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Spurring Minimum Value Collaboration: Tool-Supported Demand Alignment

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This paper presents the Collaborative Demand Aligner (CDA), an open-source software solution for demand capacity management in the context of the Silicon Economy. CDA aims to simplify the coordination between manufacturers and suppliers in order to optimize the production and delivery capacities of both players. By providing efficient communication and collaboration, CDA facilitates the process of matching demand and capacity, resulting in improved resource utilization and increased operational efficiency in the ecosystem. The software offers a promising approach to improve the coordination and optimization of supply chain activities, ultimately benefiting all stakeholders involved.

[Demand Planning, Supply Chain, Silicon Economy, International Data Spaces, Open Source]

1 INTRODUCTION

Manufacturers are dependent on the capacities of their suppliers. Capacities are planned based on sales forecasts. However, such forecast models are often inaccurate and difficult to interpret, leading to a limited usefulness in practice [Fat18, Ma21]. Thus the actual order volume differs from the forecasts [Fil22]. As a result, the required production quantity fails because certain capacities are already fully utilized or other committed capacities are not fully utilized. The situation is further aggravated as today's manufacturing environments are highly complex and influenced by dynamic production conditions and volatile markets [Usu20]. More complexity is added when orders must be realized at short term. To overcome this, an expensive process begins, in which efforts are made to resolve bottlenecks by short term capacity adjustments. In practical terms, suppliers are asked one by one to provide more capacity, with the potential issue that the adjustment of the production plan may fail at a single supplier, even though many others could make the short-term adjustments possible. The coordination is often done by phone, e-mail or fax and generates, under certain circumstances, high but futile efforts and delays [Düs22]. The reasons for this can be found in the lack of interfaces for exchanging production programs and capacities, as well as the insufficient automation of capacity planning. The coordination process carried out under the scenario is expensive, so the primary goal is to optimize costs. Secondary goals such as high-capacity utilization or avoiding empty spaces or empty runs will receive less consideration. One way to reduce the costs for coordination can be to automate the process. The more intense coordination between partners is taking place, the better predicting your company's performance gets [Bri09].

The potential of digitizing planning and coordination for optimization must be compared with the effort required to provide an end-to-end supply network with the necessary interoperable and scalable services and interfaces. The willingness of the individual supply chain participants towards this supply chain integration is crucial. Open innovation, open source, transparency of the alignment process and interfaces and respective data exchange, are therefore key issues to address, in particular in the case of imbalanced stakeholders. In order to address this problem, a software development project was initiated to promote the exchange of information between partners in a supply chain using digital technologies. The project aims to improve planning and proactively detect and mitigate supply chain risks such as delivery disruptions. The proposed solution is centered around collaborative demand alignment.

The Collaborative Demand Aligner (CDA) is an open-source solution designed to align supplier capacities with manufacturer demands in a transparent, fair, and simple manner within the supply chain network. The vision behind this solution is to provide a platform where the production planner can access information about supplier capacities to optimize planning and provide reliable delivery dates. The system enables interactive communication, allowing manufacturers to make requests while suppliers report their availability.

The primary objective of this project is to enable a secure exchange of demand information in supply networks while reducing the number of planning runs and deviations from the target. By achieving these goals, the project aims to enhance planning reliability and mitigate risks in the supply chain. The intended results of this project are as follows:

- Creation of a reconciliation tool for demand alignment (quantity and time) between manufacturers and suppliers to enhance planning reliability, while respecting data sovereignty.
- Development of a web application demonstrating secure and trust-building exchanges of demand data and delivery commitments, serving as the foundation for collaborative production planning.

This project is part of the Silicon Economy[1], a research project focused on developing infrastructure for future logistics platforms and providing a platform framework for logistics software. The Silicon Economy is led by Fraunhofer Institute of Material Flow and Logistics in Dortmund, Germany. In its context companies can collaborate on building powerful digital platforms to manage the complexity of logistics and supply chains and their increasing demands on communicating data. Since its start in 2020, software developers, technicians and logistics experts have been working on multiple software and hardware applications for a variety of logistics use cases to improve collaboration, communication, digitalization, and data exchange processes in the logistics world. All developed software is published open source and available for all logistics companies to use and advance in their specific niche. The CDA is one of the tools developed within the context of Silicon Economy and was published in the Git Repository[2] of the Open Logistics Foundation[3] in August of 2022.

The development project spanned a duration of 8 months, with 2 months dedicated to the conceptualization phase, followed by software development. The project adopted agile product development methods, utilizing SCRUM as the framework for agile software development. This approach allowed for flexibility and iterative progress throughout the development process. Not limited to those, here are some of the methods used:

A clear product goal was defined to guide the development efforts. This goal provided a vision for the desired outcome of the project. Potential business models were explored and documented using the Business Model Canvas framework. This step facilitated a comprehensive understanding of the potential value propositions and revenue streams associated with the solution. Relevant personas were identified and characterized to represent the target users of the software solution. These personas helped shape the design and development decisions by providing insights into user needs and preferences. The solution concept was transformed into a Minimum Viable Product (MVP) by translating it into a story backbone. This backbone represented the core features and functionalities required for the initial release. The MVP concept was then transferred to the development backlog for further refinement and implementation. Continuous stakeholder engagement was performed throughout the development process by regular presentations and updates to industrial partners. This ensured that the project remained aligned with the stakeholders' expectations and allowed for valuable feedback and input from the industry experts.

By leveraging the agile product development approach and utilizing SCRUM as the framework, the project aimed to foster collaboration, adaptability, and responsiveness to evolving requirements and stakeholder needs. This iterative approach facilitated incremental progress and enhanced the overall success of the software development project.

The theoretical background is discussed in Chapter 2, providing the necessary foundation for understanding the project's context. Chapter 3 focuses on conceptual potentials and challenges, highlighting the key considerations in the development process. Finally, Chapter 4 delves into the details of the software that was developed as part of this project.

2 State of the Art

This chapter gives an overview over the state of the art in demand and capacity management. In chapter 2.1 the current situation, its challenges and existing solutions are discussed. Chapter 2.2 gives an overview of the Silicon Economy and its potentials for demand and capacity management.

2.1 Current Situation of Demand and Capacity Management

The current coordination process in demand and capacity management, which must be carried out under time pressure, is costly and time-consuming under the given circumstances. Still inaccurate data can result in failure and significant costs [Fat18]. Therefore, the primary goal is to find a solution at all, whereby secondary goals, such as a high-capacity utilization or avoided empty space or empty runs, are barely considered. The potential of what could be realized by the digitalization of the planning and coordination process is offset by the effort required to equip an entire supply network with the necessary services and interfaces. For the suppliers the incentive is also low if a solution for one customer cannot be transferred to others.

Past works use models and simulations to try to overcome current problems in demand and capacity management [Ras11, Wad22]. While these ideas improve forecasts, they are still based on estimations. Current solutions for capacity management are mostly focused on internal capacities. If capacities of external suppliers are considered, these are included in the planning as inflexible restrictions or optionally serve as a capacity buffer to cushion short-term bottlenecks. A solution that tends to be overlooked is one based on better communication and collaboration

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

[2] https://git.openlogisticsfoundation.org/silicon-economy/services/collaborative-demand-aligner/cda

[3] https://openlogisticsfoundation.org/

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between supply chain partners. While solutions that connect supply chain partners exist, they are not open source [o9s22]. Thus, the participation of the entire supply network cannot be ensured. To further complicate the situation, many suppliers do not want to fully disclose their actual capacity availabilities to the customers, as the exchange of data is always based on trust [Düs22]. The lack of freely available and easily integrable services further complicates the realization, as the full potential can only be unleashed when all of a manufacturer's suppliers are integrated in the overarching automatic planning process. If suppliers could put their own flexibility at the disposal of their customers, the gained leeway by the entire supply network could be used for optimization.

2.2 Silicon Economy as an Ecosystem

The recent progression of supply chains creates a need for digital solutions specific to the logistics sector [Hof17, Sku22]. However digital communication and collaboration are challenged by a lack of common standards and languages [Sku22]. The Silicon Economy as an open-source infrastructure for platform economy can act as a solution. The decentralized and open platform economy is a counter design to monopolistic platforms [Sku22]. The platform economy connects all relevant partners in a supply chain on a digital platform [Sil22]. Services are federal and decentralized, allowing them to be used across companies and platforms. The aim of the Silicon Economy is to develop a software and hardware environment for tomorrow's autonomous logistics. In the future, flexible and globally connected value networks will replace today's rigid and well-defined value chains [Sku22]. Silicon Economy components are open-source software that are made available on the *Open Logistics Foundation* repository. Thus, the Silicon Economy ecosystem enables a supply chain ecosystem where goods autonomously go through AI (artificial intelligence) controlled processes [Sil21]. It allows for the diversity and coexistence of different logistical and industrial B2B platforms [Reu20].

The *International Data Spaces* (IDS) initiative came together in 2014 in order to preserve digital sovereignty for data and services in business and society (Sku22). The *IDS* can be viewed as an alternative to existing concepts that either manage data centrally or negotiate each data exchange (Ott19, Sku22). It is one approach for secure data exchange in decentral organized ecosystems (Sku22). It enables the secure exchange and easy combination of data in networks. One of the core concepts of the IDS is data sovereignty which refers to the ability of a natural person or corporate entity to determine and exercise rights of use with respect to its data (Ott19). As data sovereignty is also one of the principles of the Silicon Economy, the *IDS* technology is used in each participating ecosystem. Thus, it is a prerequisite for smart services, innovative value propositions and automated business processes. The combination of *IDS* and Silicon Economy creates a safe data space.

The CDA is one of the components of the Silicon Economy. Therefore, the CDA follows Silicon Economy's goals and guidelines. One important aspect that is considered throughout all developments is that of maintaining data security and data sovereignty [Ott21]. Especially in the use case concerned with the exchange of demand data and delivery commitments, data security and a trustworthy service are important. As an integrable service that exists in a conglomeration of different Silicon Economy services it also follows the principle of avoiding isolated applications and dependencies [Reu20]. As open-source developments allow for many benefits, it is an important principle of the Silicon Economy to provide the developments open-source [Cul22]. When open-source solutions are developed through collaboration they encourage innovation [Tao22]. Such solutions can also be started on a small scale and be scaled as wanted [Akr20]. Similarly, they can also begin as generalized solutions and then be specialized, for example to the needs of specific companies or user groups [Zoj19]. Lastly security can be ensured through tests and verifications, it can be verified as the source code is not a black box [Zoj19].

3 Concept of Collaborative Demand and Capacity Management

This chapter describes the concept behind the tool and its development potentials. Chapter 3.1 summarizes the product vision. In 3.2 the minimum viable product is presented, which describes the scope of the development realized in the project. Chapter 3.3 classifies all further development potentials. The tool is described technically in the use case in chapter 4.

3.1 Product Vision

Production programs or production planning must be coordinated with various suppliers to optimize and synchronize the production programs. To perform this optimization, two factors are important: The internal capacities must be known, which are mainly the manufacturer's production capacity. In addition, the external capacities such as supplier capacities and logistics capacities must be taken into consideration. The external capacities are often unknown. The assumption of unlimited capacities on the supplier side leads to the manufacturer's production planning being unrealistic - the availability of the supplied parts is not guaranteed. Demand and supply are not congruent, and the whole process must be reiterated. This often results in poor on-time delivery, bottlenecks, or even failures. Generally, there is the following relationship: If there is more transparency about the availability of capacities in the entire supply chain, e.g., what products can be delivered by whom at what time etc., uncertainties are reduced, and the supply chain will be more resilient. The effects are fewer failed delivery promises and more demand-driven deliveries from suppliers. Demand and supply continue to align. This research project therefore follows the approach of developing a system that enables the exchange of demand information (quantity and time) in supply networks (between manufacturer and supplier). It is an interactive system in which the manufacturer makes requests, and the supplier reports back whether the requested requirements can be provided at the required time. The system includes both the requesting and the responding parties. Thus, it will be possible to integrate the system for each player in the supply chain. To achieve scaling in federated structures, the system will be integrated into a higher platform project, a decentralized supply chain platform ecosystem and made open source in high software quality. Open innovation and open source are guidelines of the Silicon Economy.

Besides the integration into the Silicon Economy the goals and benefits of the product vision are as follows:

Table 1: Impact on involved stakeholders

Stakeholder	Impact
User	Less planning, less information gathering → Basis for planning automation and decision support
(intra) Company	More on-time delivery, prevention of bottlenecks, more reliability, more customer loyalty → More orders. Setup optimization and cost savings in production and logistics
Inter-company (supply chain network)	Harmonized and leveled material flows, reduced inventories, less bullwhip
(Data) Ecosystem	Independence, sovereignty, sustainable architecture

3.2 Minimum viable Product

As part of our agile approach, we actively utilized a minimum viable product (MVP) implemented as a prototype in the development project. The purpose is the fast delivery of a freely available (open source) and testable prototype to the industry. The designed minimum functions of the MVP are briefly described here.

The solution idea of the CDA is a communication system for the exchange of demand information in supply networks, as mentioned in the product goal section. At its core, this requires two personas, representing a user on each side. The MVP limits communication to these two personas, the production planner, and a supplier (in a closer context, we assume it might be a sales representative).

For manufacturers, the production planner is responsible for collecting the information needed for its production planning and to use it to optimize the production plan. The production planner's workflow is shown in Table 2. The supplier has a corresponding counterpart to fulfill, which can be performed, for example, by the persona of a sales representative. His workflow is also shown in Table 2.

Table 2: Production planner and supplier workflow

Step	Action	Actor	Part of the MVP
1	Import of relevant master data	Manufacturer	No
2	Demand overview (part, quantity, and time)	Manufacturer	Yes
3	Ability to request the demand from relevant suppliers	Manufacturer	Yes
4	Send request	Manufacturer	Yes
5	Request overview	Supplier	Yes
6	Capacity check against open requests	Supplier	No
7	Replying to the customer (here manufacturer)	Supplier	Yes
8	Receiving the answer from the suppliers	Manufacturer	Yes
9	Interpreting the response (what does it mean for my plan?)	Manufacturer	No
10	Processing the answer as a measure of production planning	Manufacturer	No
11	Confirming or rejecting the requested demand from the supplier	Manufacturer	Yes
12	Overview on confirmed customer requests	Supplier	Yes

Derived Requirements

Interfaces and architecture: Since the actual optimization of the production program by the production planner takes place in existing production planning systems (PPS), interfaces must be set up here. Accordingly, the CDA is to be implemented as a service for both parties. The service is connected accordingly via interfaces with the PPS or an ERP system, especially of the production planner, to import or export the corresponding information for the purpose of data exchange (Step 1). This interface to internal IT systems is not developed in the MVP.

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A new, preferably standardized open interface is needed for communication between the two instances of the CDA (Step 3, 4, 5, 7, 8, 11, 12). In addition to the interfaces, a view is required for the production planner, enabling them to make requests and maintain an overview of the status of their demands (Step 2, 3, 4, 8, 11). On the supplier side, a view is also needed that aggregates requests for the supplier, opens the possibility of a response and clearly visualizes it with the corresponding status (Step 5, 7, 12). The interpretation of the results of the data exchange (step 9) is not part of the MVP. Likewise, the processing is not part of the MVP. For the processing numerous measures are conceivable, such as the change of the production program, or the inquiries with another suppliers. Therefore, it is not a specific measure implemented in the MVP but is the responsibility of the production planner (step 10). On the supplier side, too, the MVP does not model capacities or perform an automated comparison with supplier capacities. Capacity modelling is company- or industry-specific (step 6).

3.3 FURTHER POTENTIALS

In the conceptual phase of the project, numerous aspects were identified that are relevant to the project vision but were not immediately implemented in the MVP (Chapter 4). They are outlined into three classes below as additional potentials: *Integration, optimization,* and *collaboration.*

3.3.1 INTEGRATION

Table 3: Integration types in the intersections of IT and processes with local and global integration

Process integration	Horizontal and vertical supply chain integration	Process
Internal IT-systems (input and output) e. g. at ERP, PPS	IT architecture, interoperability, interfaces, standards, open source	IT
Internal integration/ local	Supply chain integration/ global	

As shown in Table 3, the following is dedicated to the intersections of local and global integration with the process and IT view.

PROCESS INTEGRATION

Process integration allows the seamless incorporation of the Collaborative Demand Alignment (CDA) tool into the existing workflow of users, ensuring a smooth transition and adoption.

The embedding of the tool in existing processes is essential. The CDA must be integrated into existing processes and should therefore only complement the current manual processes. No functions from other existing tools, such as an ERP, should be taken over. Therefore, CDA sits exactly in the interface between manufacturer and supplier. Only the current, mostly manual processes in demand reconciliation are incorporated. For this purpose, data from the production planning program is loaded into CDA and the resulting requirements are reported to the suppliers. The contact person and user of the system on the supplier side is still the sales department, with the difference that the request comes primarily from the production planner and not from purchasing.

By conducting a thorough analysis of user workflows, identifying pain points, and designing the tool's functionality to seamlessly fit into their existing processes, the process integration can be successfully accomplished. This involves establishing interfaces for data exchange, implementing automated data loading mechanisms, and ensuring a smooth flow of information between the production planner and the sales department on the supplier side.

SUPPLY CHAIN INTEGRATION (HORIZONTAL AND VERTICAL):

The integration of the supply chain holds significant potential for collaborative demand and capacity management. This integration spans the entire network, encompassing both horizontal collaboration among different partners and vertical integration across various tiers. The overarching goal is to foster effective cooperation and facilitate the seamless exchange of information.

To achieve this, the tool should enable real-time data exchange, enhance demand visibility, and support robust capacity planning among suppliers, manufacturers, distributors, and other stakeholders. The following features follow those goals:

- Consider dependencies of suppliers' delivery capabilities in planning
- Enable rolling planning cycles
- Implement reminders for unanswered requests
- Simplify confirmation process with one-click confirmation of a planning period
- Integrate an evaluation model for supplier selection with multiple options
- Highlight changes in demands or requests since last login

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To realize these functionalities, standardized communication protocols should be implemented, data sharing agreements established, and technologies such as APIs leveraged to enable seamless integration and data flow within the supply chain network. The implementation should prioritize user-friendly interfaces to facilitate efficient and transparent interactions, and technological solutions such as automated reminders and real-time data updates should be incorporated.

INTERNAL DATA:

To ensure that the tool can work in real time with relevant data sources within the organization, the data sources must be available for CDA. This requires the development of data connectors, APIs or data integration middleware. Hereby, a seamless and secure data exchange between the tool and the internal systems is enabled, so that communication and synchronization of information is possible in real time. The CDA is thus able to access and exchange data from internal systems such as ERP, CRM and inventory management databases.

IT INTEGRATION

It is essential to embed new software into existing IT infrastructures. Without an interface to connect to existing master and emerging demand data, it is required to load the production program into the tool with each new demand alignment. With an interface, this data can be loaded automatically. Currently, the import of data is based on a CSV file. The master data for the articles is usually integrated via an interface to the ERP system and the data for the demands is taken from the production planning. If necessary, the production data must be refined by means of a parts list explosion, which can be found in the ERP system. This simplifies the use of the tool considerably and the maintenance effort is well in line with the benefits. The planned production orders are displayed within CDA by means of a "Job Overview" and color coding indicates which orders can be produced, which orders still require feedback from the supplier and which orders will have to be postponed.

INTEGRATION IN DECENTRAL PLATFORM ECOSYSTEMS AND ARCHITECTURE

The goal is to capitalize on platform effects and unlock the potential benefits that come with a well-integrated ecosystem or network. CDA provides its full value in a network, connecting many participants to holistically optimize of the volumes e.g., of one Supply Chain.

The tool needs to support interoperability, standardization, and data compatibility across various platforms and systems. This ensures smooth collaboration and data exchange. Open-source technologies play a crucial role in promoting standardization and providing a common framework for data integration. Brokers or intermediaries can facilitate data exchange and translation between different systems, enabling seamless communication. The utilization of a microservices architecture enables modular and scalable solutions, allowing for flexible integration with different components of the ecosystem.

By implementing these measures, efficient data integration can be achieved within a complex ecosystem or network. The Open Logistics Foundation, founded as part of the Silicon Economy project, connects supply chain participants and promotes open innovation and development. It offers the Collaborative Demand Alignment (CDA) tool on a public repository to facilitate collaboration and customization. This approach aligns with open-source principles and supports the broader ecosystem approach of decentralized platform architecture. By encouraging collaboration and knowledge sharing, the foundation aims to enhance open platforms for logistics. Such structures should be utilized when implementing a collaborative approach in demand and capacity management.

By addressing these integration aspects, the collaborative demand and capacity management tool can effectively streamline processes, enhance supply chain collaboration, facilitate data exchange, and integrate seamlessly within the broader network.

3.3.2 AUTOMATION AND OPTIMIZATION

In a collaborative demand and capacity planning, multiple criteria decision problems arise that can be holistically optimized. For example, various production programs can be realized through different compositions of supplier parts and multi-sourcing. Different demands, in turn, lead to varying capacity and cost evaluations among suppliers. In other words, each program entails different efforts. Therefore, the implementation of optimization methods to solve the decision problem would be valuable. For instance, in a further expansion step, the consideration of dependencies between products and suppliers, would increase the planning quality and reduce rescheduling. If the capacity restriction and cost structures are also modeled by the suppliers and provided with data, functions such as scenario-based planning and holistic optimization can be implemented.

Furthermore, the decision as to which products the supplier can and cannot deliver could be further automated on both sides. For example, after a production plan has been created, the requirements can be automatically transmitted to all possible suppliers. These are then transferred to the supplier's own production program and an automated response is sent back. This logic could additionally be automated across several supply chain levels. This achieves an even better planning quality and problems such as the bullwhip effect can be efficiently eliminated.

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3.3.3 COLLABORATION

COMMUNICATION STYLE

Simple and transparent communication, clear decision-making, negotiation options, and the confidence that only my business partners have access to as little information as possible, but as much information as necessary, are key to build trust in supply chains and thus an enabler for collaboration. In the next development stage, the possibility to report back a partial quantity is planned as an additional feature. This will be needed if the supplier's capacities are not sufficient to cover the entire demand. This way, the production planner can schedule a portion of the orders in the originally planned week and does not have to reschedule all the orders that the part cannot be provided for in total. This avoids multiple coordination efforts between supplier and manufacturer and fewer coordination loops are needed.

In addition, the supplier must be able to report production bottlenecks to its customers. For example, the supplier overbooks its own production due to its theoretical call-off obligations. Since not all customers usually end up needing the reported requirements, this is usually unproblematic. However, if more customers than expected call off the requested quantity, the supplier must be able to partially revoke its committed capacities if there is no confirmation of actual demand from the customer. This can become particularly problematic in the case of time-delayed confirmations.

NEGOTIATIONS

If the feature of confirming partial quantities is added, it is also possible to include multiple options. For example, it should be possible for the supplier to confirm a partial quantity of, say, 50% and at the same time apply a surcharge to the remaining 50%. These can be caused by necessary overtime or weekend work, for example. In this way, the manufacturer can decide for himself whether he wants to bear the additional costs or accept the first 50% for the time being. This further minimizes manual reconciliation processes, since requirements can currently only be accepted or canceled in full, and negotiations then usually take place by telephone. It would also be conceivable to negotiate the time horizon. For example, if the items are delivered earlier or later, the production planner needs warehouse capacity or has to adjust the planned production period.

4 SOFTWARE APPLICATION

4.1 USE CASE/ PROBLEM/ SCENARIO

Currently most of the communication between manufacturer and supplier is not digitized. This leads to added coordination efforts, still coordination does not always work out. On the manufacturer side production planners assume unlimited supplier capacities for both rough and fine planning, as they have no information about the actual capacities. Consequently, adherence to delivery dates cannot be ensured, as the supplier is not informed about the manufacturers planning and the manufacturer does not know whether the supplier can deliver as planned. Still, the manufacturers use these uncertain plannings as a base for delivery dates for their customers. Due to the uncertainty of the planning efforts delivery dates can often not be kept which leads to unsatisfied customers.

This is especially critical in use cases where products and their components are specific and not interchangeable. Such use cases could be SMEs (small and medium enterprises) that produce machines or electronics. Their products are specific, still they are produced in series. As the needed components are not interchangeable single, missing components can hold up whole production lines. In sectors such as electronics this can quickly become critical due to the scarce market. Due to the criticality of single components currently a lot of coordination efforts are needed. Still, as those efforts are very time consuming and often not successful, improvements are needed. Thus, quick communication and collaboration allowing for correct information about demands and capacities is especially important for those and similar use cases.

With the CDA, we developed a tool that already considers the capacities of suppliers in production planning to improve adherence to delivery dates and to minimize coordination efforts. The developed application supports collaborative planning in the supply chain by communicating demands transparently and re-communicating availabilities, which implicitly takes supplier capacities into account. It allows for a secure and trustworthy exchange of demand data and delivery commitments via IDS. Thus, it builds the basis for collaborative production planning. The aim is an increase in planning security to ensure adherence to schedules while minimizing coordination efforts. Overall, the amount of planning runs that need to take place until a manufacturing order can be completed is reduced. Deviations between actual and target capacities are minimized.

The coordination process was digitized by implementing models to describe production programs and the available capacities. These were then used in a web-based application to match demand and capacity of several alternative scenarios among all stakeholders to determine which production programs can be realized. The survey process is similar to widely used online scheduling services. The exchange of information takes place via the IDS, which allows requirements from the areas of data governance and data sovereignty to be taken into account and adhered to.

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4.2 Technical Solution & Architecture

The technical solution was reached through an application that consists of two child applications: Backend and frontend. The backend processes manage all logical input to and output from the other participant of the supply chain to the own frontend. They also handle the whole database communication. The frontend on the other side provides a web browser view to the user and sends data to and receives data from the backend. An overview of the architecture is given in Figure 1.

Via the web browser view, the user can interact with the application – depending on his role. As a manufacturer, the user can see his demands. Every demand has a production week reference and its own number of articles which are needed to produce a specific product. For each number of articles, there is a different number of suppliers who can deliver the full amount or a part of it. The manufacturer can request each supplier to deliver the displayed amount of an article. When this request is placed, the frontend communicates with its backend to send the request to the according supplier. The backend receives the action from the frontend and as a first step starts the communication with the supplier's backend while sending a request for a specific article and its amount. The backend of the supplier receives the request, processes it, and sends a 200 HTTP status code as response. We assume that everything works well. With this response, the manufacturer's backend creates a new database entry for this request and informs the frontend that the supplier was successfully informed.

Afterwards, a new request with a quantity and a delivery week now appears at the supplier's view because the supplier's backend has sent the necessary information from the request to the frontend. The supplier now has the option to respond to the new request with *confirm* or *reject*. The response to the request is then sent to the backend and identified by the request ID. After that the response is transmitted to the manufacturer.

Next the manufacturer receives the supplier's response in the original demand in his web view. If the answer is positive, the manufacturer can confirm or reject the answer. If he chooses one of the two options, the response is sent to the supplier via the backend, like it was at the beginning of the initial request.

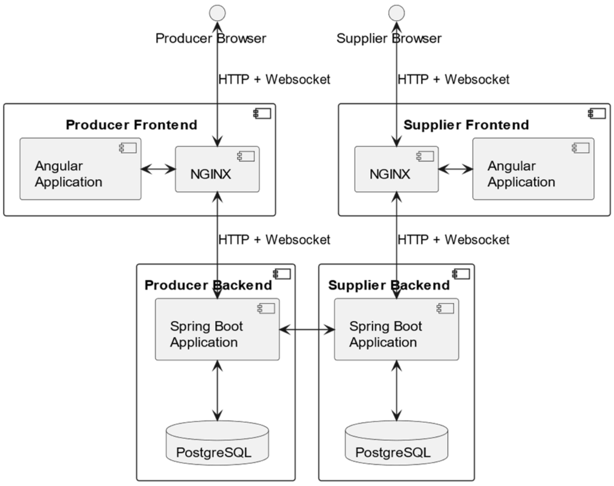

Figure 1: Architecture of the CDA.

4.3 Demo: Views & Functionalities

When the manufacturer and the supplier use the CDA, they each have their own views of the tool with different functionalities provided to them.

The manufacturer sees an overview in his web browser of all the demands that are pending for the next few weeks in his company, as shown in Figure 2.

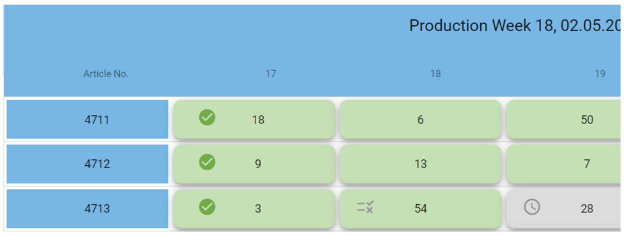

Figure 2: Demand overview of the manufacturer.

The overview represents a table in which each demand is listed with its corresponding quantity. The corresponding article number and the production week are entered in the margin of the table. Depending on the status of the demand, the field is colored green (positive response from a supplier), gray (response from suppliers pending) or red (all responses from suppliers were negative). If the manufacturer clicks on a field, the detail view of the demand opens. An example of the detail view is shown in Figure 3.

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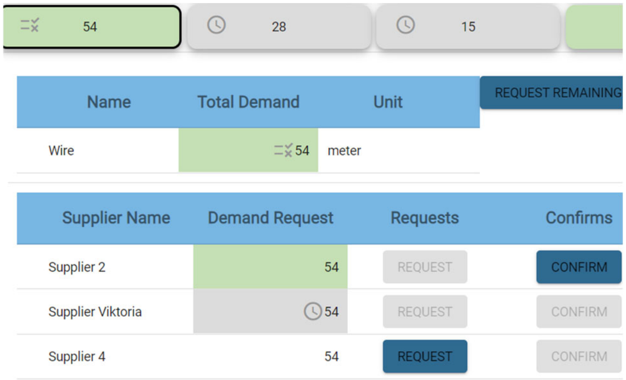

Figure 3: Demand detail view of the manufacturer.

The manufacturer gets an overview of the name, the total demand, and the unit of the item for the demand as well as an overview of all suppliers that can be requested by the manufacturer. In the overview, each supplier has a different color depending on the status of the respective request. At the beginning, if a supplier still has the color white, the manufacturer can send a request for the total demand for the article. If the request is successful, the status turns gray. Afterwards, if the status turns green or red over time, the supplier has either accepted or rejected the request. In the case of a positive response from the supplier, the manufacturer can still confirm or reject the response. Accordingly, an additional symbol on the green status would indicate this. If the request was rejected, the manufacturer will not be able to interact further with the supplier.

The supplier sees an overview of all requests submitted by manufacturers to his system in his web browser, as shown in Figure 4.

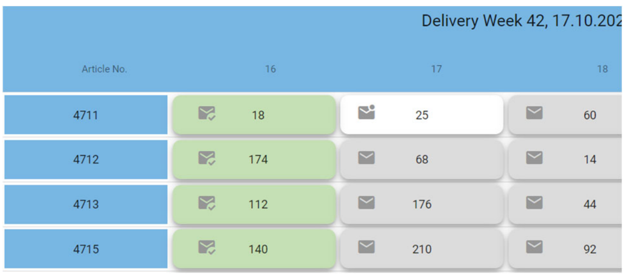

Figure 4: Request overview of the supplier.

The overview represents a table in which each request is listed with the corresponding total quantity. The corresponding article number and the production week are indicated in the margin of the table. Depending on the status of the request, the field is colored green (all requests have been answered), gray (requests are still open; at least one request from a manufacturer has been responded to) or white (all requests are still unanswered). When the supplier clicks on a field, the detailed view opens. An example of the detail view is given in Figure 5.

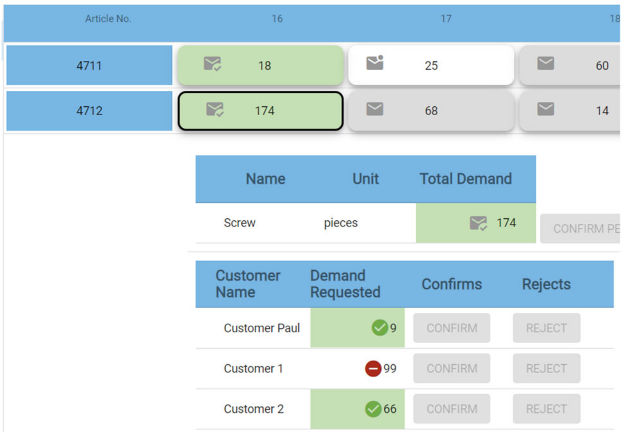

Figure 5: Request detail view of the supplier.

The supplier receives an overview of the name, the total quantity, and the unit of the article for the requirement as well as an overview of all manufacturers from which the supplier has received a request for this article and the specific production week. In the overview, each manufacturer has a specific requested quantity and a color that changes depending on the status of each request. At the beginning, each manufacturer has the color white. The supplier can now confirm or reject each request. If the request was confirmed, the status will be green. Otherwise, the status becomes red for a rejection. At any time, if no final confirmation has been received from the manufacturer, the supplier can set any confirmed request to reject and vice versa. If the manufacturer has decided in favor of a supplier who has sent him a confirmation, the status at the corresponding supplier for this manufacturer gets a green check mark. All other suppliers for the same request of the manufacturer get a red bar on their status. In this case no further communication is possible.

4.4 Specifications for Companies

For the integration of the CDA tool, it is necessary to either find a suitable partner (supplier or customer) within the supply chain or to test it with a mock company. Within the company a project team is needed, including testing personas and a process owner. On the manufacturer side a person acting as a production planner is needed to be able to send a capacity request to a supplier. On the supplier side, a person acting as a sales partner is needed to react to such request. In order to test the applications both personas could be covered by people on the project team of one company, one person representing the mock company. Each project team should also include a developer for implementation and setup of the tool.

The CDA was developed open-source and can be used and further developed by anyone. It is possible to commission the project team of Fraunhofer IML or use in-house developers. Competencies required of developers include Typescript and Angular for frontend development. Java, Spring Boot and JPA/Hibernate are used for the backend,

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as well as the testing frameworks Mockito/MockMVC for Java and Karma for Typescript.

As the open-source code of the CDA is published in the Open Logistics Foundation Git Repository, the only technical requirements are Docker and a common web browser. The installation of CDA is described in its corresponding README.md document.

5 DISCUSSION AND CONCLUSION

Inaccurate coordination with suppliers leads to uncertain forecasts along the entire supply chain and to uncertain planning. The result is often inaccurate production or sales programs and broken delivery schedules, and everyone in the supply chain sees someone else as responsible. For example, requirements have not been communicated in time or capacity limits have simply been ignored. At Fraunhofer IML, the CDA was developed as a web application to improve collaboration through communication in planning. Open, decentralized platforms for logistics services are the perfect basis for topics in supply chain collaboration. Especially in planning, collaboration between partners within the supply chain is crucial, but often not profound enough. With the developed application, producer and supplier are brought together in a very simple way. The producer regularly communicates his requirements as a planning status and gets quick feedback from his supplier. Everyone can participate since the development is transparent and accessible to everyone through open source. The topics of data sovereignty and data security have been considered from the very beginning, so that the players can speak at eye level and only necessary information is shared in great networks with many participants.

The connection to internal systems enables automation of the processes to further optimize and accelerate the coordination process in the future. Horizontal and vertical integration can help to reduce stocks in the supply chain and eliminate the bullwhip-effect.

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