Modular Production Onboarding

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Goal of the document

This onboarding document gives an overview about results of the Use-Case "Modular Production" in the Catena-X Project[1]. It opens the concepts and results to a wider community, allowing them to participate in the Catena-X, Modular Production Use Case without being part of the consortium. We are addressing providers of factories and developers of software services for factories as well as researchers.

The paper starts with a general overview about the idea of Modular Productions and then enriches them by requirements collected in Catena-X. Afterward we introduce the newly developed concept of Modular Production Services as defined in the project. So far, one Modular Production Service has been published, we will introduce this service here, together with some guidelines on how to implement the service and how to embed this into the Catena-X landscape.

At the end we are giving an overview about the next steps considered in Modular Production.

Definition Modular Production and challenges in a production network

The continuous increase in product segments, models and variants, and the shortening of product life cycles caused a far-reaching shift, which redefined the dynamics of the automotive industry and initiated a transformation to a more customer-oriented approach. As a result, traditional assembly lines are confronted with the ever-increasing diversity and dynamism of the modern automotive landscape. The challenges posed by this growing complexity are expected to intensify as the drive for greater product individualization, the integration of new product technologies and the emergence of novel drive concepts continue. Consequently, the adaptation of assembly systems has become inevitable to meet the demands of this evolving landscape (Kern, Rusitschka, & Bauernhansl, 2016). This is particularly true for the automotive sector, which has already started to move towards Modular Production Platforms (Lampón, Frigant, & Cabanelas, 2017), as the use of them is particularly relevant for automakers with large product portfolios and high production throughput (Lampón, Frigant, & Cabanelas, 2019).

The goal of Modular Production is to support batch size 1 product manufacturing at the price of mass production. This is achieved by automating the orchestration of production resources and planning of production processes as much as possible, thereby significantly reducing the time and effort required for planning. As such, Modular Production is an approach to a flexible, adaptable production system to, among other things, better respond to changing market demands (Huber, 2019). It also addresses resilience as the ability to survive crises and setbacks caused by internal and external disruptive factors and to emerge stronger (Wieland & Wallenburg, 2013; Zhang & van Luttervelt, 2011).

However, modular initiatives have encountered unexpected technological and organizational barriers (MacDuffie, 2013). Higher-level, external supply chain factors, such as delays in the logistics chain for supplier parts or last-minute order changes, can invalidate a production plan that has already been

[1] https://catena-x.net/

drawn up. Today, such short-term changes in the production environment can often only be indirectly addressed through manual corrections.

To alleviate these pain points, the Modular Production (MP) Kit in Catena-X defines services, interfaces and data models based on industry standards with the goal to increase flexibility and reliability of industrial production. The first released service is the Shop-Floor-Information-Service for production Forecast, additional services are in preparation. The goal of these services is, for example, to provide information about production status and planning, which may be required by other use cases.

Requirements from Catena-X

With Catena-X, more than 150 companies set out to create the first open and collaborative data ecosystem to optimize industry value chain processes, addressing the current problems of the automotive sector, especially in areas such as supply resiliency, sustainability, systematic coverage, and cost of innovation. The idea is to create a sovereign, multi-tier data exchange network across the entire value chain. Using Catena-X, companies can benefit regarding digital sovereignty, reduce time to value, minimize costs and foster innovation[2].

The focus of the business domain resiliency in Catena-X is to improve the resiliency of the supply chain and related manufacturing processes. The supply chain is analyzed from tier-n suppliers to car manufacturers and vice versa. Each of these applications uses a collaborative model, utilizing information from higher or lower tiers. This information exchange is standardized for all Catena-X use cases. By using these applications or Catena-X compatible applications, an effective management of tasks across the supply chain can be achieved. Some of the use cases in the business domain resiliency have an impact on operations, such as adjusting production to meet changing customer demand, or, conversely, adjusting production capacity based on data from operations[3].

As part of our efforts in the Business Domain Resiliency, the Modular Production KIT conducted a survey on the use of shop floor data among members of the Catena-X consortium and external partners (see Figure 1 and Figure 2). Our goal was to learn at which occasions data from the shop floor is accessed and shared across the value chain and which requirements need to be fulfilled. The analysis of the survey provided us with valuable insights and helped us to design appropriate service offers meeting the needs of Catena-X users. Parts of the results have already been and will be directly incorporated into our future work.

All companies participating in the survey are in the process of sharing data across the supply chain or plan to do so in the near future. For half of them, this exchange is critical to their business operations. Thereby most of the companies are providing shop floor data to partners as well as using data from external partners themselves. The most important use cases for data exchange are traceability along the supply chain and quality assurance, followed by sustainability, circular economy, capacity management and manufacturing-as-a-service. Companies using data from partners are often interested in data from lower automation layers including machine data, sensor data, quality data, and performance data, which confirms the need for a direct connection of the shop floor with the Catena-X network. Moreover, half of the participants expect advantages from using standardized data exchange within Catena-X.

By conducting the survey, we could confirm that there is a need to share shop floor data with partners across the value chain which can be fulfilled by offering corresponding services such as the shop floor

[2] https://catena-x.net/de/vision-ziele
[3] https://eclipse-tractusx.github.io/docs-kits/next/kits/Resiliency/

information service described below. However, data providers usually do not want to reveal details of their production or to give external partners direct access to shop floor related information. The type and amount of shared data as well as the access model are subject to negotiation between data providers and users. Thus, an appropriate service should serve as an interlayer between the partners and implement these restrictions.

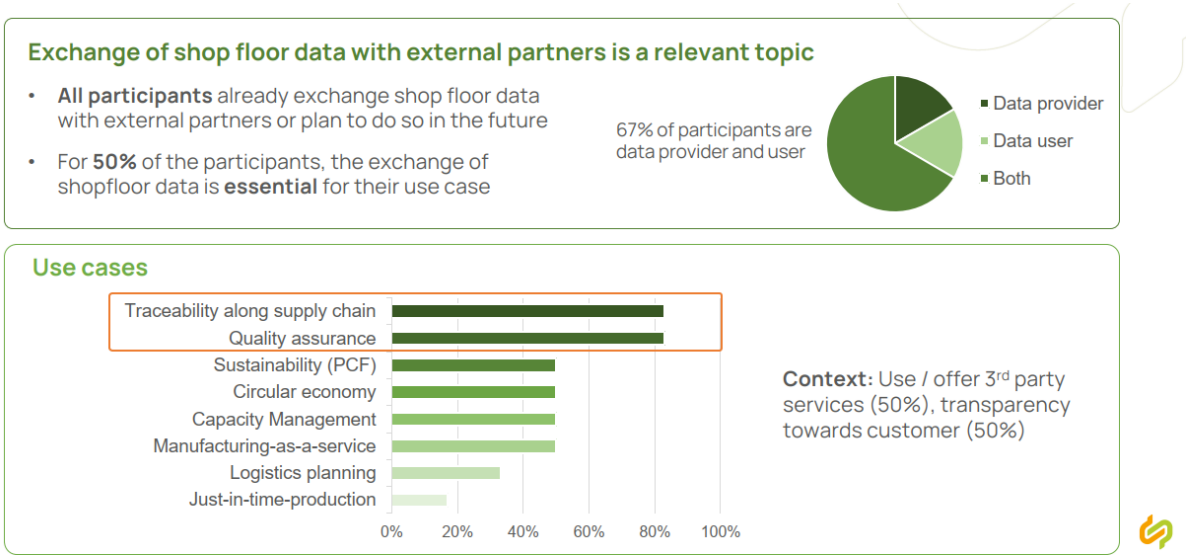

Figure 1 Key findings on shop floor data exchange

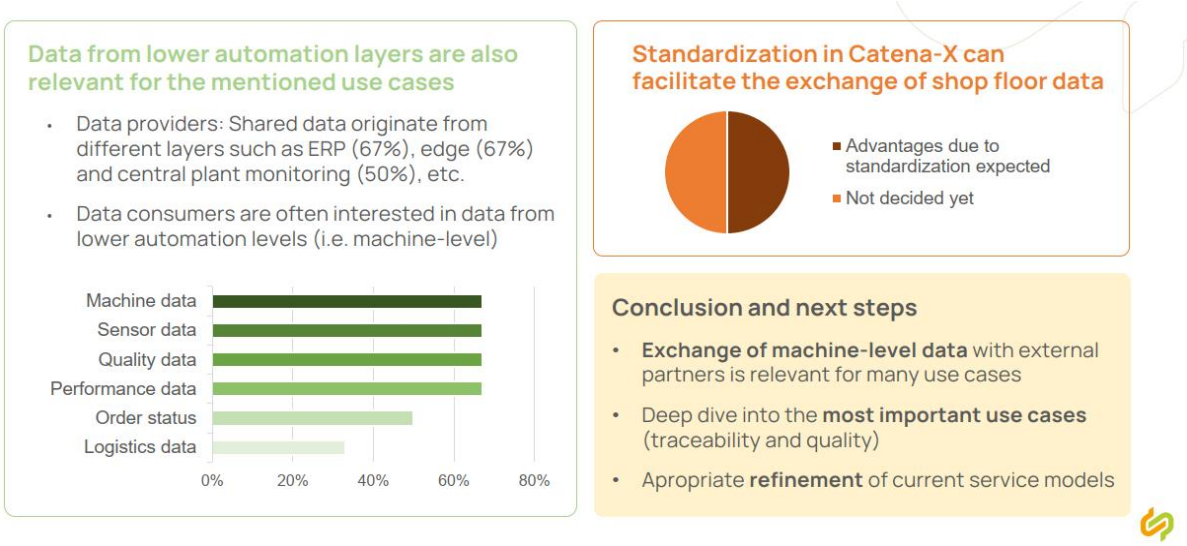

Figure 2 Key findings on data and use of Catena-X

Catena-X Approach

In order to deal with the challenges described in the previous sections several services have been developed to support the Modular Production. It has been crystalized that these services can be classified into two types of services. One type deals with services that are used within the Modular Production to support the processes on the shop floor. The second one addresses services that are dealing with the communication outside the Modular Production with the Catena-X network.

Services within Modular Production

Services within Modular Production are addressing services to support the production on the shop floor to guarantee flexibility, supporting the workers, reaction to deviations in the supply chain etc.

Without any claim of completeness, we are addressing some as follows:

- Step Decomposition: For the assembly process of a product the assembly steps are not known in advance and are not part of the 3D-CAD drawing. Step decomposition services are generating the assembly process based on the analysis of the 3d drawing.
- Skill Capability Matching: To manufacture a part, there are certain requirements for the machines in each manufacturing step. These are called skills (e.g., drilling a hole with a required depth, diameter). If a product is manufactured for the first time in a Modular Production facility, it is necessary to decide which machines can perform which step according to their capabilities. A skill-capability matching service can therefore find possible assignments between machines and production steps. The skill-capability-matching also covers reconfiguration of devices by consideration of the capabilities of single components, which can be combined to new or different configurations.
- Scheduling: For flexible production with small lot sizes, it is necessary to avoid standstill and reconfiguration times. The scheduling service is a mathematical algorithm to find an optimal sequencing of manufacturing tasks to worker and/or workpieces to reduce waste.
- Operator Guidance: Modular Production also requires more flexibility from the workers. They have to work at several workstations and produce different products. An operator guidance service provides them with information about what to manufacture next and at which place, as well as additional information about the necessary machines, materials and production steps required.
- Virtual Commissioning: As the operation of one day or one week consists of many interdependent steps, a virtual commissioning service can be used to analyze the robustness of the production before execution to avoid bottlenecks and other unforeseen problems.

Services regarding addressing the Catena-X network

In the Catena-X network, a Modular Production usually communicates with the T-1 tier, the T+1 tier or with some substitutes such as logistic partners. From a Modular Production point of view, we assume that the orders have already been placed, which means all data is already available in the systems of both the customer and the producer, therefore the relationship has already been defined and the Modular Production comes into play when the orders enter the shop floor planning. The information exchange between partners will be centralized in form of shop floor information as outbound information. This could be information about the production states or forecasting information. In addition, incoming information are also centralized and will then be distributed inside the shop floor as needed.

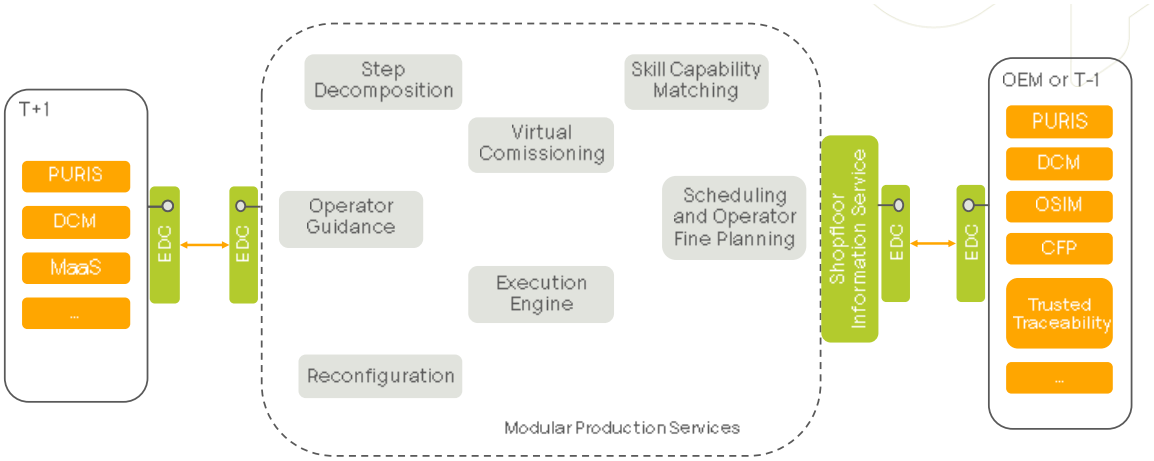

Figure 3 Services in Catena-X from Modular Production

Shop-Floor-Information-Service

In Catena-X the Modular Production team published a first version of the Shop-Floor-Information-Service. The Shop-Floor-Information-Service supports the communication between a Modular Production and its customer or a substitute like a logistic company. In the first version, the focus lies on forecasting the estimated production date. For example, if a customer wants to know the estimated production date, he can use the Shop-Floor-Information-Service to get the information either directly, via cyclical messages or via notifications when the calculated production dates change.

Figure 4 describes the communication between Modular Production and the customer, as always in Catena-X the communication between partners is accomplished by utilizing the Eclipse Data Space Connector (EDC) to ensure data sovereignty:

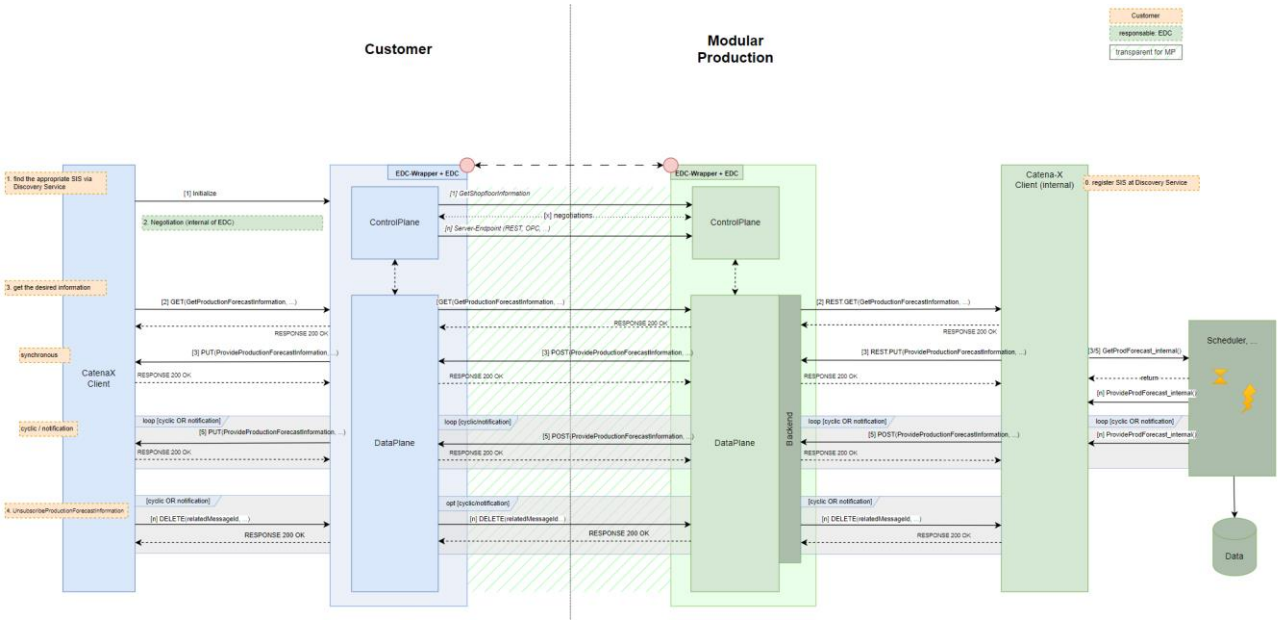

Figure 4 Customer interaction with the Modular Production KIT

The communication consists of three parts which will be called in a canonical order for the expected communication in different phases:

1. *GetProductionForecastInformation*(...) - the call of the customer: Here a customer or a defined delegate can request the desired information via
2. *ProvideProductionForecastInformation*(...) – transfers the relevant data by Modular Production (synchronous, cyclic or notification-like) to the recipient.
3. Unsubscribe from the "*GetProductionForecastInformation*" service to receive no further information.

The two boxes in the middle represent the EDC of the partners. The communication between the respective EDC is transparent to the user (shaded). The transmission of the data for the request, as well as the response to the *ProductionForecast* is transmitted via the payload of the message. The immediate response (http response) does not contain any technical information. The left side represents the customer with his different requests. On the right is the Modular Production with a scheduler that generates the requested answers.

The customer uses the *GetProductionForecastInformation* call to request a production forecast. Then the Modular Production generates the required information internally by internal services as described in the previous section and answers accordingly by calling *ProvideProductionForecastInformation*. In case of a cyclic messages or notification mode, the customer has to unsubscribe from the service, if the service is not needed anymore.

The Shop-Floor-Information-Service uses the *GetProductionForecastInformation* model and the ProvideProductionForecastInformation model. They are modeled as Asset Administration Shells (AAS) and then serialized as a JSON string which is sent through EDC mechanism.

The *GetProductionForecastInformation* model contains the request for the forecasting data which is sent from a Modular Production partner to a customer or a third party on the next lower level. All participants, using the Shop-Floor-Information-Service in the role of a customer or third party, must be able to send the *GetProductionForecastInformation*, whereas all participants using the Shop-Floor-Information-Service in the role of a Modular Production must be able to receive and process the *GetProductionForecastInformation*.

Beside the standardized Catena-X Header containing the sender's and receipient's Business Partner Number (BPN), the context, the messageID, the sentDateTime and the version, specific data elements are exchanged, the most important ones are descibed here:

- customerId: Customer ID in order system,
- orderId: Order ID defined between factory and customer in contract,
- communication mode: Selection if information is sent synchronous, cyclic or notification-like.

In addition there are some parameters dependig on the communication type.

ProvideProductionForecastInformation is the answer to the request. Therefore companies, which use the Shop-Floor-Information-Service as a customer or third party must be able to receive ProvideProductionForecastInformation information, whereas companies using the Shop-Floor-Information-Service as a factory must be able to send ProvideProductionForecastInformation information.

As the *GetProductionForecastInformation* model the ProvideProductionForecastInformation again includes the Catena-X Header. Besides them, specific data elements are exchanged, the most important ones are descibed here:

- communication mode: Selection if information is sent synchronous, cyclic or notification-like,
- a iteration number as a counter in case of repeating information,
- a list of forecasting items consisting of product id, estimated forecast date, its precision and a production state. In case of delays this can also be communicated.

In the following we are describing the necessary steps in order to participate at the Shop Floor Information Service.

Implementing the Shop-Floor-Information-Service as a provider (factory)

Every factory offering the Shop-Floor-Information-Service has to implement the following elements.

- It has to provide the API for *GetProductionForecastInformation*
- It has to provide the API for *Unsubscribe*
- And it has to implement the Rest-call for *ProvideProductionForecastInformation* in order to send the information to the customer

Implementing the Shop-Floor-Information-Service as a consumer (customer)

Every consumer of the Shop-Floor-Information-Service like customers or third party has to implement the following elements.

- It must be able to implement the rest call request *GetProductionForecastInformation*
- It has to implement the API call to *Unsubscribe*
- And it has to provide an API for *ProvideProductionForecastInformation* in order to receive the information provided by the factory to the consumer.

Onboarding the Shop-Floor-Information-Service

Both partners - customer and producer - must be members of the Catena-X network in order to communicate with each other. By registering a Modular Production in advance with the Discovery Service, a customer can find it via a so-called Business Partner Number (BPN). It is planned to use the Business Partner Number Site (BPNS) in the future as the communication of customers is usually with factories and not with the entire company. With the help of Self Sovereign Identity (SSI) the correct identity is guaranteed.

The execution of the endpoint which is used as the base URL in the asset definition is done via an EDC connection. As parameters for the execution of the endpoint are sent as path parameters, they are added to the call of the endpoint at the data plane of the EDC which will forward them to the endpoint at the Modular Production EDC and endpoint.

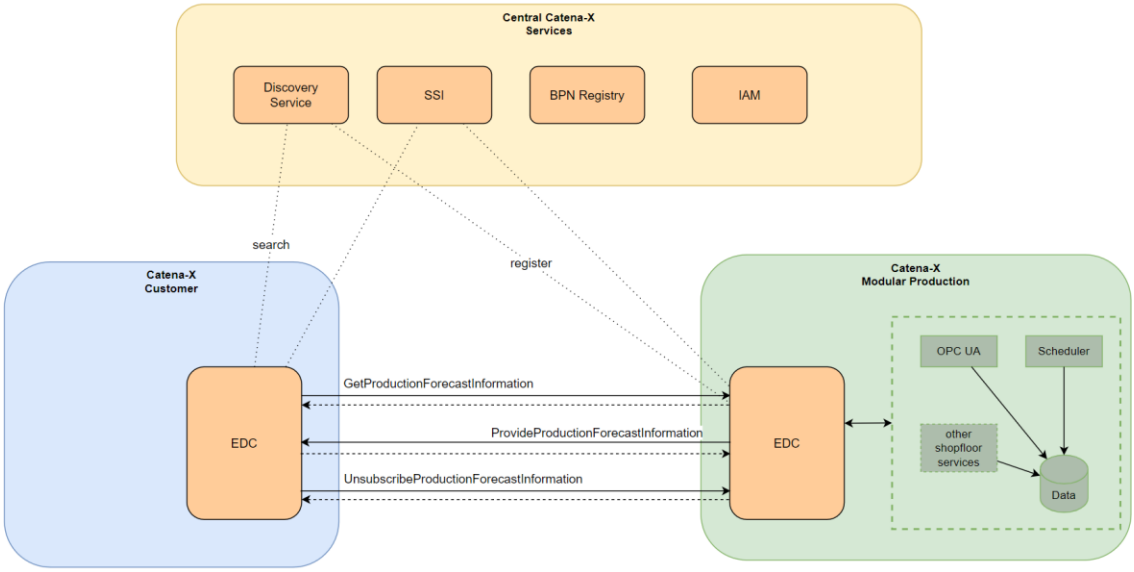

Figure 5 EDC Interactions between Catena-X Core Services, the Customer and the Modular Production KIT

Summary and Outlook

In this document, we described the current state of the Modular Production KIT and how to onboard in order to use the Shop-Floor-Information-Service for forecasting data.

As a next step, an adaption of the Shop-Floor-Information-Service is planned. Besides the forecasting data, it will also offer the possibility to send historic tracking data, protocoling the machines assigned, during the different production steps. This service can then be used by customers interested in traceability questions for example.

In addition, an assembly request service is also planned. In contrast to the Shop-Floor-Information-Service it addresses the inputs of the factory. Before a product can be manufactured the assembly request service offers an interface to provide the production input data like CAD data, bill of material and bill of processes to start the planning of the assembly processes and the assignment to the machines.

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