EPiC Series in Computing
Volume 89, 2022, Pages 31–40
Proceedings of 35th International Conference on Computer Applications in Industry and Engineering

Development of a Prototype for a Process Support and Analysis Platform for Small and Medium-sized Enterprises

Jonas Kallisch[1] and Christoph Wunck[1,2,3]
[1] Emden/Leer University of Applied Sciences, Germany
[2] Department of Computer Science, Iowa State University, Ames, USA
[3] OFFIS Institute for Information Technology, Oldenburg, Germany

Abstract

This paper presents a prototype for an information exchange system, which allows information exchange between companies without actually sharing data. First, the need for such an intercompany exchange platform is explained and the value for supply chains resulting from such a platform is described. A literature review presents the existing concepts and techniques contributing to the development of an architecture. Finally. The information exchange concept and the prototype implementation are explained in detail.

1 Introduction

Machine Learning, advanced analytics and other methods have become a major element of modern production systems. Reduction of waste, improvement of manufacturing timings and quality are some of the contributions that these methods have brought to the companies own manufacturing infrastructure[1]. Because of this fact, many companies have started to analyze their shop floor data to profit from the benefits described. The increasing availability of customizable analytic tools and the decreasing of their prices enables even small businesses to use them. As a result, companies are more empowered than ever to identify and address the vulnerabilities of their manufacturing infrastructure. Parallel to this development, supply chains cooperation has deepened, which means that value creation depends more than ever on the cooperation of the companies[2].

Despite this reliance on collaboration, many companies, especially small and medium enterprises (SME), do not share data with their customers or suppliers and so do not optimize their joint

Funded by the Lower Saxony Ministry of Science and Culture under Grant Number ZN3489 within the Lower Saxony "Vorab" of the Volkswagen Foundation and supported by the Center for Digital Innovations (ZDIN).

manufacturing [3]. There are many reasons for this lack of data exchange. An interview series conducted by the authors investigated into these reasons, found that a common issue is, that companies have recognized the value of the data captured in manufacturing, and fear disadvantages from sharing it.

The fear is that the companies could lose control over the data shared in the supply chain (SC), for example if the data is stolen [4]. In some cases, the losing of control about their intellectual property could even threat the existence of the affected company, because competitors could use the information to improve their own production. Therefore, the fear of many companies of sharing data from their manufacturing systems is justified and understandable.

Another issue for SMEs is their lack of technical knowledge to create their own platforms and systems to exchange data with other SMEs [5]. SMEs often work on a low budget with external technical service providers, which must be able to support the solution of the company to exchange data with a customer or a supplier. The advantages of sharing data rely on the ability to analyze them and understand the results of the analysis. Many SMEs don't have these abilities within their businesses, as our interview partners told us and other studies found out as well [6].

By waiving to share shop floor data in the supply chain they give up many opportunities to improve the overall production efficiency along the value creation inside their SC [3].

A first step to data integration is to reduce the costs of data generation inside the SC [7]. Much of the data used by the participants is collected multiple times for different purposes. This results in costs that could be lowered by sharing the data between the members of the SC. In addition, the companies that are involved in the SC can be seen as members of a community of trust, as they should have a shared interest to improve the results of the group like quality or efficiency.

A second step towards integrating SC data is to create new data through combination of already existing data. By combining data from different stages relations between incidents appearing in late stages of the manufacturing process and data patterns appearing at earlier stages of the SC can be found [8]. This helps to reduce waste and optimize the overall production system.

To summarize, it can be stated that data exchange on a shop-floor level is not widespread and SMEs in particular rarely exchange manufacturing data with other companies. The authors propose that in addition to the lack of trust between companies, the existing solutions for data exchange do not meet all the requirements of companies.

To demonstrate this, the paper will first present the existing architectures and evaluate them with a view to their use by SMEs. Particular attention will be paid to the aspects of data security and usability for SMEs. The paper will show that existing architectures and concepts do not meet the requirements for all companies and that a concept is therefore needed for the secure networking of corporate data assets. Such a concept and a prototype have been developed by the "Zukunftslabor Produktion" [Futurelab Manufacturing] (ZLP) [9]. This interdisciplinary project is developing solutions and models especially for small and medium businesses in the manufacturing sector. Based on a use-case of the production of die-cast aluminium parts, the project examines how technical manufacturers can use data analytics and other industry 4.0 methods to improve their shop floor systems and create more resilient SCs. The concept and the reference implementation will be presented in the third part of this paper. The paper will close with a discussion of the findings.

2 Existing Concepts and Solutions

To identify existing concepts and implementations of intercompany communication in SCs, more than 100 papers have been examined and evaluated in a structured literature review. This section presents the concepts identified by the literature review and shows which SME requirements they do not meet.

2.1 Data Spaces

Data Spaces have been defined by Franklin, Havely and Maier as a next step in the evolution of data integration architectures[10]. The evolutionary step is that Data Spaces combine storing of data with services, to merge data from different sources to extract information. Key of this approach is the integration of data from different domains and the mapping of their different data elements. Therefore, Data Spaces can represent a SC as a number of related data sources, which can be connected. This data connection allows the whole system to improve its value. Similar to a SC the Data Spaces' value depends on the level of compatibility – mapping and matching – between the different suppliers [11].

One implementation of these data Spaces is the International Data Space (IDS) [12]. The IDS is a system of data providers interacting on a platform. Each participant can be provider or user of data and has the right to negotiate about the rights on the data. The platform allows to connect the data on a contract base. The full model of the IDS is displayed in Figure 1.

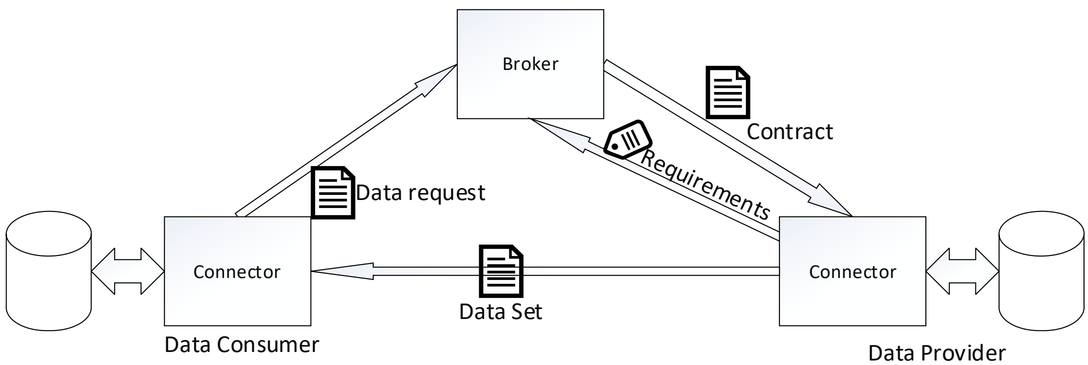

Figure 1: Model of the IDS [Based on 13]

The model consists of data providers and consumers that hold their data in their own physical storage locations. However, these physical storages do not interact directly with each other. The interaction is controlled by the broker, which offers two main services to the participants. Firstly, the broker lists and categorizes the data delivered by the data providers. This service enables the searching companies to find the data they need. The companies can search based on labeled data or based on the types of data they already have – e.g. a certain type of application or asset. If the system includes a data provider with the needed data, the broker connects the two – or more – companies. As the data can be traded anonymously, it is even possible to buy data from trusted sources without knowledge about the very company supplying the data.

Eventually, a service provider intermediating between the entities is part of the model. A service provider can be part of a whole ecosystem of service providers. These can for example be infrastructure services – e.g. data storage, computing power or other infrastructure – that allow participants to be part of the data space without having their own hardware.[14] Beyond this Infrastructure as a Service (IaaS), other providers can add services – e.g. data analysis or searching services – or Software as a Service (SaaS) – e.g. analytics tools or data mining software – via a dedicated App Store.[8] Therefore, the IDS delivers a solution for sharing data between companies on a contract base. However, the concept explicitly assumes sharing of data and thus cannot preserve the privacy of the participants. Therefore, the concept cannot be used to network companies without exchanging data.

2.2 GAIA-X

The European GAIA-X project can be considered as a solution for connecting different kinds of data stores. These data stores might also be IDS infrastructure elements. It contributes an architecture concept that allows the sharing of data in a public catalog, where everybody can see the available data, but can only access data when the access is granted [15]. Similar to IDS brokers, GAIA-X enables companies to give permission for sharing data on an individual level.

The GAIA-X foundation guarantees data sovereignty as a service. This means that participants have the capability to fully self-determinate their data exchange and sharing. The secure exchange is realized by a function called Data Contract Transaction. This service initiates a handshake between the data provider and the requesting party. The service validates the contract and, if the content is valid and both parties have confirmed the transaction, the Data Contract Service distributes the Data Contract to both companies. After that, the requesting company can access the requested data and may analyze it. The distribution of data is observed by a function called Data Exchange Logging, which enables companies to restrict the usage of their data to a certain extent or for a specific purpose.

The model of GAIA-X allows sharing of data in a secure and customizable way but still needs to actually exchange the data to analyze them inside of the SC. A very interesting part of the solution is the way the catalogue combines data identification and services by self-description. The value of this for companies that are interested in sharing data has also been examined by Dumss et al. [16]. They suggest an architecture model called EuProGigant, which allows exchanging data in a scalable way. They also describe how services can enrich the generated data and emphasize the importance of self-description in GAIA-X. However, they did not give a suggestion how to secure the data exchange or how to keep the intellectual property of the companies. This means that the concept, as it is proposed at this point, is not able to protect the data ownership interests of the SC companies.

Summed up the GAIA-X foundation provides a reliable, effective and secured solution for sharing data. For companies that are interested in sharing or selling their data the GAIA-X Federated Catalogue is a fitting solution. In the case of an interconnected SC GAIA-X might also be a very good communication platform, but by itself is not able to create an information exchange without actually exchanging the data. By that, the author's opinion is that GAIA-X does not fulfill the requirement of protecting data ownership.

2.3 Federated Learning

Federated Learning (FL) is a concept to analyze datasets, which are distributed over different devices that are connected with a central station [17]. It can be divided in horizontal and vertical FL [18]. The difference between these two types of FL is the selection of elements they share. As Figure 2 shows horizontal FL shares features, e.g. temperature measurings or other kind of data points, but not the samples – a concrete case of measurement, while vertical FL shares samples, but not features.

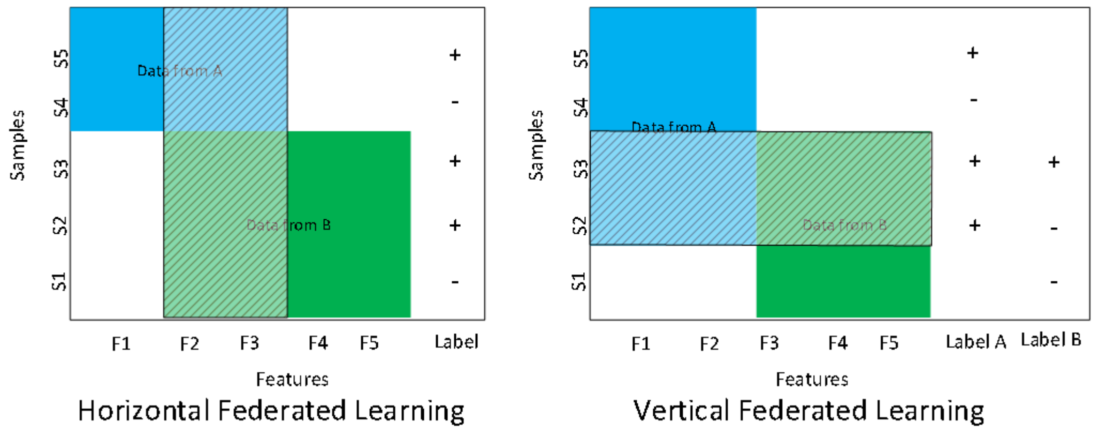

Figure 2: Difference between Types of Federated Learning (based on [18])

The more common case of FL is the horizontal FL as it is used in mobile devices, to improve their ability to analyze their user data, without transferring them. A horizontal FL starts with an initial algorithm, which is created on a data sample. In a second step, the model is decomposed into sub models, matching the data elements of the different storages. The different data stores, e.g. smartphones, then train the model on their own data. In the fourth and last step the results of the individual models can be transferred to the central application to improve the model. The result is that the different data stores are able to improve their analytical models of their data without sharing with each other. The limitation of the horizontal FL is that it requires similar data structures on the different devices.

In SCs, that do not share common data architectures between different companies, vertical FL can be used. As shown in Figure 2 the data stores in a vertical FL model are not sharing the same features – data structures – but the different data stores share the same samples. For example, two companies in the same city might not collect the same data, but collect the data from the same customers. If these companies share a common interest, they could combine their data and use it to improve the quality of their prediction algorithms.

Therefore, the usage of vertical FL requires to exchange the data or at least the labels of the data between the companies. A way to solve this problem of exchanging data between the company might lay in the work of Yang, Liu, Chen and Tong [18]. They propose a framework for secured vertical FL, which allows participants to exchange analytical models but frees them from having to share their data with each other. According to this, the issue could be consider as solved, but even these variant of vertical FL comes with some limitations.

The first limitation of the model is that it still requires the companies involved to share their labels of all samples to improve the training of the model. This might lead to leakage of information possible as Bagdasarya, et.al. have shown [19]. The second limitation comes with some assumptions on the data of the participants. One of these is, that all participants are sharing the same labels and have a combined goal, e.g. reduction of waste or overall cost reduction [20]. This is would be an issue, if a company is involved in different SCs, with different goals or might profit from a certain kind of waste. The third and last mentioned limitation relates to the value of information contributed by each individual party involved in the vertical FL. The problem is called 'unbalanced clients'. This means that some participants of the SC are able to contribute more to the whole system than others. The issue of this is that a federated learning architecture isn't able to balance these different feature relevance, without exchanging of datasets [17]. It should be mentioned that Zhang, et.al. have found that by selecting an adaptive number of local training rounds for each party can lead to better models, but this also increases the danger of data leakage.

2.4 Commercial Solutions

Beside the implementation of any of the concepts evaluated in the preceding sections the question remains if there is any existing commercial solution to securely connect SME SCs without giving up their individual data ownership interests. The authors have investigated various available products to see if commercial solutions are available that solve the problem away from scientific issues. The products investigated are described below and, in the authors' view, represent a good range of the systems available on the market.

- SAP Business One

SAP Business One is focused on small businesses and is able to deliver a ERP system that does not share much with the main SAP Products S3 and S4 [21]. Companies can chose to run the software on their own server or use a cloud server hosted by SAP [22]. The product allows builtin analytics and SC automation of business transactions [23]. Business One is a solution that can help small companies to get to the earlier described state of the art of SC communication. It also allows the companies to get analysis of their business decisions, but is not able to solve the issue of intercompany communication.

- SAP Business ByDesign

SAP Business ByDesign aims at medium businesses [23]. The product is cloud based and provides a customizable ERP system, which can be integrated in a SC [24].The solution is able to create build in analytics to create real time dashboards of the company´s situation [21]. In addition to the features of BusinessOne, it delivers the features of SC Management, like functions to support sourcing and purchasing [21]. As BusinessOne, Business ByDesign did not involve the SC partners manufacturing infrastructure.

- Microsoft Dynamics

Microsoft Dynamics delivers functions for integration of warehouses, material flow planning and collaboration with other companies [25]. The SC management component delivers similar functions to the given by the SAP product [26]. The review also found that all investigated ERP systems enable the integration of suppliers on the level of business communication. Another study also shows the state of ERP MES integration in Microsoft Dynamics and the lag of a integration of intercompany shop floor data exchange in the solution [27].

- Microsoft Azure

Microsoft Azure enables collaboration between companies in a SC with a cloud application that integrates inventory, factory status and logistical data in a twin of the SC elements [28]. The concept is that a SC member delivers all relevant data to the gateway and connects them to the data of the other members. The results can be combined with public data, for example weather information [29].

3 Towards a Data Securing Information Exchanging Architecture

The authors have shown that none of the existing concepts or products meet all requirements to solve the problem of information exchange between companies without direct data exchange. Based on the requirements and the existing approaches, an architecture was developed that on the one hand offers the option to interact with data ecosystems such as IDS or GAIA-X in the future and on the other hand protects the control over the intellectual property of the companies. Our concept provides for the sharing of information via a linking platform, which neither requests data for centralized processing, nor passes it on to other participants in the platform. To create these links, existing connections in the data traffic can be used. In an SC, these usually consist of the flow of goods between the respective companies.

In many cases, these goods are identifiable, for example via a batch or serial number. These identifiers can be used to find and link the products within the cross-company workflow and the data collected during processing.

In theory, the data values recorded by one company *A* therefore have a direct influence on the measurement results of a second company *B*. If company *B* finds that different results are determined for comparable process variables in its own data stock, the cause can therefore lie in a deviating process variable in company *A* or in a pre-production stage of *A*. By using a process support platform, these correlations can be analyzed without direct data exchange. In addition, the leakage of information is less likely, since only in defined cases, analysis will be started and the results do not even have to be shared between the companies.

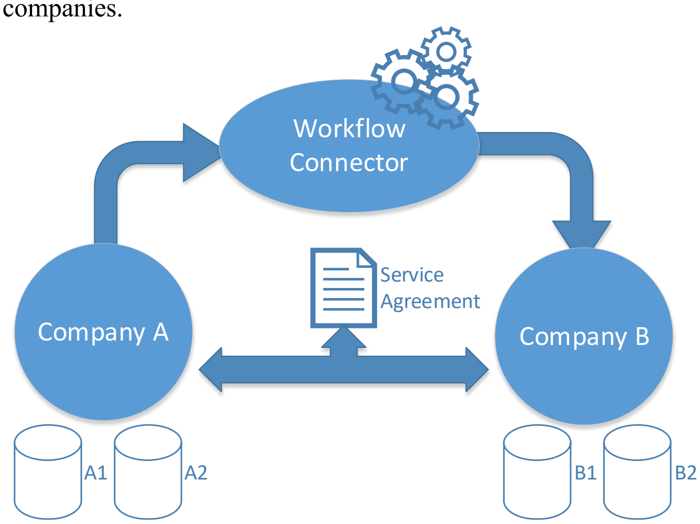

Figure 3: Concept of the project

This description of a possible network results in a concept whose core is a value-oriented relationship between at least two partners. As displayed in Figure 3 the partners are connected via a process support platform that distributes information based on the stored exchange relationships. The participants would be company *A* with data *A1* and the derived information *A2*, company *B* with data *B1* and the derived information *B2*. *A2* and *B2* are exchanged in the scenario. Thus, participant *A* holds *A1, A2* and *B2* and participant *B* holds *A2*, *B1* and *B2*, whereby each participant can determine the concrete information provided. Based on this core concept, the participants of the process support platform can improve their own analyses through the exchange and agree on individual agreements Services. Such a service can be, for example, a cross-company fault cause recognition, which is passed on to supplier *A* in the event of a fault at *B* that cannot be explained by its own processes. *A* would then be obliged to determine whether this error can be traced back to processes in its production.

Based on this concept, a prototype for cross-company information exchange was developed at ZLP. The development was carried out iteratively and in coordination with the requirements of the companies. The prototype model can be described as a three-layer system:

- Communication layer
- Service layer

- Analytics layer

The first layer provides a link between enterprise data states. On the one hand, it provides the process links and thus represents cross-company production, and on the other hand, it stores the contracts between the individual partners. From a technical point of view, this architectural component, referred to as the Workflow Connector in Figure 2, was implemented in the prototype as a JADE Agent [30]. The agent is realized as a containerized application and stores agents of the partners in service contract lists in order to map the agreements.

In order to be able to use the application as easily as possible in the companies, the associated components were implemented as containerized applications. The service layer is also created as a containerized application and offers a possibility to connect to the communication layer based on individual networking with other system participants. For this purpose, a platform participant creates a communication relationship, which reports to the Workflow Connector. The message tells the participant, which information that can be provided by the service. It also declares which information, e.g. a serial number, the service needs. Within the service layer, the defined and offered service can be designed. This is done either via automated data returns, for example on quality data, or via analyses provided by the company. These are integrated in the analysis layer.

The analytics component itself was implemented as part of the prototype based on a Hadoop [31] platform. However, it is not the concrete technical implementation that is important for the concept, but rather the linkability with the data inventories of the partner companies. Therefore, the concrete design of the analysis components will have to be customized for each company. The disadvantage of this is, that it requires knowledge of analysis processes in all companies. Nevertheless, the process offers considerable advantages, and the establishment of an information exchange platform alone can bring benefit for many companies.

4 Conclusion and further Work

This paper described the need for a secure information exchange system for companies in SCs. The current lack of suitable concepts and solutions was shown. for the The authors devised an architecture that protects the data ownership of the involved parties and enables information sharing. The advantages and disadvantages of the architecture have been briefly discussed and will be further evaluated within the project and addressed in future work. The concept achieves networking through an exchange platform that allows companies to exchange information based on individual contracts without having to disclose data. The concept adopts some mechanisms and ideas of existing concepts. On the one hand, this improves the quality of the architecture by using tried and tested systems and, on the other hand, it enables companies to easily integrate into platforms such as IDS or GAIA-X. In the future, the authors will build further implementation variants, such as a microservice architecture, and investigate them with regard to their potential. For this purpose, experimental setups with industrial partners and on-site laboratory infrastructure will be used.

References

[1] J. A. Marmolejo-Saucedo, M. Hurtado-Hernandez, and R. Suarez-Valdes, “Digital Twins in Supply Chain Management: A Brief Literature Review,” in *2020 – Intelligent Computing and Optimization*, pp. 653–661.

[2] M. Holweg, S. Disney, J. Holmström, and J. Småros, “Supply Chain Collaboration,” *European Management Journal*, vol. 23, no. 2, pp. 170–181, 2005, doi: 10.1016/j.emj.2005.02.008.

[3] P. Radanliev, D. C. de Roure, J. R. C. Nurse, R. M. Montalvo, and P. Burnap, “Supply Chain Design for the Industrial Internet of Things and the Industry 4.0,” 2019.
[4] C. Colicchia, A. Creazza, C. Noè, and F. Strozzi, “Information sharing in supply chains: a review of risks and opportunities using the systematic literature network analysis (SLNA),” *SCM*, vol. 24, no. 1, pp. 5–21, 2019, doi: 10.1108/SCM-01-2018-0003.
[5] S. Wang and H. Wang, “Big data for small and medium-sized enterprises (SME): a knowledge management model,” *JKM*, vol. 24, no. 4, pp. 881–897, 2020, doi: 10.1108/JKM-02-2020-0081.
[6] J. Stentoft, K. W. Jensen, K. Philipsen, and A. Haug, *Proceedings of the 52nd Annual Hawaii International Conference on System Sciences: January 8-11, 2019, Maui, Hawaii*. Honolulu, HI: University of Hawaii at Manoa Hamilton Library ScholarSpace, 2019. [Online]. Available: https://scholarspace.manoa.hawaii.edu/handle/10125/59952
[7] V. Alcácer and V. Cruz-Machado, “Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems,” *Engineering Science and Technology, an International Journal*, vol. 22, no. 3, pp. 899–919, 2019, doi: 10.1016/j.jestch.2019.01.006.
[8] K. Rong, G. Hu, Y. Lin, Y. Shi, and L. Guo, “Understanding business ecosystem using a 6C framework in Internet-of-Things-based sectors,” *International Journal of Production Economics*, vol. 159, pp. 41–55, 2015, doi: 10.1016/j.ijpe.2014.09.003.
[9] ZDIN, *Zukunftslabor PRODUKTION.* [Online]. Available: https://www.zdin.de/zukunftslabore/produktion (accessed: Jun. 27 2022).
[10] M. Franklin, A. Halevy, and D. Maier, “From databases to dataspaces,” *SIGMOD Rec.*, vol. 34, no. 4, pp. 27–33, 2005, doi: 10.1145/1107499.1107502.
[11] A. D. Sarma, X. Dong, and A. Y. Halevy, “Data Modeling in Dataspace Support Platforms,” in *Lecture notes in computer science*, vol. 5600, *Conceptual modeling: foundations and applications: Essays in honor of John Mylopoulos*, A. T. Borgida, V. K. Chaudhri, P. Giorgini, and E. S. Yu, Eds., Berlin: Springer, 2009, pp. 122–138.
[12] Fraunhofer-Gesellschaft, *International Data Spaces.* [Online]. Available: https://www.fraunhofer.de/en/research/lighthouse-projects-fraunhofer-initiatives/international-data-spaces.html (accessed: Aug. 27 2020).
[13] International Data Space Assoziation, *International Data Space Reference Architecture Modell.* [Online]. Available: https://www.fraunhofer.de/content/dam/zv/en/fields-of-research/industrial-data-space/IDS-Reference-Architecture-Model.pdf
[14] S. Shah, M. Bolton, and S. Menon, “A Study of Internet of Things (IoT) and its Impacts on Global Supply Chains,” in *2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM)*, Dubai, United Arab Emirates, Jan. 2020 - Jan. 2020, pp. 245–250.
[15] *GAIA-X: Technical Architecture.* [Online]. Available: https://www.data-infrastructure.eu/GAIAX/Redaktion/EN/Publications/gaia-x-technical-architecture.html (accessed: Jul. 13 2021).
[16] S. Dumss *et al.,* “EuProGigant – A Concept Towards an Industrial System Architecture for Data-Driven Production Systems,” *Procedia CIRP*, vol. 104, pp. 324–329, 2021, doi: 10.1016/j.procir.2021.11.055.
[17] J. Zhang *et al.,* “Adaptive Vertical Federated Learning on Unbalanced Features,” *IEEE Trans. Parallel Distrib. Syst.*, p. 1, 2022, doi: 10.1109/TPDS.2022.3178443.
[18] Q. Yang, Y. Liu, T. Chen, and Y. Tong, “Federated Machine Learning,” *ACM Trans. Intell. Syst. Technol.*, vol. 10, no. 2, pp. 1–19, 2019, doi: 10.1145/3298981.
[19] Eugene Bagdasaryan, Andreas Veit, Yiqing Hua, Deborah Estrin, and Vitaly Shmatikov, “How To Backdoor Federated Learning,” *International Conference on Artificial Intelligence and Statistics*, pp. 2938–2948, 2020. [Online]. Available: https://proceedings.mlr.press/v108/bagdasaryan20a.html

[20] L. Lyu, H. Yu, J. Zhao, and Q. Yang, "Threats to Federated Learning," in *Federated Learning*: Springer, Cham, 2020, pp. 3–16. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-030-63076-8_1

[21] K. Schneider, "SAP Business ByDesign – Integrated Cloud Suite," (in De;de), *HMD*, vol. 55, no. 1, pp. 44–61, 2018, doi: 10.1365/s40702-017-0380-8.

[22] SAP, *Übersicht Produkte | Unternehmenssoftware für KMU | SAP Mittelstand.* [Online]. Available: https://www.sap.com/germany/products/sme-business-software/products.html (accessed: May 30 2022).

[23] SAP, *ERP-Software für kleine Unternehmen | SAP Business One.* [Online]. Available: https://www.sap.com/germany/products/business-one.html (accessed: May 25 2022).

[24] K. Kurbel and D. Nowak, "Customization of On-Demand ERP Software Using SAP Business ByDesign as an Example," in *Innovation and Future of Enterprise Information Systems*: Springer, Berlin, Heidelberg, 2013, pp. 289–297. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-642-37021-2_21

[25] Microsoft Corporation, *Supply Chain Management | Microsoft Dynamics 365.* [Online]. Available: https://dynamics.microsoft.com/de-de/supply-chain-management/overview/ (accessed: May 30 2022).

[26] F. M. Elbahri, O. I. Al-Sanjary, M. Ali, Z. A. Naif, O. A. Ibrahim, and M. N. Mohammed, *Difference Comparison of SAP, Oracle, and Microsoft Solutions Based on Cloud ERP Systems: A Review*, 2019. [Online]. Available: https://www.researchgate.net/profile/omar-al-sanjary/publication/333457778_difference_comparison_of_sap_oracle_and_microsoft_solutions_based_on_cloud_erp_systems_a_review/links/5ffbad6292851c13fe02ecd5/difference-comparison-of-sap-oracle-and-microsoft-solutions-based-on-cloud-erp-systems-a-review.pdf

[27] S. Oman, R. Leskovar, B. Rosi, and A. Baggia, "Integration of MES and ERP in supply chains: effect assessment in the case of the automotive industry," *Teh. vjesn.*, vol. 24, no. 6, 2017, doi: 10.17559/tv-20160426094449.

[28] Microsoft Corporation, *Advancing reliability through a resilient cloud supply chain | Azure Blog and Updates | Microsoft Azure.* [Online]. Available: https://azure.microsoft.com/en-us/blog/advancing-reliability-through-a-resilient-cloud-supply-chain/ (accessed: May 30 2022).

[29] J. Sunny, N. Undralla, and V. Madhusudanan Pillai, "Supply chain transparency through blockchain-based traceability: An overview with demonstration," *Computers & Industrial Engineering*, vol. 150, p. 106895, 2020, doi: 10.1016/j.cie.2020.106895.

[30] Telecom Italia SpA, *Jade Site | Java Agent DEvelopment Framework.* [Online]. Available: https://jade.tilab.com/ (accessed: Jun. 28 2022).

[31] Apache Software Foundation, *Apache Hadoop.* [Online]. Available: https://hadoop.apache.org/ (accessed: Jun. 28 2022).