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Requirements Elicitation / Specification

Semantically Connected Semiconductor Supply Chains

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1 Introduction

The communication and support action “SC3” is focused on validating the industrial applicability and the benefits of the main results developed in the previous IA “Productive4.0”. Specifically, the Generic Semiconductor Data Model, which has been developed in Productive4.0, is validated, extended, hosted and industrially exploited and applied in this communication and support action.

The Generic semiconductor Data Model has been prototypically developed and published during Productive4.0 by a collaborating of semiconductor manufacturers like Bosch, Infineon, and STMicroelectronics. In SC3 it is now industrially applied in different use cases by different industrial partners.

The partners intend to apply the Generic Data Model as a framework for data exchange within and beyond the internal supply chains.

Establishing the Generic Semiconductor Data Model as a “quasi-standard” enables production partners of a supply chain to link their simulation and planning tools with each other to establish an entire supply chain simulation and optimization network across company borders. The description of the required data structures in the Generic Semiconductor Data Model helps to link external production partners to the tool-network without requiring detailed data insights of their facilities. The generic data format enables automatic tool communication instead of manual data acceptance and transformation.

Describing a semiconductor supply chain and its factories using a data model is crucial for the operations and collaboration in a complex semiconductor production network. An actual model of how a modern semiconductor factory works is needed in a generic and therefore reusable fashion. The last publicly available model dates back to 1995. Considering the fact that this entire technological field is growing fast and is becoming more and more complex, this model became outdated. That is why the development of a Generic Data Model (GDM) describing the typical structure and behavior of a generic semiconductor supply chain as shown in figure 1 was crucial in Productive4.0. Evaluating whether the Generic model is able to describe the facilities’ behavior in accurate detail is now part of this project.

SC3 thereby supports the acceptance of the Generic Data Model and intends to prove the applicability of the Generic Semiconductor Data Model. In addition, the industrial validation shows which parts of the Semiconductor Data Model still have to be extended to make it generically applicable and meeting the industrial requirements for the described application of a shared tool network. This is the first time where different major semiconductor partners join forces to describe a generic semiconductor supply chain and thereby concentrate on the common structure of the production systems. This effort gives the public not only a stable basis for modelling semiconductor manufacturing related models and processes but also the confidence, that the data model follows the physical structure and behavior of the supply chains. Such a data model, if it is to be used by semiconductor manufactures needs to fulfill a set of requirements. Within the SC3 Project the requirements elicitation on the basis of industrial use cases is one of the targets.

2. Structure of the Generic Semiconductor Data Model

The GDM is made of many tables that are clustered in six different groups corresponding to different parts of the fab, represented by six different colors in Figure 1:

- The green part represents the infrastructure of the fab
- The blue part describes the different processes
- The purple part regroups the tables related to the products
- The dark blue part is the indicators
- The yellow is the heaviest part regarding the amount of data stored since it regroups the historical tables
- The red cluster is the snapshot tables, which are equivalent to the historical tables but for a fixed date.

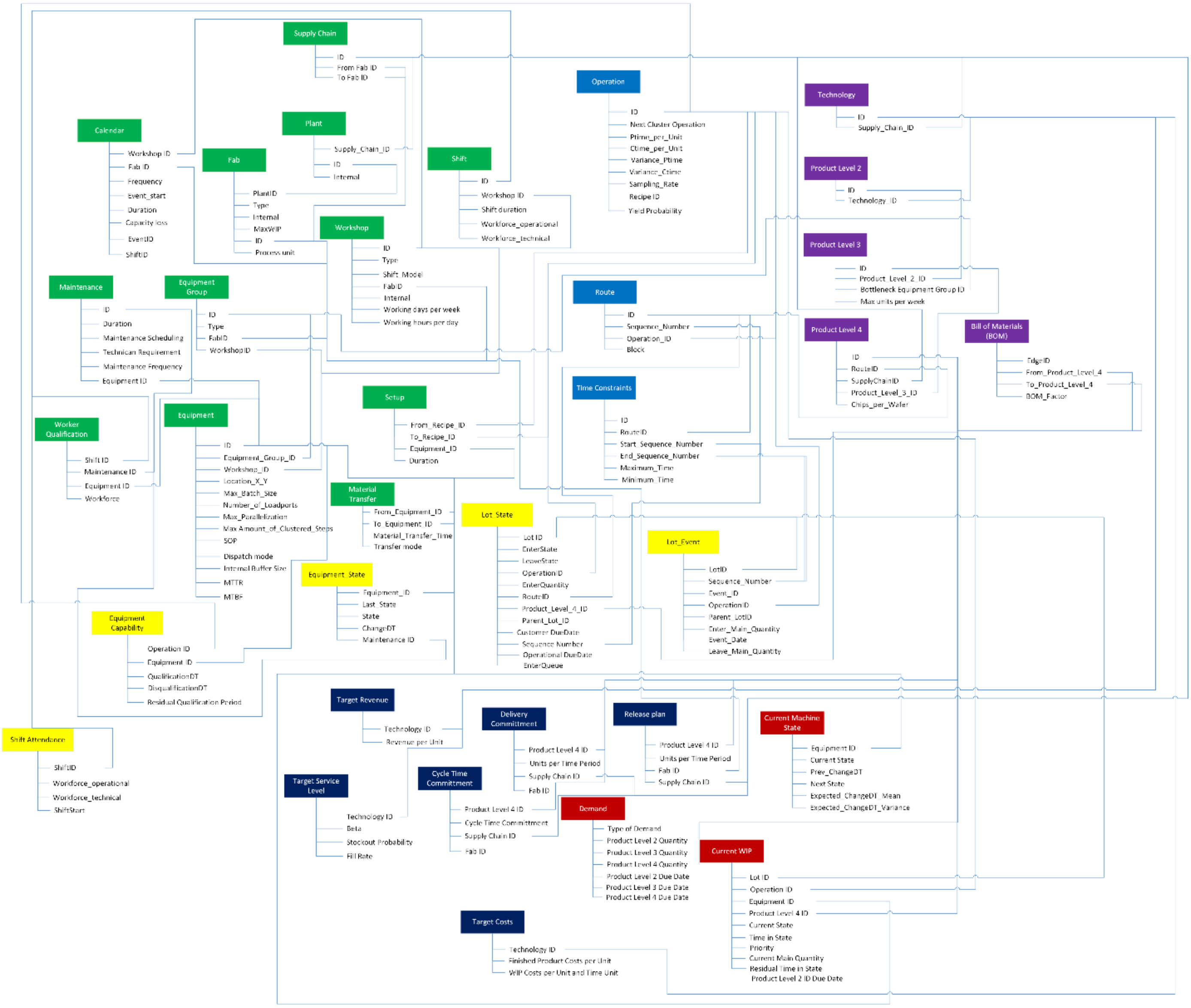

Figure 1: Generic Data Model

The advantages of such a GDM are plentiful. First, this is a way to enlarge the scientific network. Furthermore, the semiconductor supply chains are now more centralized. Consequently, the optimization of these supply chains becomes more and more complex. Therefore, relationships with academia are valuable for semiconductor manufactures to continuously improve on the state-of-the-art with regards to performance of their supply chain.

Secondly, the Generic Semiconductor Data Model will improve the communication between semiconductor manufacturers. In SC3 this will be proven by industrial application. Every partner that wants to work together will have a first overview on how a generic semiconductor supply chain works. Furthermore, the partners will be able to better choose the cooperation in which they want to work, because each partner could provide a first description of an envisioned solution in a common framework based on their understanding of the problem.

Application of the GDM will also make it possible to develop more complex simulation models, which become increasingly crucial in the semiconductor field because of the increasing complexity of the supply chains. One main use case in industrial application is a wafer-fab simulation based on the GDM. The first proof of feasibility is to compare simulation results using a fab-specific internal data model with results based on the GDM. The simulation models allow to test new planning or models without taking the risk to disturb the production. Nowadays the markets are volatile, thus it is important to have the most precise and reliable simulation model.

3. Industrial Use Case from the Project

With the following industrial use cases of different semiconductor manufacturing companies, the necessity, and benefits of a Generic Data Model for semiconductor manufacturing supply chains are highlighted from various views, and such use cases serve well the task of requirements elicitation for a Generic Data Model. To prove the applicability of the GDM, we show its ability to capture requirements from all these use cases and to help every company synchronizing itself with the supply chain to sustainably increase efficiency in dynamic collaborative supply chains.

3.1 Bosch Use Case

The semiconductor division of the Robert Bosch GmbH is integrated into a manufacturing supply network that is continuously expanding both internally and externally, adding recently for example a new frontend manufacturing site in Dresden. To be able to efficiently plan, control and optimize this complex dynamic network, it is necessary to synchronize the planning processes of all the different contributors. The unification of individual planning frameworks is therefore beneficial. The first elementary step towards company overarching supply chain synchronization was the development of a Generic Data Model describing both the structure and the history of the dynamic supply chain. The elicitation of requirements for such a Generic Data Model is the logical next step.

With a generic semiconductor data model, manufactures can expect the following two disruptive advantages for effectiveness and efficiency in semiconductor supply chains:

1. The ability to develop unified simulation and optimization models (either from science or from industry) that can be applied to any semiconductor manufacturer without exchanging sensitive production data.
2. The ability to synchronize the dynamic, collaborative supply chains within a common planning process based on this generic data model.

One crucial requirement for such a data model is that many supply chain contributors must be able to maintain it. On the basis of this generic data model, a common planning process can be established to enable company- and site-overarching supply chain planning and synchronization to increase service levels with efficient production planning and control. Manufactures are aiming for a hierarchical, simulation-based supply-chain-optimization model to realize the following mid to long-term production use cases:

1. Integration and ramp-up of new products into a mature supply chain. Thus, capacities, capabilities and release plans can be adjusted considering given demand and maximization of service levels.
2. Integration and loading of a new wafer fab into a mature supply chain. Therefore, capacity and capability of the new fab can be adjusted and release plans for the supply chain can be determined under given demand considering maximization of service levels and balancing of utilization.
3. Change of product mix in a mature supply chain. Therefore, if capacities and new demands are given, just release plans, capabilities and control policies can be adjusted to maximize service levels.

These mid- to long-term use cases all aim for global optimization across the entire supply chain. The work and results of SC3 will be crucial to prove the feasibility of realizing these use cases based on the developed GDM.

3.2 Infineon Use Cases

Infineon Technologies operates a global production chain that is composed of eighteen owned frontend and backend fabrication sites located in North America, Central and Eastern Europe, and Asia complemented by production partners. The specialization of the fabrication sites in certain technologies and process blocks led to the emergence of complex flows of materials across the fabs. The average production process nowadays spans over at least four countries and three trips around the world. As a result, the scope of operational excellence is no longer confined to single fabs, but it also requires an efficient utilization of the resources available in the global supply chain. Thus, supply chain management became a key element for being able to match the volatile market demand with the production capacities. While the complexity of operations in and across the fabs increased, the need for a better understanding of the interactions within the supply chain arose.

Simulation offers undoubted advantages for analyzing the impact of planning decisions onto the execution system and vice-versa. But also increases the requirements a data model for the simulation needs to fulfill. Infineon Technologies pursue this approach for several years now where simulation models are built to mimic the behavior of the real-world production chain. However, the availability of data in the right quantity and quality is a major challenge to allow an accurate representation of the reality. So far, different attempts have been made to populate the simulation models with approximated data, called synthetic data. While this approach can be suitable for selected input parameters that require a tedious effort for the extraction and preparation, we believe that real data (or related statistical distributions) should be privileged when used to provide sources of uncertainty in the simulation. Thus, we see the development of this generic data model as an opportunity to provide a cross-validated set of data from which the modeler can pick relevant data to perform his simulation experiments with an accrued accuracy.

The developed semiconductor manufacturing model relies on the MIMAC data sets. Hence, with this generic data model, we aim at completing our effort towards an improved representation of the physical production system. Because this more detailed modeling comes along with an increased computational burden when simulating an entire supply chain, we expect the hierarchical structure of the generic data model to support a proper aggregation of data. One of its anticipated applications will be to enable the analysis of planning decisions taken at the supply chain level (i.e., demand planning, capacity planning, master planning) versus local planning and control decisions taken in each production sites (i.e., production scheduling, and detailed dispatching). In our focus is the top-down disaggregation of plans and schedules, the bottom-up propagation of early warnings, and the stability of decisions in a rolling horizon setting.

4. Conclusion

Based on the joint effort of the SC3 project, a Generic Data Model for semiconductor manufacturing supply has been investigated to fit the requirements derived from industrial use cases. The model includes 33 different entities, decomposed into 19 master (structural) entities and 14 tracing, snapshot and strategy entities. The overview can be globally taken from the entity-relationship model, that the interested reader can get access to by contacting the authors of this deliverable. The GDM, developed in Productive4.0, is in validation in CSA “SC3” concerning different industrial applications. First results from a full-fab simulation show that the aggregation level of the GDM is suitable to obtain comparable results to simulations at the full level of detail used in industrial practice. The final goal of this action in SC3 is to prove the general applicability to different simulation and optimization tools.

We believe the requirement elicitation work helps to provide common definitions to characterize semiconductor manufacturing systems and to synchronize planning in collaborative supply chains, but also to specify important challenges that the industry is facing nowadays through the description of use cases. Furthermore, we believe that the Generic Data Model will help to foster new research. Within the SC3 project, we will be able to get feedback from the academic and industrial semiconductor manufacturing community on the data model to refine it. The model will support the development of common planning and optimization models. New relevant testbeds should then be made available, which is recognized as a need in the literature.