Early Learnings from a Logistics Testbed

2023-08-30

Authors:

Dr. Patrick Weber
Ferdinand Steinbeis Institute
patrick.weber@ferdinand-steinbeis-institut.de

Sven Kurrle
Ferdinand Steinbeis Institute
sven.kurrle@ferdinand-steinbeis-institut.de

Prof. Dr. Heiner Lasi
Ferdinand Steinbeis Institute
heiner.lasi@ferdinand-steinbeis-institut.de

CONTENTS

FIGURES

1 INTRODUCTION

The cooperative use of data confronts companies with a variety of challenges. Companies, for instance, accumulate their data stocks in internal data silos or private clouds[1,2]. These data collaborations are called data ecosystems[3,4] and are gaining more and more relevance in science and practice. The enormous economic potential of the collaborative use of data is highlighted by the European Commission's estimate of the value of the data economy in Europe from the end of the year 2019. In this study, the value is estimated to be around €324.86 billion. For 2025, it is expected to grow about €432 billion.[5]

One example of such a data ecosystem from the automotive sector is the Mobility Data Space, other data ecosystems are also currently being established.[6,7] We are currently observing that IoT, digital twins and thus data ecosystems are increasingly gaining relevance in intralogistics as well. Intralogistics offer great potential because many tasks and processes are still manually performed and poorly optimized. Our research aims to help companies explore the opportunities to conceptualize the complex interactions in such a data ecosystem focusing on intralogistics.[8]

This article presents our preliminary findings from a data ecosystem in intralogistics. We identified three main service types, including two sub-types each that emerge when building such a data ecosystem. We put our findings in the context of the three-tier architecture showing that the nature of providable services varies corresponding to the tier.

2 TESTBED DESCRIPTION

To explore and exploit the potentials of data ecosystems in logistics, a manufacturer of wheeled excavators, an industrial service provider, an industrial sensor manufacturer and the Ferdinand Steinbeis Institute (German Regional Team of the Industrial IoT Consortium) started a joint testbed about two years ago. The three companies, coordinated by the Ferdinand Steinbeis Institute, set the aim to optimize intralogistics using digital twins that enable new ways of orchestrating internal logistics processes (tracking of goods and controlling of forklifts).

This orchestration combined the strengths of the three companies in a novel intercompany development process and a collaboration happened on all levels of the organization to jointly unlock the potential which was identified in a previously transpired project. The different

[1] Baars, et. al., 2021
[2] Lindner & Straub, 2023
[3] Oliveira, M. I. S. & Lòscio, B. F. (2018)
[4] Adner, R. (2017)
[5] Cattaneio et al., 2020, pp. 43-44
[6] World Economic Forum (2022)
[7] International Data Spaces Association (2022)
[8] Mörth, et al., 2020

capabilities of all three companies complemented each other in a way that covers all aspects of the envisioned solution. Ranging from the sensing capabilities, connectivity and cloud all the way to operational excellence and deep logistics experience.

The starting point of the testbed was the identification of a cooperative value scenario based on the capabilities of the partners. The companies defined transparency in terms of intralogistics as the basis for the value scenario. Based on transparency, the partners jointly optimize intralogistics with a focus on forklifts and the warehouse.

Therefore the companies defined the following Key Performance Indicators (KPIs) to measure the success of the cooperative value scenario: throughput, cycle time, transport performance, effectiveness, and availability. The defined KPIs were visualized in dashboards to enable continuous monitoring of the intralogistics and additionally the dashboards were used to generate insights and potentially new knowledge to optimize internal logistics systems - optimizations in a way that would be difficult to achieve with traditional methods. Based on optimization, the companies developed further value scenarios - increasing the productivity of the forklift fleet, material tracking and order management.

The digital twins were instantiated in a cooperative data space hosted by one of the companies. The forklifts' digital twins included the following states like the current position and whether the vehicle bears a load. These were complemented by the digital twins of transported goods. These digital twins included an item ID, the date of storage and the current position. Finally, a digital twin of the factory site was created, this digital twin included storage zones and the filling levels of these storage zones. Through the chosen architecture, we created interconnectivity and interaction across the intralogistics objects and systems.

The described data ecosystem was initiated in an outdoor area in an industrial plant in the south of Germany. As part of the testbed 16 forklifts were equipped with the necessary sensing equipment and connected to a cloud instance. Transparency was achieved by analyzing the vehicles' digital twins' states over a period of one and a half years. The companies evaluated the success of the testbed based on market potential, technical feasibility, costs, and risks.

After the evaluation, the project partners decided to jointly scale the offering on the market. To achieve the defined value scenarios, the partners specified and implemented digital twins. The following figure summarizes the testbed, based on the viewpoints of the Industrial Internet Reference Architecture (IIRA).

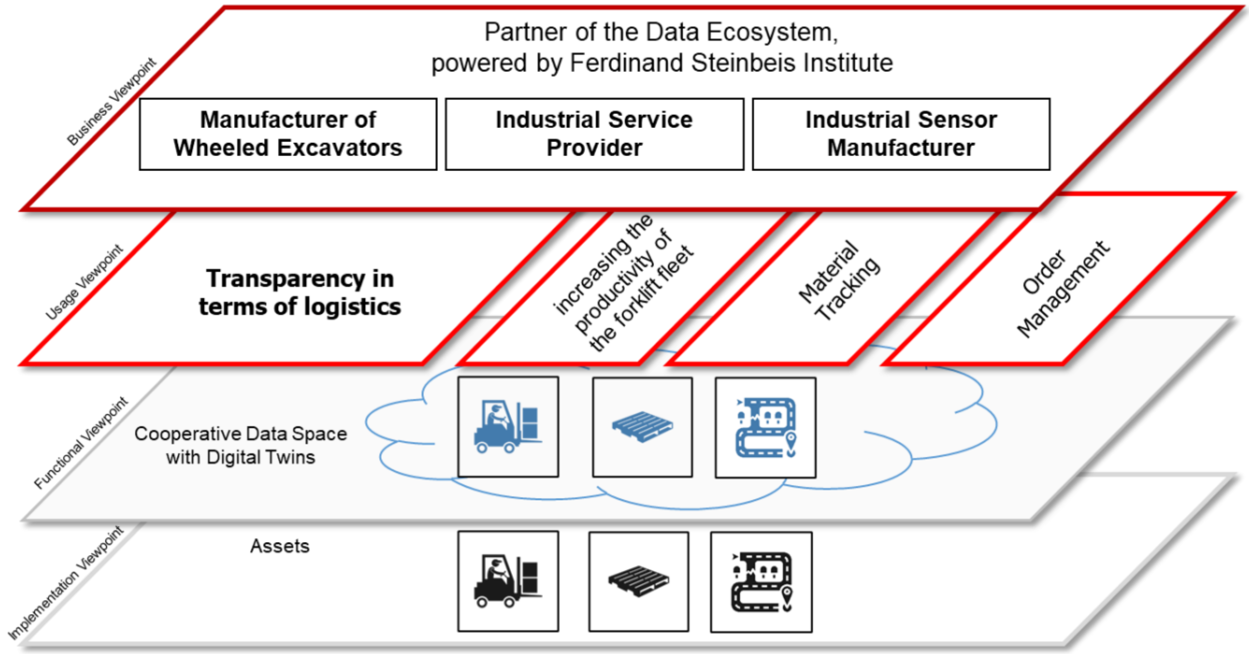

Figure 2-1: Testbed in the intralogistics.

3 Methods

To generate the research results, we used a single case study as a research method following Yin's approach.[9] To complete the testbeds, 20 workshops were held with managing directors of the three participating companies. Researchers were present during technical implementations and held an active role in coordinating the collaboration between the three companies.

Our results were collected alongside the workshop in co-operation with the participating, in the form of written protocols and photo protocols done by the researchers. The data analysis was conducted through qualitative content analysis based on Mayring.[10] The researchers identified qualitative patterns in the collected data and preliminarily aggregated those, arriving at our findings.

4 Findings

The results of the testbed show that the cooperative use of digital twins in a data ecosystem can be used to realize a variety of value scenarios in intralogistics. Our work identified preliminary service types that were placed in the context of the Industry IoT Consortium's three-tier

[9] Yin, 2018
[10] Mayring, 2014

architecture.[11] Each tier is home to its own generic service type, which can be fragmented into several sub-types.

Services are currently the topic of many discussions in research and practice, for example against the backdrop of service-oriented architecture, service dominant logic and micro services. Services "means applying specialized competences (knowledge and skills) through deeds, processes, and performances for the benefit of another actor or the actor itself.[12]" This means that services are small, independent, and loosely coupled functions. In the context of data ecosystems, business models are realized through an interplay of services from different partners and these services are independent of the specific application and can therefore be integrated into very different ecosystems.

Within the context of the testbed Data Services, Information Services and Analytic Services could be identified. In the following text, six generic service sub-types are defined based on the experiences from the testbed.

4.1 The Edge Tier

The Edge Tier processes raw sensor measurements to provide a clean set of reliable data to the Platform Tier. We observed two different kinds of Data Services that facilitate this processing. A Data Service filters the positional data acquired through the gateways GPS system to exclude any data that does not meet predefined quality criteria. This quality filter removes data points that have accuracy below a certain threshold, no GPS fix, or where the ignition of the forklift has been off for the entire measurement timeframe. By doing so, the *Data Service – Filtration* only passes high quality data on and reduces the amount of data that gets transmitted to the Platform Tier.

Another Data Service creates a new data point from existing measurement data. It transforms the data to create additional data streams. We observed that the built-in accelerometer in the gateway was used in a Data Service to calculate whether the forklift is on-duty or off-duty. This type of local processing is what we call a virtual sensor as it requires the mutation and reinterpretation of existing sensor data. The *Data Service – Virtual Sensor* has therefore been used to approximate what could be a very complex sensor setup that directly measures if the forklift is currently in use or not. Virtual sensors do come with tradeoffs but provide a convenient way to enlarge the available data on the Platform Tier.

Data Services on the Edge Tier aim to clean and transform data. They make sure that only valid and useful data is transmitted to the Platform Tier. Data Services can expand existing measurement data by creating virtual sensors. Data Services can be physically located on the sensing device or on an additional Gateway that acts as a local edge hub.

[11] Lin, Shi-Wan, et al., 2022
[12] Lusch & Nambisan, 2015

4.2 THE PLATFORM TIER

The Platform Tier processes the incoming data from the Edge Tier. In addition to the typical cloud Infrastructure Services, such as storage and computing it is home to Information Services that process incoming data into information. An example of such an Information Service is the calculation of a forklift's distance covered. This Information Service calculates how many kilometers a forklift was driven loaded/unloaded for any given timeframe. This service was implemented by the industrial service provider using the data available from the Edge Tier as *Information Service – Data Interpretation*.

Other Information Services use multiple data streams from the Edge Tier to interpret the data in a novel way. We classify them as *Information Service – Data Contextualization*. One such service in the testbed was the calculation of transported goods. It uses multiple data streams plus additional context data to calculate two new pieces of information. It produces an event that is stored whenever a good has reached his destination, be it the final assembly line or an intermediate storage area. And additionally provides the information of how many value adding transports have been performed today.

Information Services generate information based on the data provided by the Edge Tier. For this purpose, contextual information is usually integrated to obtain a better understanding.

4.3 THE ENTERPRISE TIER

The Enterprise Tier interprets the produced information in the context of the specific enterprise. Analytics Services on this layer go beyond Information Services by integrating live context from other parts of the business and integrating expert knowledge to provide actionable and specific guidance. *Analytics Services – Key Performance Indicator* provides indicators for managerial roles in an organization. These KPIs differ depending on the stakeholder and are based on the interaction of several Information Services and potential enterprise internal context.

They offer live insights into the business that can be a crucial tool to react fast to a change in one's business, but they do only provide a well-defined information point, relying on the consumer of the KPI to draw his own conclusions and act accordingly. One example in our observation was the total productivity of all forklifts today and in the context of the average for the same day of the week. This KPI gives the logistics manager a quick overview of the logistics performance up to now.

A second set of Analytics Services differs in its scope by being able to directly tie back into the live system and change relevant parameters automatically. Those services classified under the term *Analytics Services – Enterprise Autopilot* describe services that are tailored to the specific needs of the enterprise. A set of industry experts work together with internal experts to set up the underlying service that runs changes in the enterprise on autopilot. They meet periodically to reflect on the performance and tweak the system to current requirements.

One example in our observed case is the control of different storage areas and their associated storage logic. The goal of this Analytics Service is to provide the perfect storage location for a newly arrived stock of goods. The location is automatically generated based on metadata of the good, its current and destination location and historical patterns of location choices. The logic is periodically updated by a committee comprised of an external logistics expert, the internal head of logistics and the forklift coordinator.

Analytics Services generate actionable and specific guidance based on Data and Information Services. These can either be KPIs for the management of the enterprise or direct changes in the operation through control systems.

Figure 4-1 shows the different types of services in the three-tier architecture (services visualized in red). We assume there to be more different service types in these three layers than we could observe in our case.

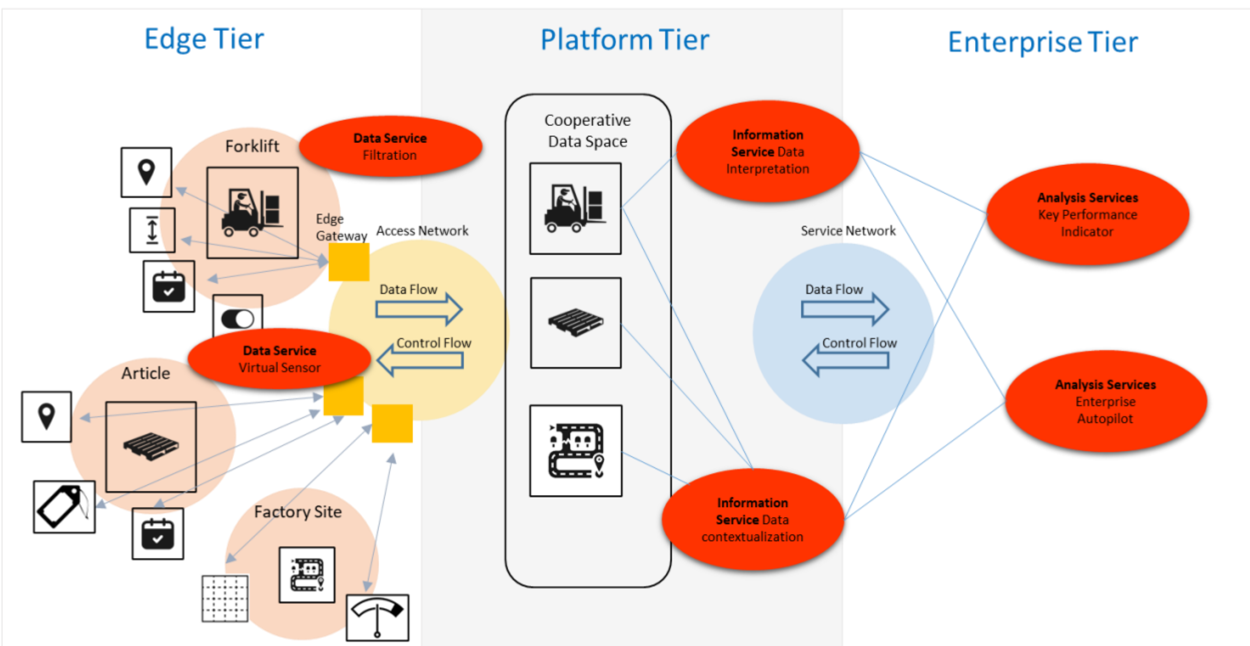

Figure 4-1: Service types.

5 Lessons Learned and Next Steps

Based on the testbed, several lessons learned could be derived for digital twins in intralogistics. We document them here along the IIRA viewpoints.

Implementation viewpoint:

- Entry via object-related data, low protection requirement and therefore lower barriers for the companies.

- Points of contact with many other corporate areas (assembly or distribution), which means that many players must be considered during implementation.
- Inaccuracies due to shielding effect with GPS (in practice the 2/3 meters cannot be reached in the testbed).

Functional Viewpoint:

- The digital twins can be quickly expanded to additional conditions (height of goods stored), less complexity than in classic IT projects.
- Third-party services can be integrated => calculation of the indoor position, not all services have to come from the consortium.

Usage Viewpoint:

- Early involvement of responsible intralogistics staff => now the driving power of the project.
- Manufacturer neutrality is important for forklifts, as they are usually mixed fleets.
- Intralogistics is very dynamic => especially in times of COVID-19, it is not always clear which action has brought about which change in KPIs, because intralogistics is constantly changing due to delivery bottlenecks.
- It is a challenge for companies to optimize intralogistics based on Information Services alone.
- Considerable effort for coordination between companies => Less speed in scaling cooperative business models.

Business Viewpoint:

- Low degree of utilization of forklifts (approx. 16%) => Offers great potential for optimization in intralogistics.
- Easier and more cost-effective implementation due to digital twins.
- Fast implementation through combination of capabilities for different companies.
- Optimization of intralogistics is only possible through the interaction of the services of the different partners.

To clarify data ownership, a separate project company was founded, which owns the status data of the digital twins. Descriptive contexts (e.g., forklift manufacturer, age, or engine type) do not lie in the project company but rather remain in the hands of the respective partner of the testbed. Through this separation, data ownership could be clarified and a high level of acceptance for data sharing could be generated. In addition, the joint legal entity offers the possibility for the partners not to go to the market alone with services, but rather that the partners can jointly offer the cooperative effort on the market via the project company.

The services presented in this paper help companies to design the business model of the data ecosystem, concerning roles and pricing because it can be clearly assigned which partner contributes which services to realize the cooperative offering.

The established legal entity also creates a governance framework to create joint decisions on the further development of the digital twins, the cooperative use of data or the expansion of the partner network.

6 Conclusion and Next Steps

This paper has shown that the three partners of the data ecosystem can realize different value scenarios based on cooperatively used digital twins. Each of the partners contributes services at different levels of the 3-tier architecture. We structured these services into six distinct service types that structure the solution space.

The testbeds' goal of producing meaningful actionable KPIs is realized by combining all services. The companies are working on expanding the value proposition and our findings will be further refined during this process. The testbed is also working intensively on scaling the existing services to new scenarios in comparable settings. The results of the testbed show that the digital twins and the cooperative data space can be easily extended and that additional value scenarios can be realized by adding individual context to the digital twins (e.g., size of the transported goods).

Together with the project company, the partners of the testbed have been using the experience gained to scale up the business model since June 2023. In a first step, the cooperative intra-logistics optimization offering will be rolled out to several friendly customers to gather experience on how transferable the offering and the services are.

In addition, the technical implementation will be extended to indoor localization. This expansion stage has already started. In addition to the expansion, the sensor setting, and the dashboards will also be evaluated based on experiences with friendly customers to increase the data quality in the digital twins and open further areas of application with smaller units.

7 References

[1] Baars, H., Tank, A., Weber, P., Kemper, H. G., Lasi, H., & Pedell, B. (2021). Cooperative approaches to data sharing and analysis for industrial internet of things ecosystems. Applied Sciences, 11(16), 7547. *https://research.rug.nl/en/publications/cooperative-approaches-to-data-sharing-and-analysis-for-industria*

[2] Lindner, M. & Straub, S. (2021).
Datentreuhänderschaft – Status Quo und Entwicklungsperspektiven. Institut für Innovation und Technik (iit) in der VDI / VDE Innovation + Technik GmbH
https://www.iit-berlin.de/

[3] Oliveira, M. I. S. & Lòscio, B. F. (2018). What is a data ecosystem? Proceedings 19th International Conference on Digital Government Research: Governance in the Data Age.
https://sci-hub.se/10.1145/3209281.3209335

[4] Adner, R. (2017). Ecosystem as structure: An actionable construct for strategy. Journal of management, 43(1), 39-58.
https://www.semanticscholar.org/paper/Ecosystem-as-Structure-Adner/51170ab7d0cf99474b5551cbdb65f4de881587b8

[5] Cattaneio, G., Micheletti, G., Glennon, M., La Croce, C., & Mitta, C. (2020). The European data market monitoring tool: Key facts & figures, first policy conclusions, data landscape and quantified stories: d2.9 final study report. (Directorate-General for Communications Networks, Content and Technology, Hrsg.). Publications Office of the European Union.
https://data.europa.eu/doi/10.2759/72084

[6] World Economic Forum (2022). Unlocking Greater Insights with Data Collaboration. Briefing Paper.
https://www.weforum.org/reports
(www3.weforum.org › WEF_Unlocking_Greater_Insights_2022)

[7] International Data Spaces Association (2022). Data spaces overview: Let's build the future data economy!
https://internationaldataspaces.org/

[8] Mörth, O., Emmanouilidis, C., Hafner, N., & Schadler, M. (2020). Cyber-physical systems for performance monitoring in production intralogistics. Computers & industrial engineering, 142, 106333.
https://dspace.lib.cranfield.ac.uk/handle/1826/15074

[9] Yin, R. K. (2018). Case study research and applications: Design and methods
https://us.sagepub.com/en-us/nam/case-study-research-and-applications/book250150

[10] Mayring, P. (2014). Qualitative content analysis: theoretical foundation, basic procedures and software solution.
https://www.ssoar.info/ssoar/handle/document/39517

[11] Lin, Shi-Wan, et al. (2022). Industrial Internet Reference Architecture. Industrial Internet Consortium (IIC), Technical Report, Version 1.10.
https://www.iiconsortium.org › wp-content › uploads › sites › 2 › 2022 › 11 › IIRA-v1.10.pdf

[12] Lusch, R. F. Nambisan, S. (2015): SERVICE INNOVATION. A SERVICE-DOMINANT LOGIC PERSPECTIVE. In: MIS Quarterly 39 (1), S. 155–176 *https://www.researchgate.net/publication/283841746_Service_Innovation_A_Service-Dominant_Logic_Perspective*

8 ACKNOWLEDGEMENTS

The views expressed in the *IIC Journal of Innovation* are the author's views and do not necessarily represent the views of their respective employers nor those of the Industry IoT Consortium®.

- Return to *IIC Journal of Innovation landing page* for more articles and past editions.