable when anonymous data is used.

As a practical tip, we recommend a systematic, structured approach to determining the types of data and data flows as the basis for an iterative process of specifying legal requirements. The developed system model can serve as a starting point for this.

Carefully document all data processing procedures relevant to data protection. A data privacy management system is a basic requirement of any corporate data privacy organization. Processes created by the collaboration project should be integrated into existing data protection policies. It is crucial to involve the relevant departments and contacts of the companies involved in the project team early on at the beginning of the concept phase.

The linked ***GitHub Repository*** contains a very detailed guide that supports decision-makers in companies so that a system can ultimately be operated in compliance with data protection law.

Business Secret Protection as Non-Functional Requirement

In addition to data protection, the protection of trade secrets may also be affected by collaboration in value networks. Overlaps occur when trade secrets are also related to individuals. Organizational and technical protection measures then fulfil a dual function, since trade secrets by definition require appropriate confidentiality measures [27].

The protection of personal data is subject to data protection law and imposes binding requirements on data processing in the context of collaboration formats. The protection of company-related data may be in the company's own interest in order to prevent valuable know-how from being disclosed to the outside world. In addition, contractual obligations may make it necessary to protect the trade secrets of third parties. Both aspects should be considered from the outset when designing collaboration in production networks so that they can be successfully implemented in practice

Similar to the approach in data protection law, a structured procedure is recommended to identify relevant data and categorize them into protection classes depending on their need for protection. This is because, comparable to the risk-based approach in data protection law, a relative standard also applies to the protection of trade secrets. Especially in the case of extensive data exchange in the context of collaboration networks, blanket classifications should be avoided because they lack the necessary differentiation and there is a risk of "dilution" of the protection of secrets. The latter is to be feared if, due to a lack of acceptance among the ranks of employees, the necessary due diligence diminishes.

Consequently, with regard to the protection of personal data and the protection of trade secrets, there is a need to sift through data flows, to determine personal preferences or confidentiality interests and to initiate appropriate measures. Suitable protective measures can be taken at the organizational level, the technical level and/or the contractual level. As a rule, a combination will make sense.

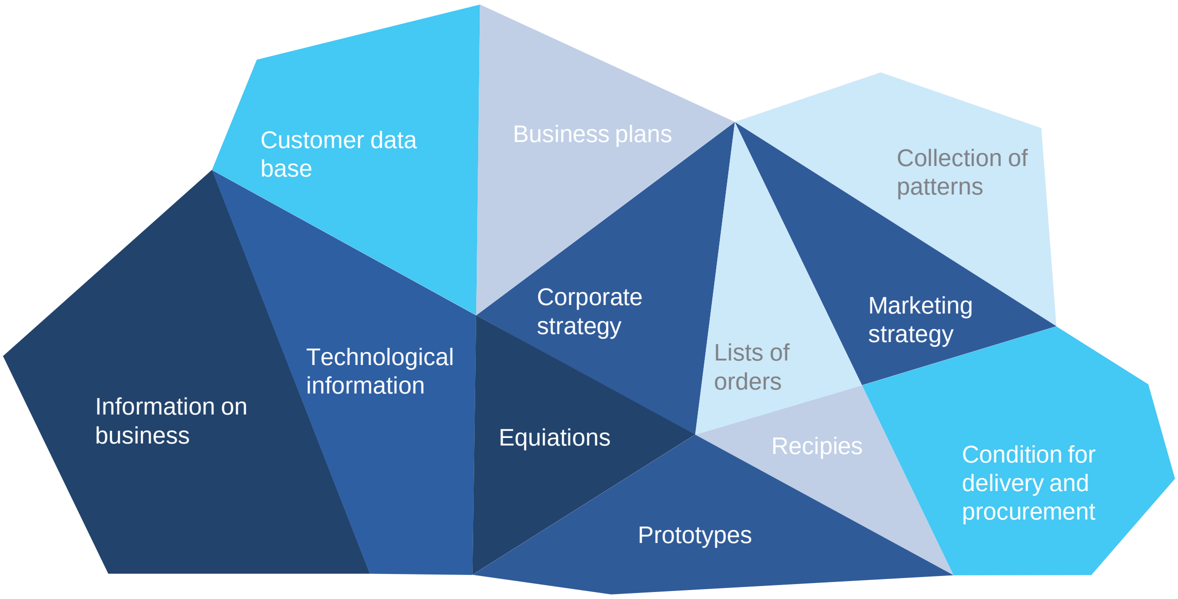


Figure 55: Examples of Trade and Business Secrets

Trends and Technologies for Business Success!

Industrial Digital Twins

A key technology for successful collaboration in Industry 4.0 is digital twins and the associated paradigm shift for handling data. In many companies, there is no transparency about today's data basis, as much data is distributed throughout the company and is only used singularly (silo effect). The lack of a process-based view of data across business units, deficits in data quality and a lack of interoperability also make data use more difficult. Within individual companies, therefore, great efforts are being made to create "end-to-end complete systems." Although this solves the data problems internally, it comes up against its limits when it comes to collaboration across value-added partners, or even creates barriers here if a large number of "end-to-end overall systems" are to be interwoven.

With the concept of a digital twin, all relevant data, models and process steps are broken down and described for a single asset (e.g., a product). The digital twin is thus empowered to talk to IT systems, manufacturing machines and other digital twins and to guide business processes. Cross-cutting and semantic data models in terms of the management shell play a prominent role in creating the necessary interoperability. Organizations such as Plattform Industrie 4.0, VDMA or ZVEI on a national level and Gaia-X and Catena X on a European level provide the framework for achieving the necessary interoperability.

Artificial Intelligence (AI)

AI can make operations and processes more dynamic, flexible and efficient, thus increasing value creation. In the use cases highlighted in this research project, data analytics and AI find selective application on limited data sets and often on-edge, close to the sensor. However, the tools developed to date in data analytics and AI are being taken to a new level, through digital twins and the accompanying data economy, and can be used in increasingly scalable ways. In a future successful collaboration, where AI is not only used selectively, it is thus not only trust in the partner that is crucial, but also trust in the transparency, robustness and accuracy of AI systems.

Product Development in Ecosystems

Interwoven business processes, data exchange and networked AI systems also lead to collaborative product development and use. Products are no longer developed from a single source for one purpose, but can be individually optimized in their further lifecycle through functional extensions in the digital twin or with new AI algorithms

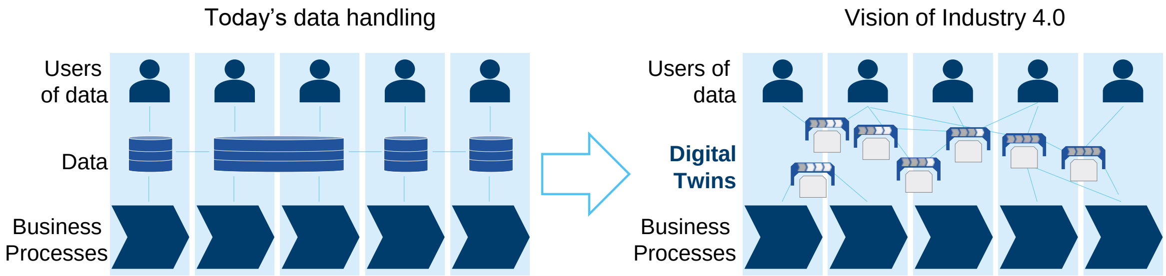


Figure 56: Key Technologies are Fuelling a Paradigm Shift in the Handling of Data (WITTENSTEIN SE)

We do it with the Cloud!

Within the research project, cloud solutions were used in every use case, so it can be named as a building block for successful co-operation.

Cloud computing is the transfer of data and programs to computers of remote service providers in order to use their infrastructure and services based on it. Particularly for cooperation in value networks, which always means the transfer of data and the use of programs outside one's own organization, the use of the "cloud" is unavoidable according to this previous definition. The further differentiation as to whether private, hybrid or public cloud and which applications based on it are used must be established as a framework on the basis of the jointly defined requirements between the cooperation partners. The selection of the appropriate mix of cloud computing resources and offerings then takes place on the basis of the framework. If the required cloud computing resources and offerings are not already provided by one of the cooperation partners, it is advisable to involve another partner.

With the optimal mix of cloud resources, at least as far as the technical basis is concerned, a fast, high-performance and stable implementation can be achieved at lower fixed costs. However, the connection of the cloud resources for transferring the data can prove to increase complexity and drive up costs. The framework for using cloud services should therefore always consider the existing IT enterprise architecture and integrate the cloud service into the business processes and IT systems with the aid of a clear interface description. In addition to the transfer of data, consideration should be given to integration into a company's user management for authentication and authorization within the cloud service in order to manage access to data and programs.

Platforms provide a uniform basis for cloud resources in order to map their application more easily and more scalably. Platforms allow integration efforts to be performed once and then used for all resources on the platform. The IT interface, user management or billing mechanisms are thus only set up once and can then be used easily in the future. Platforms thus counteract the increase in complexity and can be included in the framework for the use of cloud services as a requirement to set up collaborations even faster and more scalable.

It can also be observed that platforms and frameworks for collaborations are already forming in a larger context, such as that of the European economic area (GAIA-X) or the automotive industry and its suppliers (CATENA-X). GAIA-X has created a sovereign data and service ecosystem within which stakeholders have already agreed on a framework and common ground. The same applies to CATENA-X as a cloud for the automotive industry and its suppliers. Integrating one's own cooperation project into existing (cloud) platforms thus enables easy transfer to other partners.

"We're doing it with the cloud!", can be confirmed as a target-oriented approach on the basis of the implemented use cases in this project and also transferred to further co-operations. To illustrate and conclude this best practice tip, some of the implemented use cases are presented:

Source data in the ERP system in the private cloud of a partner is transferred via an "Integration Hub" to the "Zero Defects" application in the public cloud, which is crucial for the collaboration.

On-edge applications process data from smart products and forward it to an analysis tool in the plant operator's private cloud and additionally to the manufacturer of the product via the public cloud, which in the collaboration increased plant availability.

A data catalogue as a platform in the private cloud enables scalable access by a large number of applications.

Artificial Intelligence and the Role of Domain Knowledge

A major challenge of any collaboration can be the operational organizational overhead, which calls into question the added value of a collaboration. However, due to increasing digitization and advances in artificial intelligence (AI), we see a turning point coming where, in the assessment of many projects, the end result is a positive one. This development is also clearly reflected in the use cases described earlier, in which the use of AI has led significantly to success.

The range of use in the context of collaboration is wide here. In addition to aggregating and processing necessary data, AI offers possibilities ranging from individual decision support, to predicting product quality, to autonomous markets with smart contracts.

No matter how the use of AI is planned, our experience in the ReKoNeT and SmartCoNeT projects has shown that a key building block for successful implementation is domain knowledge. This circumstance should be a relief for both large industrial groups but especially for small and medium-sized enterprises.

However, the question now arises as to how a meaningful use of AI can be approached in the context of a collaboration - Because domain knowledge alone is not enough. What is clear is that the necessary expertise from the fields of data science and software development must in principle be available in the collaboration team. To this end, the companies involved can either provide corresponding employees or appropriate service providers must be included. Assuming this starting position, the following explanations are intended to help structure the further procedure and raise awareness of topics that experience has shown to quickly fall out of focus.

At the centre is the white box model, which has emerged from the findings in the course of the ReKoNeT project (see. Figure 57). The model places itself temporally after the creation of the collaboration vision and before the implementation of the collaboration system. In between, there are four understandings that need to be built during implementation. Thus, it is applied in the concretization phase and is supported by the system model. The model extends known data mining process models (cf. CRISP-DM) by a collaboration understanding (extension business understanding) and by the incentive understanding. The latter aims at making the motivation of each partner transparent. The understanding and transparency created also support overcoming the identified collaboration barriers.

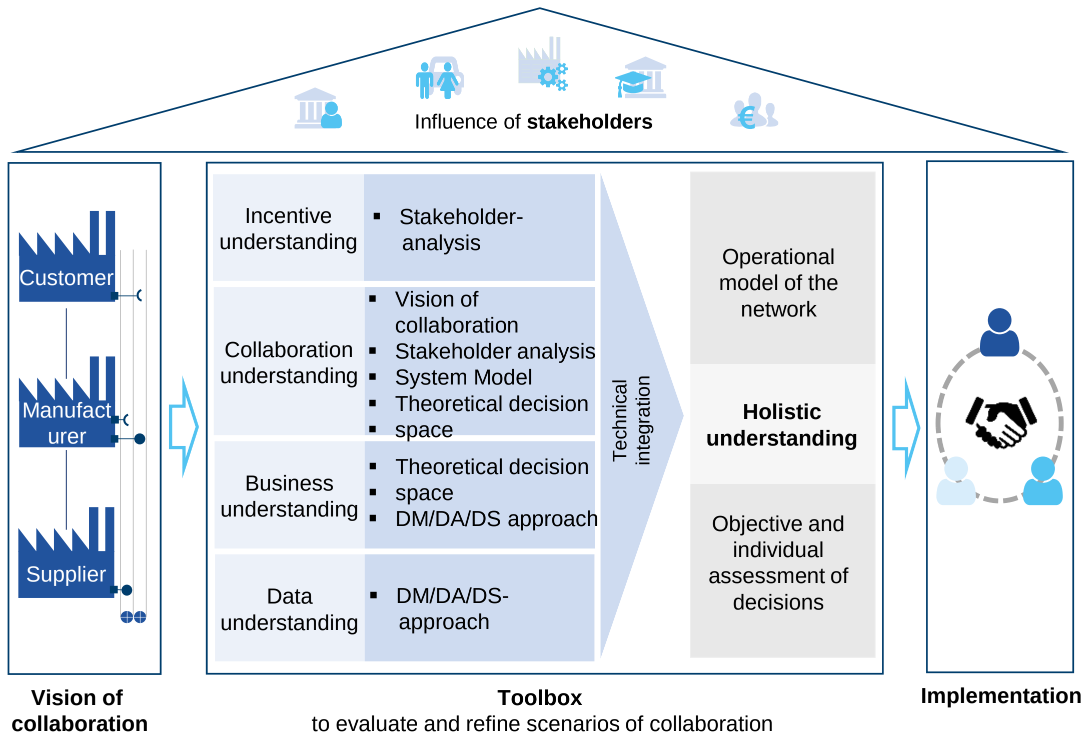


Figure 57: Whitebox model for the Development of Data-Driven Collaboration Models

Conclusion and Outlook

With this user guide for successful implementation of collaborative production networks, the ReKoNeT and SmartCoNeT projects make an important contribution to the design of fair, secure and networked value creation in future production systems.

Regardless of their different industrial contexts and goals, the five collaboration projects described have shown how important trustful cooperation between all the involved partners and secure data exchange across company boundaries are for collaborative value creation. The user guide shows relevant success factors and best practices and give valuable tips and tricks for initiating and implementing successful collaborations in value creation networks.

The described iterative procedure for successfully realising a collaboration vision and the introduced methodological tools, such as the system model for structuring and concretizing the collaboration vision or the white box model for developing data-driven collaboration models, provide practitioners with important assistance in implementing their own collaboration projects.

Based on our practical experience we can now say that it is important to plan enough time at the beginning of a collaboration project, during the development of the collaboration vision and later when concretising it in the system model, in order to find the appropriate answers to following questions, among others:

- What are the interests in the project? Who hopes to gain what benefits from the collaboration?
- Where does the data come from? Which data is suitable? How can the data be exchanged "barrier-free"? How do we arrive at data-based "intelligent" decisions for controlling collaborative value networks?
- What IT infrastructure or IoT environment do we need for secure data exchange across company boundaries?
- What legal framework conditions must be considered when exchanging data across company boundaries?
- What business models are possible within the framework of "data-based regulation of collaborative value creation networks"?

Collaborative value creation in manufacturing networks and, in particular, the collaborative use of production data in digital ecosystems - in “Manufacturing Data Spaces” - will continue to increase [28, 29]. In this context, not only vertical networking along the classic supply chains is increasing, but also in particular horizontal networking with market companions and enablers (e.g., with insurance and financial service providers). The exchange, processing and use of production-relevant data with these collaboration partners enable entirely new business models.

However, the central driver here will not be competitive pressure alone, but also the increasing socio-political demands on companies to create sustainable, circular and resilient value networks [28]. Particularly in connection with the discussion about the digital product passport that will be required in the future and the end-to-end accounting of carbon dioxide, there are major challenges for manufacturing companies. Technical approaches, such as a continuous digital twin, which is seen as a solution in this context (e.g., by the Plattform Industrie 4.0 or the Industrial Digital Twin Association), also require collaboration between the companies involved.

With this user guide, we want to provide you with a guidance for collaboration in secure data spaces. Accordingly, we cordially invite you to take a detailed look at the documents provided in the ***GitHub Repository***. To do so, simply scan the QR code on p. 10 or visit https://github.com/ReKoNeT-Collection. If you get stuck at any point, we would be very happy if you contact us. We will be happy to assist you..

Partners of the Project

Festo SE & Co. KG

Festo SE & Co. KG is an internationally active family-owned company in the field of factory and process automation with more than 20,000 employees. Festo is a global leader in automation technology and the world market leader in technical education and training. With innovative products and digital services for automation technology, the company supports the highest productivity and competitiveness of its more than 300,000 customers.

Robert Bosch GmbH

The Bosch Group is a leading international technology and services company. Its activities are divided into four business sectors: Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology. As a leading supplier in the Internet of Things (IoT), Bosch offers innovative solutions for Smart Home, Industry 4.0 and Connected Mobility. The Bosch Group's strategic goal is to provide solutions and products for connected life that either have artificial intelligence (AI) or are developed or manufactured with its help. The Bosch Group comprises Robert Bosch GmbH and its approximately 440 subsidiaries and regional companies in 60 countries.

WITTENSTEIN SE

With around 2,800 employees worldwide and sales of € 373 million in the 2020/21 financial year, WITTENSTEIN SE stands for innovation, precision and excellence in the world of cybertronic motion, both nationally and internationally. The Group possesses outstanding expertise in the mastery and further development of all relevant technologies in mechatronic drive technology and comprises six innovative Business Units. High-precision servo drives and linear systems, servo systems and servo motors as well as cybertronic drive systems are developed, produced and distributed, among other things, for machine and plant construction, aerospace or oil and gas exploration. Nanotechnology and software components round off the portfolio. The WITTENSTEIN Group is represented at 25 locations and in more than 45 countries in all key technology and sales markets.

Profiroll Technologies GmbH

Profiroll is a globally active machine tool manufacturer in the field of thread and profile rolling. The Profiroll business model is geared towards addressing the technological tasks of its customers for profiling rotationally symmetrical workpieces using the latest cold forming technology and developing an economical production process using profile rolling. The customer is supplied with machines, feed systems, the necessary rolling tools (rolling dies) as well as reliable production processes. And all this from one source. In addition, Profiroll takes over development orders for its customers up to the start-up production of a future series production. Profiroll can look back on a very successful history of innovation. Their development engineers have a large pool of technological solutions and engineering competence as well as experience.

HPO Häfner Präzisionsteile Oberrot GmbH

HPO Häfner Präzisionsteile Oberrot GmbH is a manufacturer of customised precision components in small to large series by means of mechanical processing (turning, milling, grinding, polishing). The company was founded in 1990 and has developed over the decades into a renowned production company in the area and now has more than 20 employees.

Orkli S. Coop

Orkli, S. Coop manufactures and distributes components for heating and solar systems worldwide and is an innovation leader in the field of gas safety. The company, headquartered in Spain, participated in the SmartCoNeT project with its digital tool Ekanban. Orkli has developed several solutions for the use case to optimise the flow of information and materials between customers and suppliers with Ekanban.

4flow AG

4flow combines logistics consulting, logistics software and 4PL services in a unique business model. 4flow consulting accompanies companies in the field of logistics and supply chain management from strategy to implementation. 4flow offers software for network and transport optimisation as well as for delivery optimisation. As a neutral 4PL and outsourcing partner, 4flow management takes over the daily optimisation of logistics networks and transports.

Ariatech Inc.

Ariatech Inc. is a Korean software company founded in 2003 by LG Electronics to develop mobile communication systems. In recent years, the company has focused on industrial IoT platforms, IoT devices and gateways, and the development of factory energy management and manufacturing execution systems. As part of the SmartCoNeT project, Ariatech Inc. has developed various IoT solutions for the Korean application case.

Münchener Rückversicherungs-Gesellschaft

Münchener Rückversicherungs-Gesellschaft Aktiengesellschaft in Munich is one of the leading reinsurance companies. Its "Strategic Innovation & Business Development" division pursues the goal of developing holistic insurance products based on ICT with industry partners.

Pickert & Partner GmbH

Pickert & Partner is a successful, ISO-certified software manufacturer from Pfinztal near Karlsruhe. The family business was founded in 1981 and currently employs over 50 people. Our more than 380 customers with over 215,000 users are at home in 28 countries. We access the international market through a stable and long-standing partner network. Pickert is the first point of contact for SMEs in the metal and plastics industry and also specialises in discrete manufacturing. For years, we have been involved in various research projects, working groups and associations to promote topics such as Industry 4.0.

FZI Forschungszentrum Informatik

The FZI Research Centre for Information Technology (FZI) is involved in the project with four main research areas. The Competence Centre for IT Security (FZI-KIS) contributes expertise on mechanisms and architectures for comprehensible, secure and trustworthy data processing. It also has many years of experience in the legal analysis of complex ICT infrastructures.

The research area Information Process Engineering (FZI-IPE) has expertise in the areas of data mining as well as predictive and prescriptive analytics. In addition, there is expertise in the design and conception of incentive systems and digital business models in the structure of modern market mechanisms.

Korea Institute of Industrial Technology

The Korea Institute of Industrial Technology - KITECH was founded with the aim of strengthening the technological performance and international competitiveness of small and medium-sized enterprises in South Korea and thus making an important contribution to industrial growth. KITECH focuses on the research and transfer of manufacturing technologies. As part of the SmartCoNeT project, KITECH developed technological solutions for Korean applications in the areas of simulation, dashboards and analysis modules, among others.

wbk Institute of Production Science

The wbk Institute of Production Science at the Karlsruhe Institute of Technology (KIT) is one of Germany's leading scientific institutions in the field of production science and Industry 4.0. The three areas of production and materials engineering, machines, plants and process automation as well as production systems are dedicated to application-oriented research, teaching and innovation in the field of production engineering. They are jointly led by the three professors Prof. Dr.-Ing. habil. Volker Schulze, Prof. Dr.-Ing. Jürgen Fleischer and Prof. Dr.-Ing. Gisela Lanza. The aim is to convey an integrative understanding of processes, systems and automation, right through to networked factories. In cooperation with industrial partners, the wbk works out solutions for diverse problems in production technology and develops new methods and processes for the production of the future.

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