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Use Case “Equipment Lifecycle Management”

Sub-Working Group Industrie 4.0/Intelligent Manufacturing of the Sino-German Standardisation Cooperation Commission

A joint project of

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Summary:

Introduction:

Background

This report is a result of the cooperation line “Use Cases and Applications” in the context of the Sino-German Sub-Working Group Industrie 4.0/Intelligent Manufacturing. The overall objectives of the Sub-Working Group are the discussion of standardization aspects in the focus of Germany and China in order to intensify and deepen the Sino-German cooperation by defining concrete issues and steps to be taken.
The objective of the cooperation line “Use Cases and Applications” is to analyze business strategies and customer needs in the manufacturing industries manifested by concrete customer-projects. The findings will be compiled into descriptions –

so called “use cases” – based on well-known best practic-es, e.g. the Industrial Internet Reference Architecture (IIRA), see [1]. These use cases facilitate a common understanding of markets, trends, drivers, concepts and solutions and then serve as basis to articulate requirements for standardization aspects.

There are many projects in the context of Industrie 4.0/Intelligent Manufacturing in Germany and Chi-na, but nevertheless, it is challenging to come to a common mutual understanding. Therefore the cooperation line “Use Cases and Applications” came to the conclusion to work out some rigid descrip-tions of “use cases” to overcome these obstacles.

Common Understanding of “Use Cases”

The term “use case” as used nowadays has a diverse range of meanings. The term is mainly used as follows:

- A “use case” in the sense of a business scenario, in which, in accordance with business model logic (e.g. business canvas), business relationships within a value-added network are described.

- “Use cases” in the sense of general understanding as to how a technical system is viewed in the context of its application. It is used to describe the interaction of a technical system with actors (such as other technical systems or humans). This is the understanding of the term “use case” in the cooperation line “Use Cases and Applications”.

- “Use cases” in the sense of specific projects.

Use cases can be described on different level of detail. A description can be very condensed, for example, by describing concise user stories requiring a scope of very few pages. A more detailed description requires the description of a so-called usage view according to the Industrial Internet Ref-erence Architecture (IIRA), see [1]. The experience has shown that this requires a 20-page descrip-tion. The description becomes even more detailed when based on the template of IEC 62559-2, which typically requires a description of at least 50 pages. In practice, even more detailed descriptions of use cases can be found.

Figure 1 illustrates the possibilities to use for the description the IIRA template or the more detailed template of IEC 62559-2 and shows this in connection with the overall understanding about use cases.

The cooperation line “Use Cases and Applications” decided to use the IIRA template for description, thus, to elaborate so-called usage views resulting in description paper of about 20 pages. The coop-eration line also decided to elaborate the following concrete use cases according to the mentioned methodology:

- Labs Network Industrie 4.0 elaborated the usage view for the application scenario “Value-Based Service”. This work has been already finished and published, see [3].

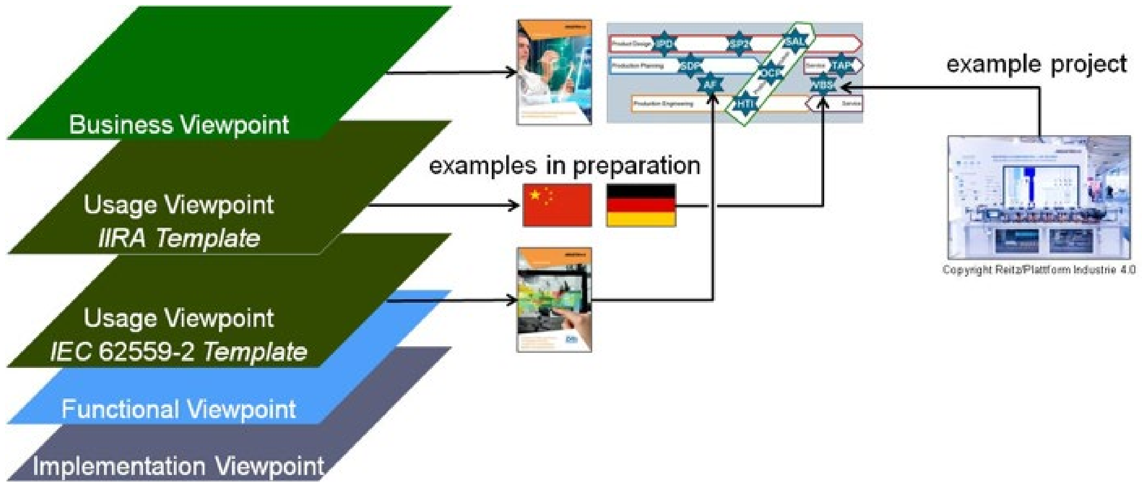

Figure 1: Proposed structure for use cases (according to [2])

- CESI elaborates the usage view of the intelligent manufacturing mode “Mass Customization”. This work is still in progress.

- In the context of the Baowu and Siemens Go to Industrie 4.0 (BSG2I4.0) project the use case “equipment lifecycle management” was elaborated. The result of this work is documented in this paper.

China’s economy is stepping into a new era. The development of intelligent manufacturing is the best way to integrate the development of the emerging industries with an upgrade of traditional industries. At the same time, it has an important and far-reaching impact on deepening the integration of manufacturing and the internet, while strengthening the foundation of the real economy. “Made in China 2025” makes Industrie 4.0/Intelligent Manufacturing a priority. To build manufacturing power, it puts a special emphasis on the following points:

Introduction to Equipment Lifecycle Management

The intelligent factory, which is composed of industrial robot and large numerical control machine, is the result of deeper integration of the information technology and the automation technology. It is also an important carrier of intelligent manufacture. One of the most pressing issues in the field of intelligent manufacturing is how to avoid unexpected downtime in the production process and ensure production efficiency of the intelligent plant.

An integrated overall plant model can be used through the entire lifetime of the plant, especially:

- Design and engineering

- Construction and erection

- Installation, commissioning, and handover

- Operation and maintenance, refurbishment, modernization, life extension

- Decommissioning and land rehabilitation.

Such an integrated overall plant model enables an effective plant lifecycle management. In this paper we do not address the business view of equipment lifecycle management resp. plant lifecycle man-agement. Some discussions about the business view can be found in [4], but there the scope of the discussion is broader compared to this paper.

From a technical point of view equipment lifecycle management has to consider and integrate all dif-ferent discipline-specific views of the equipment. In addition, all relations of the equipment to other equipments always have to be established and kept up to date. A proper equipment lifecycle man-agement will result in consistency between the digital integrated overall plant model and the real physical plant.
In general, there are two different applications of equipment lifecycle management:

- Green field approach, where a new plant has to be built: Here all data and documents provided by engineering service provider and/or components and systems supplier are handed over digital-ly and integrated in an overall plant model.

- Brown field approach, where an existing plant has to be digitalized: Here all relevant existing technical data and documents along the life of the plant so far have to be captured by forward modeling (i.e. transforming the existing data and documents) and/or reverse modeling (i.e. manu-ally building a new model based on the available data and documents) and integrated in an overall plant model.

Overall Procedure and Overview

The basis for this use case description was a concrete project between Baowu and Siemens, for de-tails see chapter “Basic information about the Baowu project”. One of the central tools used in this project is the plant engineering software COMOS of Siemens, for details see chapter “Basic infor-mat-ion about COMOS”.

The various scenarios implemented in this project and the features of COMOS used during the im-plementation were then abstracted and elaborated in the form of a general use case description fol-lowing the IIRA template, see chapter “Usage View”. The relationship between the general use case description and the features of COMOS and the scenarios implemented in the project is illustrated in chapter “Linking Usage View and COMOS resp. the Baowu project”.

From a technical point of view, the Baowu project addresses the engineering and operation of a plant. Plattform Industrie 4.0 has described the associated challenges and possible future scenarios in an application scenario called SDP “Seamless and Dynamic Engineering of Plants”, see [4]. As already mentioned, “Equipment Lifecycle Management” considered in this paper is a specialization of the application scenario SDP.

Usage View

The usage viewpoint proposed by the Industrial Internet Consortium comprises the following con-cepts, for details see [1]:

- The basic unit of work is a task . A task is carried out by a party assuming a role.

- A role is a set of capacities assumed by an entity to initiate and participate in the execution of, or consume the outcome of, some tasks or functions in a system as required by an activity. Roles are assumed by parties.

- A party is an agent, human or automated, that has autonomy, interest and responsibility in the execution of tasks. A party executes a task by assuming a role that has the right capacities for the execution of the task. A party may assume more than one role, and a role may be fulfilled by more than one party.

- An activity is a specified coordination of tasks required to realize a well-defined usage or process of a system. An activity has the following elements:

  o A trigger is one or more condition(s) under which the activity is initiated.

  o A workflow consists of a sequential, parallel, conditional, iterative organization of tasks.

  o An effect is the difference in the state of the system after successful completion of an activity.

  o Constraints are system characteristics that must be preserved during execution and after the new state is achieved.

At this point we would like to point out the difference regarding the terms "viewpoint" and "view": An (architecture) view expresses the architecture of a system from the perspective of specific system con-cerns, whereas an (architecture) viewpoint establishes the conventions for the construction, interpre-tation and use of architecture views to frame specific system concerns. For more details we refer to [1].

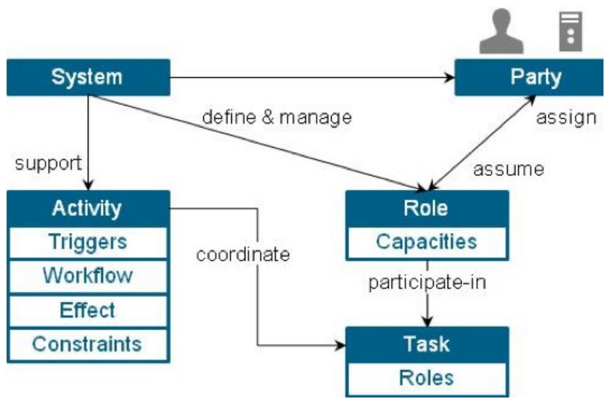

Figure 2: Overview of Usage Viewpoint (according to [9])

System under Consideration

For the system under consideration we refer to a common logical structure as shown in Figure 3.
The first core element of the logical structure is a so-called overall model of plant composed by interre-lated models of equipments. The second core element of the system under consideration is the engi-neering tool.[4]

Overall Model of Plant

The overall model of plant is a set of model of equipment in-

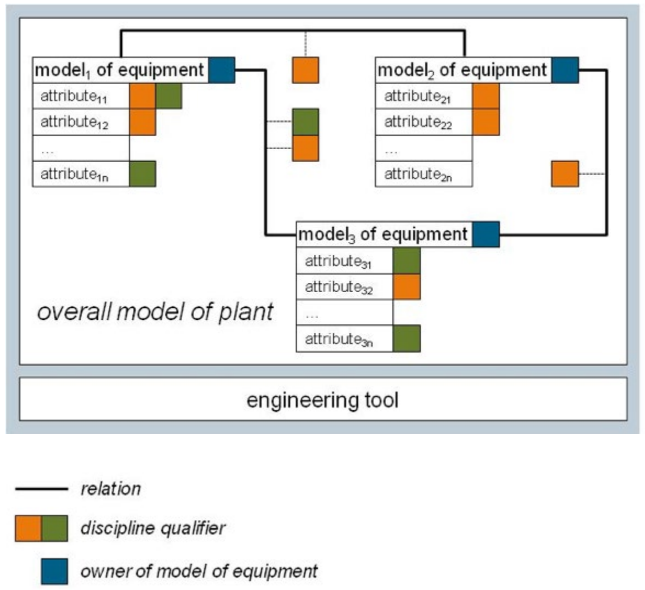

Figure 3: Overview of the system under consideration

cluding their interrelations.
A model of equipment is a building block with attributes and relations to other building blocks (i.e. model of equipments). A model of equipment belongs to a set of owners (see chapter "Roles"), which are authorized to create resp. delete attributes resp. delete the model of equipment, and who can grant modification rights with respect to the value of attributes to other stakeholder.
Attributes and relations of a model of equipment can be tagged by a discipline qualifier. In addition, an attribute resp. a relation belongs to a set of owners. The initial ownership of attributes is inherited from the ownership of the associated model of equipment, later the ownership can be modified by stakeholder having appropriate modification rights. The stakeholder, who creates a relation, is the initial owner of the relation. The owner of an attribute can modify or delete an attribute and can grant modification rights with respect to modify

[1] The tasks according to [1] include a Functional Map referring to the Functional Viewpoint and an Implementa-tion Map refereeing to the implementation Viewpoint. Since we are focusing on the Usage Viewpoint only, we do not consider Functional resp. Implementation Maps. [2] The bold marked terms refine and illustrate the single term "participate-in" in Figure 2. [3] Parties strongly depend on the business setup and the internal organization of the companies involved. We do not address the association of parties in this paper, because we do not discuss a business viewpoint here. [4] We focused our description on selected core elements. The description could be extended by adding further elements to the system under consideration, for example libraries of model of equipment.

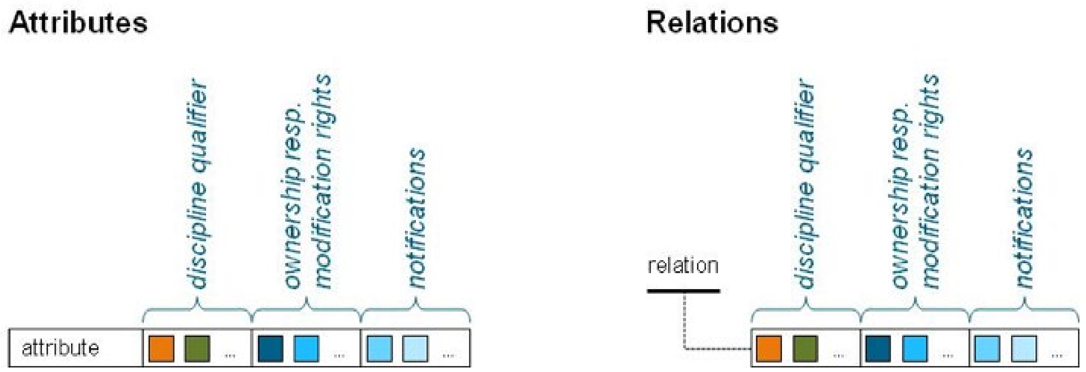

Figure 4: Details about attributes and relations

the value of the attribute. The owner of a relation can modify or delete a relation. An attribute can be tagged by some stakeholder to be notified, if the value of an attributes has changed and a relation can be tagged by some stakeholder to be notified, if the rela-tion was modified or deleted. Figure 5 illustrates the details about attributes and relations.

Discipline Specific Model of Plant

A discipline specific model of plant is a view on the overall model of plant. It is a "network" of related building blocks (i.e. model of equipments), where each relation between building blocks in the "net-work" is tagged by the discipline qualifier and only the attributes of the building block, which are tagged by the discipline qualifier, are relevant for the discipline specific model of plant. Figure 4 illus-trates the relation between an overall model of plant and two discipline specific models of plant, where the two disciplines are indicated by the colors "orange" and a "green".

Engineering Tool

- The engineering tool offers capabilities to manage models of equipment and discipline specific models of the plant in the context of an overall model of the plant. More details about these ca-pabilities resp. requirements for these capabilities are described in the activities, see chapter "Activities".

The engineering tool has to provide editing, visualization, and navigation capabilities:

- There have to be provided generic capabilities for editing and visualization of the overall model of the plant. This includes capabilities to edit and visualize models of equipments. In addition there should be provided specific (i.e. depending on the discipline) capabilities for editing and visual-iza-tion of a discipline specific model of the plant.

- There have to be provided generic navigation capabilities within the overall model of the plant (generic capabilities) resp. the various discipline specific models of the plant (may be also specific capabilities depending on the discipline) and there have to be provided navigation capabilities be-tween the various discipline specific models of the plant.

The engineering tool has to provide import and export capabilities to import resp. export a discipline specific model of the plant from resp. to an external software application. There should be also import and export capabilities to import resp. export the overall model of the plant.

The engineering tool has to provide management capabilities of the overall model of the plant, espe-cially in the area of collaborative engineering (i.e. different stakeholders are working simultaneously with the overall model of the plant) and bulk-engineering (i.e. a large amount of attributes and re-la-tions is processed and modified in an automatic way based

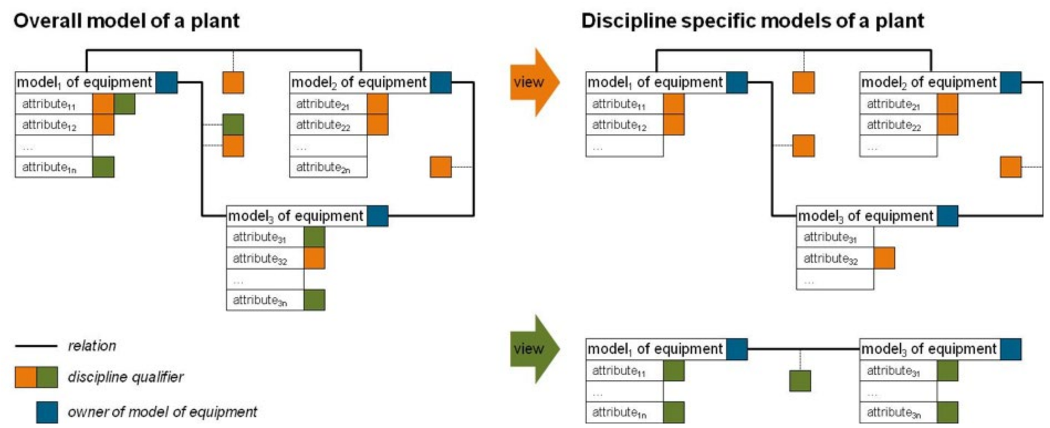

Figure 5: Illustration of discipline specific models of a plant

on specific rules):

- Management of the different “copies” of the overall model of the plant of different stakeholders working in parallel

- Management of commitment of changes, if a stakeholder wants to finally commit his personal “copy” back to the overall model of the plant

- Provision of resolution strategies in case of conflicts because commitments of different stakehold-ers are conflicting each other

- Capabilities to formulate queries and to execute bulk-edit-ing: based on a query a stakeholder can select a set of mod-els of equipments, which then are processed by some rule in an automatic way.

In addition, there could be offered specific management capa-bilities for specific discipline specific (i.e. depending on the discipline) models of the plant.

The engineering tool has to provide management capabilities of stakeholders and various functionali-ties, especially

- There have to be provided capabilities to manage the own-ership of models of equipment, attrib-utes, and relations.

- There have to be provided capabilities to grant modification rights with respect to attributes.

- There have to be provided capabilities to manage discipline qualifier, i.e. creation, modification and deletion (a discipline qualifier can be deleted if it is no longer used by any stake-holder).

- There have to be provided capabilities for the management and forwarding of notifications with respect to attributes and relations.

The engineering tool has to provide capabilities to connect a specific (i.e. depending on the disci-pline) data source, which provides some time series, and to visualize the effect of this in a discipline specific model of the plant. There could be also provided capabilities to connect a generic data source and to

Roles

Figure 6 summarizes the roles we identified in order to de-scribe the usage view of equipment lifecycle management. If we use the term “stakeholder” this is either a supplier of model of equipment or a designer of an engineering discipline.

- The supplier of a model of equipment provides a model of equipment. After provision the supplier is the owner of the model of equipment. The supplier defines the attributes of the model of equipment and may can grant the ownership of the model of equipment to other stakeholders.

- The designer of an engineering discipline can create a disci-pline qualifier. He designs a discipline specific models, i.e. he

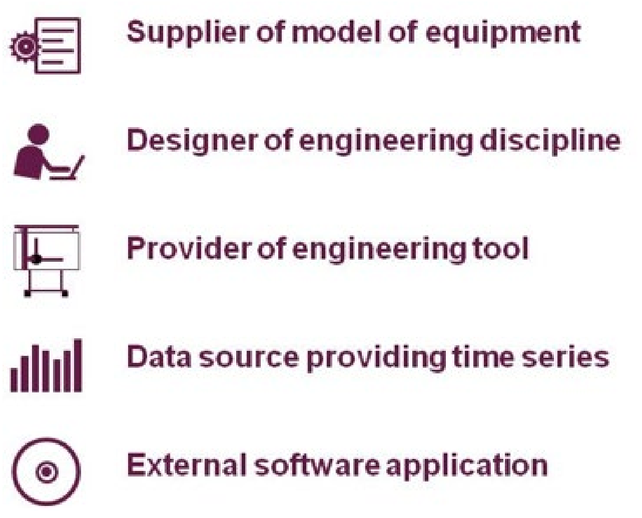

Figure 6: Overview of roles

uses some models of equipment, creates relations between these models, and tags specific attributes resp. relations with the discipline qualifier. By the creation of a relation he be-comes the owner of the relation and can grant ownership of this relation to other stakehold-ers.

  - o If he “uses” some model of equipment, it depends on the modeling purpose whether he uses an ex-isting model of equipment (e.g. creating additional relations, changing attribute values, etc.) or whether he creates a new model of equipment on the information of the “used” model of equipment (e.g. he can create an “instance”-object based on the “use” of a “type”-object). In the case that the designer of an engineering discipline creates a new model of equipment he acts in the role of a sup-plier of a model of equipment.

- The provider of an engineering tool provides an engineering tool environment. This comprises the provision of the tool including a user-specific customizing of the underlying plat-form, i.e. we as-sume that the provision of the engineering tool is “out-of-the-box” with respect to the user.
- A data source providing time series delivers time series of some specific data and can be associ-ated to an attribute of some model of equipment. The time series data can result from real opera-tion of the plant or be generated e.g. by a simulation.

- An external software application is a specific purpose soft-ware application being able to export resp. import a disci-pline specific model of the plant. The discipline qualifier is specific for the soft-ware application. It is also conceivable that an external software application can process the overall model of the plant.

Activities

We have grouped the various activities into four main clusters, which are described in detail in the following chapters:

- Core engineering activities concerning the usage of the en-gineering tool

- Provision of the engineering tool

- Activities using the engineering tool together with other ap-plications

- Advanced engineering activities concerning the usage of the engineering tool

Core engineering activities concerning the usage of the engi-neering tool

The core engineering activities concerning the usage of the engineering tool follow a common overall structure as illus-trated in Figure 7:

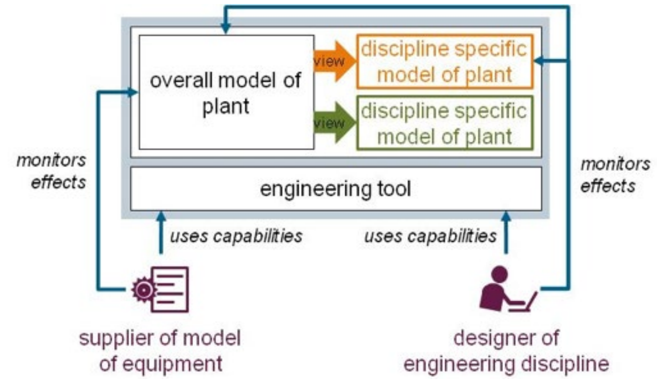

Figure 7: Overview of the core engineering activities concerning the us-age of the engineering tool

Activity “Provision/integration of a model of equipment”

Triggers: This will be triggered by the supplier of a model of equipment in an explicit way.

Workflow:

- Task 1 “Definition of the requirements for the intended model of the equipment”: role supplier of model of equip-ment

- Task 2 “Definition of the model of the equipment according to the requirements using the capabili-ties provided by the engineering tool”: role supplier of model of equipment

Effects:

- The created model of equipment is integrated in a consist-ent way (as determined by the supplier of equipment) in the overall model of the plant.

- After creation of the model of the equipment the supplier of the model of equipment is the owner of the model of equip-ment.

Comment: A model of equipment can be also created during engineering of a discipline specific mod-el of the plant by the designer of an engineering discipline, who is then the owner of the model of equipment. In this case the designer of an en-gineering discipline acts in the role of a supplier of a model of equipment.

Activity “Modification of a model of equipment”

Triggers: This will be triggered by a stakeholder (i.e. supplier of a model of equipment or designer of engineering discipline) in an explicit way.

Workflow:

- Task 1 “Definition of the requirements for the intended modification of the model of the equip-ment”: role stake-holder

- Task 2 “Modification of the model of the equipment accord-ing to the requirements using the ca-pabilities provided by the engineering tool”: role stakeholder

- Task 3 (in the case of modification of a value of an attribute) “Notification of all stakeholders which are affected by the modification, i.e. want to be notified, if the value of the at-tribute has changed”: role engineering tool

Effects: The modification of the model of equipment is inte-grated in a consistent way (as determined by the stakeholder) in the overall model of the plant and all affected discipline specific models.

Constraints:

- The modification can be done only by a stakeholder being an owner of the model of equipment.

- It is in the responsibility of the notified stakeholders to react on the modification in a suitable way.

Activity “Engineering of a discipline specific model of the plant“

Triggers: This will be triggered by the designer of an engineer-ing discipline in an explicit way.

Workflow:

- Task 1 "Definition of the requirements for the intended discipline specific model of the plant": role designer of engineering discipline
- Task 2 (optional) "Creation of a discipline qualifier": role designer of engineering discipline
- Task 3 "Engineering a discipline specific model of the plant according to the requirements by us-ing existing models of equipments, creating relations resp. modifying or deleting existing relations between the models of equipments, modifying attributes of some models of equipment (e.g. noti-fications), and tagging specific relations and attributes by a discipline qualifier using the capabili-ties provided by the engineering tool": role designer of engineering discipline
- Task 4 (in the case of modification or deletion of a relation) "Notification of all stakeholders which are affected by the modification, i.e. want to be notified, if the relation was modified resp. delet-ed": role engineering tool

Effects:

- All effects of the engineering of a discipline specific model of the plant are integrated in a con-sistent way (as determined by the designer of engineering discipline) in the overall model of the plant.
- After creation of a relation the designer of engineering discipline is the owner of the relation.

Constraints:

- The modification or deletion of a relation and the modification of an attribute can be done only by a designer of engineering discipline being an owner of the relation resp. attribute.
- It is in the responsibility of the notified stakeholders to react on the modification in a suitable way.

Activity "Generation of (engineering) view/documents for a specific discipline"

This is a special case of the activity "Engineering of a discipline specific model of the plant". Here nei-ther new relations are created nor existing relations nor attributes are changed. The purpose is to create a specific view of the overall model of the plant to support some specific task (e.g. mainte-nance).
Triggers: This will be triggered by the designer of an engineering discipline in an explicit way.

Workflow:

- Task 1 "Definition of the requirements for the intended discipline specific model of the plant": role designer of engineering discipline
- Task 2 (optional) "Creation of a discipline qualifier": role designer of engineering discipline
- Task 3 "Orchestrate a discipline specific model of the plant according to the requirements by using existing models of equipments and relations between the models of equipments and tagging specific relations and attributes by a discipline qualifier using the capabilities provided by the en-gineering tool": role designer of engineering discipline
- Task 4 "Designing the visualization of the discipline specific model (e.g. data sheet format, list format, document format) using the capabilities provided by the engineering tool": role designer of engineering discipline
- Task 5 "Displaying the discipline specific model of the plant according to the visualization require-ments": role engineering tool

Effects: not applicable

Constraints: Only the attributes and relations tagged by the discipline qualifier are considered to be displayed.

Provision of the engineering tool

Figure 8 illustrates the overall setup for the provision of the engineering tool:

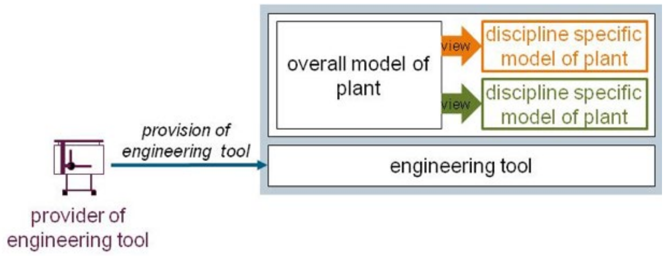

Figure 8: Overview of the provision of the engineering tool

Activity "Provision of engineering tool"

Triggers: This will be requested by the business responsible, who wants to execute equipment lifecy-cle management, in an explicit way.

Workflow:

- Task 1 "Customizing of an underlying engineering platform": role provider of engineering tool
- Task 2 "Deploying and testing the customized engineering platform": role provider of engineering tool
- Task 3 "Providing the customized engineering platform as engineering tool": role provider of engi-neering tool

Effects: The provision of an engineering tool is the basic precondition for executing equipment lifecy-cle management.
Constraints: The constraints of this activity are not in the focus of this paper.

Activities using the engineering tool together with other applications

The activities using the engineering tool together with other applications, i.e. engineering applications or data sources providing time series of data, follow a common overall structure as illustrated in Figure 8:

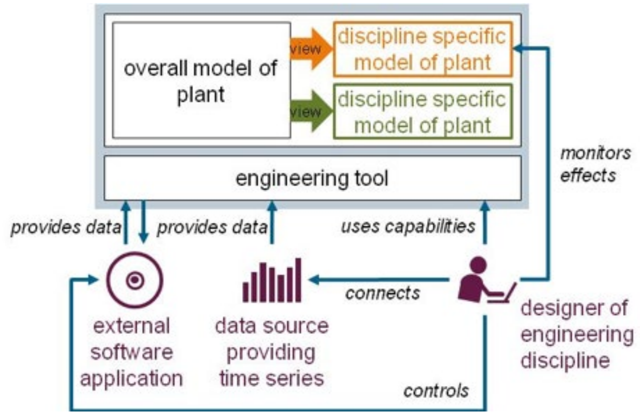

Figure 9: Overview of the activities using the engineering tool together with other applications

Activity "Import of a discipline specific model of plant"

Triggers: This will be triggered by the designer of an engineering discipline in an explicit way.

Workflow:

- Task 1 "Defining the scope of information to be provided by the external software application": role designer of engineering discipline
- Task 2 "Defining the concept how information provided by the external software application is related to information of the overall model of the plant, e.g. name conventions, mapping rules": role designer of engineering discipline
- Task 3 "Creating a new discipline qualifier": role designer of engineering discipline
- Task 4 "Importing the information provided by the external software application as a discipline specific model of the plant, i.e. creating an "independent" model because of the new discipline qualifier": role designer of engineering discipline
- Task 5 "Merging the imported discipline specific model into the overall model of plant using the resolution capabilities of the engineering tool in the case of conflicts": role designer of engineering discipline
- Task 6 (optional) "Deleting the imported discipline specific model, i.e. removing the created disci-pline qualifier" role designer of engineering discipline

Effects: Engineering data provided by some external software application is integrated in a consistent way into the overall model of a plant (including all links between the former overall model of a plant and the additional information provided by the external software application).

Constraints: The constraints concerning architecture requirements of the external software application are not in the focus of this paper.

Activity "Export of a discipline specific model of plant"

Triggers: This will be triggered by the designer of an engineering discipline in an explicit way.

Workflow:

- Task 1 "Defining the scope of information to be provided to an external software application": role designer of engineering discipline
- Task 2 "Defining the concept how the information provided to the external software application has to be structured according to the requirements of the external software application": role de-signer of engineering discipline
- Task 3 "Creating a new discipline qualifier": role designer of engineering discipline
- Task 4 "Defining mapping rules how the information to be provided to an external software appli-cation can be generated from the overall model of the plant in form of a discipline specific model using the capabilities provided by the engineering tool": role designer of engineering discipline
- Task 5 "Creating the discipline specific model using the capabilities provided by the engineering tool": role designer of engineering discipline
- Task 6 "Exporting the discipline specific model in a format satisfying the requirements of the ex-ternal software application": role designer of engineering discipline

Effects: A self-contained and consistent extract of the overall model of the plant is provided to an external software application.

Constraints: The constraints concerning architecture requirements of the external software application are not in the focus of this paper.

Activity "Connect a data source providing time series"

Triggers: This will be triggered by the designer of an engineering discipline in an explicit way.

Workflow:

- Task 1 "Identifying an attribute of the overall model of the plant (resp. a specific discipline specific model), which will be linked to the data source": role designer of engineering discipline
- Task 2 "Defining the concept how the data source is technically associated to the identified attrib-ute": role designer of engineering discipline
- Task 3 (optional) "Designing a specific discipline specific model, which includes the identified at-tribute, to be used for representation of the effects of the time series provided for the attribute": role designer of engineering discipline
- Task 4 "Connecting the data source from a technical point of view using the capabilities provided by the engineering tool": role designer of engineering discipline
- Task 5 "Visualizing the effect of the time series (e.g. in the overall model of plant as well as in any discipline specific model of plant) over the time": role designer of engineering discipline

Effects: The consequences of the change of an attribute over the time are made transparent based on a discipline specific model in combination with the capabilities of an engineering tool.

Constraints: The constraints concerning architecture requirements of a data source providing time series of data are not in the focus of this paper.

Advanced engineering activities concerning the usage of the engineering tool

The advanced engineering activities concerning the usage of the engineering tool follow the same overall structure as the core engineering activities, see Figure 7.

Activity "Bulk engineering"

Triggers: This will be triggered by a stakeholder (i.e. supplier of a model of equipment or designer of engineering discipline) in an explicit way.

Workflow:

- Task 1 "Definition of the requirements for the intended bulk engineering task": role stakeholder
- Task 2 "Formulation of a query using specific capabilities provided by the engineering tool": role stakeholder
- Task 3 "Generation of a list of attributes of models of equipments including the values of the at-tributes based on the query": role engineering tool
- Task 4 "Values of the attributes in the list of attributes are edited using specific bulk-editing capa-bilities provided by the engineering tool ": role stakeholder
- Task 5 "Changes of values of attributes are committed using specific capabilities provided by the engineering tool": role stakeholder
- Task 6 ""Commitment including resulting notifications is executed": role engineering tool

Effects: The changes of the values of the attributes are integrated in a consistent way into the overall model of a plant.

Constraints:

- The changes can be done only by a stakeholder having modification rights to modify the values of the attributes.
- It is in the responsibility of the notified stakeholders to react on the modification in a suitable way.

Activity "Collaborative engineering"

Triggers: This will be triggered by a stakeholder (i.e. supplier of a model of equipment or designer of engineering discipline) in an explicit way.

Workflow:

- Task 1 "Creating a copy of the overall model of the plant (without losing the link to the models of equipments and relations, which were the basis for the copying) for some own purpose using specific capabilities provided by the engineering tool": role stakeholder
- Task 2 "Working on the personal copy of the overall model of the plant independently using the capabilities provided by the engineering tool": role stakeholder
- Task 3 "Committing the local copy back to the overall model of the plant using specific capabilities provided by the engineering tool": role stakeholder
- Task 4 "Evaluation of the delta of the local copy compared to the overall model of plant and re-vealing conflicts": role engineering tool
- Task 5 "Resolution of revealed conflicts using specific capabilities provided by the engineering tool": role stakeholder
- Task 6 "Modifying all attributes and relations based on the resolved conflicts": role engineering tool
- Task 7 "Notification of all stakeholders which are affected by the modification, i.e. want to be noti-fied, if a relation or attribute was changed": role engineering tool
- Task 8 "Deleting the initially created copy of the overall model of the plant": role engineering tool

Effects: It is ensured that at the same time several stakeholders can execute engineering activities independently of each other on the overall model of the plant and that the various resulting changes of attributes and relations can be synchronized.

Constraints:

- Task 5 (resolution of conflicts) may be executed by another stakeholder than the stakeholder of Task 1, Task 2 and Task 3.
- The resolution capabilities of the engineering tool have to consider whether the stakeholder has modification rights to modify the attributes resp. relations.
- It is in the responsibility of the notified stakeholders to react on the modification in a suitable way.

COMOS and the Baowu project

Basic information about COMOS

In this chapter we briefly introduce some selected functionality of the plant engineering software CO-MOS of Siemens:

- Object orientation is the foundation of the software concept of COMOS, see Figure 10. Compo-nents are described in a holistic and realistic way. All data associated to a component including the graphical representations form a unit within the database – an object. All applications of CO-MOS access these objects in all engineering and operating phases of a plant. Changes to ob-jects are thus available to every user of any application. Engineering documents, data sheets and lists are directly linked to the corresponding objects. Objects are tagged based on a flexible, intel-ligent, rule-based labeling system.
- COMOS provide capabilities for navigation, visualization, and easy handling of the various engi-neering documents and individual objects, see Figure 11. COMOS offers an ergonomic, easy-to-use user interface including drag-and-drop function, bidirectional editing of object properties, nav-igation between documents and objects and standard functions conforming to Microsoft stand-ards.
- The COMOS platform offers powerful capabilities for customizing with respect to specific customer needs. In addition, COMOS offers a powerful role concept, which distinguishes for example be-tween administrators and users and which is the basis for user management.
- COMOS supports various standard exchange formats like for example XML, MS Excel, MS Ac-cess, and text files. A highlight is the flexible and easy creation of data sheets via drag & drop, see Figure 12. Data sheets allow a bidirectional editing of the data sheet and the object proper-ties. They can be exported for example to MS Excel and re-imported to CO-MOS including any modifications.
- COMOS Enterprise Server in connection with standard XML connectors enables a powerful inter-action with individual applications. The COMOS Enterprise Server ensures that anytime during a project the data is always consolidated, no matter where it was created. Rules can be defined in-side COMOS for validating the data created in third party systems. Upon receiving the external data, the rules will be used to check the validity of the data, the COMOS Enterprise Server may then accept or reject the data and the third party system is automatically notified when its data has been rejected.
- COMOS provides working layers, see Figure 14, which are superimposed views of an engineering project, in which work can be done in parallel without modifying the common database (i.e. the original project). The main advantage of the working layer technology is that changes do not af-fect the as-built status of a project as long as they are performed in the working layer. Multiple working layers can be created on the basis of an as-built status and compared. Document changes made in other working layers are displayed. This facilitates both working in parallel and an exchange with other sites. Working layers can be processed, exported, and re-imported to an-other site. On import, the changes are also visualized.
- COMOS supports bulk processing and list generation. Based on a query-technology user-defined queries can be created and executed. This will result in a list, which can be edited, exported and afterwards any changes made by subcontractors can be re-imported in a controlled way.

Basic information about the Baowu project

The overall Baowu and Siemens Go to Industrie 4.0 (BSG2I4.0) project was launched in 2015 when the former Baosteel Group

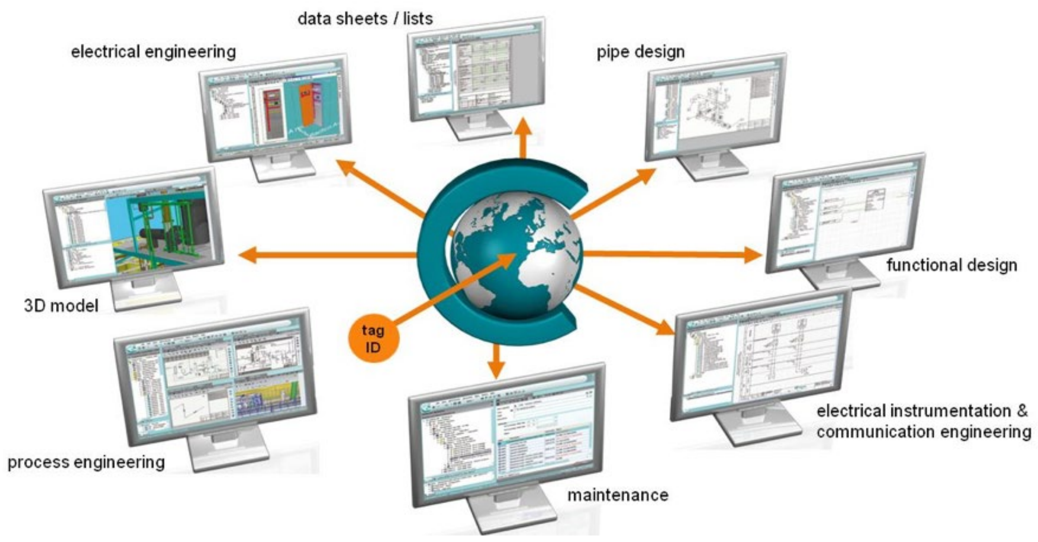

Figure 10: Illustration of object orientation of COMOS

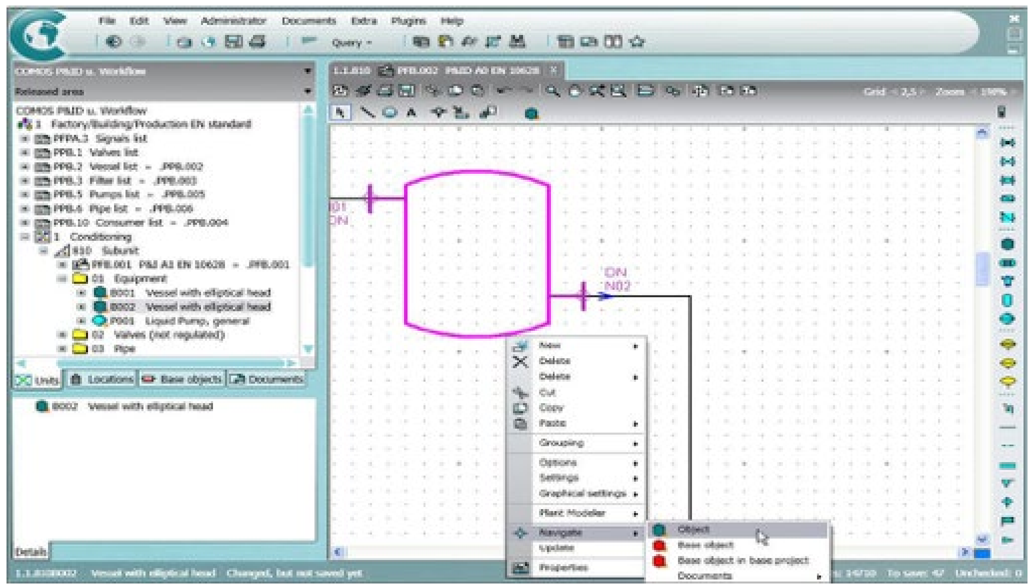

Figure 11: Illustration of navigation, visualization, and easy handling capabilities of COMOS

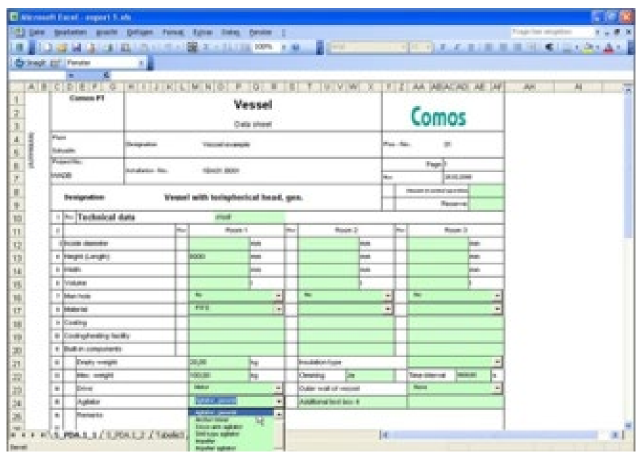

Figure 12: Illustration of flexible and easy creation of a data sheets with COMOS

announced its blueprint for intelligent manufacturing in iron and steel pro-duction. The key objectives of the project are to create greater plant and process visibility through a higher level of automation, integrate and connect the various pro-duction systems, implement an infra-structure for obtaining real-time information and production performance, and en-sure data consisten-cy and accessibility along the entire value chain. All this will help Baowu to improve production ef-fi-ciency, increase production flexibility, and make better and more sustainable use of resources.

In this project, Baowu and Siemens collaborate in many fields of technology, including visualization, digitalization and simu-lation, reducing energy consumption at the workshop level, equipment monitor-ing and diagnostics, sensor and detector technology, intelligent manufacturing operations man-age-ment, big data in industry, industry information structure,

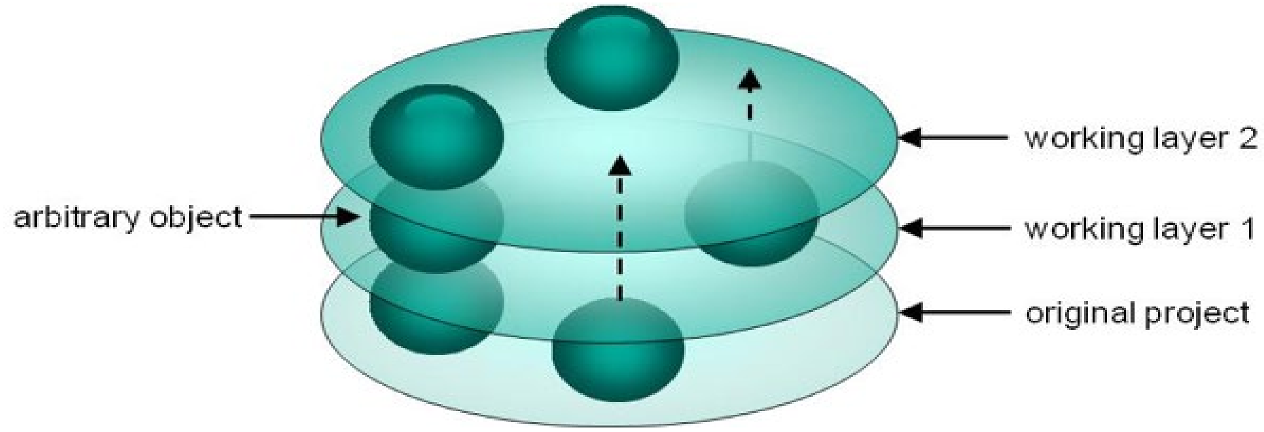

Figure 13: Illustration of working layer technology of COMOS

and security. In collaboration with Baowu experts, Siemens co-defined twelve technical subjects to summarize all these technical fields to be applied in iron and steel production, see Figure 14. Equipment Lifecycle Management is one of these concrete projects in the subject of Digital Plant.

Equipment lifecycle management was implemented in the Ba-osteel 1580 hot milling plant. This plant was built in 1996 by Mitsubishi Heavy Industry and Mitsubishi Electric as the me-chanical and electric equipment supplier. The plant provides hot rolled low carbon steel coil for a galvanized line (auto-mo-bile steel), an oriented and non-oriented silicon line (transformer, motor, compressor steel) and a color coating line (electric appliance steel). Figure 15 illustrates the hot milling process of the plant.

In 2015 the electrical equipment of the Baosteel 1580 hot milling plant was upgraded by Baosight. The main drives (i.e. 1#, 2# roughing mill and 1#-7# fine rolling mill) were kept for retention, but the other basic automation and drive systems were replaced by Siemens products. In 2016 the Baosteel 1580 hot milling plant was taken as the Intelligent Manufacturing Demonstration Line issued by the Chinese Ministry of Industry and Information Technology.

Equipment lifecycle management was implemented based on the plant engineering software COMOS of Siemens. Based on COMOS a so-called equipment digital hub was created and integrated in the already existing systems at Baosteel. Key fea-tures are the connection of the equipment digital to the exist-ing equipment and distributed control system at site and the synchronization with the master data of the equipment man-agement system. Figure 16 gives an overview of this system architecture.

The modeling based on the COMOS application focused on the 2# roughing mill in the Baosteel 1580 hot milling plant. There were built 2D models using the COMOS models P&ID, I&C and Logical and a 3D model using COMOS Walkinside. Baosight was responsible for the engineering with CO-MOS and system inte-gration, Siemens provided training and technical services. Figure 17 gives an overview of the COMOS application.

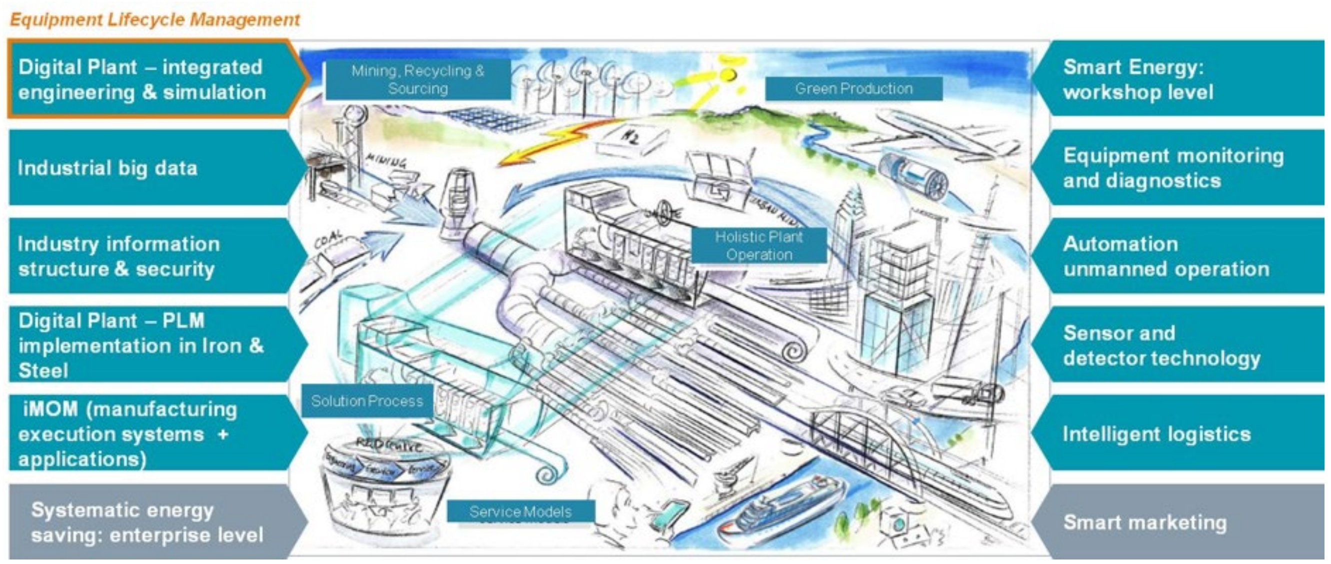

Figure 14: Scope of the overall Baowu and Siemens Go to Industrie 4.0 (BSG2I4.0) project

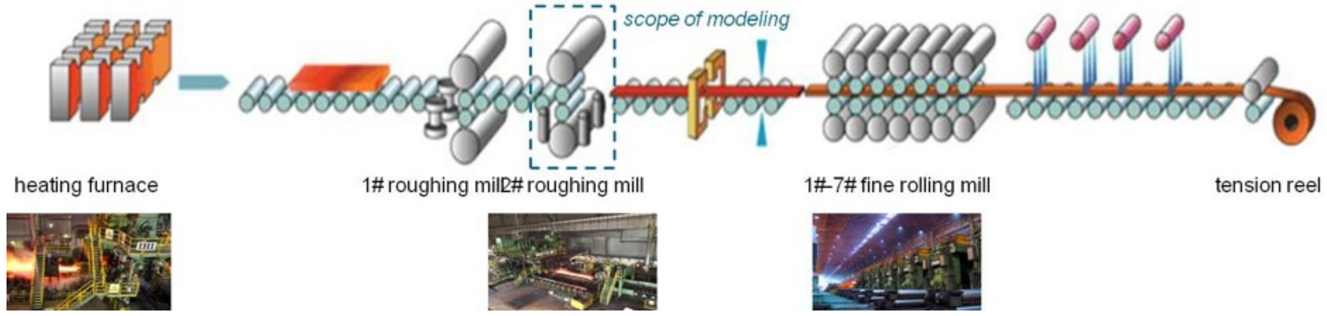

Figure 15: Hot milling process flow of Baosteel 1580 plant

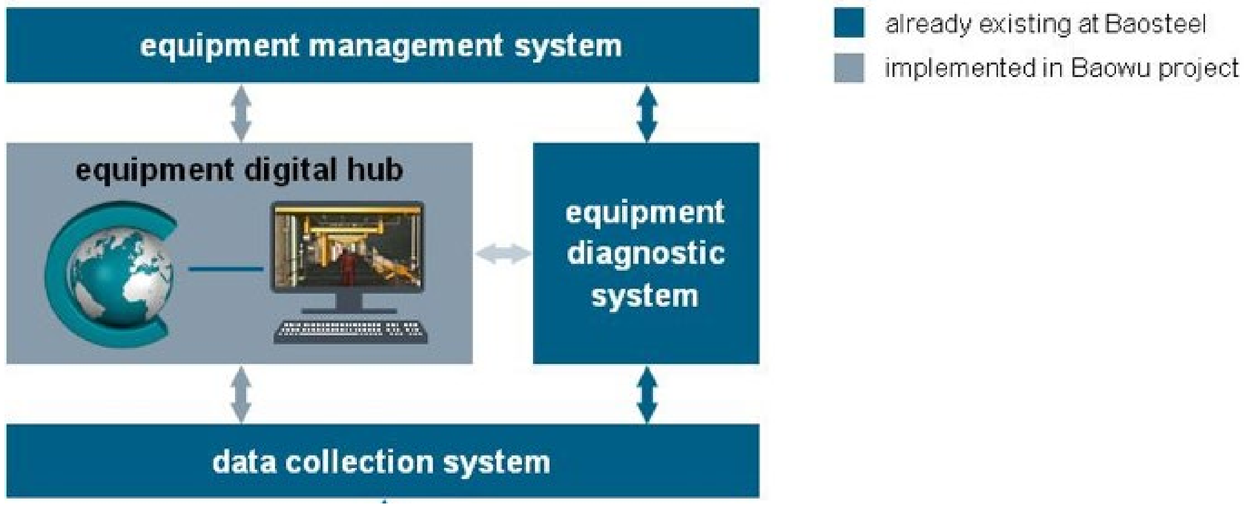

Figure 16: Overview of system architecture in Baowu project

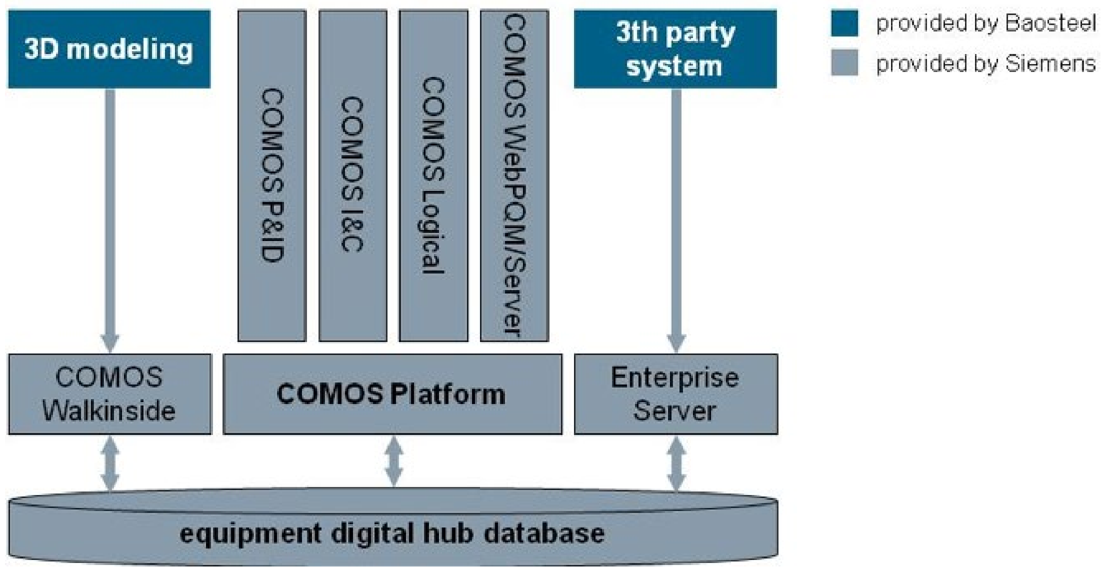

Figure 17: Overview of COMOS application in Baowu project

Key scenarios implemented in the Baowu project

In this chapter we briefly describe some selected scenarios im-plemented in the Baowu project using the plant engineering software COMOS of Siemens.

Scenario 1: Management of engineering data of mechanical equipment

- This scenario implemented the creation, modification, and management of different models of mechanical equipment, for example a 3D model, a mechanical drawing, and various property documents. The plant engineering software CO-MOS of Siemens provides bi-directional navigation capabili-ties between these different models of mechanical equip-ment, thus provides an embed-ded document management. Figure 18 illustrates this showing some aspects of the so-called au-tomatic width control cylinder in 2# roughing mill as an example.

Scenario 2: Management of engineering data of electric equip-ment

- This scenario implemented the creation, modification and management of different models of electrical equipment, for example a component structure of a cabinet, an electrical wiring between components, and a logical communication structure between components. The plant engineering soft-ware COMOS of Siemens provides bi-directional navigation capabilities between these differ-ent models of electric equipment, thus enforcing integrated engineering capabili-ties. Figure 19 il-lustrates this showing some aspects of ET200 components as example.

Scenario 3: Synchronization of engineering data between CO-MOS and PCS 7

- The hardware structure of the existing process control sys-tem, see Figure 16 is represented in COMOS as well as in the distributed control system PCS 7. As both systems COMOS

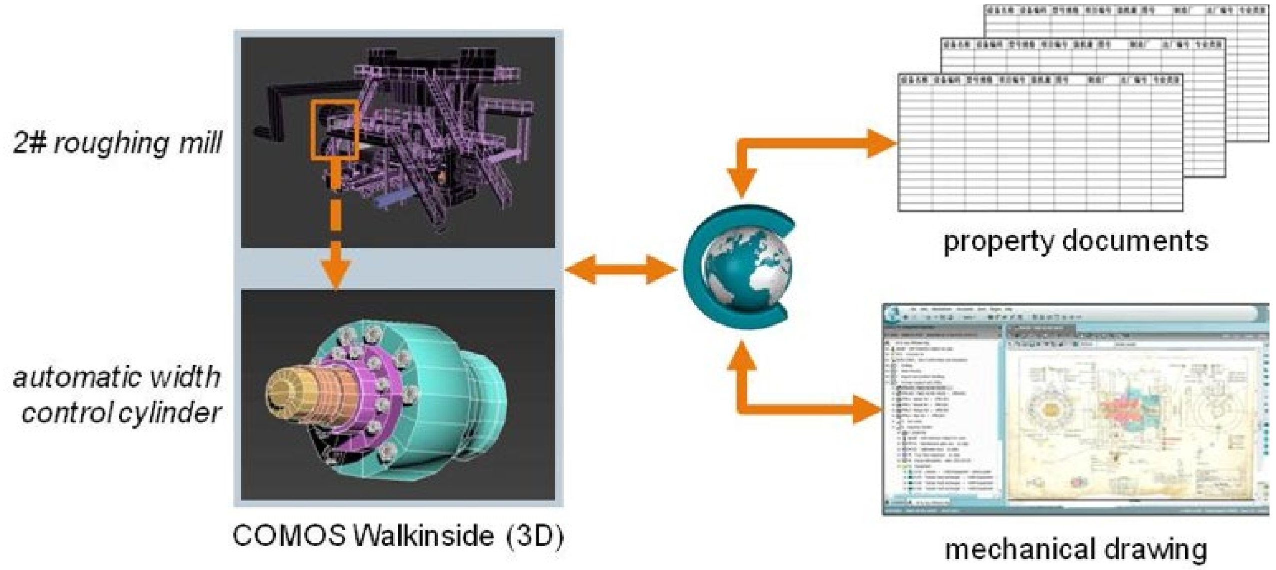

Figure 18: Illustration of management of engineering data of mechanical equipment

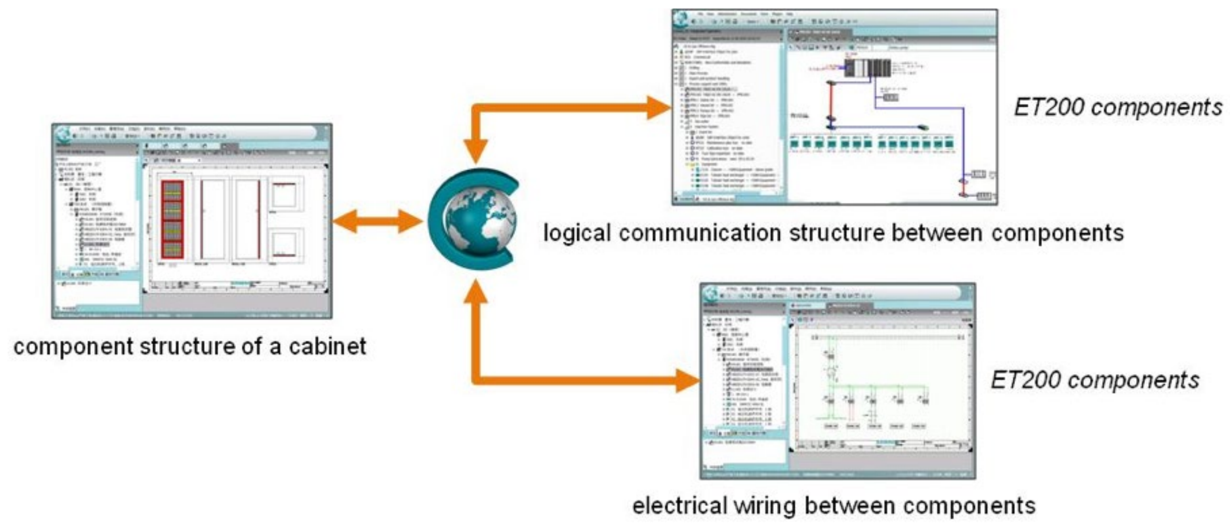

Figure 19: Illustration of management of engineering data of electric equipment

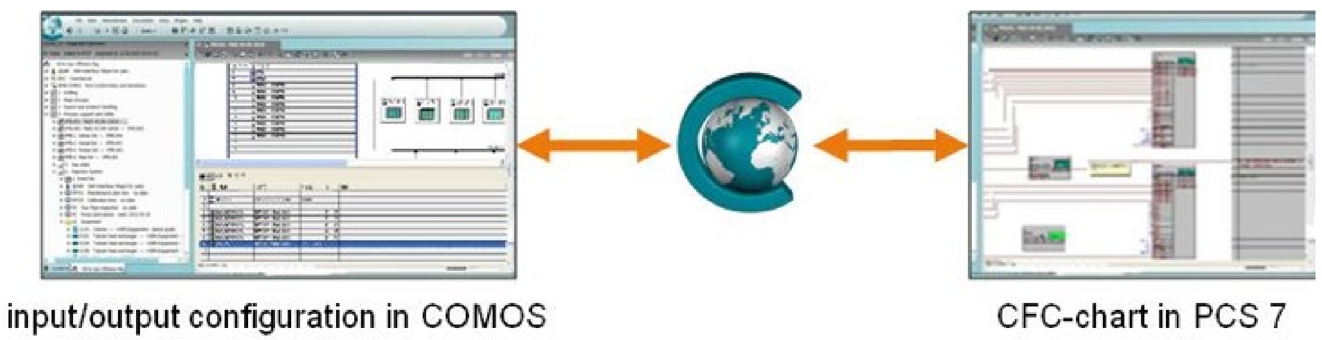

Figure 20: Illustration of Synchronization of engineering data between COMOS and PCS 7

and PCS 7 are provided by Siemens there exist bi-directional synchronization capabilities of COMOS and PCS 7 of the hardware structure. The hardware structure can be modified in either COMOS or PCS 7 and can be synchronized later, thus there is a bridge from plant engineering to process control engineering during all project phases. Figure 20 illustrates these synchronization capabili-ties for some inputs and outputs of the Baosteel 1580 hot milling plant.

Scenario 4: Navigation capabilities in case of an equipment alarm

- During operation of a plant sometimes alarms are generated by some I/O module connected to the controller of the distributed control system. Theses alarms are forwarded to the server of the distributed control system and typically displayed to the operator of the plant by some capabilities provided by the distributed control system. Often an alarm indicates some anomalies with respect to some (mechanical) equipment. This scenario implemented navigation capabilities from an alarm displayed in the distributed control system PCS 7 to the corresponding I/O module as represented in PCS 7 to the corresponding electric equipment as represented in COMOS to the affected (me-chanical) equipment as represented in COMOS, thus enforcing integrated operation capabilities and implementing embedded maintenance.

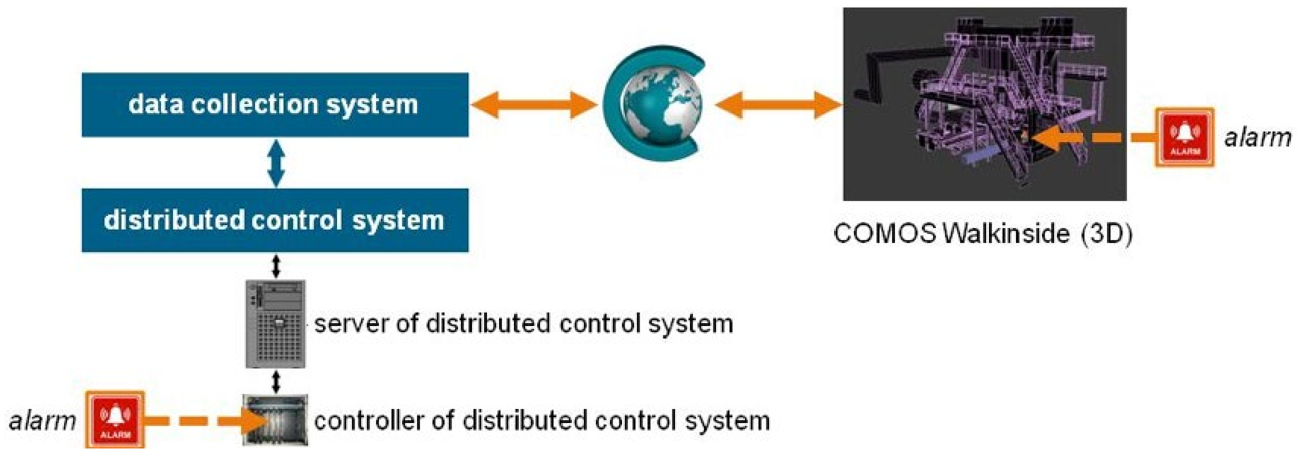

Figure 21: Illustration of navigation capabilities in case of an equipment alarm

Figure 21 illustrates the display of an alarm in the 3D model of COMOS Walkinside.

Scenario 5: Integrating engineering data of existing equipment into COMOS

- Especially in Brownfield scenarios a lot of physical equipment as well as engineering documents already exist. Information of the existing physical equipment, for example 3D information, has to be captured by some 3D data capturing application. Also information from the existing engineer-ing documents, for example data sheets, mechanical resp. electrical drawings, has to be provided using some specific data capturing applications. This scenario implemented the integration of all captured resp. provided information of existing equipment including all associations between the captured information into the plant engineering software COMOS of Siemens. Afterwards naviga-tion, visualization, editing, etc. capabilities of COMOS are available for the Brownfield project. Fig-ure 22 illustrates the capturing of data of the existing 2# roughing mill and the display in form of a COMOS Walkinside 3D model.

Scenario 6: Data exchange between equipment management system and COMOS

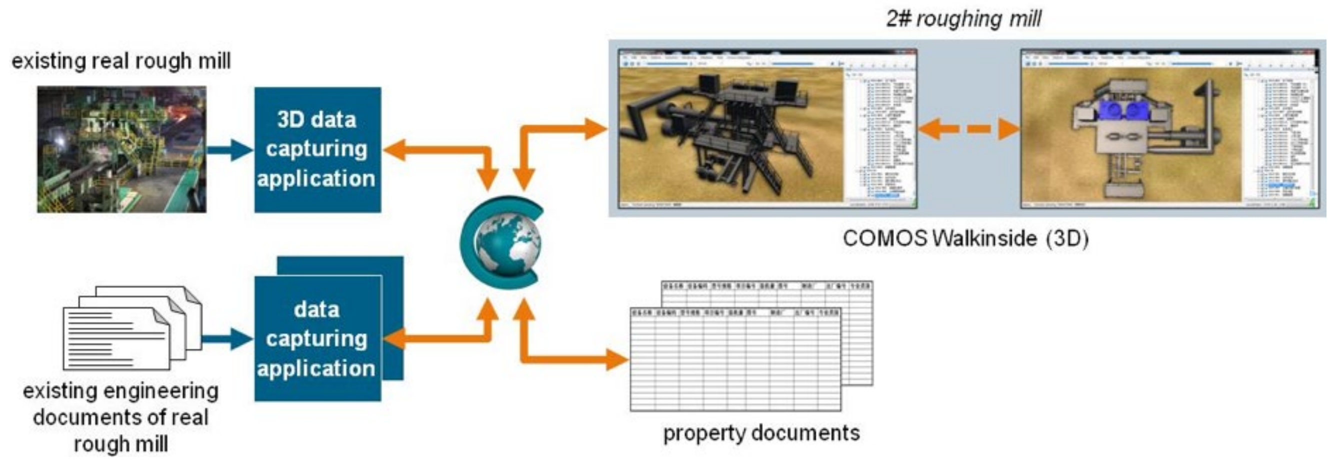

Figure 22: Illustration of integrating engineering data of existing equipment into COMOS

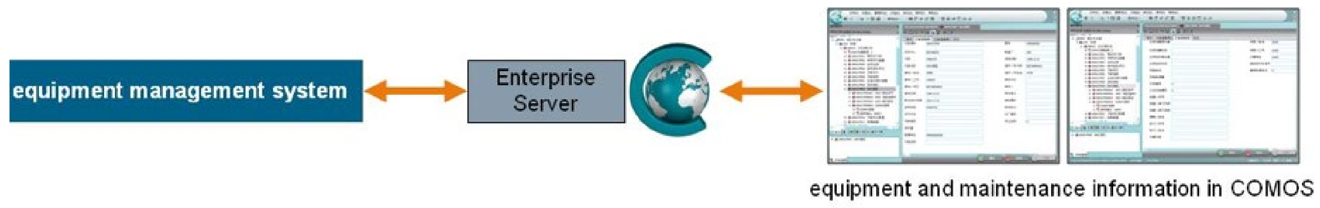

Figure 23: Illustration of data exchange between equipment management system and COMOS

- Various systems, for example the equipment management system, see Figure 16, are in use by the operator of the plant, but COMOS offers additional capabilities to improve for example the operation and maintenance processes of the operator of the plant. This scenario implemented the exchange information between the equipment management system, for example requested spare parts, with COMOS. To support the work of an service engineer COMOS enriches the exchanged information and supports the affected business processes, for example the requested spare parts are enriched by workflow guidance how to replace the existing equipment by the new equipment including monitoring of all requested quality checks. Figure 23 illustrates this data ex-change based on COMOS Enterprise Server, see Figure 17.

Finally, Figure 24 illustrates the relationship between the usage view of equipment lifecycle manage-ment and the features of the plant engineering software COMOS, see chapter “Basic information about COMOS”, as well as the key scenarios implemented in the Baowu project, see chapter “Key scenarios implemented in the Baowu project”. The upper part of the table in Figure 24 relating to the features of COMOS indicates

how the individual features of COMOS support the different concepts of the usage view of equipment lifecycle management. The lower part of the table in Figure 24 relating to the key scenarios of the Baowu project indicates which concepts of the usage view of equipment lifecycle management support the implementation of the key scenarios.

Linking Usage View and COMOS resp. the Baowu project

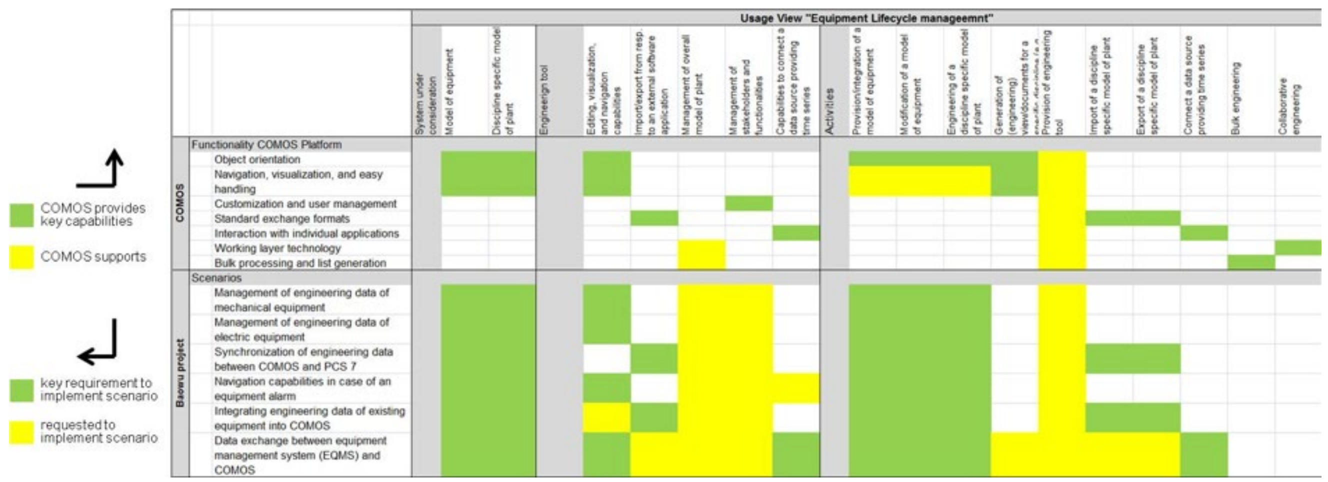

Figure 24: Linking Usage View “Equipment Lifecycle Management” and COMOS resp. the Baowu project

References

[1] The Industrial Internet Reference Architecture Technical Report, Link

[2] German Standardization Roadmap Industrie 4.0, Version 3, Link

[3] Usage Viewpoint of Application Scenario Value-Based Service, Link

[4] Application Scenario SDP – Seamless and Dynamic Engineering of Plants, VDI-Statusreport, Link

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