Chapter 18
Model-Based Guide Toward Digitization in Digital Business Ecosystems

Anna Sumereder and Tor Dokken

Abstract Digitization is popular in today's business ecosystems. However, digitization is not straightforward and introduces challenges such as sensor issues, edge computing, network dependencies, and security. Therefore, the idea is to propose a modelling method enabling to guide key aspects for the digitization process. For this reason, the proposed modelling method prototype concentrates on (a) the collection of requirements, (b) the analysis of the contextual environment, as well as (c) the monitoring by guiding the selection of an appropriate digitization device. The modelling method is extended by a physical OMiLAB Innovation Corner experiment that eases, on one hand, understanding the domain problem and, on the other hand, facilitates the selection of an appropriate digitization unit by taking into account potential physical issues as well as the requirements related to the business perspective.

Keywords Digitization · OMiLAB Innovation Corner · Physical experiment

18.1 Introduction

Digitization is popular in today's business ecosystems. However, digitization and in particular devices at the edge introduce challenges such as network stability, connectivity, and security. To minimize problems like hardware failures and to identify essential dependencies, guidance seems to be required throughout the digitization process. Benedict [1] characterizes digital (business) ecosystems as a platform-independent and sociotechnical system that focuses on coevolution, coopetition, openness, recombination, and self-organization. A differentiation between technical

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and social relationships can be conducted, where the former is highly agile and dynamic—consisting of technology components such as digital devices or hardware parts. A basic overview of the relationships in a digital ecosystem is provided in Fig. 18.1. Here the fundamental parts of such an ecosystem are addressed like digital/smart objects and sensors. Gosh et al. [2] consider the combination of artificial intelligence (AI) and the Internet of Things (IoT) as a breakthrough that enables an easy human life, also in a business environment.

Digitization in general and the creation of a digital twin are mega trends not only in a research context but also in today's business world. For instance, small- and medium-sized enterprises in manufacturing are looking for guidance when digitizing their processes [4]. By focusing on a specific production process setting, which serves as a sample for introducing and explaining our idea, three major digitization challenges were identified in [5]. These are expected also to be relevant for other application cases. The three challenges are (1) the digitization of the production process, (2) the digitization of the raw material, and (3) the digitization of the product itself. The mentioned characteristics and challenges imply that digital ecosystems are not trivial to understand. For this reason, a sort of complexity reduction and simplification can be introduced to support transparency when tackling a specific domain problem. Particularly, the introduction of abstraction facilitates the identification of patterns so that the digitization process in similar domains is supported by concepts such as reusability, simplification, and modularity.

Therefore, the idea (see Sect. 18.2) is to propose a modelling method to guide key aspects related to the digitization process. By supporting documentation and

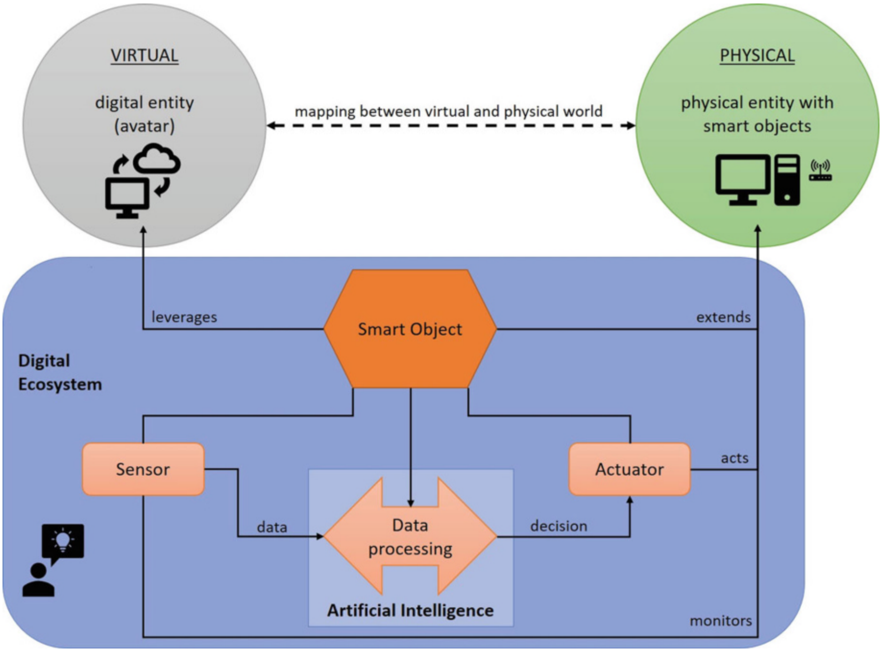


Fig. 18.1 Digital ecosystem connecting physical and virtual world (Based on [2, 3])

consulting features, understanding of the potentially complex domain problem can be highly facilitated. For this reason, the proposed modelling method prototype concentrates on the (a) collection of requirements, (b) analysis of the contextual environment, as well as (c) monitoring by guiding the selection of an appropriate digitization device. The focus areas are supported by the OMiLAB Innovation Corner and its layer-based architecture [6] (see Fig. 18.2)—consisting of three main layers—throughout all stages of digitization and digital transformation. The OMiLAB Innovation Corner facilitates digital innovation by providing a digital innovation and laboratory environment that supports design, engineering, and training activities related to digital transformation.

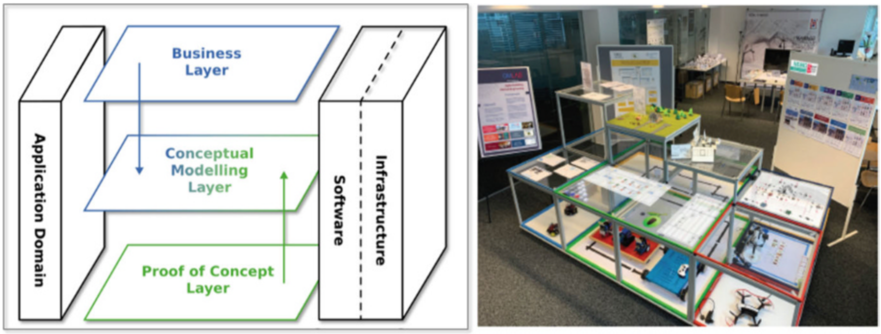


Fig. 18.2 Introduction of the three abstraction layers (left) and the realization of an industrial OMiLAB Innovation Corner at BOC in Vienna (right) [6]

The proposed model-based approach in combination with an OMiLAB Innovation Corner experiment should facilitate the requirement engineering from a business perspective (business layer). It should as well tackle questions such as if a new business model is required or if the existing business model can be used to tackle the requirements of the particular system under study. Furthermore, the organizational structure (conceptual model layer) is considered by focusing on relationships as well as dependencies. This can on the one hand leverage the customer relationship by offering additional services, while on the other hand, a need for adapting the business model might be identified based on increased information, data, and service orientation. The different abstraction layers in the OMiLAB Innovation Corner facilitate holistic considerations from multidisciplinary stakeholders. Additionally, digital devices are introduced and can be tested in the provided experimentation infrastructure (proof-of-concept layer) of the OMiLAB Innovation Corner.

To take into account different perspectives and shed light on the complexity of the digitization problem in digital business ecosystems, a combination of a bottom-up and a top-down approach was chosen. The approach is detailed in Sect. 18.3 and provides further insights on the description and foundation of the method. Furthermore, the method conceptualization including the meta-models is described. This sets the basis for the proof-of-concept experiment (see Sect. 18.4) that consists of the modelling method and a supporting physical model. Finally, an outlook is provided in a short conclusion in Sect. 18.5.

18.2 Method Description

The World Economic Forum report [7] states that the industry is transformed by technologies such as AI, autonomous vehicles, big data analytics and cloud, custom manufacturing and 3D printing, IoT and connected devices, robots and drones, and social media and platforms. These technologies have in common that they can drive new efficiencies, advanced customer experiences, and adapted business models. Agile and digital-savvy leadership, forward-looking skills, ecosystem thinking, data access and management, and technology infrastructure readiness are considered as key enabler for maximizing the return on digital investments. To establish competitive advantage, a combination of products and services can create a unique experience. Aspects such as personalization and access-based ownership models must be considered as well. Therefore, the disruption of existing businesses and the adaption of business models are required to survive the battleground of digital transformation and digitization within digital ecosystems.

Five operating/business models can be identified in the era of digital enterprises [7]. These business models are:

- Customer-centric—The major goal is to make customers' lives easier, and therefore, front office processes are focused.
- Extra frugal—This model concentrates on standardizing the organizational structure and creates a culture where fewer is better.
- Data-powered—The major focus is set on capabilities in the context of intelligence related to analytics and software.
- Skynet—The main objective for production is to increase productivity and flexibility by using machines.
- Open and liquid—Ecosystems are created, and a focus is set on the concept of sharing and collaboration.

The focus areas of those business models differ quite a lot, for instance, some are concentrating on a standardized organization for optimization and automations, while others tend to decentralize to empower people and enable collaboration and a sharing ecosystem. In general, digital transformation is expected to unlock value of more than $100 trillion not only for businesses but also for society [7].

To handle the complexity introduced by new business models and digital transformation, the OMiLAB Innovation Corner [6] has the potential to be a helpful consulting environment. It is an environment that elaborates on digitization in the light of new business models that follow a layer-based approach that ranges from business to conceptual and physical considerations. For this reason, we consider the proposed modelling method and especially the proof-of-concept experiment as a good starting point for further research and innovation relevant for digitization in industry.

To manage the complexity of the mentioned aspects, a hybrid approach was followed when designing the modelling method. The chosen combination of a bottom-up approach and a top-down approach has been tested out of a set of challenges. These range from a smart energy management ecosystem case, over standards and frameworks, to a pilot study within the context of the Horizon 2020 EU project “Change2Twin”.

The foundation for this modelling method was laid by [3], where a bottom-up approach was applied to tackle the model-based application of artificial intelligence technologies within digital ecosystems. The growing demand for battery packs creates a need for improving their lifetime by battery management services. Therefore, a smart energy management ecosystem including a model-based prototype was developed. As the development of a self-ordering battery system is a quite specific use case, the goal of this modelling method is to leverage the meta-model shown in [3]. This is done by introducing more abstraction and therefore allowing a broader application domain for digitization problems.

While the mentioned bottom-up approach is based on a prototype, a top-down notion is provided by having a look at established reference frameworks such as the reference architecture model for Industry 4.0 (RAMI 4.0) [8]. This model suggests creating value based on information flows by focusing specifically on communication. This is done by introducing a layer model as well as standardization. The reference architecture model provides insights on what digitization means for companies and fosters worldwide interoperability. In particular, common standards are seen as prerequisite for digitized production including (a) communication structures such as networks and protocols, (b) guidelines for security and data protection, and (c) terminology and understanding.

RAMI 4.0, and specifically its three-dimensional reference architecture map, consists of several layers, life cycle value streams and hierarchy levels following a service-oriented architecture that serves as a foundation for a common understanding in Industry 4.0 by providing a multi-dimensional view. Therefore, the hierarchy of the factory is considered as well as the product lifecycle and the architecture layers. We assume that the presented architecture and specifically its components can serve as a starting point for the proposed modelling method. This is done to ensure that relevant considerations are captured, while at the same time, the complexity is reduced by introducing abstraction. Bridging the business and the physical world by keeping in mind various viewpoints seems to be an essential requirement for the modelling method.

Shedding light on aspects related to managing data and relationships makes the complexity of bridging physical and digital/business worlds even clearer. The role of different relationships in digital (business) ecosystems as shown in [1] creates a need for managing those by establishing a “global, digital economy with International Data Spaces (IDS), a secure, sovereign system of data exchange in which all participants can realize the full value of their data” [9]. The centerpiece of the data space idea is the connector that brings together all components and services in order to deliver value. IDS presents various white papers including criteria catalogues for the components. The IDS Association White Paper [10] focuses on the operational environment by considering, for example, aspects such as assets, business continuity, communication, security, compliance, monitoring, or access management. It provides a reference architecture consisting of business, functional, process, information, and system layer while at the same time focusing on security, certification, and governance perspectives [11]. Comparing this layer-based structure with the OMiLAB layer architecture presented in [6], a proof of concept within the OMiLAB Innovation Corner seems to be at the cutting edge.

Also, well-known members [12]—like Allianz, Audi, IBM, PWC, Rewe, SINTEF, TNO, Thyssenkrupp, and others—of the IDS clearly show the applicability for various industries and the importance in today's business world. In particular, as data and data exchange are cornerstones for digitization and digital (data-driven) business ecosystems, we consider the mentioned concepts as very important for the modelling method.

Based on the concepts found in reference architectures and frameworks, for example, RAMI 4.0 and IDS, the idea for a modelling method that guides digitization by transforming business environments into digital ecosystems emerged. As a result, the key concepts of [3, 8–10] were brought together to design the meta-model. This served as a foundation for the proof of concept, in Sect. 18.4, that shows the applicability of the abstract schema within an experimentation setup and established the foundation for further industrial investigations.

The introduction of abstraction and simplification fosters transparency, reusability, and understandability. To ensure that specificities of the domain are supported by expert knowledge, we propose that the modelling method is used by two actors with domain/expert knowledge. The first expert is responsible for the collection of requirements arising due to the contextual environment as well as for the description of the system under study. The second expert can provide recommendations for the selection of management units based on the gathered information. Thus, the modelling method serves as a platform that offers a playground for interoperability and interdisciplinary discussions based on information captured in models. This idea ensures that the domain experts can discuss and present their viewpoint in a simplistic way that is easy to understand by other stakeholders.

The high-level goal of the modelling method is to relate business requirements with physical world requirements. This is achieved by guiding the digitization process by instructions and through consulting capabilities. The idea is that based on a set of physical objects and/or a business process/model digitization, units can be identified. Therefore, we consider the following major steps in our prototype process. The first is the collection of data, which is realized by visual modelling, where the externalization of knowledge is conducted by humans so far. The second is monitoring of the status of candidate digitization units, which allows the following of status information. Based on the first two steps, suitable digitization units can be identified. The third step is continuous improvement and development required due to the fast development of digital devices on the market.

These steps are the foundation for the building of the meta-model. Therefore, the main concept of the meta-model and hence the centerpiece is selected to be the digitization unit. The selection of the digitization unit is highly influenced by the system under study and the environmental context. More specifically, the system under study is a physical object or a domain-specific digitization case. The abovementioned reference frameworks are currently not directly integrated in the modelling method. However, the design of the modelling method allows for the integration of a semantic lifting approach by being easily extendible in the context of introducing reference ontologies.

Summarizing, the modelling method focuses on simplification, abstraction, and transparent documentation to pave the way for improving the understandability and interdisciplinarity of different domain stakeholders. Accordingly, the complexity of digital transformation and specifically digitization problems can be reduced. The following section provides more details about the modelling method based on a description of the meta-model.

18.3 Method Conceptualization

The meta-models described in this section were created with CoChaCo [13], which is a tool that supports the creation and design of meta-models. The eponymous CoChaCo—Concept, Characteristic, and Connector—is a concept that allows the construction of a meta-model supported by Purpose and Functionality that depict the usage. The tool facilitates the meta-model creation in a framework, platform, and implementation-independent environment. The CoChaCo meta-modelling tool provides three major model types. Those are concept overview, concept pool, and procedure, which serve as a basic outline for the meta-model description section.

18.3.1 Concept Overview

A high-level meta-model was designed so that the focus is set on the characteristics of the concepts. The main concepts are displayed in Fig. 18.3, indicated by rectangles, while the major relationships are depicted by ellipses. All of the shown concepts have basic characteristics such as a name and a description attached. Furthermore, they are detailed with advanced characteristics shown in the concept pool.

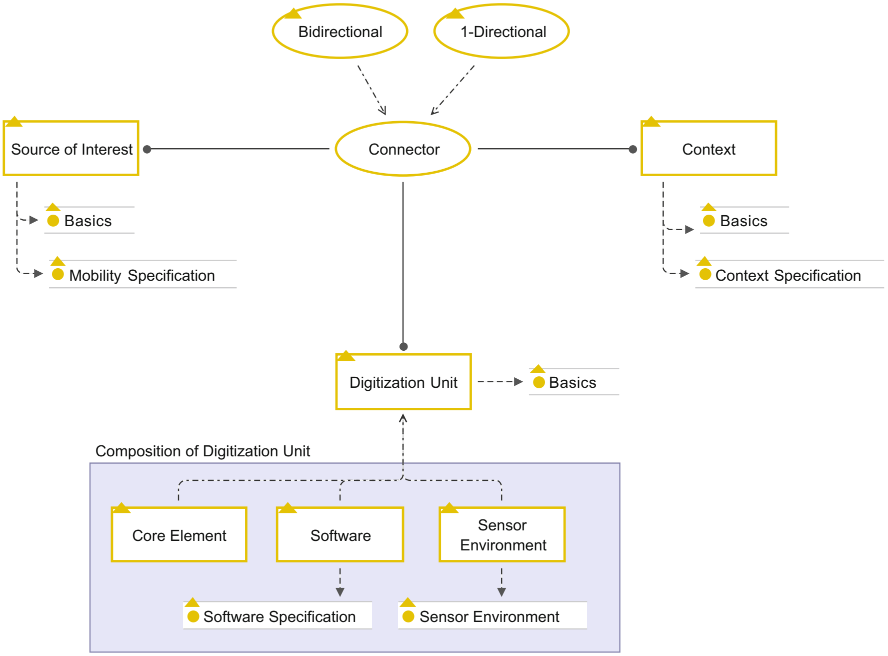


Fig. 18.3 Meta-model concept overview

As mentioned, the meta-model was designed by abstracting the meta-model shown in [3]. Therefore, the major concepts of the smart energy management system meta-model—such as an energy source, a management unit, a device, and a location/owner—are supported by introducing more abstraction. This resulted in three major concepts, which are the source of interest—also known as system under study—the context, and the digitization unit. The connector is seen as a center that connects the three major concepts. In particular, the selection of the digitization unit is highly influenced by both, the source of interest and the context.

The source of interest is characterized by having a tight relation to the business ecosystem. The major idea is to capture the varying characteristics of the system under study, which can consist of physical objects—in order to digitize the source of interest. This allows a new business model to be found or existing business models to be adapted so that they fit the complex requirements of digital business ecosystems. Remembering the smart energy/battery management sample described in [3], the source of interest could be an energy source, for instance. However, by introducing the concept of source of interest in our proposed modelling method, also, more complex problems related to (industrial) business challenges can be outlined. For example, digitizing the warehouse or raw material management can be described. In particular, the modelling method allows the transparent and easy understandable description of the digitization challenge. This is done by on the one hand allowing for a textual description as well as offering the possibility of collecting the requirements emerging based on the business case while on the other hand affecting the context and the digitization unit. In particular, the gathered business aspects might pose specific requirements on the digitization unit, for instance, the selection of particular sensors. The source of interest can have different characteristics related to mobility such as semi-mobile, mobile, and fixed. The exact source of interest addressed will have an influence when selecting the digitization unit, as some devices require a fixed power cable, while others can be operated with wireless power sources, for instance.

The context describes the external influences as well as the environment of the source of interest. Each physical object within a system under study must be seen as a component within an environment, as all objects are operated within a specific context, for instance, related to public laws or regulations. Therefore, the context can be detailed by different contextual specifications such as location, compliance, or owner. As the complexity of such environmental influences might be out of scope for this modelling language, the implementation with the open-source meta-modelling platform ADOxx [14] offers the possibility to outsource semantic lifting by means of ontologies. This is enabled by introducing a key-value pair consisting of context group and value. For example, a context can be specified by choosing a context group such as location and a specific value like Austria. Multiple context group and value pairs might be required to describe the contextual environment of the source of interest.

The digitization unit in the form of an edge device—such as an Arduino device, a Raspberry Pi, a mobile phone, or other microcomputers—is a composition of three key components. The first, the core element, describes the basic hardware. The second, the software component, describes possible operating systems or applications. In particular, close relationships and dependencies between hardware and software can be recognized, for example, most Arduinos are usually not operated with a Windows operating system. The third, the sensor environment, can be seen as an enlargement of the core hardware component that allows the introduction of further advanced functionalities, for example, enabled by software extensions. Specifically, currently available sensors range from cameras supporting image recognition, scales, or temperature sensors for monitoring to sound and visual systems allowing for detailed control. It could be recognized that the digitization unit is highly dependent on the source of interest and the context. Therefore, the clear and transparent description of the domain problem and related external influences is critical for the successful recommendation of a digitization unit.

Summarizing, this meta-model overview and the resulting modelling method should support the mapping of business requirements with physical requirements so that digitization is facilitated. The overall meta-model is geared to being flexible and generic enough so that the appropriate standard can be introduced by means of semantic lifting in order to serve various business models. Specifically, the platform [14] chosen for implementing the modelling method supports the creation of interfaces to other modelling objects by allowing the integration of standards. For instance, BPMN [15] models relevant for business process descriptions can serve as a foundation for further extension and description with attributes specifically required for digitization. On the one hand, this flexibility ensures that common standards are not changed, while on the other hand, interfaces enable the usage of BPMN concepts so that the business perspective is considered during digitization.

The OMiLAB Innovation Corner [6, 16] enables the combination of physical objects with creativity approaches so that businesses and related processes are supported with their domain-specific digital transformation challenges. The added value is the selection of a digitization unit based on the creation of a reference between the business process, the physical world, and the meta-model. This allows the tight integration of business requirements when modelling the context and the system under study. For instance, if a business requirement is that the business phone power bank is always loaded more than 10 percent, the compliance context can refine this context by describing the process of sending a low-battery warning. Such a scenario might involve some kind of warning system, either visual or sound based, which poses requirements on the digitization unit.

18.3.2 Concept Pool

The concept pool in Fig. 18.4 shows the major constructs of CoChaCo [13] in a hierarchical structure. Notice that not all potentially reasonable constructs could be captured within the concept pool, as this would have gone beyond the scope of this modelling method and unnecessarily complicate the presentation of providing a model-based digitization guide.

Most of the concepts were already outlined above; therefore, we would like to go into detail for the mobility specification only, which is detailing the source of interest by describing potential real-world samples. The mobility aspect can be specified by nomadic/semi-mobile, mobile, or fixed/stable. Selecting the nomadic characteristic can mean, for instance, that we are talking about pallets in a warehouse that are shifted from time to time. This specification might indicate that the digitization unit must be small and could be operated via a mobile battery. On the other side, when talking about fixed shelves in a warehouse, a digitization unit with a cable-based power source and a big screen providing an overview might be better.

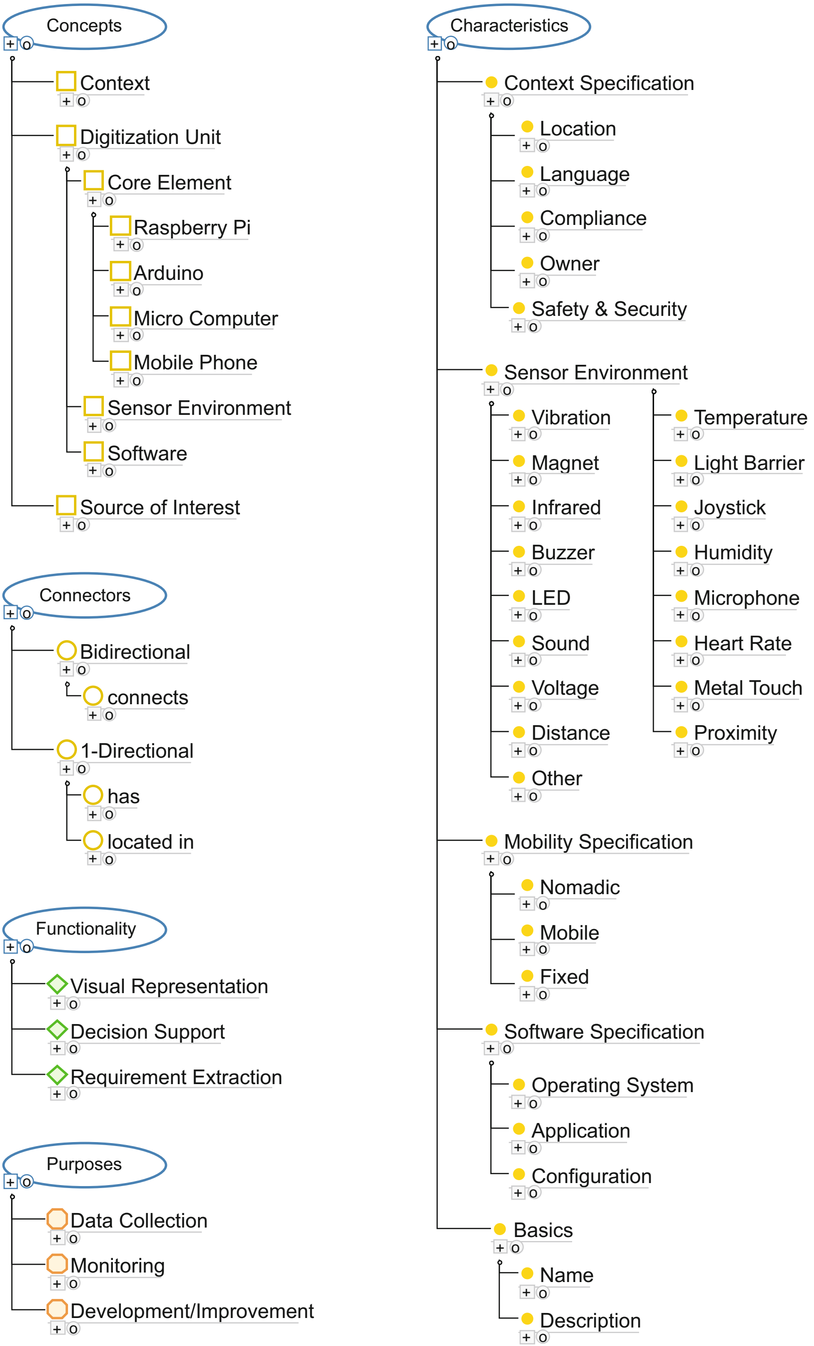


Fig. 18.4 Meta-model concept pool

As we assume that the source of interest is highly related to a domain-specific case such as the digitization of the raw material warehouse within a production company, we did not explicitly depict the requirements emerging from the business context here. Furthermore, only a sample set of characteristics is presented in the meta-model concept pool, as including all would have gone beyond the scope of the meta-model sample in Fig. 18.4. However, this kind of scope reduction should not influence the understandability of the basic idea behind the meta-model.

18.3.3 Procedure

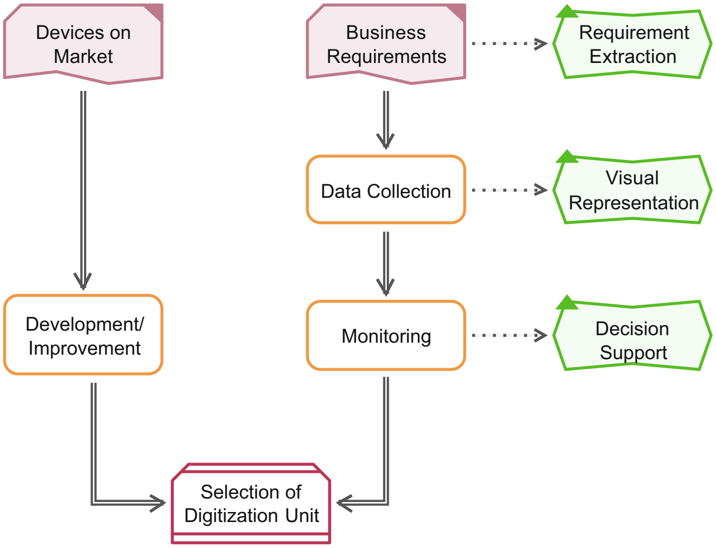


Fig. 18.5 Meta-model procedure

The procedure for the modelling method is quite generic and should mainly support the requirements mapping of business and physical world to facilitate digitization. Therefore, the procedure builds on the two key pillars shown in Fig. 18.5. These are data collection and monitoring and continuous improvement. External business requirements serve as a foundation for the data collection and provide the basis for the requirements extraction. To ease understandability, data collection is supported by visual representations and so-called notebooks, which describe modelling elements. These notebooks capture detailed information about the major concepts such as the source of interest, the context, or the digitization unit. Monitoring the aspects should ease the decision and pave the way for selecting a digitization unit. Furthermore, monitoring can indicate that the chosen digitization unit is not appropriate anymore. In this case, the devices on the market could provide external input by showing the actual status of the technology. As the development for devices is fast going, continuous improvement and development with respect to the selected digitization unit might result in exchanging the whole digitization unit or adapting components such as the software or the sensor environment, for instance.

As mentioned, we propose that two modelling actors work with the modelling method. Steps such as the data collection and the monitoring can be taken over by domain experts, while the actual selection of a digitization unit should be conducted in tight collaboration with a technical expert.

The following proof-of-concept section shows the journey from a physical object, respectively, a business process, to the selection of the digitization unit. This journey might be relatively easy when thinking about a smart energy management system that should simply reorder batteries when those are nearly empty. However, the complexity is highly increased when thinking about a production process with different materials and a set of requirements.

18.4 Proof of Concept

The proof of concept builds upon two main pillars, the modelling method and a physical experiment in the OMiLAB Innovation Corner using the Dig4Biz tool. The physical experiment serves as a playground for identifying the context and refining the source of interest, so that the findings can be used to specify the requirements for the digitization unit on the one hand and test the feasibility on the other hand. The material for the physical experiment—including documentation, videos, and a fast deployment package—is available open source online [5] and allows for accessing the experiment remote.

The major idea of the physical experiment is to provide a discussion platform that allows interdisciplinary discussions and eases the understanding of the digitization problem. The high-level domain for our physical experiment is about production processes, where a bunch of products is produced at once and afterward packaged in smaller portions. Examples would be paint production, convenience food production, or products from advanced biotech industry. As the real production of paint, food, or biotech products would go beyond the scope of a laboratory experiment, we decided to apply simplification and abstraction to develop an experiment setup that can be associated with the real production as the characteristics are similar. This results in a tea production scenario facilitating the identification of digitization challenges—three digitization challenges could be identified. Those are (1) the digitization of the production process, (2) the digitization of the raw material, and (3) the digitization of the product itself.

First, digitizing the production process can highly enhance efficiency and ensure continuous documentation while at the same time reducing manual documentation effort. To digitize the production process, the concept of timestamps was introduced that captures each production process step. The description of the source of interest, which is in this sample a shop floor, revealed that the machines are stable in fixed areas. The employees bring the material to the machines (for instance, a mixer or an oven). However, as the production facilities have currently no digital information attached, all the documentation must be handled manually, which is quite time-consuming and error prone. For this reason, the selection of a suitable digitization unit able to capture the timestamps should release the employees from this manual effort and improve the quality as well as the accuracy. To bind the information to a specific production, the order can be digitized, for example, by means of RFID technology. Therefore, we add a RFID tag to the order as the order production sheet must be controlled at each production stage anyway. Contextual considerations such as machines in a production hall with high humidity must be considered as well as legal obligations for production documentations and related standards.

Second, the digitization of the raw material seems to be critical to monitor the raw material status. A differentiation of three types of raw material [17]—ABC material—is used: (1) A material is characterized by low number and high value. (2) B material is characterized by medium amount and value. (3) C material is characterized by large amounts with low value. In the physical experiment, only B and C material was addressed so far. We focus on B material as C material is normally quite cheap and available in large amounts. For the tea production association tea bags, sugar, and milk are considered as B material. As digitizing the raw material directly could be considered as impossible, for instance, counting each crumb of sugar is simply not reasonable, the approach of digitizing the slot—where the raw material is stored—was chosen. The collection of timestamps when reducing the raw material allows continuous monitoring and facilitates production stops when charges of raw materials are considered to be problematic. Again, based on describing the scenario with the proposed modelling method, the suitable digitization unit for tackling the above-described challenge can be identified.

Third, digitizing the product itself might be important for both, customers to track their product and companies to monitor their production. The captured information can be further used for simulation and analysis such as evaluating the standard time from the raw material until the finished product leaves the company. The chosen digitization technology must allow for storing the information on the product packaging. At the same time, this information must be readable from any location and at any time. Further considerations such as easy usage are important for the customer experience.

The physical experiment architecture for tackling the digitization challenges is shown in Fig. 18.6. KPIs, data, and process models from the domain scenario serve as input to identify requirements and describe the source of interest and the context. A dashboard and simulation functionalities serve as a foundation for monitoring—supported by microservices offering database operations. On the bottom, physical devices and machines are described, extended by the digitization unit. Each layer of the experiment is supported by an expert—a method/modelling expert, a domain/business expert, and a technical expert.

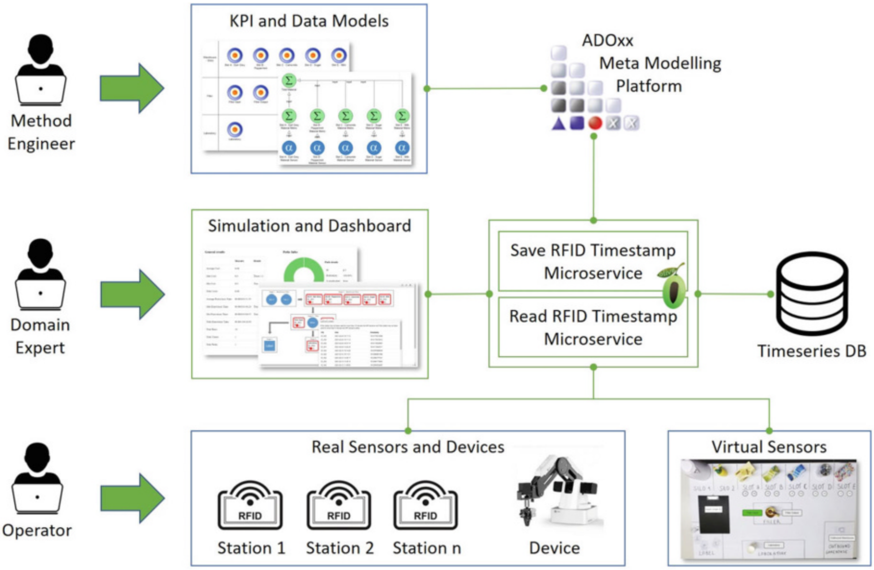


Fig. 18.6 OMiLAB Innovation Corner physical experiment architecture

The shop floor and the raw material warehouse of the experiment are shown in Fig. 18.7, where digitization units (microcontrollers with RFID readers) for capturing the timestamp information are already introduced. The physical experiment setup consists of a warehouse with silos and slots, a production area with filler and mixer, a laboratory, a final product labelling station, and an outbound warehouse.

The second pillar of the proof of concept, the modelling method, can be filled with the information resulting from the physical experiment. However, it provides not only the opportunity to describe the situation; additionally, the modelling method allows to identify requirements directly related to the business perspective. A specific feature allows using BPMN models, which can describe a real-world production process, as a foundation for extracting the tasks as requirements. This technique is also known as graph rewriting and realized by the ADOxx [14] script language AdoScript.

Figure 18.8 shows a code snippet containing the major procedure for the graph rewriting. The “dataInput” is a BPMN process file in BPMN DI format. The file is parsed, and all the tasks are extracted. The extracted tasks are directly mapped to a requirement of our proposed modelling method. The business requirement input can be triggered by the modeler. As shown in Fig. 18.9, the modeler can create a model of model type “Requirements Collection.” Afterward, “Extras” and “Import Requirements” can be selected (Fig. 18.9, step 1). Choosing the path (Fig. 18.9, step 2) for the BPMN model of interest starts the creation of requirement objects based on the business tasks. The graph rewriting directly maps the BPMN tasks to the requirements (Fig. 18.9, step 3). The collection of requirements can afterward be extended by creating additional requirements not directly related to BPMN tasks or by specifying the imported requirements (Fig. 18.9, step 4) with the introduction of detailed descriptions.

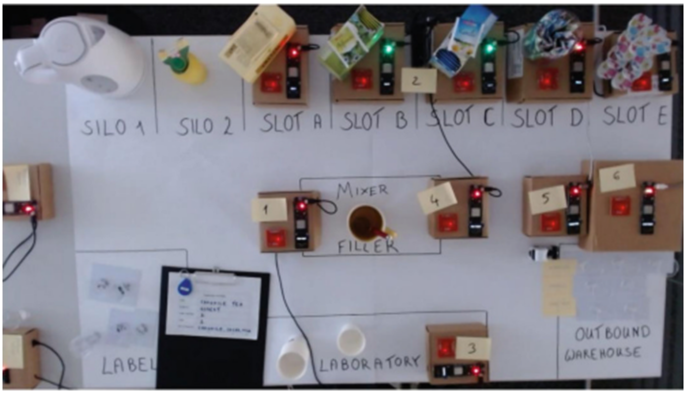
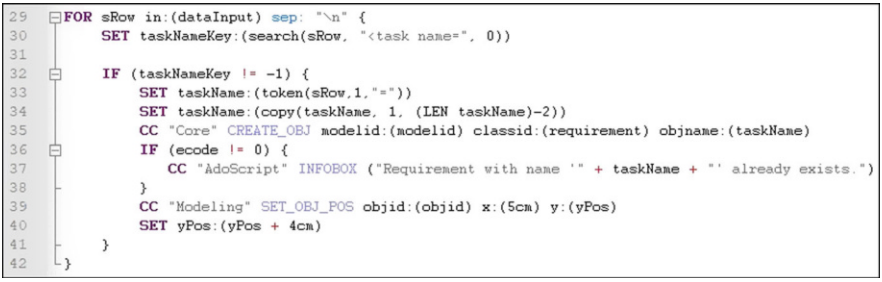


Fig. 18.7 Physical experiment setup in the OMiLAB Innovation Corner

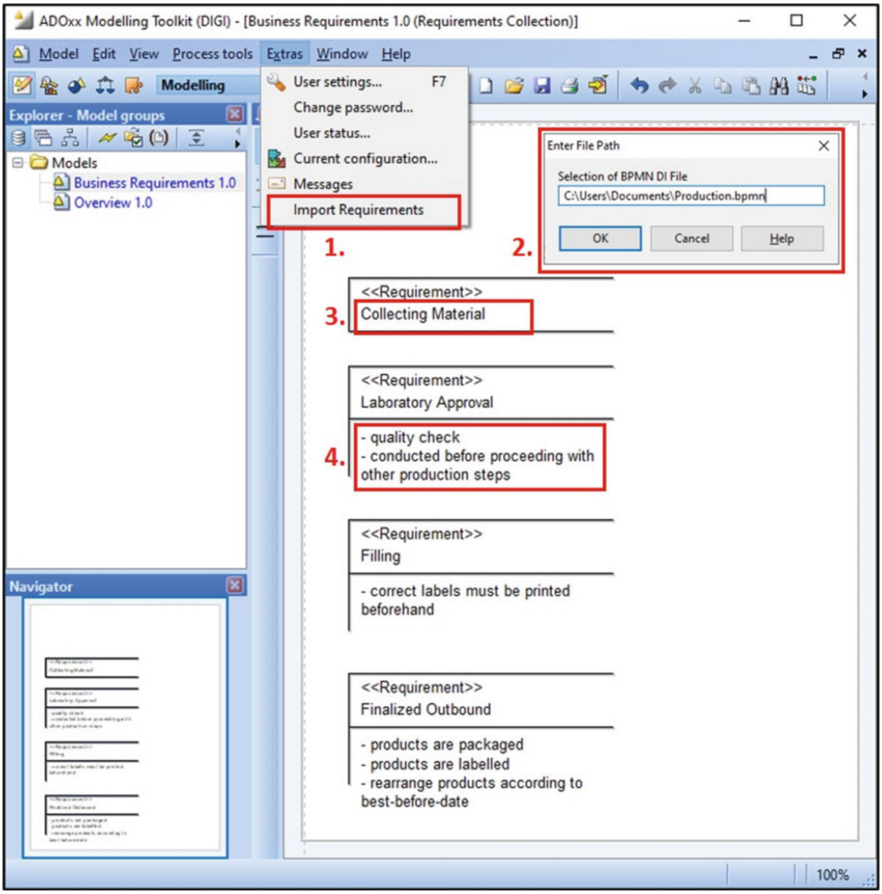


```
FOR sRow in:(dataInput) sep: "\n" {
    SET taskNameKey:(search(sRow, "<task name=", 0))

    IF (taskNameKey != -1) {
        SET taskName:(token(sRow,1,"="))
        SET taskName:(copy(taskName, 1, (LEN taskName)-2))
        CC "Core" CREATE_OBJ modelid:(modelid) classid:(requirement) objname:(taskName)
        IF (ecode != 0) {
            CC "AdoScript" INFOBOX ("Requirement with name '" + taskName + "' already exists.")
        }
        CC "Modeling" SET_OBJ_POS objid:(objid) x:(5cm) y:(yPos)
        SET yPos:(yPos + 4cm)
    }
}
```

Fig. 18.8 Code snippet for graph rewriting

Aside from the requirements collection models, an overview model type is also provided. This model type consists of the source of interest, one or more context elements, and the digitization unit. For the simple example shown in the middle of Fig. 18.10, we used one object of each class. Additionally, the notebooks of the objects are presented to provide further insights. In the example, the source of interest is a paint production factory. The major business process in this factory consists of four tasks—material collection, laboratory approval, filling, and outbound warehouse—which are also mapped to the requirements collection model shown in Fig. 18.9. The factory environment implies that the source of interest is fixed. The source of interest could be subdivided in smaller challenges, such as the digitization challenges presented above. For instance, an individual source of interest element for digitizing the raw material warehouse can be created. Compared to the factory, slots in a raw material warehouse must not necessarily be fixed with respect to the mobility characteristic. Therefore, wherever various characteristics seem to be relevant, a division of the major source of interest in finer grained objects is suggested.



1\. Import Requirements

2\. Selection of BPMN DI File: C:\Users\Documents\Production.bpmn

3\. <<Requirement>>
Collecting Material

<<Requirement>>
Laboratory Approval

4\. - quality check
- conducted before proceeding with other production steps

<<Requirement>>
Filling
- correct labels must be printed beforehand

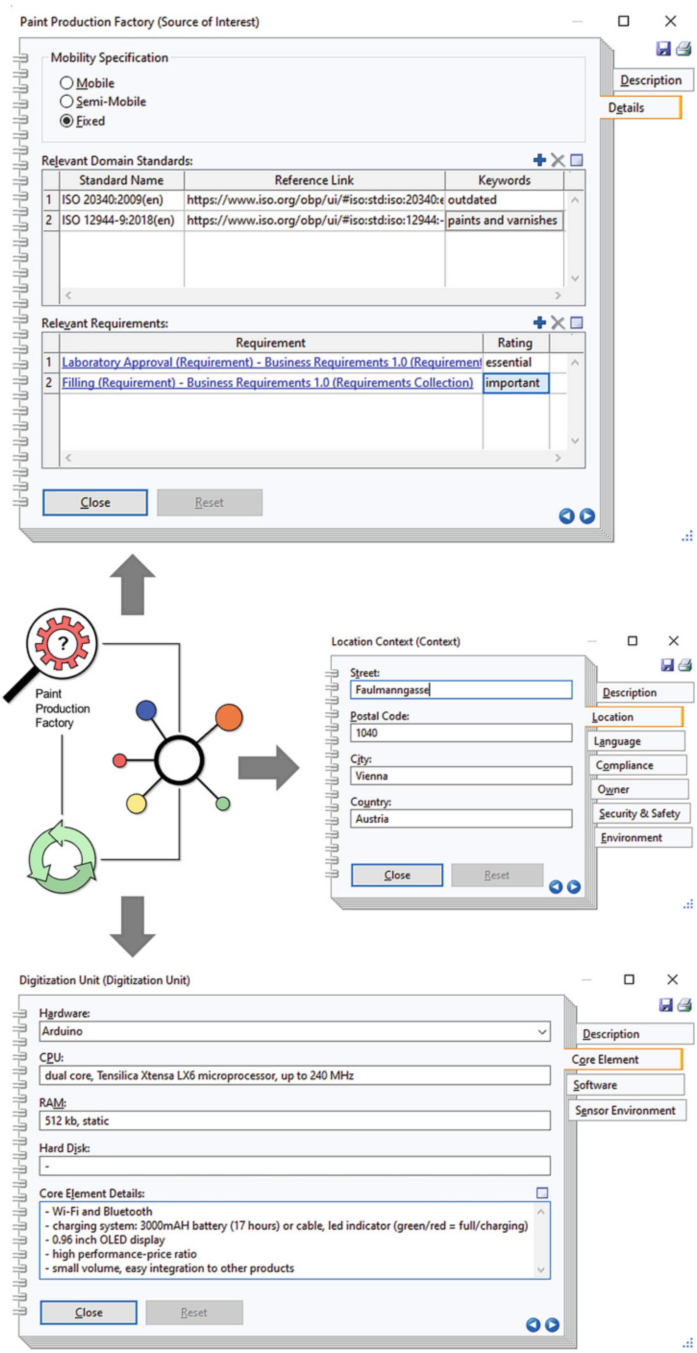
<<Requirement>>
Finalized Outbound
- products are packaged
- products are labelled
- rearrange products according to best-before-date

Fig. 18.9 Requirements import from business process model

With respect to the business context, domain standards can be captured for the source of interest. These standards may also have a tight interconnection with identified requirements. The basic requirements created from a BPMN process by means of graph rewriting can be connected with the source of interest. Technically, this is done by introducing the concept of model pointers, specifically “interrefs.”

Those allow to refer from the attribute in the overview model directly to one or more objects in the requirements collection model. Prioritization is supported by introducing a rating of the referenced requirements. The location context in the sample is straightforward and therefore requires no further explanations. However, it is important to point out that all of the objects in the model are somehow interconnected and dependent on each other. For instance, the location context "Vienna" may create the need for specific standards and requirements posed on the source of interest by Austrian government regulations. Furthermore, specific digitization units might not be certified for use in relevant business settings. For this reason, we recommend that the identification of requirements, the description of the source of interest, and the collection of context related details are taken over by a domain expert, whereas the selection of the appropriate digitization unit is conducted in close collaboration between business and technical experts.

For the production process digitization sample, it was identified that RFID technology could be one potential solution to capture timestamp data that can be used for documentation. The original manual documentation process should be facilitated by the introduction of technological support. For this reason, the digitization unit must be capable of a RFID sensor module for our sample. Furthermore, existing databases—as mentioned currently filled with information manually—can be reused for capturing the timestamp data. This implies that the digitization unit must allow some kind of network connectivity mechanism for sending the data to the database. Assuming a stable network connection, the digitization device requires no hard disk, as all of the data should be stored in a database anyway. In addition to a simple database, also, a connection to a potentially existing ERP system might be reasonable. Due to the fixed mobility characteristic of the source of interest, different power sources ranging from mobile battery packs to a power cable are possible. To digitize the machine stations, a power cable might be more reasonable as those are fixed, and potential problems with wireless power sources must not be taken into account. Production workers might need some kind of visual confirmation that sending the data was working, as they are not familiar with capturing the production process data automatically. For our example, we assume that so far this was conducted only manually with sheet and paper. For this reason, having a small display connected to the device might be beneficial. Furthermore, the conditions in a production hall, such as dusty air, should be no problem for the digitization unit. The price performance ratio should be reasonable so that the initial investment for the digitization devices is manageable. As those are needed at several stations within the production hall and the warehouse, maintenance costs must also be considered and comparable to the benefits of digitization.



Mobility Specification

○ Mobile
○ Semi-Mobile
● Fixed

Relevant Domain Standards:

	Standard Name	Reference Link	Keywords
1	ISO 20340:2009(en)	https://www.iso.org/obp/ui/#iso:std:iso:20340:e	outdated
2	ISO 12944-9:2018(en)	https://www.iso.org/obp/ui/#iso:std:iso:12944:-	paints and varnishes

Relevant Requirements:

	Requirement	Rating
1	Laboratory Approval (Requirement) - Business Requirements 1.0 (Requirement	essential
2	Filling (Requirement) - Business Requirements 1.0 (Requirements Collection)	important

Street: Faulmanngasse

Postal Code: 1040

City: Vienna

Country: Austria

Hardware: Arduino

CPU: dual core, Tensilica Xtensa LX6 microprocessor, up to 240 MHz

RAM: 512 kb, static

Hard Disk: -

Core Element Details:

- Wi-Fi and Bluetooth
- charging system: 3000mAH battery (17 hours) or cable, led indicator (green/red = full/charging)
- 0.96 inch OLED display
- high performance-price ratio
- small volume, easy integration to other products

Fig. 18.10 Overview model objects including notebooks

Taking everything into account, a combination of the physical model, paving the way for a common understanding, and the modelling method allowed us to choose the suitable digitization device for the sample use case of paint production. By considering the source of interest as well as the context—involving, for instance, local regulations—we identified an Arduino microcontroller ESP32 and a NFC (RFID) module as an appropriate digitization unit for the production process as well as for the raw material.

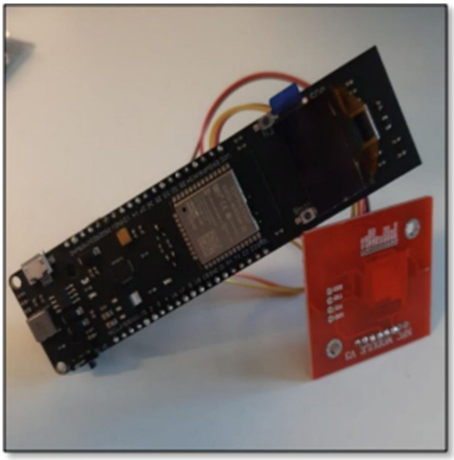


Fig. 18.11 Digitization unit

Figure 18.11 shows the selected digitization unit. A sample overview model for the physical experiment setup is shown in Fig. 18.12. The main source of interest is the production scenario and related production processes. Those can be subdivided in more specific sources of interest—such as the raw material warehouse, the filler/mixer, the laboratory, and the outbound warehouse. All the sources of interest can be further detailed with one or more context elements posing requirements for the digitization units that are connected to the sources of interest. For instance, the raw material warehouse source of interest has five digitization units connected. Those digitize different raw material slots.

The final step of our proof of concept was the testing of the digitization unit within the physical experiment setup to identify any problems before testing the device in a real business setting.

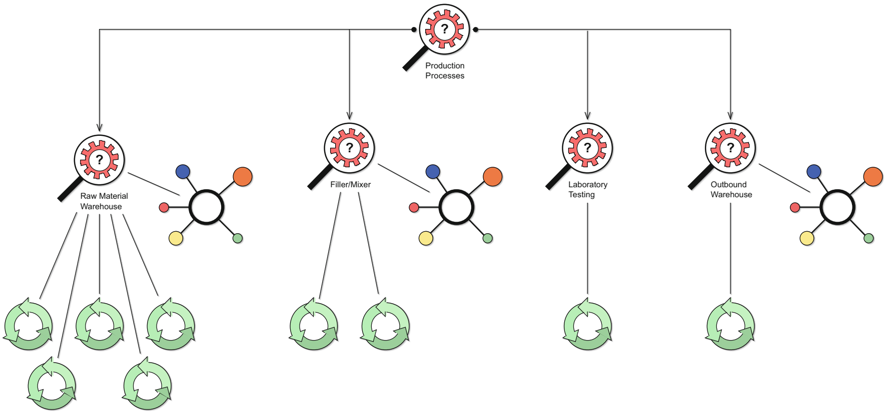


Fig. 18.12 Sample overview model for physical experiment setup

18.5 Conclusion

Digitization is popular in today's business ecosystems, in particular as digital transformation is expected to unlock incredible value for businesses as well as for society. However, digitization is not straightforward and introduces a lot of challenges. To handle the emerging complexity, the OMiLAB Innovation Corner was used as a consulting environment for testing the proposed model-based guidance approach toward more digitization in digital business ecosystems.

A hybrid approach was followed for establishing the modelling method and a modelling environment that describes and configures digitization scenarios such as the aforementioned production process. This resulted in the proposed modelling method prototype focusing on (a) the collection of requirements, (b) the analysis of the contextual environment, as well as (c) the monitoring by guiding the selection of an appropriate digitization device. The modelling method is highly supported by a physical OMiLAB Innovation Corner experiment that eases the understanding of the domain problem by serving as a discussion platform and playground for further studies. Furthermore, the experiment facilitates the selection of appropriate digitization units by taking into account potential physical issues as well as the requirements related to the business perspective.

Considerations for further research are based on the identification of patterns guiding digitization. These include but are not limited to production processes, manufacturing robotics, or mobile/driving devices in different environments. Beginning with the production process scenario, the physical experiment in combination with a model-based approach paves the way for shedding light on a specific digitization scenario from different perspectives. The physical experiment supports the description of a variety of aspects—ranging from sensors over networks to edge devices—that are potentially relevant for the description of digitization patterns.

Finally, the presented modelling method is a first prototype for guiding digitization in digital (business) ecosystems. It is planned to conduct further studies in order to improve and extend the modelling method. Currently, we are testing the applicability of the first modelling method prototype in a real-world production domain in the context of pilot studies for Change2Twin [4]. In its current version, two types of experts are needed to work with the modelling method—domain and technical experts. However, in the long run, we plan to optimize and automate the selection of the digitization unit based on the gathered information within the model to provide additional value. Although we believe that this extension will not completely supersede the technical expert, it should provide the foundation for better decision-making and continuous development to find the optimal digitization unit for any digital business ecosystem use case.

Another idea for further research is the integration of AI. This poses questions such as how the introduced concepts as well as the physical infrastructure need to change when new technologies are implemented. A good starting point for finding suitable innovation items could be the Change2Twin [4] marketplace.

Tool Download https://www.omilab.org/dig4biz

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