Fraunhofer IML

Silicon Economy Integration Guideline

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1. Introduction

The Silicon Economy Integration Guideline gives interested readers an overview of the results of the Silicon Economy project and provides tools for deploying these results within the own company environment. With a duration of five years (2020-2024), the project was funded by the Federal Ministry for Digital and Transport. The aim of this project was to create open-source software and hardware solutions as well as qualitative concepts to enable a B2B-driven platform economy in the field of logistics. More than 150 researchers from the Fraunhofer Institute for Material Flow and Logistics (IML) and Fraunhofer Institute for Software and Systems Engineering (ISST) as well as TU Dortmund University have created more than 50 open-source software and hardware components that help companies to digitalize logistical and supply chain-related processes.

Parallel to the Silicon Economy project the Open Logistics Foundation was founded. The aim of the Open Logistics Foundation is to foster and empower open-source software solutions within the domain of logistics and beyond. The Silicon Economy software components are hosted and advanced in the Open Logistics Foundation.

The underlying guideline does not only explain the concept of open-source software but also gives an overview of how digital platforms work in general, explains the differences between B2B- and B2C- or C2C platforms and shows how challenges in implementing B2B platforms can be tackled. Stemming from the domain of logistics a use case evolving around a fourth-party logistics service provider was designed to demonstrate the benefits of digitalization and digital platforms along supply chain processes. Along this use case, several aspects and tools provided by the Silicon Economy are highlighted.

Specifically, the Silicon Economy Integration Guideline provides a Platform Alignment Canvas that helps companies design their B2B platform business models. In addition to that, a Challenge Checklist is provided – addressing major challenges when setting up digital platforms such as the addressing of different market sides or their integrability considering the digital skills level. These two tools cover strategic- and business-related aspects that should precede the technical implementation. It is essential to understand which information needs to be retrieved and which process is required to implement business logic on digital platforms. This information is provided by the Logistical Standard Functions. How this information can be obtained and processed is covered by the Silicon Economy software components such as AI-based estimated time of arrival or electronic freight documents. Finally, the Reference Architecture provides a first idea of how all those services can be connected in a platform logic.

The integration guideline closes with motivation and deep-dive into the strategic aspects and benefits of open-source development and invites all interested companies to be part of the open-source community.

To ensure readability, the underlying guideline chose to highlight only some results and insights of the Silicon Economy. All further results and relevant materials can be found at: **https://www.silicon-economy.com/**

2. The Silicon Economy: the big picture

The Motivation for the Silicon Economy is rooted in the fact that digital platforms in the consumer area, such as Meta or Amazon, are increasingly engaging in traditional B2B segments, such as logistics, but also dominate the digitalization of B2B processes and infrastructure, such as cloud computing, hosting, and various applications of artificial intelligence (Rotgang et al. 2023; Hompel and Henke 2022).

However, to sustain **competition, pluralism and growth** possibilities for the industry and especially small and medium sized players, own B2B platform concepts and digital solutions are required (Cichosz et al. 2020). Thereby, the platform economy is not only a challenge for traditional companies but a huge **opportunity to master current economic obstacles** such as scarce labor, unstable supply chains, or environmental concerns: In a world where value creation factors such as labor and capital respectively materials are getting scarce, the idea of efficiently sharing, distributing, and managing those value factors becomes attractive. Digital platforms encompass the respective tools and provide the environment for organizing value creation processes: Via digital platforms, labor, capital, or the flow of information alike can be orchestrated (Tiwana and Bush 2014). Various stakeholders and parties involved can be integrated, connected, and **create value together** in an autonomous way. However, digital platforms and the digitalization of business processes also alter and change existing supply chains. One example from the B2B domain is decentralized additive manufacturing marketplaces:

A product that previously consisted of many individually turned, welded, or bolted components can be manufactured using a suitable printing device such as a 3D metal printer. This means that fewer suppliers of individual components are required, and the complexity of the supply chain is reduced accordingly. In addition, if the corresponding plans and design or print data are available, production can also be decentralized or carried out at any location, e.g., at the customer's premises or in other production facilities (Attaran 2017). Digital platforms can depict and coordinate this decentralized production and use additional technologies, such as distributed ledger technologies, to ensure that sensitive information, such as design data, is not passed on to unauthorized third parties. In addition, smart contracts can be used to automate payment after completion of the corresponding component (Kurpjuweit et al. 2021). This makes it possible to decentralize and autonomize production as far as possible. As a result, companies save cost, increase efficiency, and can focus on design expertise and build new, digital business models by selling, e.g., construction data or offering their customers highly specialized, individual products that would have been uneconomical to manufacture using conventional production methods (Attaran 2017). Thereby the focus is not on reducing existing business, but rather on fostering and sustaining new business models in the **light of environmental challenges, supply chain shocks, and scarce labor expertise.**

Although the benefits of such platform concepts and business models are apparent, the practical implementations are still challenging. The **underused potential of a B2B platform** economy is rooted in the various obstacles companies face when implementing platform business models on their own. This is caused by the fact that industrial business processes in B2B sectors are characterized by much higher complexity, uncertainty, and different levels and capacities of digitalization of the parties involved. The industrial landscapes are much more scattered, fragmented, and dependent on specialized solutions and procedures compared to B2C or C2C solutions, where individuals can make choices, e.g., consuming or buying via digital platforms on their own (Abendroth et al. 2021). Unlike natural individuals, companies face a tremendous number of legal questions and challenges when re-designing and digitalizing their business processes towards digital platforms. Apart from legal challenges, traditional companies may also lack competencies and capacities for digitalizing their business processes – aggravated by the lack of standardized solutions and concepts.

The Silicon Economy provides a starting point for companies that wish to digitalize their business processes – proceeding from logistical applications – and engage in a B2B platform economy. The solutions provided by the Silicon Economy are tools, open-source software components, and open-source hardware applications that enable companies to participate in an industry-driven B2B platform economy. Specifically, the Silicon Economy thereby addresses companies **from the field of logistics and supply chain management but also engineering and software development** of all sizes and backgrounds that wish to digitalize their value chain and engage in platform thinking.

The Silicon Economy envisions a federal platform economy. A federal platform economy contrasts monopolistic platform trends from the B2C or C2C sector by allowing industrial platforms to co-exist but connect to an overarching ecosystem of equal partners. The basic idea is that companies can build or use digital platforms that co-exist with other platforms and are equal partners in the ecosystem (Rotgang et al. 2023). The different platforms are compatible with each other, and digital services offered by different companies can be integrated into their IT landscapes easily by using standardized connectors and brokers that help to detect services and solution offerings. From a business perspective, companies can and should specialize and focus on their core competencies and can use digital platforms to add value creation factors that they cannot or do not want to provide on their own due to cost reasons or lacking expertise.

The open-source soft- and hardware components focus on addressing challenges in logistics and supply chain management. Logistical applications are a core element of every business transaction and operation (Hompel and Henke 2020). Thus, most companies rely on and wish for digital, well-functioning logistics as a key competitive advantage. In addition, most companies outsource logistical processes, already. Therefore, logistics is a value-adding factor dependent on external service providers. This underpins the basic idea of digital platforms in the B2B domain where non-core activities of companies can be outsourced and orchestrated via digital platforms. Moreover, logistic applications are a valuable ground for digital applications in the field of hardware, as well as software starting from digitalizing freight documents to developing pucks and sensors in addition to tracking technologies for sensitive goods and services. The digital data-driven world meets solid, practical, and human-driven business processes such as handling and packaging as well as shipping. Therefore, digital platforms have the potential to foster visibility and standardization as well as enable the digitalization of complex and still manually driven processes dependent on scarce labor, scarce physical space, and transportation capacity, as well as specific know-how for the needs and demands of individual industrial segments.

However, since logistical processes and connected B2B applications are mostly individual and not standardized, companies need open access and low entry barriers for solutions that aid them in digitalizing and harmonizing their processes. The harmonization and standardization of processes lays the basis for a well-functioning B2B platform economy.

This is the reason why all Silicon Economy solutions are provided as **open-source software and open-source hardware**, respectively, under an open-source software license. Thereby, open-source refers to a type of software license that grants the users specific rights. In general, open-source software is software that can be freely redistributed and allows full insights into the source code. Moreover, the software can be modified and adapted to individual needs and, dependent on the license, be redistributed with the modifications again also for commercial needs.

This leads to various benefits for companies: First, they can see and understand the source code of the components and assess whether the software provides a useful application for them or not. Moreover, they can adjust and adapt the component for their specific business purposes. Finally, they can even use the components and create products that can be commercialized (Hompel et al. 2022).

Open-source however, is not only a licensing model; it is much more **work- and innovation culture** and can help to develop **de facto standards** (Hompel et al. 2022). Open-source software is developed in communities where developers mutually work on codes. Developer communities can differ along the various projects and mostly are a mixture of corporate developers but also private individuals. Through the various sources of input, the code quality of open-source projects often is high, and bugs can be easily detected. Without complicated legal agreements or granted access to work results, different companies, as well as individuals, can work on joint projects and thereby foster quasi-standards, as the same – mutually developed and agreed solution can go into practice in each company (Steffen et al. 2024). Especially for logistical applications, those standards are beneficial as they ease inter-company exchanges of goods, services as well as data. So-called **commodity applications** have been proven to be suitable and attractive for open-source developments. Commodities are products or services and solutions that are an established part of the business process. In principle, it does not matter who offers this solution as it is not market-differentiating. Therefore, it may be even more beneficial if commodity applications are similar within the same application field, such as, e.g. certain data models and standards or the handling of specific forms (Hompel et al. 2022).

To foster and stabilize the idea of open-source software activities within the logistics community, the **Open Logistics Foundation** was founded in 2021. A growing community of logistics companies and software providers develop open-source solutions that can start from the Silicon Economy components evolving into new and community-driven projects.

The Open Logistics Foundation is the prime source to consolidate the software components of the Silicon Economy. They can be found in the respective repository. Additional information can also be obtained via the project website of the Silicon Economy[1] and the Open Logistics Foundation[2].

The Open Logistics Foundation invites interested companies and developers to use the components for their projects and developments as they are put under an open-source license. At the same time, membership in the attached support associations is possible. Members of the respective Open Logistics Foundation support association are invited to participate in the active development and design of new projects beyond the activities of the Silicon Economy. At the same time, the open-source software components lay the foundation for further research projects and developments at the Fraunhofer IML and TU Dortmund University or Fraunhofer ISST – in projects such as SKALA.

Beyond that, companies are invited to make use of the different applications and create their business models, own digital platforms, and foster and grow open-source communities. The underlying guideline provides an initial starting point for developing an understanding of the potential of platform business models and shows how platform applications can be built by using the Silicon Economy components.

[1] https://www.silicon-economy.com/

[2] https://openlogisticsfoundation.org/

3. Functionalities and roles of digital platforms

Digital platforms such as Google, Amazon, and Facebook have shaped today's concept of platforms and are deeply anchored in everyday life (Tiwana and Bush 2014; Asadullah et al. 2018). However, "platforms" have existed for centuries, with markets and bars being the analog counterpart to the aforementioned digital platforms. In their basic function, platforms aim to connect different actors, such as consumers and producers, to promote value creation through interactions between them (Rochet and Tirole 2003). Accordingly, platforms fulfill the purpose of bringing together different stakeholders to transparently match demand and supply to use resources as efficiently as possible (van der Aalst et al. 2019).

Digital platforms can be described from two different perspectives: Representatives of the **market-oriented view** describe platforms as an intermediary instance for processing transactions, whereas the **technology-oriented view** characterizes platforms as a modularly expandable technological infrastructure (Schreieck et al. 2016). The market-oriented view describes

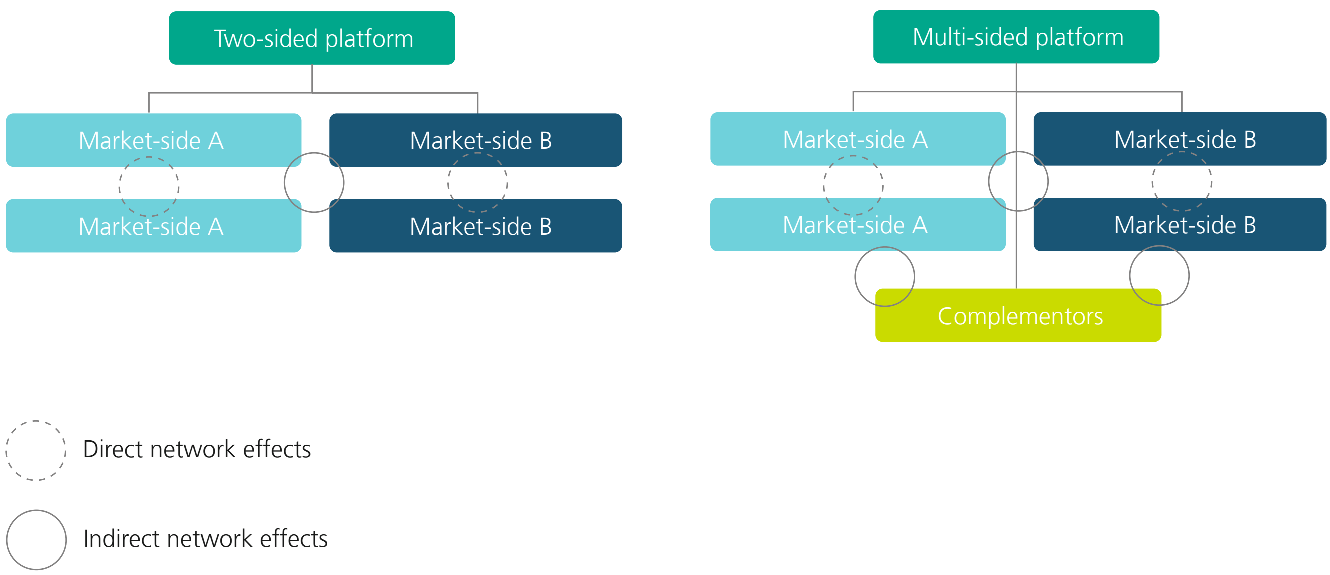


Figure 1: Direct and indirect network effects based on ten Hompel et al. (2022)

platforms as a type of marketplace where various parties carry out economic transactions. In this view, the platform acts as a third party between two or more groups of actors and enables and controls the processing of the transactions carried out. The higher the number of transactions carried out on the platform, the more attractive the platform becomes for the stakeholder groups (King 2013). Typical examples of market-oriented platforms are online marketplaces or online communities, such as the online market platform eBay or the social platform Facebook (Schreieck et al. 2016).

The technological perspective describes a platform as an IT infrastructure that provides a code base consisting of core functions and interfaces. Depending on the individual's intended use, the modular components of the platform can be expanded or linked as required. The aim here is to enable innovation and co-creation through the development of new modules by external users (Schreieck et al. 2016). Here too, the attractiveness of the platform increases with the number of users and available modules. Prominent examples of technological platforms are the open Android platform and the Linux operating system (Asadullah et al. 2018).

Both types of platforms aim to facilitate interaction between two or more actors or groups of actors (two-sided or multi-sided platforms). Accordingly, the value of platforms depends on the number of active users, which favors the phenomenon of „network effects" (Tiwana 2014). Network effects are divided into **direct and indirect network** effects. Direct network effects can often be observed on social networks such as Facebook or LinkedIn and result from the interaction of users within the same user group (McIntyre and Srinivasan 2017). Indirect networks result from interactions between different groups and are often found on platforms that offer complementary goods and services. Examples of indirect network effects include app stores: the higher the number of smartphone applications – the complementary product to the actual hardware and initial operating system, the more attractive the platform becomes for users. At the same time, the high number of users increases the incentive for developers to make their applications available in the app store (Tiwana 2014).

Network effects are fundamental to the success of platforms. At the same time, however, they promote the "winner takes it all" phenomenon, as users tend to converge on one platform. Many platform markets can be served by a single platform so that the winner of the battle for market power „takes it all". Once a platform has achieved market leadership, it is almost impossible for competitors or state-sponsored platforms to dethrone the dominant monopolistic platform (Eisenmann et al. 2008). As a result, monopolistic platforms have the power to dictate terms and suppress smaller competitors and platform participants. For example, the online e-commerce platform Amazon is continuously expanding its logistics infrastructure, acquiring new organizations from competitors, and expanding into new markets (e.g., voice technology or cloud services) (Durkee 2021; Hermes et al. 2020).

4. B2B platform business models in logistics and supply chain management

In general, the platform economy in the B2B sector is rather emerging. Big players from former B2C domains such as Amazon or Google are already – for quite some time – changing and designing various business processes. At the same time, start-ups and young companies, that specialize in the field of digitalization, are altering supply chain and logistical processes (Möller et al. 2020; Möller et al. 2019). However, for many fields and business processes, the potential for digital platform solutions is yet underexplored (Culotta et al. 2024; Anderson et al. 2022). At the same time, those processes and industrial applications are often so specialized and narrow, respectively have such a specific customer segment, that scaling is hampered due to weak network effects. A B2B platform economy is much more scattered and diverse. However, in the field of logistics, some platforms have managed to be successful and so-called fourth-party logistics[3] (hereafter 4PL) business models are advancing.

These digital platform enterprises often aim at enhancing efficiency by facilitating communication and collaboration between supply chain partners, such as suppliers and buyers (Möller et al. 2019). Additionally, they leverage data analytics and real-time information to streamline logistics processes, optimize resource allocation, and improve decision-making across the supply chain to help companies outsource their logistics activities (Acevedo Cote et al. 2021). They use various technologies ranging from digital twins, sensor solutions, and the connection with artificial intelligence.

The distinction between market-oriented and technology-driven platforms is also observed in the B2B sector (Möller et al. 2019). Beside traditional players from the B2C or C2C domain, specialized platform start-ups that combine the knowledge of traditional logistics and digital platform companies also drive the digitalization and networking of the industry (Mikl et al. 2021). The new players offer logistics and additional services via their digital platforms, which coordinate supply and demand in various sectors to increase resource efficiency (Atasoy et al. 2020; Gruchmann et al. 2020). Well-known examples of market-oriented transaction platforms in the B2B logistics sector are TIMOCOM and Sennder.

TIMOCOM is one of the largest European **freight exchanges** that aims to offer or find freight capacities.[4] The company advertises a comprehensive range of services, a high level of user-friendliness, and security, the reduction of empty runs, the reduction of the ecological footprint, and the expansion of the network. Furthermore, the logistics platform offers the possibility to search for freight to avoid empty runs and also to offer freight that is to be transported. The same principle applies to offering and searching for loading spaces. The company Sennder pursues a similar mission "to connect shippers and carriers in Europe to increase their productivity and opportunities for success". The aim here is also to use the loading capacities of trucks as efficiently as possible and to achieve this goal with the help of networking via logistics.

The digital transport marketplace for regional trucking services is a popular business model for B2B platforms in the logistics sector and a typical example of market-oriented platforms (Culotta and Duparc 2022). Digital marketplaces serve as infrastructures for connecting suppliers and customers in transportation services, leveraging customer-provided data to facilitate transactions. These platforms often offer additional digital services, such as real-time tracking, analytics, ratings, and dashboards, enhancing transparency and efficiency in the delivery process. Predominantly, these B2B platforms function as intermediaries for regional intercompany truck transport services (Möller et al. 2019).

Second, **Software-as-a-Service (SaaS) platforms** cover the technological perspective of B2B platforms in logistics as they provide a technological infrastructure for managing logistics processes. The platforms are becoming an increasingly popular vehicle for 4PL providers, offering scalable solutions that enhance operational efficiency and integration across complex supply chains. Providers offer, for example, fleet and inventory management software through SaaS platforms to optimize processes, enable tracking, and even outsource complex supply chain management tasks. These platforms utilize diverse data sources—such as customer data, tracking data, and generated data—to deliver robust services. The offerings are typically highly scalable, as they can be adapted to a global scope, offer different modules that are ideally easily integratable and are independent of specific transportation modes (Möller et al. 2019).

An example of a SaaS platform is the „Rhenus Supply Chain Visibility" platform developed by the Rhenus Group[6]. The neutral 4PL platform creates transparency for all partners along the supply chain, combining all modes of *transport*. The platform offers different services for its customers, such as full order tracking, shipment tracking, integrated document management, KPI reporting, and predictive alerting. The goal is to provide transparency along the supply chains and decrease the administrative effort for their customers, such as companies from the automotive, manufacturing, or chemical industries. An example of a recent start-up that emerged in the ecosystem of the Silicon Economy is Logistikbude which helps manage reusable assets such as pallets or containers via their platform-based software solution[7].

In conclusion, the landscape of B2B platforms in logistics is characterized by various business models that encompass both market-oriented and technology-driven approaches. While platforms like TIMOCOM and Sennder exemplify market-oriented transaction models, SaaS platforms provide the technological infrastructure needed for efficient logistics management. However, many platforms especially platforms with a market-oriented approach develop into **hybrid platforms** offering elements of both respectively adding new elements to their initial portfolio and thus offering more and more options to manage the supply chain. One example from procurement is Unite formerly known as Mercateo. Starting as a B2B market place for office supplies but also tools or electronics the platform offers more and more full solutions for holistic procurement and supplier management. It is no longer an online marketplace but rather a procurement platform with the possibility to integrate various other enterprise resource systems.

[3] 4PL service provider is someone who offers logistical services without having own physical assets. A 4PL orchestrates and manages supply chain processes via digital platforms by connecting the relevant parties and other service providers.

[4] https://www.timocom.de/.

[5] https://www.sennder.com/de

[6] https://www.rhenus.group/de/en/supply-chain-solutions/supply-chain-visibility/

[7] https://www.logistikbude.com/

[8] https://unite.eu/de-de

5. Use Case: outsourcing and digitalization of logistical processes

To enhance understanding of how and why digital platform solutions alter logistical supply chain processes in such a way that all parties involved can benefit, a use case is a suitable demonstrator. Within this fictional use case, the technological perspective on platforms is stressed. However, at the same time, the use case highlights the benefits a platform solution provides also from the business perspective:

Imagine a **classical manufacturing company** called "Meyer Drilling" that builds and distributes vertical drilling machines to industrial clients. The vertical drilling machines vary depending on the customer's needs. Meyer Drilling currently operates its warehouse at its site for the various components required to assemble the vertical drilling machines. In addition to the warehouse, Meyer Drilling also carries out all the conventional logistics processes. This means that Meyer Drilling not only carries out the ordering process with the suppliers but also calls off the corresponding partial quantities. Once the relevant components have been received, the incoming goods are processed by an employee, the goods are then picked and prepared for assembly by warehouse employees. After assembly and quality control, the goods are collected by the warehouse employee, packed, and handed over to the logistics service provider via the outgoing goods department. Once the goods have arrived at the customer, they are invoiced via the accounting department.

However, Meyer Drilling would like to **outsource its logistics process**. Logistics is not part of the company's core business - its core business is assembly, sales, product development, and customer service. In addition, outsourcing logistics processes would also simplify expansion to other assembly sites. As a starting point, Meyer Drilling would like to outsource the logistics process at its location in Dortmund, Germany. To this end, Meyer Drilling is looking for a suitable service provider that offer all services from a single source.

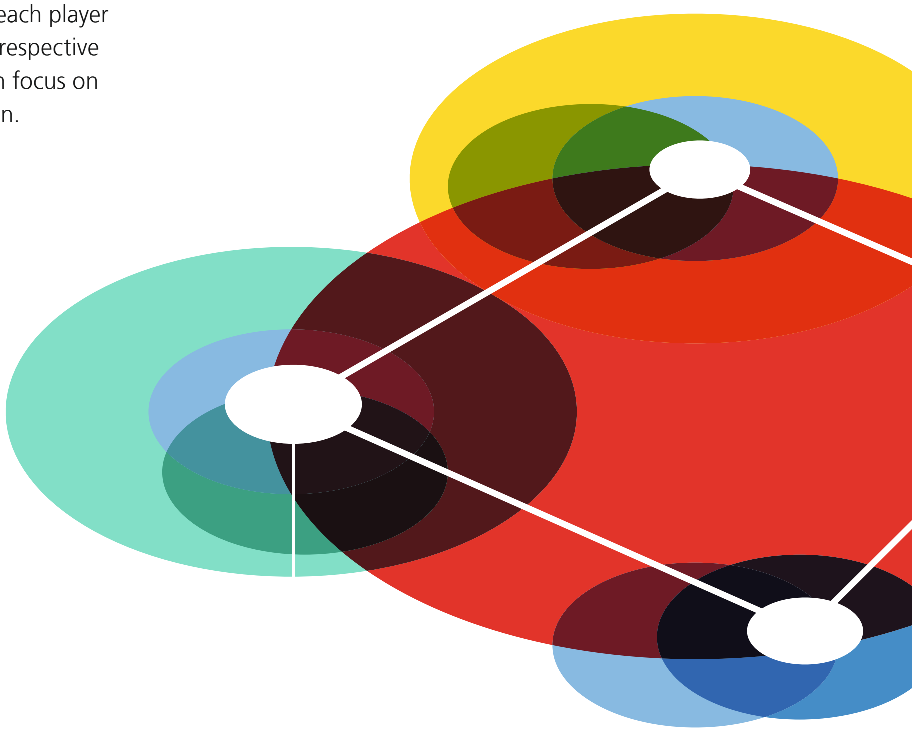
The company "Logi" is a **4PL service provider**, i.e., a "digital" freight forwarder without its own physical assets and can orchestrate the logistics processes via its platform solution. Meyer Drilling's suppliers are integrated into this platform, as are the logistics service providers. The logistics service providers are a third-party logistics service provider (hereinafter referred to as 3PL) and several second-party logistics service providers (hereinafter referred to as 2PL). The 3PL will take over the logistical activities on Meyer Drilling's premises, i.e., it will operate the warehouse for the company by having employees of the 3PL perform these tasks on site. They will take care of incoming goods, order picking, and the provision of the correct components for assembly (the bill of materials will be transmitted by Meyer Drilling or via the platform solution), as well as collecting the finished product after quality control, packaging, and outgoing goods. At the goods issue, the 3PL hands over the goods to the 2PL, who brings the goods to the customer but also brings the corresponding components to Meyer Drilling's warehouse. The 2PL has no activities on the factory premises in the narrower sense - it is responsible for pure transportation tasks such as bringing and collecting goods. Meyer Drilling – on its own wish - is still responsible for purchasing the goods and invoicing the customer. In addition to purchasing and invoicing, its tasks now only include assembly and quality control, as well as providing the parts lists (i.e., information on which components are needed for assembly).

The 4PL, respectively Logi, is the **orchestrator of the entire process**. The 3PL can be seen as the organizer or operational manager of the process. All information comes together at Logi, i.e., they receive status respectively process information about:

- Goods are requested from the supplier
- Goods are ordered from the supplier
- Goods are dispatched by the supplier via the 2PL
- Goods are received at Meyer Drilling on the factory premises by the 3PL, picked and then handed over for assembly
- Goods are completed and sent to outgoing goods and then packed and dispatched again via the 3PL
- The 2PL sends the goods to the customer
- The customer has paid the invoice or the process has been completed

Once the process is complete, Logi issues an aggregated invoice for the entire logistics services - i.e. the 2PL and 3PL do not have to bill the end customer themselves but instead bill Logi. In addition, Logi could also take over the import and export activities in the future, i.e. it can automatically provide the corresponding waybills and information when goods are transported abroad, for example. New suppliers and logistics service providers can be easily connected and integrated via the 4PL platform solution. As a result, Meyer Drilling can also easily set up its **manufacturing activities at other locations**.

All these activities require integration and information flows via the various systems of the companies such as enterprise resource planning systems or transportation management systems. Logi provides a **digital infrastructure** and application programming interfaces to facilitate and allow integration. Beyond that, certain information could also be directly saved and transmitted via platform applications. All information is merged and depicted on the platform solution that grants access to the relevant information for the respective parties. Such a solution and the easy integration of additional suppliers or 3PL and 2PL partners allow the **scaling of logistics activities** beyond the initial site of Meyer Drilling. Consequently, it is easy for Meyer Drilling to expand production sites to other locations. In addition, a platform solution of Logi can also help balance bottlenecks and undersupplies of individual production sites as the platform provides an overview of all materials in stock – which means that materials could be exchanged between the sites. The potential for scaling a business model such as Logi's is huge. At the same time, it enables the OEM respectively Meyer Drilling to scale its own business more easily. This is a classical example of a 4PL business model that already exists. However, it shows that digitalization and the depiction on digital platforms are not a threat but rather allow each player to focus on their core activities and specialize in their respective tasks – also the 3PL and 2PL service providers that can focus on high quality service on the premise or in transportation.



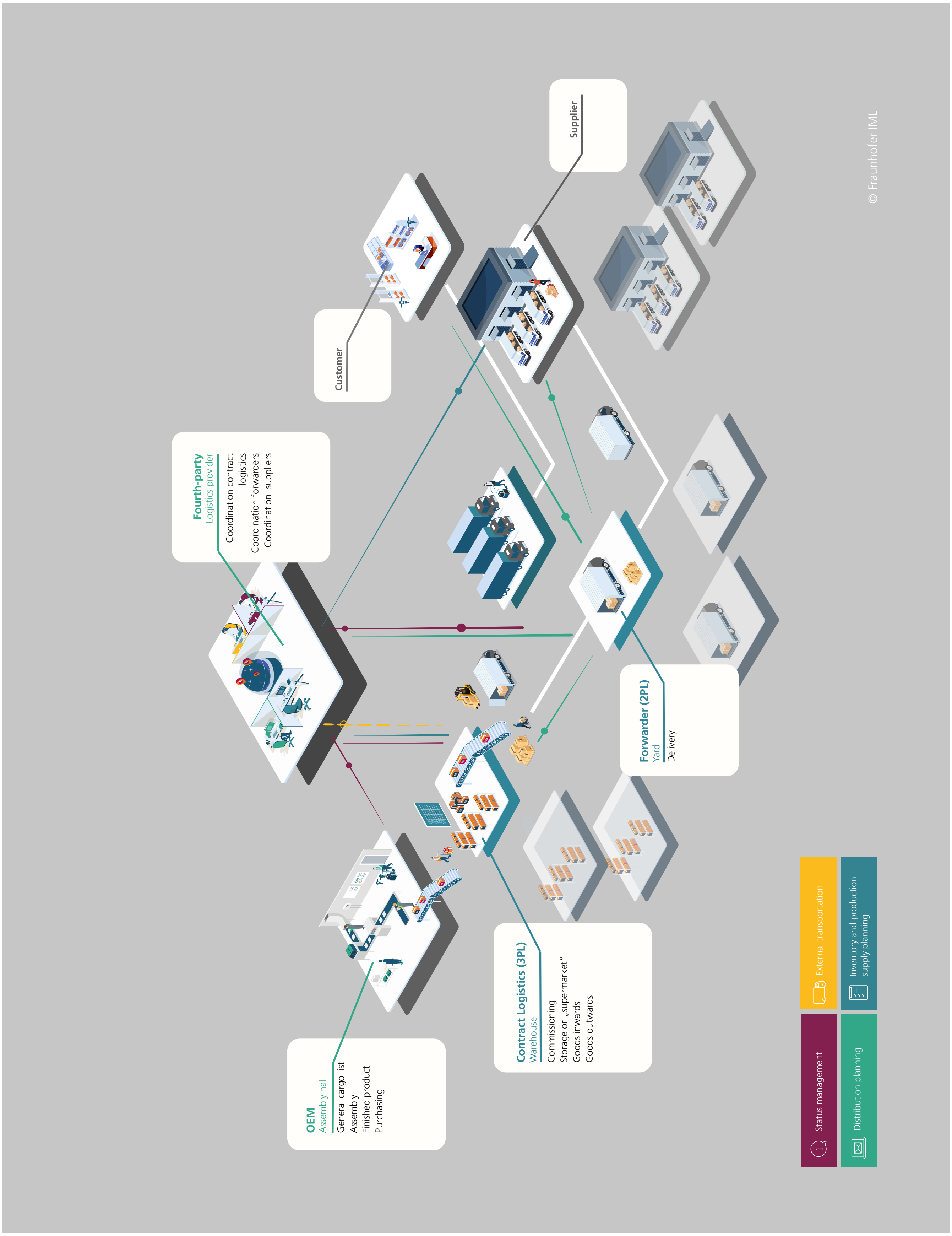


Figure 2: Use case of a 4PL business model

6. Challenges of building own B2B platform business models

Within the Silicon Economy project, it became apparent that implementing B2B-based platform business models is often challenging, especially from a market-oriented perspective. B2B platforms do not seem to scale to the same level as B2C or C2C counterparts. This is related to the observation that network effects are much weaker for B2B platforms than for B2C or C2C platforms (Anderson et al. 2022; Culotta et al. 2024; Henke and Culotta 2023). This has many reasons, amongst others:

High complexity

First, industrial processes are characterized by complexity and a high degree of individual (integration) requirements of the individual players. A large number of stakeholders must be integrated and motivated to participate in the platform to generate corresponding added value. A lack of willingness to participate due to high integration requirements and respective costs hinders the development of platforms.

Lack of standards

Related to that, individuality, complexity, and specialization of various industrial processes lead to a lack of standardization. This, in turn, harms the ability to offer modular, standardized products via the platform and to develop complementary products as a third-party provider.

Missing scalability

The initial development of digital platforms is associated with high, and often unclear costs. The integration requirements and individual interfaces are also a cost and resource factor due to the lack of standardization among customers and partners. As a result, the platform business model can be unprofitable, or growth opportunities fail to materialize.

Lack of openness and cooperation

In the context of digital platforms, companies are confronted with the need to operate beyond their known networks and established supply chains. Cooperation and openness represent a departure from traditional value creation logic. The sharing of data and open business processes are often associated with concerns about the loss of competitive advantages. This, in turn, leads to a lack of trust and inhibits participation in digital platforms.

Unknown boundaries of the firm

Related to the potential lack of openness is the uncertainty of the boundaries of the firm. The boundary of the firm comprises those actions that the firm undertakes to create value such as e.g., production or research and development activities. Wherever the value creation activities can be acquired for lower costs via the market mechanism, it may be reasonable to outsource activities or buy them from suppliers (e.g., expertise, specific parts for production, or services such as logistics). Digital platforms are, however, firm and market alike. They vanish the boundaries of the firm in general, and it is difficult for companies to decide when and how to create value via the digital platform.

Low levels of digitalization skills

Digitalization skills vary along supply chains. Similarly, some existing service providers are not in a position to implement digital solutions. However, the prerequisite for successful digital B2B platforms is a common minimum degree of digitalization in the companies that are meant to participate in the platform.

7. Solutions offered by the Silicon Economy

The challenges indicated above explain why it may be difficult to establish B2B platform business models. In light of these challenges, the Silicon Economy provides several tools and solutions to enable companies to build their own B2B platforms.

The **Platform Alignment Canvas** can be seen as a useful starting point for describing the cornerstones of the intended platform business models. Thereby, the Platform Alignment Canvas addresses companies that envision themselves as platform provider respectively platform owners. However, also for providers of complementary products, it may be a useful tool for analyzing different platforms and selecting the most suitable one.

After the initial platform business model is understood, companies can use the **Challenge Checklist**. It provides several solution approaches to address the challenges outlined above.

In addition to that, the Silicon Economy provides a catalog of **Logistical Standard Functions**. Those functions describe quintessential logistical processes from a process perspective and information perspective. The Logistical Standard Functions answer the question of which data would be necessary if these logistical standards need to be implemented. Understanding the basic business processes is especially relevant if companies wish to digitalize logistical processes and depict them on their platform. The corresponding data for realizing the platform logic and delivering the unique value proposition worked out via the Platform Alignment Canvas can emerge from the integration of the Silicon Economy Services.

The **Silicon Economy Services** comprise more than 50 different open-source software (and hardware) components addressing well-known digitalization challenges in logistics and supply chain management. Thus, companies can draw on a rich pool of software components to create their platform business models. Thereby, resources are saved, and eventually lacking digitalization skills are circumvented. Moreover, the software components provide a vital starting point for building own platform-based business model based on the data and information flows rendered possible by integrating these solutions.

Finally, the **Reference Architecture** shows how various actors within the platform logic of the above-outlined use case can exchange their data in a safe way along the platform logic.

7.1. The Platform Alignment Canvas

The Platform Alignment Canvas is a strategic tool for designing digital platform business models, particularly in the industrial context, and follows Steffen et al. (2022). It helps structure the strategic and operational aspects of platform development. Twelve components are outlined, each playing a crucial role in the design process.

The first component is the **owner's purpose.** Here, the focus is on defining why the platform owner is initiating the platform. This involves the company's long-term vision and strategic direction. The purpose can vary, such as aiming to become a market leader in a specific field, establishing a new business model, or strengthening existing customer relationships. It is essential to clarify what specific benefits the owner aims to generate for themselves and their stakeholders and whether there is a strategic objective, such as market expansion or value chain optimization.

Another key aspect is the **value of the platform**, also known as the Unique Value Proposition (UVP). This component defines the platform's unique selling point. The UVP answers the question of why the platform is attractive to its users and how it differen-tiates itself from others. The platform's value proposition must be clearly articulated to ensure alignment with the company's strategy and to provide a sustainable competitive advantage. This can be achieved through exclusive services, improved access to resources, or innovative features.

The next essential point is the **problems that need to be solved**. Platforms should be designed to address specific issues faced by their target audience. This involves identifying and analyzing both the challenges that arise during the platform's creation and the problems the platform aims to solve for its users. A precise problem definition is critical to ensure efficient and targeted platform design. Examples of such

Figure 3: The Platform Alignment Canvas following Steffen et al. (2022)

problems could include process optimization, more efficient data processing, or improved communication channels.

One of the most important strategic decisions concerns determining the **platform type**, known as the platform model. The platform type should be selected to best align with the company's vision and objectives. The strengths of the platform should be leveraged within its chosen type to maximize its impact. At the same time, companies that are part of the value chain are categorized as **providers**. Identifying the role and benefits of these providers is vital to emphasize the value the platform offers them. The careful selection of the platform model determines how well the platform can occupy its niche and provide optimal value to customers.

The **customers** of the platform constitute another central aspect. They come from a wide range of backgrounds, including start-ups, small and medium-sized enterprises (SMEs), and large industrial companies. The potential target customer group must be clearly defined to understand the market potential and the requirements for the platform. The customer profiles and their specific needs significantly shape the platform's design and the services offered. The platform should focus on providing maximum value to the customers and meeting their expectations.

In addition to the main providers, **complementary providers** are also essential for the platform's success. They supply additional products or services that enhance the main offering's value and expand the platform's ecosystem. Careful selection and integration of complementary providers ensure that they sensibly supplement the platform and provide real added value to customers. Collaborating with these providers can also strengthen customer loyalty and create new revenue streams.

Another key element are the **transactions on the platform**. This involves the nature and quality of interactions, exchanges, or co-development activities occurring on the platform. Transactions can include data exchanges, components, services, or financial transactions. Effectively structuring transactions is crucial to keeping the platform's ecosystem dynamic and value-generating. Alongside this, selecting appropriate channels is important. **Channels** are the means through which the platform reaches its customers, whether digital channels like websites and apps or physical channels like events and trade fairs. The selection of channels should be tailored to the habits of the target audience to ensure effective customer engagement and accessibility of the platform's services.

The **cost structure** is another critical aspect of platform design. It includes both the direct and indirect costs associated with developing and operating the platform. Direct costs might involve development, maintenance, and marketing, while indirect costs could include administration or licenses. A comprehensive understanding of costs is indispensable for financial planning and the platform's long-term sustainability. It is also important to consider how these costs might change over time, for instance, due to scaling or the addition of new services.

Correspondingly, the **revenue model** plays a pivotal role. It concerns the various revenue streams available to both the platform owner and the providers. Potential sources of revenue include transaction fees, membership fees, advertising, or the sale of additional services. The model must be designed to be sustainable and flexible enough to respond to changing market conditions.

Finally, the platform's **requirements** must be precisely defined. This includes the functional requirements that must be met to solve customer problems and fulfill their expectations. This encompasses technical requirements, such as data security and scalability, as well as user requirements, like user-friendliness and multi-language support. Clearly defining these requirements allows for a structured development process and ensures customer satisfaction.

Challenge	Potential solution approaches	Questions to be asked and answered
High complexity	In the course of building the platform, it can make sense to first implement specific use cases with trusted and well-equipped stakeholders. This allows the platform concept to be tested and unmanageable costs to be avoided. After a successful implementation phase, other companies can be integrated. In addition, open-source software components can be provided: Companies can use the open and free interfaces to carry out integration and customization work themselves.	✓ Who are the critical partners I have to win for my platform use case? ✓ Are all market sides represented? ✓ Is the business case depicted on the platform? ✓ Can it be simplified, and does the platform still deliver its USP? ✓ Is everyone motivated to be part of the platform? If not, how can I win them over? (e.g., make them partners instead of users or offer discounts/ free usage)
Lack of standards	Industry consortia can jointly develop de facto standards. The aim is to identify commodities or processes and products that do not differentiate them from the competition and to establish corresponding standardized solutions. Open-source software is a key driver for new de facto standards.	✓ Is the solution taken into account already a commodity or is it still market-differentiating? ✓ If yes, how long will it still be market-differentiating? ✓ Do we have enough process knowledge to define and determine the de facto standard? ✓ What are other suitable and related standard implementations?
Missing scalability	Platform strategies can be implemented where services and products can be offered in a modular and scalable way. Consequently, de facto standards should be worked on in advance with trustworthy partners or via open-source approaches. However, in the best case, the digital platform is built in a market where standardization is already present or market sides are at least open to it. Mostly, it is recommended to adopt a slow scaling strategy and start with trustworthy partners. However, they also need to be integrated and handled.	✓ Is the addressed market segment already standardized and ready for modular products? ✓ How scattered and diverse are processes, products, and services in the targeted market? ✓ If the market is quite scattered, is it realistic to foster standardization? Are there partners that can push this standard, e.g., via open-source software? ✓ Are customers and platform participants open to standardized solutions and open-source approaches? ✓ Are there sufficient funds for initial integration costs for my first customers? ✓ If certain market sides are not convinced yet, can it be afforded to subsidize them?

Challenge	Potential solution approaches	Questions to be asked and answered
	Also, if firms start "small" the initial investment and integration costs must be taken into account. Revenue-sharing, direct and indirect sources of income, as well as cross-subsidization, must be considered as well if key partners need to be incentivized.	
Lack of openness and cooperation	New technologies, such as distributed-ledger technologies, can create trust. With the help of smart contracts, decentralized identifiers, and verifiable credentials, sovereign platform participation can be achieved without dependencies on centralized systems. In addition or as an alternative, it is helpful to build on established data exchange standards and formats provided by e.g., the International Data Spaces. However, a new, platform-oriented, and network-driven mindset is also required as the basis for platform business models and participation. Companies must first develop this within themselves and then gradually pass it on, for example, through open innovation approaches to their customers. In doing so, the added value for the whole ecosystem takes precedence over their own profit maximization.	✓ Is trust an issue for my customers' participation on the platform? ✓ If yes, whom do they not trust? ✓ How can trust between the different market sides, respectively customers be established? ✓ Are they strong competitors and thus afraid to use the platform? ✓ Can the personal relationships between the different platform participants by, e.g., joint workshops or meetings in a ramp-up phase be strengthened? ✓ Is the technological design and governance of the platform set up in such a way that no sensitive information is revealed? ✓ Are there other technologies that ensure trust between the different actors? Do the actors trust respectively understand the technology? ✓ Do I have positive examples of platform-based co-operation that I can use to demonstrate the benefits? ✓ Is it clear from the governance that the ecosystem and the platform aim to maximize the value for all actors?
Unknown boundaries of the firm	Companies that engage in a platform economy often leave the boundary of their firm and well-known supplier relationships. Platform firms have to acknowledge the fact, that this is a shift for their customers. However, if customers also see a chance to change and shift their boundaries, this could be beneficial for the platform as customers move value creation towards the platform. At the same time, if the platform firm has initially been a traditional company that now builds a platform business, the boundary of their own firm also changes – this means that value creation happens outside a controlled frame (e.g., production and value creation within the firm or by selected well-known partners). On digital platforms, value creation happens more autonomously, spontaneously, and with – given the large size of the platform – unknown partners.	✓ What constitutes the customer's core business and their core competencies? ✓ What will remain in their boundary of the firm in the sense of their knowledge, skills, and the resources provided to create their value propositions? What can be „outsourced" to the platform? ✓ Can the platform provide the necessary value creation factors at lower costs compared to the internal provision of value creation factors at my customer's company? ✓ What constitutes the platform's core business and where do I draw the boundary of my firm?

Challenge	Potential solution approaches	Questions to be asked and answered
Low levels of digitalization skills	Companies that want to set up their own B2B platforms must carry out a stakeholder analysis in advance to identify which partners are necessary to make the platform attractive. The resources and skills of the partners are crucial. If the partners do not have the necessary expertise, low-threshold offers or a high level of usability must be guaranteed. The provision of open-source solutions is a complementary, valuable approach. However, if the necessary partners have low digitalization skills, they need supporting firms and advisors who help them to use the technology or integrate the open-source components. Either the platform company can provide such service or it partners with other service providers and ensures the financial reasonableness for the partners. Especially small and medium-sized firms have only small funds for digitalization projects.	✓ What kind of resources and skills do the critical stakeholders have? ✓ How is their competence level towards digitalization, and will they be able to use the platform solution? ✓ If not, how can I help them? ✓ Is the platform even attractive for them, respectively are they willing to undergo a digitalization process? ✓ Are there other partners and firms that can support their digitalization process? ✓ Does the platform have the funds to eventually provide support for this ramp-up phase? ✓ If not, are there public funds or public entities that could be project partners (e.g., research institutes, offices for economic development, chambers of commerce, start-up incubators…) for an initial ramp-up phase supporting customers with a low level of digitalization and platform expertise? ✓ Is the design of the platform technology set in such a way that it is easily useable and has low barriers? (e.g., usable on various devices, low integration effort, intuitive accompanying material…)

Table 1: Challenge Checklist for building own digital B2B platforms

7.2. Challenge Checklist

After filling out the Platform Alignment Canvas, companies have obtained a comprehensive understanding of their intended business model. However, as outlined, the implementation may be hampered by several challenges. Thus, it is worthy to analyze and address these challenges in advance to allow for scalability and healthy growth of the platform.

The following overview in Table 1 builds upon Henke and Culotta (2023) and Culotta et al. (2024) and helps companies prepare for addressing typical challenges in the B2B platform domain.

7.3. Logistical Standard Functions

One major challenge when digitalizing existing processes in every industrial application is the creation of a data standard. Over time, every company and supply chain develops certain standards of how processes are carried out – this holds true for manual processes such as order picking processes or pallet exchanges but should also hold true for the respective digitalization. However, although processes may be standardized within a certain supply chain, it does not necessarily mean that they are standard within the entire industry. Especially when it comes to data exchanges, the formats may still differ – they often require the same information, such as date, time, or address, but may still be presented differently. This lack of standard causes tremendous costs as for every new partner, individual integration and harmonization are required.

Therefore, the Silicon Economy provides a catalog of so-called Logistical Standard Functions which can be retrieved ***here***. This catalog presents the most common logistical processes, such as e.g., operation scheduling, inventory planning, or border-crossing transport, as well as common supply chain-related information, such as estimated time of arrival.

The standards presented in this catalog are the result of research that strives to create a uniform process and data landscape in the logistics area of activity, which companies can refer to in data exchange and integrate the same data structures into their own systems. The standard functions provide a valuable starting point for the design and creation of digital business models and platforms as they help to understand the underlying business processes as well as provide the needed data exchange format, respectively indicating which data would be required to realize and handle the process. Therefore it provides a valuable addition to the software components developed in the Silicon Economy that help to create and process the data. To this end, typical, recurring standard functions are described in three areas: A **fact sheet** details the scientific background for the standard processes and a typical process description highlighting the context and relevance of the process. A **process diagram**, noted in the Unified Modeling Language (UML), draws a graphical ideal representation of the process, which is derived from the scientific literature and thus represents a graphical context for the process. The process diagrams are augmented by **data objects** in JavaScript Object Notation format (JSON) to indicate where uniform interfaces are required in the process to enable smooth digital communication.

7.4. The Silicon Economy open-source software components

The Silicon Economy has created more than 50 software components that are provided under an open-source software license via the repository of the Open Logistics Foundation. In addition several open-source hardware plans are also published. The components offer software solutions for intralogistics, transportation, or general process-oriented challenges and general obstacles in harmonizing digital infrastructures. The full list of all open-source software componentes can be found ***here***.

In the presented use case of Meyer Drilling and Logi, the Silicon Economy software components provide a vital starting point for digitalizing the logistical processes. In this scenario, Logi would integrate and use these open-source software components to build respective services and solutions for the different platform actors comprising Meyer Drilling as OEM but also the 3PL and 2PL. In the following some **exemplary components** are highlighted.

Within the **production, the warehouse and the yard** of Meyer Drilling, the VDA5050 Standard for autonomous vehicles, and components from Yardlense on Edge can improve the digitalization and automatization of the activities of the OEM and 3PL. If a 3PL uses autonomous vehicles for the physical warehouse process, the implementation of the **VDA5050 Standard** can support the introduction of such vehicles by providing standardized interface descriptions. For yard

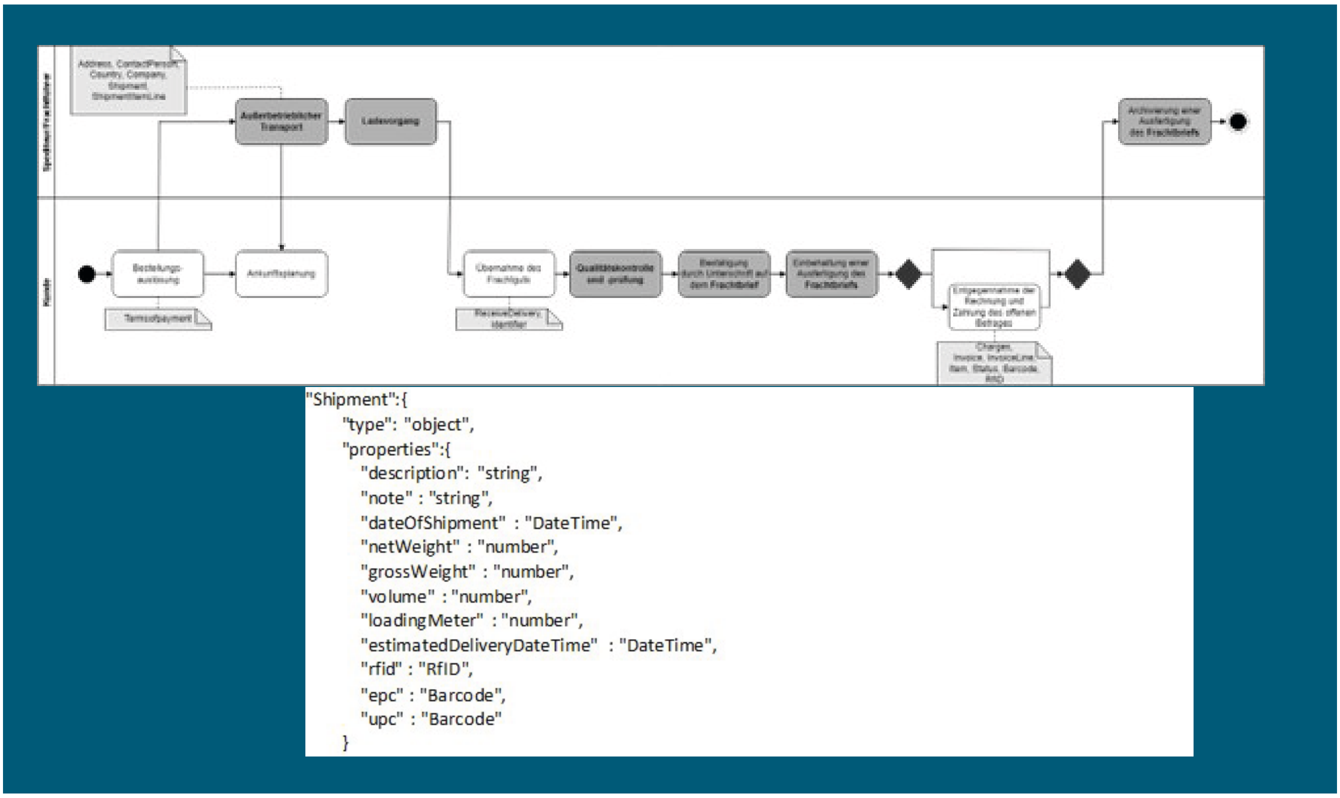


Figure 4: Exemplary process of delivery process diagram and excerpt from JSON object

management, the project **Yard Lense on Edge** can support the identification and tracking of vehicles on the yard and the allocation of shipments. Thereby, the component addresses the challenges of missing real-time synchronization of real pitch occupancy. In practice, reports and scans have to be entered manually. However, the solution envisaged in the Yard Lense on Edge project is the AI-based tracking of trucks in the yard using a multi-camera setup. Asset and truck positions in the outdoor area of company premises are transmitted in real time which allows more smooth and effective yard management.

For **transportation processes**, components such as the eCMR, the Sensing Puck, and Modular Open-source IoT-Devices can be applied. Transport processes are usually performed through 2PL, several developments have taken place in this realm. To digitize the management of documents accompanying shipments like the waybill, the **eCMR** was developed. It represents a digital version of the waybill containing all necessary information for the transport to commence. To further enhance functionality, the eFreightfolder is a follow-up project to the eCMR, allowing the storage of additional documents for transportation processes. In these projects, services for generating, storing, and forwarding digital waybills in human- and machine-readable format have now been designed and implemented as a reference implementation, taking into account established templates and international standards. It is also possible to guarantee the authenticity and integrity of the transport information by a digital signature, a version history that includes all changes, and the storage of the hash value in a blockchain. Great importance is attached to the use of existing standards during implementation. For example, the UN/CEFACT data standard, the IRU's CMR template, and the ECDSA signature process are used. By digitalizing freight documents, high manual documentation tasks can be reduced, conveying errors reduced, and process speed increased since information is available digitally to all parties involved. At the same time, the carbon footprint can be reduced as the process is paperless.

To allow tracking and tracing of, e.g., sensitive shipments in progress, such as products that need to be cooled constantly, the **Sensing Puck** can be utilized, which represents a compact hardware device for this purpose. Also created in the project Modular Open-source IoT-Devices is the **IoT-Broker**, which supports the integration of IoT devices like a sensing puck in general.

There are also developments that are not restricted to certain scenarios but can be used agnostically across many roles. One of them is the **ML-Toolbox** with the **Guided Training Service**, which supports the development of machine learning software by providing tools for reoccurring tasks during the development process. The **IDS Integration Toolbox** is a software library that supports the integration of components developed for **International Data Spaces** applications. The project **SERUM** supplies the community with many applications and tools, like drivers for IR sensors, LED panels or inertial modules, components to manage the measurements of sensors, a rust wrapper for constrained embedded devices, and communication implementations for specific processors.

Along the outlined use case, a 4PL but any other logistical company has many opportunities to enhance the digitalization of the respective processes and obtain data along the supply chain. Thereby platform business models can be fostered as the integration and the curating of the information allows for a full depiction of the supply chain. This enables the 4PL to have transparency regarding the individual partners in the supply chain, such as the 3PL, the 2PL, and their respective tasks. On the one hand, this leads to the value proposition of providing real-time information and an overview of the logistical processes for the customer (Meyer Drilling) but also allows the 4PL to counteract if necessary. This is especially relevant if the production is further decentralized and many different logistical partners and suppliers have to be integrated beyond various places and facilities.

7.5. Silicon Economy Reference Architecture of B2B platforms

Beyond the subject-specific software components, the project provides a reference architecture that shows how a platform solution could be designed from an information systems perspective. The Silicon Economy favors the idea of federal platform ecosystems where participants can provide and find services within an ecosystem of many, co-existing platform applications. Participants can register with their own connectors. A broker manages and orchestrates the respective services and processes.

In specific the reference architecture describes how potential platform participants can register their platform services, can be discovered, and how they can be interacted with. Thereby, the reference architecture offers scalability within a platform ecosystem.

The reference architecture was iterated in several steps and followed the fictive use case in the sense of a domain-driven design approach (see Figure 2). In this final form of the architecture, all participants in the logistics platform have a connector. The **connector** enables the creation of data spaces and the sharing of data in them. In this architecture, it is only used as a framework for the latter. The process groups marked in color are now part of the connectors in the form of

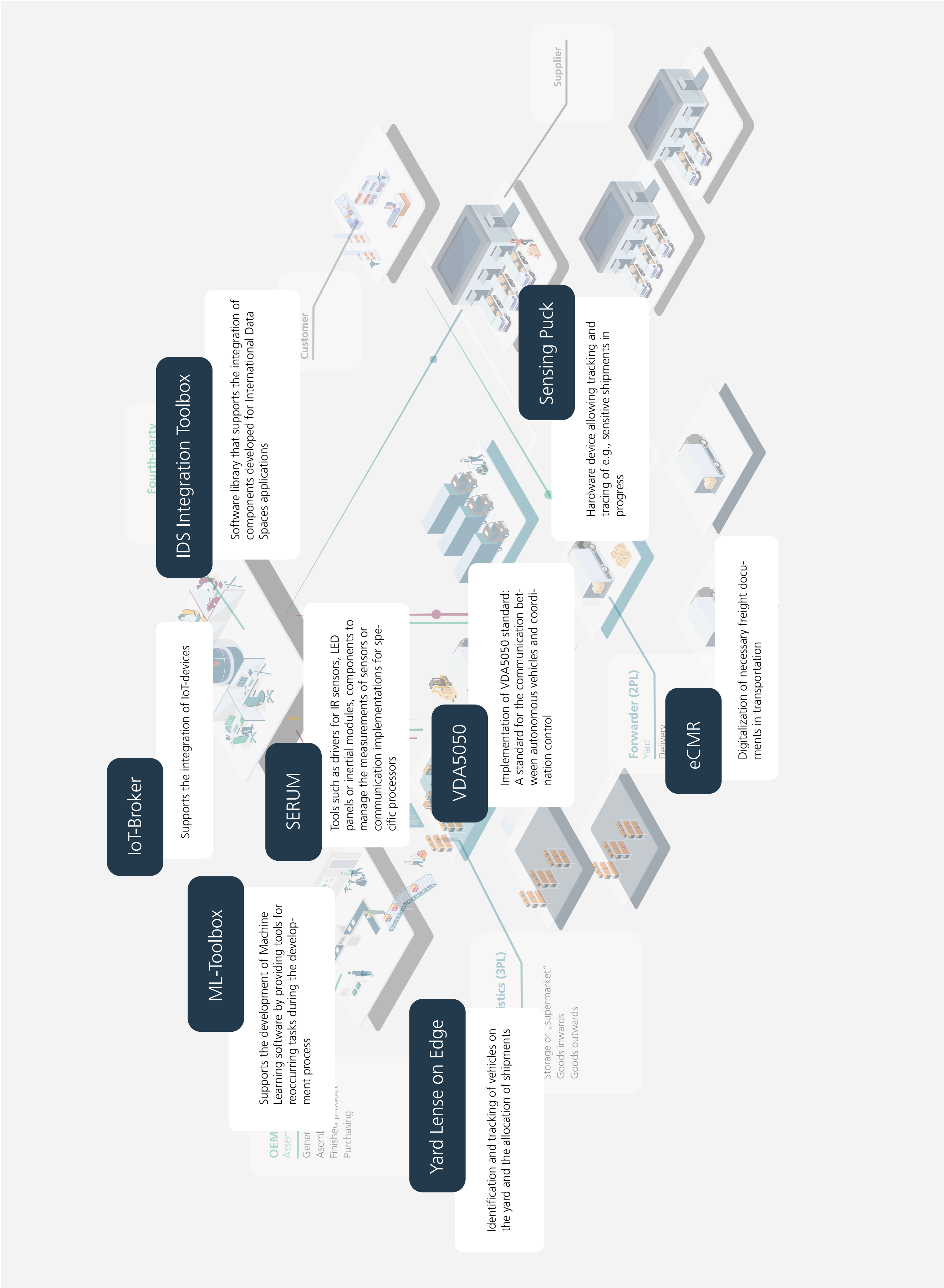


Figure 5: Integration of the Silicon Economy components into the use case

so-called extensions. These can be used to expand connectors in a modular way. Only the communication between the participants is marked with arrows in the architecture. In addition to the extensions it contains, each connector has two more, which are shown on the edge of the logistics platform: **database and service information**. Each connector thus has a database for storing the exchanged data objects. The extension service information is used to communicate with the broker. The **broker** is a separate instance that is part of the platform. Each participant provides the necessary meta information to the broker so that other participants can find and interact with each other.

In sum, the reference architecture consists of three aspects: the connector, the broker, and their relationships to each other. Any number of connectors can exist, depending on the desired size of the data space. All interactions between broker and connectors as well as inter-connector and external actions are carried out over HTTP interfaces.

The extensive documentation of the reference architecture can be found ***here***.

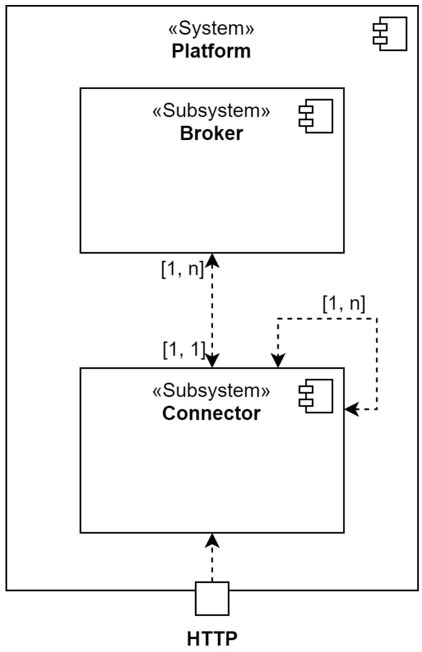


Figure 6: Abstracted reference architecture (building block view)

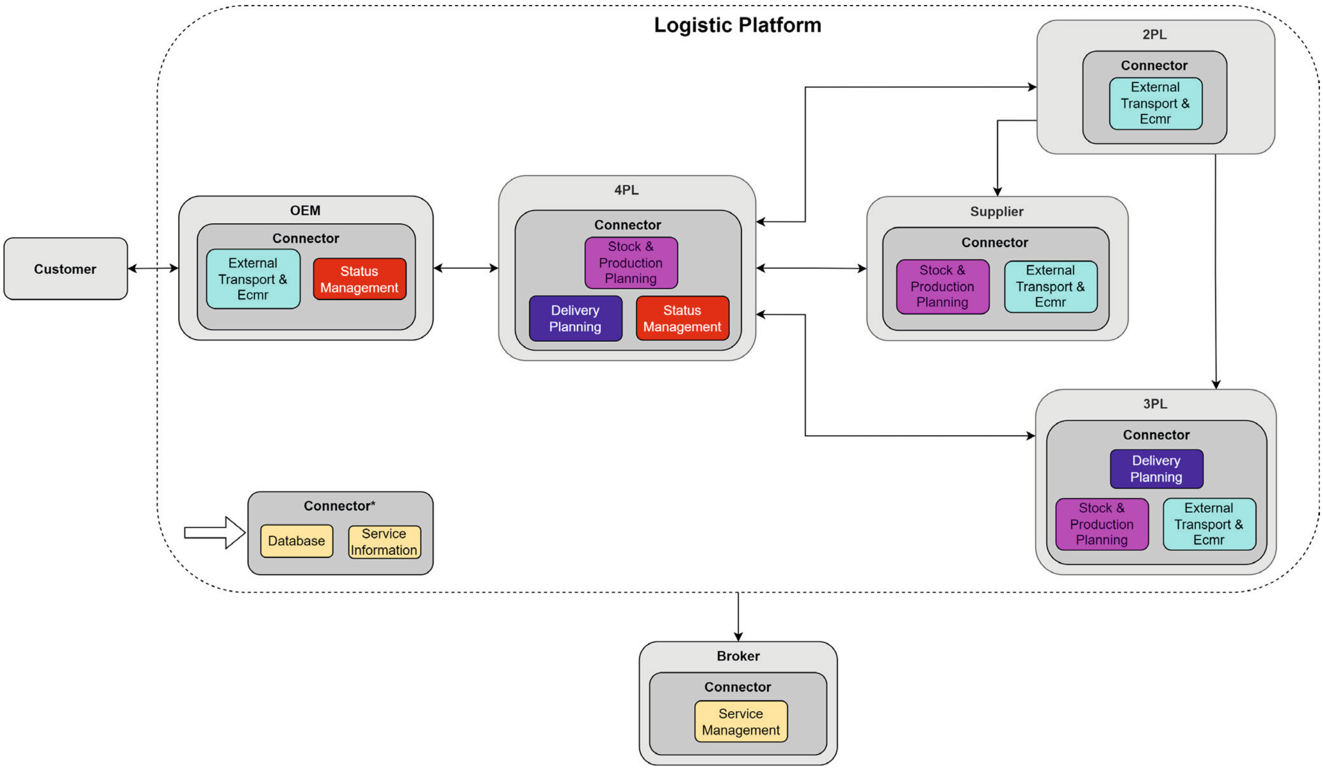


Figure 7: Reference architecture of a logistical platform along a 4PL use case

8. Motivating strategic open-source

The solutions provided by the Silicon Economy and fostered by the Open Logistics Foundation are put under an open-source software license. The open-source software license allows the free use and modification of the source code as well as the commercialization. Consequently, the solutions provided can be easily integrated and used, allowing a quick diffusion and potentially the development of de facto standards. However, not only from the perspective of a funded project such as the Silicon Economy or a foundation but also from an individual company's perspective, open-source can be a useful tool and general strategy for fostering innovation. Rather than being a license model, open-source is a key process innovation for companies that supports the use of Industry 4.0 technologies such as blockchain and artificial intelligence (Aceto et al. 2019) and accelerates the speed of innovation and adaptability of companies (Fukawa et al. 2021). In the software industry, open source has evolved from a development method to a common innovation strategy in recent decades (Schrape 2019), giving rise to new business models (Shahrivar et al. 2018). In times of accelerating digitalization and Industry 4.0, the interest in digital innovations is growing beyond the software industry and therefore justifies a cross-industry, increasing interest in open-source solutions.

Degree of open-source involvement and benefits

For companies, there are multiple ways to get involved with open-source software (Hompel et al. 2022):

First, they can **consume open-source software** and, dependent on the license, modify, integrate, and redistribute the source code. A high motivation for using open-source software lies in the savings compared to a proprietary solution. At the same time, active community engagement leads to high security and actuality of the software – as many developers observe the software, detect bugs, and provide solutions for fixing those problems. In sum, open-source software is therefore often of high quality and actuality.

Second, companies respectively their developers can get involved in open-source software communities and engage in **contributions of their own source code** – such as fixing bugs or contributing to existing projects by providing additional features or further developments. Therefore, companies use the opportunity to actively shape the development in their favor and be informed about current developments.

Third, companies can **publish their own projects** under an open-source license. Thereby they build their communities consisting of, e.g., partners, suppliers, customers but also every software developer or firm interested. Mostly, the motivation for this is to either establish de facto standards in their own interest or to foster open-source business models.

Although the software itself is "free", every other service or product related to open-source software can be provided fee-based. Examples of **open-source business models** are: dual licensing (a free basic version and a professional proprietary version is provided), professional services (such as integration, support, or consulting), or open API's (boundary resources or, e.g., development tools are provided open-source whereby the core product is proprietary).

In addition to the mentioned benefits, companies use their engagement in open-source projects also strategically to **increase visibility** for their products or attract developers as human resources. Especially for developers, the possibility to work for open-source projects within the context of their employment is attractive. Table 2 provides a list of incentives that affect the decision of open-source involvement for companies (Paffrath and Henke 2024).

Open-source strategies

As open-source software is more than only a licensing model and cost saver compared to proprietary licenses but rather a cooperation and collaboration model, a potential business model, or a way to foster de facto standards, it is worth it for companies to view open-source software as a **strategic tool**. Especially for building B2B platform business models, open-source can ease and facilitate not only the integration of partners but also foster complementary products and services and thus enable the growth of the ecosystem.

Not only for platform-related aspects but also on many other levels open-source software can help to achieve the overall goals of a company such as an increase in performance, innovativeness, or an increase in access to new partners, networks,

Incentives	
Supply chain collaboration	Design and improvement of supply chain performance through open-source solutions and interorganisational collaboration with suppliers or customers
Spillover-effect	Increasing demand and attractiveness for complementary, proprietary products
Savings	Reducing spending on proprietary alternatives and allocating resources for open-source development
Market position and image	Competitive positioning within the market through increased visibility and differentiation from competitors
Quality and security	Increasing maturity and usability of innovations for internal and external consumer
Standardization	Developing standards and establishing standards in the market
Vendor lock-in	Reducing dependency on a vendor for products and barriers to choose alternatives
Individuality and flexibility	Involving functionalities according to individual needs under principles of flexibility and agility
Power and speed of innovation	Increasing the power and speed of innovation through simplification of innovation processes and using external resources as innovation sources
Employee motivation	Incentivisation of employees through open-source practices leading to personal fulfilment

Table 2: Incentives and motives for using open source following Paffrath and Henke (2024)

and industries. Thus it is valuable for companies to consider open-source software strategies.

Implementing an effective process of managing open-source strategies requires a shift in basic organizational principles. However, there is not “the one” strategy for all circumstances. Instead, companies have to find the right strategy according to their motivations.

The following **four questions** help companies to initiate their open-source strategy (Paffrath et al. 2023):

Which external source is used to obtain open-source solutions?
Open-source communities and projects can be leveraged as an external source of supply to discover innovative solutions. By collaborating with various stakeholders, resources can be shared, dependencies on software vendors can be reduced through standardization, and development capacity as well as expertise can be expanded. Defining a set of required characteristics of communities can support companies in partnering with the right community. If no existing open-source projects meet their requirements, companies can also initiate new open-source projects themselves or establish communities.

How do companies interact with open-source communities?
Open-source solutions are available to companies free of charge. However, to leverage open-source projects using the main benefits of strategic open-source, firms should collaborate with the consortium. The level of involvement is reflected through membership status or financial support, which enables companies to influence the vision of the consortium or projects. Overall, both technical and social participation must be considered in planning the interaction with open-source communities.

How are open-source solutions deployed within the company?
Open-source components can help transform business processes and expand or improve the product offering. The strategic management of open-source solutions, therefore,

requires collaboration between innovation management, IT management, and procurement management. On the one hand, internal needs of components should be aggregated in a central department to evaluate the potential of open-source strategies for a company. On the other hand, the internal customers must be integrated into the open-source development process to fit the project's internal needs.

What benefits are expected from integrating open-source solutions?
Open-source strategies must be evaluated against traditional purchasing strategies and in-house development. Instead of saving as a performance indicator, the strategy for integrating open-source solutions heavily depends on qualitative factors. Open-source consortia often promote advantages such as reduced dependency on software vendors through standardization, increased innovation, and greater flexibility.

Open-source management model

After having elaborated on the general open-source strategy respectively the motivation for using open-source, firms need to set up a general open-source management process: Through multiple iterations of evaluation and design, an open-source management model was developed within the Silicon Economy (Paffrath and Henke 2024), building on the category sourcing cycle (Schiele 2019). In the following, the activities involved are outlined:

1. Demand identification and planning: This activity can be initiated in three distinct ways, depending on where the process starts and the focus of demand planning. The most common approach occurs when an operational user or developer identifies a specific technical or functional need within the organization. In this case, the demand is more solution-oriented rather than based on a general need for open-source concepts. Occasionally, through bottom-up communication, the issue may be expanded into a broader problem space. In the second scenario, the process begins with the identification of a need to advance innovation or sourcing strategies on a more general level, often communicated top-down. This type of demand typically arises from strategic goals, such as digitalizing processes. The third approach involves external open-source organizations or stakeholders driving the demand identification and planning process. For instance, research institutions or open-source foundations may encourage companies to adopt open-source solutions, or the focal firm may identify an open-source option and develop demand from it. At a more advanced stage of open-source integration, this activity can also be outsourced to a community that proactively addresses internal needs. However, for non-software companies, a major challenge in this step is the limited awareness of open-source solutions.

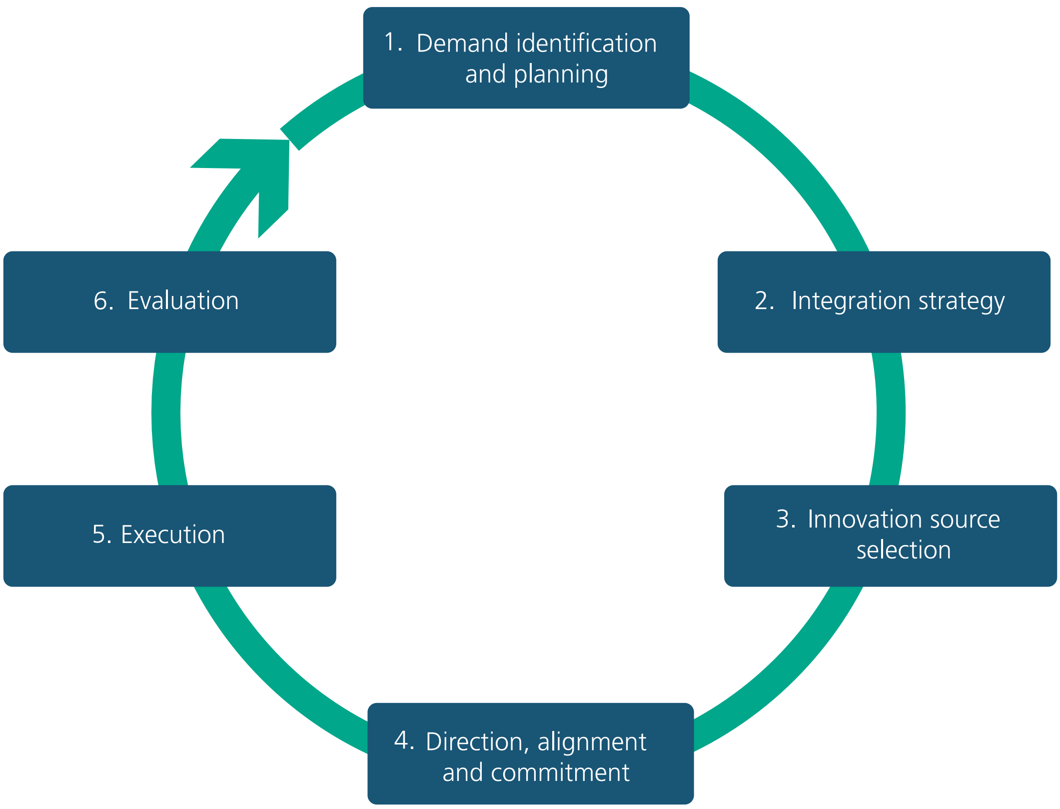


Figure 8: Open-source management process on the level of integration strategy following Paffrath and Henke (2024)

2. Integration strategy: Based on the identified needs, firms implement integration strategies that outline how open-source activities are managed internally across the stages of acquiring, integrating, and deploying open-source innovations, as well as interacting with partners and communities. The definition of these strategies is aligned with overall sourcing decisions and proprietary alternatives. Like the process of need identification, each integration strategy can be tailored to address either a specific innovation or a broader problem-solution framework. As a result, integration strategies can be implemented at one or more of the following levels: (1) innovation category, (2) community, and (3) specific open-source projects. The cycle time of the open-source management process tends to be faster for operational implementations compared to more strategic ones. In practice, integration strategies are often not formally defined and are instead carried out ad-hoc. However, since each strategy comes with its own risks and challenges, additional support - such as through Open-source Program Offices (OSPO) - may be required. Furthermore, maintaining awareness of integrated open-source activities within the company allows for a more accurate evaluation of both the innovation source and the strategy applied toward it.

3. Innovation source selection: Since there is no single supplier for open-source software, the term „innovation source" is used to encompass both open-source communities and projects. In many cases, identifying alternative communities and projects is closely tied to the demand identification and planning stage within operational software development. Selecting an innovation source involves assessing and evaluating the structure of the community or project, as well as the open-source software developed, in alignment with the integration strategy. Some companies use a predefined set of criteria (not necessarily specific to open-source) to guide their selection of open-source solutions. Additionally, companies may opt to create or contribute to their own communities and projects. In these instances, a key challenge lies in acquiring partner companies that share similar interests and goals.

4. Direction, alignment, and commitment: In open-source development, formal agreements specifying development details are uncommon. Instead, open-source principles tend to emphasize decentralization and individual autonomy over strict commitments. Given the need to manage risks and uncertainties independently, some companies establish internal mechanisms for adaptation. However, as companies increasingly collaborate on open-source solutions - such as within open-source foundations - agreements have gained importance. In these consortia, aligning interests and committing to project objectives, often by abstracting individual concerns, presents a significant challenge. Companies face a key trade-off between community involvement and resource investment, compounded by risks and uncertainties. This trade-off is also reflected in community membership models, where higher membership levels offer greater influence over projects but come with increased financial risks due to higher sponsorship obligations.

5. Execution: This step involves all activities related to the implementation of the integration strategy. Companies allocate sufficient resources to manage the technical development of open-source innovations or provide additional support, such as handling legal issues until the innovation is fully integrated into internal systems and deployed to end users. In open-source communities, working groups form the foundation for the practical execution of strategies. Communication with internal stakeholders, including users, is essential for evaluating the development process and interim outcomes. Given the maturity of open-source components, they often require further refinement and evaluation before they are ready for use. The complexity of the software supply chain can be significant, as tracking numerous individual open-source components is challenging. Although integrated solutions require ongoing activities, such as updates or maintenance, the execution phase concludes when the integrated solution is no longer in use or is replaced by another solution.

6. Evaluation: In the final step, the integration strategy and associated activities are assessed. Given the agile nature of open-source development, evaluation is a continuous process that occurs throughout the execution of integration strategies. Due to the challenges in quantifying the financial value of open-source investments - such as comparing them to sourcing alternatives - decisions are more often based on qualitative measures and other contextual factors.

Community is key: finding the right one

Regardless of whether companies only consume open-source software code or wish to be an active part of a community by contributing or even publishing their open-source software projects: **The community is key.** Therefore, companies are well-advised to take a thorough look into the community. According to Hompel et al. (2022), indicators for a healthy and vibrant community are, amongst others:

- **Conservation capacity**, defined as the ability of a community to provide the resources needed to maintain its products (measured by size, activity, and cohesion, among other things)

- **Sustainability**, understood as the likelihood that a community will be able to maintain the products it has developed over a longer period (determined, among other things, by the heterogeneity and regenerative capacity of the community, balance of participation and visibility of the project or ecosystem)

- **Process maturity**, understood as the ability of a development community to consistently achieve development-related goals by following established processes (e.g., through established governance regulations or a functioning code of conduct)

Communities differ not only concerning their general "quality" but their openness and also concerning their purpose. Thus, companies should also assess whether the community is a good fit for them with respect to their own intentions and business goals. In general, a trend towards B2B industry communities is observed. Such as the Open Logistics Foundation focusing on open-source software solutions for logistics, other industries also create their own communities such as automotive or finance (see table 3).

In addition to the community quality, companies should also assess the project quality. For assessing the project quality Hompel et al. (2022) provide the following helpful indicators:

- **Vitality**, indicated by the
  - activity within the project, such as the number of commits, forks, and releases and their currency, number of downloads, or number of processed tickets)
  - size of the project indicated by the number of committers and users
  - growth, visible by, e.g., the growth of commits over time and speed of development
  - resilience seen by e.g., duration of the project since founding time, number of supportive technologies, number of partners

- **Structure**, indicated by
  - documentation and project structure derived from the quality, accessibility, and visibility of documentation accompanying the software development and also by the communication about e.g., the project goals and the clarity of structure for responsibilities
  - code and its quality stemming from e.g., runtime efficiency, test coverage, tested subroutines, tested statements, runtime optimized, storage efficiency

- **Ecosystem**, dependent on the quality and support of
  - diversity stemming from the number of supported languages and participation of various developers
  - communication and outreach to external stakeholders about the project (e.g., social media, press releases…)
  - license and its clarity and approval by the Open-source Initiative
  - project culture fostered by e.g., code of conduct and the respective adherence.

Community	Industry	Year of foundation	Example projects	Website
Open Logistics Foundation	Logistics	2021	eCMR: The eCMR enables the electronic creation, storage, and transmission of waybill data	openlogisticsfoundation.org
COVESA	Automotive, IoT	2012 (as GENIVI)	GENIVI Development Platform: A reference platform for infotainment systems that enables car manufacturers and suppliers to work together on open standards.	covesa.global
Finos	Fintech	2018	FDC3 (Financial Desktop Connectivity and Collaboration Consortium): Standardizes communication between different financial applications to improve interoperability.	finos.org
Open Konsequenz	Energy	2014	openKONSEQUENZ: A framework for the development and integration of secure and reliable IT solutions for energy suppliers.	openkonsequenz.de
OSADL	Manufacturing, automatization	2005	Real-time-Linux: Adaptations of the Linux kernel to support real-time requirements in industrial applications.	osadl.org
The Autoware Foundation	Automotive, autonomous systems	2018	Autoware.Auto: An open-source software for autonomous vehicles that supports sensor data processing and vehicle control.	autoware.org
3MF Consortium	3D-Printing	2015	Autoware.Auto: An open-source software for autonomous vehicles that supports sensor data processing and vehicle control.	3mf.io
OpenMDM	Measurement engineering, data management	2014	openMDM: A platform for the management of measurement data that supports the entire data life cycle from acquisition to archiving.	openmdm.org

Table 3: Examples of B2B open-source communities

9. Outlook: continuation of B2B platforms and open-source software in the field of logistics and beyond

The underlying Silicon Economy Integration Guideline provides a first starting point for interested companies to get in touch with B2B platforms. The guideline shares insights into the differences between B2B platforms and their B2C counterparts and the challenges arising from B2B platform business models. At the same time, it presents solution approaches developed in the Silicon Economy project such as qualitative approaches encompassing the Platform Alignment Canvas or the Challenge Checklist. Beyond that, the Logistical Standard Functions, the Silicon Economy open-source software components, and the Reference Architecture help companies implement platforms from a technological point of view.

The five years of conducting the Silicon Economy project and the exchange with different industry partners have also fostered general insights and learnings about digitalization and the potential of B2B platforms in logistics: Logistics and supply chain management as crucial value-adding factors in the economy are prone to platform applications. B2B platforms provide value where processes can be outsourced and goods and services are not part of the company's core intellectual property. This holds especially true for logistical activities that most companies need but are not part of their core competencies. Those outsourced activities, knowledge, skills, and resources can be retrieved from platforms and emerge through collaboration with external partners. Companies may require the necessary value-adding factors via digital platforms whenever the platform solution provides a "cheaper" or better alternative to internal provision. Digital platforms can be seen as a market form enabling the consumption and retrieval of those necessary value-adding factors by the help of digital solutions. Especially in times of scarce resources and environmental concerns such collaboration via digital platforms for saving resources and pairing knowledge is necessary to ensure a sustainable economy. However, for that, several steps have to be undertaken such as increasing the general level of digital skills among supply chain partners, increasing standardization of commodity activities, and also fostering a new mindset that values the community and joint value creation.

Companies should not be afraid of embarking on platform solutions and digital tools as they fear losing existing boundaries but rather see the opportunities and benefits of growing within their ecosystem.

10. Contact and further information

All relevant information about the Silicon Economy and all documents for further reading (Logistical Standard Functions and Reference Architecture) can be found at:
https://www.silicon-economy.com/
http://www.silicon-economy.com/standardfunktionen
www.silicon-economy.com/reference-architecture

All open-source software components can be found at:
https://git.openlogisticsfoundation.org/explore

General information regarding the Open Logistics Foundation can be found at: https://openlogisticsfoundation.org/

If you have further questions about the Silicon Economy please contact:

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