Digital Optimization in Action: From Models towards an Industrial Application

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Abstract

Digital transformation is currently a mega trend in business and society that offers opportunities while at the same time posing challenges on companies. As digital transformation in general and specifically the establishment of a digital twin is not straight forward, companies require guidance during this journey. In this paper, findings of a pilot from the European Horizon 2020 project Change2Twin are revealed, in which a digital twin of a paint production process will be established. For this reason, the OMiLAB Innovation Corner – an experimentation laboratory coming with a set of methods and tools enabling digital innovation by supporting physical experiments – is introduced for facilitating digital transformation and optimization. A model-based approach towards industrial digital twinning is presented to ease digital optimization by fostering abstraction and simplification. Based on the industrial paint production pilot, digitization challenges were identified and a proof-of-concept implementation within the OMiLAB Innovation Corner was used to gain experiences on how to guide industrial digital optimization. Among other findings, it was observed that reducing the complexity for a better understanding among heterogeneous stakeholders as well as focusing on the digitization relevant aspects and interdependencies is critical.

Keywords

OMiLAB Innovation Corner, Digital Optimization, Digital Twin, Physical Experiment, Production Processes

1. Introduction

The World Economic Forum [1] estimates that $100 trillion could be unlocked by digital transformation for both, businesses, and society. While on the one hand the digital disruption offers new opportunities, on the other hand it also poses challenges to companies and their present business models as well as processes. Among other aspects, the integration of digital technologies influences the organizational structure, the process landscape, the stakeholders, the companies' culture and the KPI measurement. Developments on those aspects may even result in a new digital operating model.

However, as digital transformation and optimization are not considered to be straight forward. Means of guiding companies during this transformation journey are required like but not limited to consulting approaches including digital twinning. As an enabling environment, the industrial OMiLAB Innovation Corner [5] – facilitating the establishment of application cases within industrial contexts – is introduced to leverage the paint production pilot of the European Horizon 2020 project Change2Twin [4] that focuses on digital twins for manufacturing SMEs. According to a recent market research [14], in 2020 the global digital twin market was estimated to 3.1 billion USD, by 2026 a growth to 48.2 billion USD is projected. Gartner [6] defines that "A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes." Particularly, the data is an important asset that can be collected on three different evolution stages towards a digital twin – digital model, digital

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shadow and digital twin [2] shown in Figure 1. The digital model is created based on a digitization challenge and provides the foundation for abstraction and simplification enabled by automated data exchange. It paves the way for digitization, visualization, simulation, emulation, extraction, orchestration, prediction or advanced individual usage scenarios [3]. While a digital shadow allows for automatic unidirectional data flows between physical and digital objects, fully automated data integration between the physical and the digital world results in a digital twin.

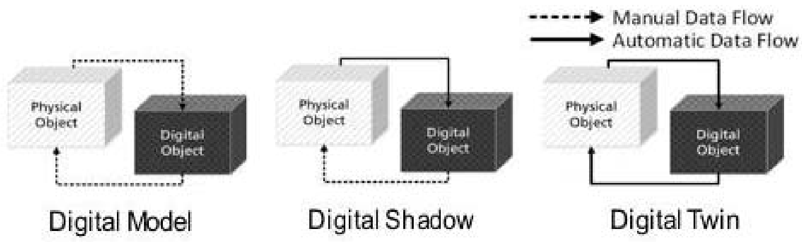

Figure 1: Digital Twin Evolution [2]

Digital optimization and digital transformation can be differentiated. While digital optimization builds upon existing business models, digital transformation follows a more radical approach by considering new business models. In this paper digital optimization is tackled – ranging from the development of digital models towards the introduction of digital technologies in an industrial setting. Process modelling is applied as well as digital twinning is started in collaboration with the pilot company Graphenstone [27] from the aforementioned Change2Twin project. Specifically, digital twins of production (manufacturing) processes are considered to have impressive application potential [15], as those can bridge virtual and real-time actions on the factory floor. By integrating data (eg: captured by sensors) from various dimensions along the production process such as environmental conditions (eg: temperature or humidity) or production machine characteristics (eg: downtime, speed or maintenance requirements) the way for performance analysis and potential optimization is paved.

However, the introduction of appropriate digital transformation/optimization technologies seems to remain a challenge. Therefore, the research question is how a model-based approach including digital twinning can be applied to support a manufacturing company with digital optimization. Graphenstone is a global producer of paints, finishes and related products with a European factory in Spain. Currently, the company relies on a fully paper-based documentation, which is error prone and does not allow the necessary level of control for optimally managing the production processes. For this reason, the major digital innovation idea for the company tackles the introduction of digital technologies to optimize and automate the documentation by focusing on the material and warehouse management as well as the production processes. A particular challenge for bringing the innovation idea to live is that the whole optimization journey must be guided virtually, as due to Covid-19 there are several access restrictions on the production site. In this paper, a physical experiment in the OMiLAB Innovation Corner is introduced to identify the digitization challenges in the paint production company and tackle those by means of digital twinning. Among other findings, it could be observed that reducing the complexity of digitization scenarios in order to create a common understanding among heterogeneous stakeholders is essential. Hence, abstracting from negligible details and focusing on the relevant digitization aspects as well as interdependencies is critical.

In the following chapters, related work is presented and the OMiLAB Innovation Corner environment is introduced. Those chapters are followed by a description of Graphenstone's digitization challenges, the support of a physical experiment and the role of conceptual modelling. Finally, the observations are summarized and a reflection on potential contributions to digital industry trends is provided.

2. Related Work

Historically, digital replicas of real-world assets are often related to manufacturing machines, while these so-called digital twins can be created of nearly everything [21]. For instance, a digital twin of an organization enables to adapt by supporting organizations' transformation journeys [22]. Not only manufacturing devices or organizations, but also business processes can be mapped to the digital twin definition [4]: "A digital twin is a digital replica of an artefact, process or service that is so accurate that it can be the basis for decisions. The digital replica and physical world are often connected by streams of data.”

According to [25], manufacturing can be revolutionized by introducing digital twins facilitating for instance the optimization of throughput time. For example, mass customization results in assembly line adaptions creating a need for digital twins reducing bottlenecks and production delays when producing water bottles [19]. Also, monitoring and predictive capabilities of digital twins can be used for process optimization building upon mathematical process models [20]. Less digitized industries such as the construction industry are often characterized by low visualization and inefficient organization of logistics processes, where digital twins can be applied for optimization by reducing the decision-making complexity [12]. Hence, identifying appropriate digitization mechanisms for adapting existing production lines or processes enabling the application of digital twins in an understandable way seems to be a critical prerequisite for optimization. Increasing digitization is considered to accelerate the creation and feasibility of digital twins in an organizational context [26]. Especially organizational digital twins are characterized by a dynamic evolution including the continuous update of models capturing information like but not limited to processes, data flows or interactions. In contrast to traditional digital twins focusing on machines and attached sensors, organizational digital twins provide a more integrated model allowing for advanced optimization with respect to simulating for instance (a) production processes for increasing efficiency, (b) customers for increased competitiveness, or (c) decisions for higher flexibility.

Generally speaking, modelling may be a good starting point for the introduction of new technologies towards digital twinning and the sharing of information among various stakeholders in complex ecosystems [23]. Industries such as pharmacy or oil/gas for instance rely on digital twins for optimizing their production processes by using simulation and prediction. However, due to the plethora of modelling methods (eg: BPMN, UML, Petri Nets, Flowcharts, ERM, etc.) selecting the most appropriate one is not trivial. Modelling methods are composed of [24]: (a) the modelling language comprised of syntax, semantics and graphical representation, (b) the mechanisms and algorithms for functionalities, and (c) the modelling procedure. Due to the emerging complexity of organizations, artefacts, processes or services, the modelling method must be sufficiently expressive to enable the intended digital twin usage. Beginning with, in this paper widely known BPMN models are used to depict the production processes for the paint production in order to show that a model-based approach with digital twinning is applicable for digital optimization. Also, it is shown that companies in need of improving their digitization level can successfully apply (organizational) digital twins.

3. The OMiLAB Innovation Corner

In general, a design science approach [13] is followed, where the OMiLAB – Open Model Initiative Laboratory – Innovation Corner is used as a research and experimentation environment. The OMiLAB Innovation Corner is structured in three abstraction layers, which are the business, the conceptual and the proof-of-concept layer [5] – see Figure 2. This architecture allows for considerations throughout the digitization journey by providing different perspectives on layer-related questions such as:

(a) should a new business model be developed or is optimizing the existing one appropriate,
(b) which organizational structure is needed so that the processes can be managed by diverse stakeholders, and
(c) how an innovation idea could be implemented and operated in an industrial context.

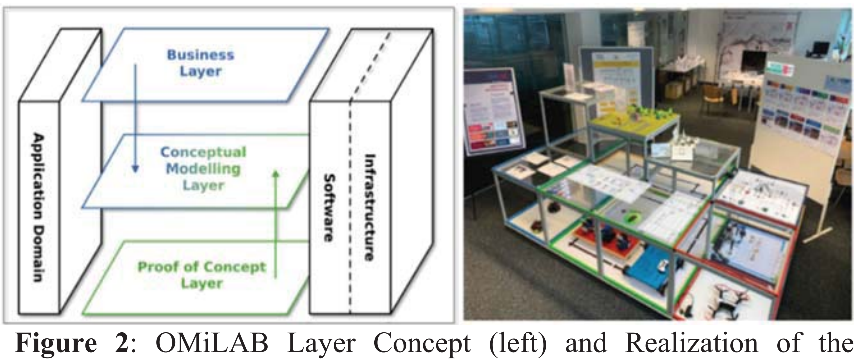

Figure 2: OMiLAB Layer Concept (left) and Realization of the Industrial OMiLAB Innovation Corner at BOC Vienna (right) [5]

In particular, a variety of methods and tools – like but not limited to modelling software and physical experimentation spaces – available in the OMiLAB Innovation Corner environment paves the way for (a) the ideation of digital innovation solutions, (b) the formalization of relevant knowledge assets by means of (process) modelling, and (c) the testing in a secured physical environment, by providing guidance to lift conceptual digital transformation/optimization innovations towards an industrial application.

Specifically, the modelling components are highly leveraged by the meta modelling platform ADOxx [17] – free for academic purposes – that facilitates the development of domain-specific modelling languages and comes with an open community with more than 5.000 developers as well as a microservice framework [11]. Additionally, also the underlying OMiLAB NPO [18], powering the OMiLAB laboratory environments, provides community support including various training materials. Generally speaking, the model driven OMiLAB environment provides a laboratory ecosystem for innovation workshops. For instance, physical infrastructure such as sensors and microcontrollers allow for the creation of tangible experiments in order to transfer conceptual innovation ideas and digital models towards industrial application cases.

In the following chapter, light is shed on the Graphenstone pilot case of the Change2Twin project, where the OMiLAB Innovation Corner environment sets the scene for the establishment of a physical experiment towards the creation of a digital twin of the paint production processes.

4. The H2020 EU-Project Change2Twin: Focus on the Graphenstone Pilot

Industrial manufacturing seems to lag behind other industries when considering digitizing products and services as well as core operations [16], although there are numerous promising technologies. A critical barrier is that digitization is considered to be expensive – particularly due to rapidly evolving technologies and disruptions influencing the whole way of working.

Table 1: Graphenstone's Digitization Challenges

Digitization Challenge	As-Is Situation	Digital Innovation Idea
DC1 – Digitization of the Raw Material	There are two types of raw material relevant (a) the material that is not labelled is stored in silos, and (2) the labelled material that is stored in slots. Each change in inventory is captured manually by the workers with pen and paper.	A real-time inventory should be enabled by attaching RFID readers to the raw material slots so that any raw material event can be digitally documented in form of timestamps.
DC2 – Digitization of the Production Process	The production process runs through three major machines – oven, mixer and filler. It is performed on one of three parallel production lines. The product is tested in a laboratory to ensure quality. All raw material and production steps are documented manually by the production supervisor.	The relevant production stages/machines are equipped with RFID readers and the paint buckets are labelled with RFID tags, which pave the way for the digital monitoring of the production status.
DC3 – Digitization of the Product Information	Each product bucket is labelled (with company logo, ingredients, …) in parallel to the paint production. The labelling process must be finished before filling the product in the labelled buckets.	The RFID tags on the labels linked to the production order, the raw material and the production steps should allow for product tracing, production plan optimization and additional customer services.

Graphenstone works with completely analogue machines so far; therefore, the digitization is not conducted on machine level in this first digital optimization initiative. Nevertheless, it is shown that digital twinning is an opportunity to pave the way for advanced technologies with respect to depicting, imitating, and predicting the reality such as simulation. For this reason, a digital twin of the production process was established for Graphenstone. In particular, a digital twin of an organization allowing for adaption [7] was developed, supported by following a model-based approach. In order to identify the applicability of digital twinning for the pilot case and identify specific digitization challenges, (a) the BPMN 2.0 standard was applied for modelling Graphenstone's current production processes in process modelling workshops, (b) a physical experiment in the industrial OMiLAB Innovation Corner was created to ease the understanding among heterogeneous stakeholders as well as served as a playground for innovative solution approaches, and (c) co-creation workshops were conducted to identify diverse requirements ranging from suitable infrastructure components to business aspects.

All workshops were guided by a modelling expert – the head of research from BOC [28], a medium-sized enterprise specialised in conceptual modelling. Graphenstone's leading computer engineer and their leading external software engineering consultant contributed by providing relevant domain knowledge on behalf of the production manager and the production workers. In the context of the modelling workshops, three digitization challenges – summarized in Table 1 – could be revealed based on the detailed description of the production processes created by using the modelling standard BPMN [9]. As a first starting point, BPMN was used due to the familiarity of the stakeholders. However, during modelling, the limitation of a missing material flow concept in BPMN was faced, raising the question, if BPMN is the optimal modelling method in the pilot context. As an interim workaround, the information message flow was used to describe the sending of materials between sub-processes to overcome the limitation. In future, further research on the appropriateness of the modelling language is required to identify if either (a) a targeted domain specific modelling language, or (b) an extension of BPMN for industrial production scenarios may be favoured to optimally support optimization based on digital twinning. A targeted Industrial Business Process Management Toolkit may support among other aspects for instance material/tool flows, as well as consider different production process stages from a macro and micro perspective [29].

However, the company operates three production lines, the laboratory and the labelling station in parallel. As the overall process model captures confidential business information, a simplified and abstracted version is presented in Figure 3 focusing on the digitization of the actual production. After receiving the production order, the main production process starts. The raw materials from the silos are preheated in the oven and the raw materials from the slots are then manually added to the mixer. A sample of the mixed product is tested in the laboratory to ensure high quality before filling the product in smaller labelled paint buckets. In particular, emerging complexity such as interdependencies of process paths (eg: the labelling must be finished before filling the paint buckets, etc.) requires abstraction and simplification to identify the aspects critical for the digitization challenges.

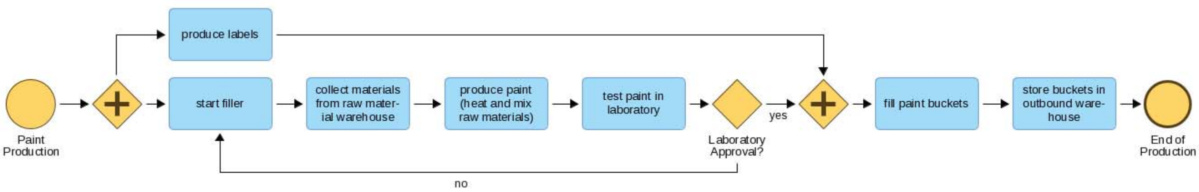

Figure 3: Simplified and Abstracted Production Process depicted in BPMN

Beginning with DC1, not only capturing the raw material flows in the BPMN models, but also digitizing the actual material is a challenge creating a need for a raw material classification. Therefore, the ABC material concept [8] is applied: (a) A material is specific, expensive, and needed in limited quantity, (b) B material is of medium specificity and needed quantity, and (c) C material is of low specificity, cheap, and needed in large quantity. Relevant raw materials for the Graphenstone pilot case are unlabelled materials stored in silos (C material), and labelled material stored on pallets in slots (B material). It is assumed that unlabelled material (eg: water, etc.) is always available in sufficient quantity. As a preparation for raw material monitoring, a focus on the more specific labelled materials stored in slots was set, as those are the once that require sophisticated planning to reduce delivery and storage times. When modelling the raw materials, it could be observed that their characteristics pose some additional challenges to enable a real-time inventory monitoring. In particular, some raw materials cannot be digitized and labelled directly (eg: labelling of materials such as sand grains or colour particles is neither reasonable nor efficient). Hence, the raw material slot is digitized. Further on, the introduction of timestamps enables capturing so-called raw material slot events. RFID and QR are among the plethora of digital technologies for wireless data exchange. Starting with, RFID tags associated with order IDs facilitate digitizing the production process documentation ranging from the raw material collection to all production stages. Each time a raw material is taken from a slot, this event is captured by attaching the RFID tag to the slot reader. Additionally, advanced technologies such as weight or image recognition approaches can be installed to improve the monitoring quality. The introduction of digital technologies such as RFID allows for digitizing the entire production process – compare DC2. Timestamp information for relevant production stages is collected throughout the production process and serves as a basis for advanced product information. This digital innovation allows for real-time monitoring of the production status paving the way for detailed analysis and predictions like but not limited to production delays directly forwardable to customers. In contrast to QR codes, RFID tags allow for reading and writing. With respect to DC3, the whole product can be digitized by writing all the collected information onto the product buckets and enabling the customer to retrieve the product information from any location. Production information can be retrieved as well as additional services for customers (eg: webinars recommending how to use the specific product in the customers setting based on raw material characteristics, etc.) can be offered to leverage the overall customer experience.

4.1. The Physical Experiment

The establishment of a physical experiment in the OMiLAB Innovation Corner environment was a major building block for dealing with the digitization challenges. Required software (eg: BPMN modelling tool, microservices, etc.), hardware (eg: microcontrollers, sensors, camera, etc.) and infrastructure assets (eg: experimentation space, network, etc.) for the experiment are provided in the OMiLAB environment.

Based on the developed production process models, the experiment (a) facilitated the overall understanding of the digitization challenges by applying means of abstraction, simplification and association, (b) directed the focus on the relevant aspects for digitization, and (c) paved the way for an implementation in the real factory setting. By creating the physical experiment, the awareness for Graphenstone's challenges could be increased. In particular, a discussion platform for bringing together diverse stakeholders and aligning the journey towards a digital twin was offered. The overall production process was abstracted by reducing the complexity in order to focusing on digitization relevant process steps, simplified by making assumptions such as that labels are always available and associated with a tea production sample so that a familiar scenario minimizes discussion barriers.

The physical experiment area is shown in Figure 4 and consists of (a) the raw material warehouse divided into silos and slots (the focus lies on labelled raw material in slots), (b) the production machines (mixer/filler) combine all raw materials and fill the product into buckets, (c) the labelling that prepares the labelled product buckets, (d) the laboratory ensuring quality approval before packaging, and (e) the outbound warehouse storing the finalized product buckets. The experiment consists of following OMiLAB Innovation Corner hardware assets: 10 microcontrollers with 10 RFID readers attached, 1 microcontroller with 1 RFID writer attached, a Raspberry Pi with a USB camera attached, 5 RFID tags simulating production orders and 12 RFID tags for storing the product information. The physical experiment including documentation material can be downloaded and accessed remotely: https://adoxx.org/live/web/change2twin/downloads [10].

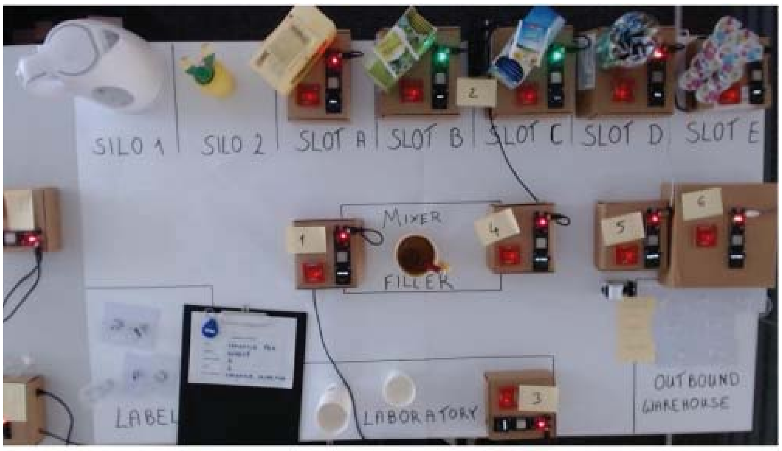

Figure 4: Physical Experiment – OMiLAB Innovation Corner [10]

Table 2: Comparison of Graphenstone's Paint Production with the associated Tea Production

Building Blocks	Graphenstone's Paint Production	Associated Tea Production Sample
Raw Material Warehouse	Among others, water is used as unlabelled raw materials from silos as well as colour particles from the slots.	Water and lemon juice serve as raw materials from silos as well as tea flavours, milk and sugar from the slots.
Mixer / Filler	Analogue production machines are used to combine the raw materials and produce the paint.	A cup and a spoon serve as machines for tea production.
Labelling	RFID tags attached to the company labels are used to leverage the product buckets.	RFID cards attached to shot glasses show the labelling of a tea serving.
Laboratory	The paint is approved by using a small probe of the mixture.	The tea is approved by tasting a sip.
Outbound Warehouse	The filled and labelled product buckets are stored before transferring to the customers.	The tea is stored in shot glass servings to be delivered to the customer.

Table 2 presents the similarities between Graphenstone's production and the associated tea production sample for the major building blocks of the production process. Although the tea association looks trivial at the first glance, the physical form of modelling facilitated the discussion of domain specific challenges, such as parallel production activities and interdependencies. In particular, communication among different stakeholder groups ranging from technical and digitization experts to paint production domain experts can be fostered. As a new dimension focusing on physical considerations is introduced based on the BPMN model. Furthermore, the physical experiment including digitization devices serves as a proof-of-concept before the actual implementation and is transformed stepwise to the real application case by means of co-creation workshops with relevant modelling, technology and domain stakeholders. The digital twinning approach is expected to support Graphenstone in improving their efficiency with respect to time and cost savings as well as the reduction of production faults and the stock. Moreover, changeover times between different series should be reduced by a sophisticated real-time inventory planning. In general, by improved planning and simulation approaches, insights will be obtained that can be used for production process optimization so that lead times and production downtimes can be reduced. Furthermore, a more innovative and attractive image for customers, as well as employees is established by adding value with digital technologies. Some factory impressions of the first introduction of RFID tags and readers can be seen in Figure 5.

Figure 5: Impressions from Graphenstone

4.2. Conceptual Modelling: KPI and Data Calculation

Modelling is a cornerstone throughout the digital twinning journey of Graphenstone ranging from BPMN process models to the physical experiment. Further on, conceptual models facilitate advanced processing and visualization. Digitization relevant KPIs such as the inventory status can be identified in combination with the challenges based on the physical model. Targeted KPI models capturing KPIs for the inventory and the major production line parts serve as a foundation for a monitoring dashboard building upon the microservice framework OLIVE [11]. Figure 6 depicts the main KPIs and the related data calculation metrics. The data is provided in form of external data inputs from digitization sensors (eg: RFID). Both, KPIs and metrics can be further specified in the models, for instance by defining an alert range or metric functions. Currently, a timeseries database is used for collecting the timestamp data generated throughout the production process. Figure 7 shows the real-time monitoring dashboard including the raw material slots in the warehouse, the three production lines considering the major production stages (mixer, laboratory, labelling and filling). Based on Graphenstone's production plan, the planned figures and the actual RFID measured figures are compared. The real-time monitoring dashboard provides a colour coded visualization indicating whether the production is in line with the planning or not. Some first feedback of Graphenstone's production workers and the production plan manager indicates that the model-based approach facilitates overall understanding and creates awareness for the challenges related to digitization. Further analysis will be conducted when the transfer of the physical experiment to the company setting is finalized.

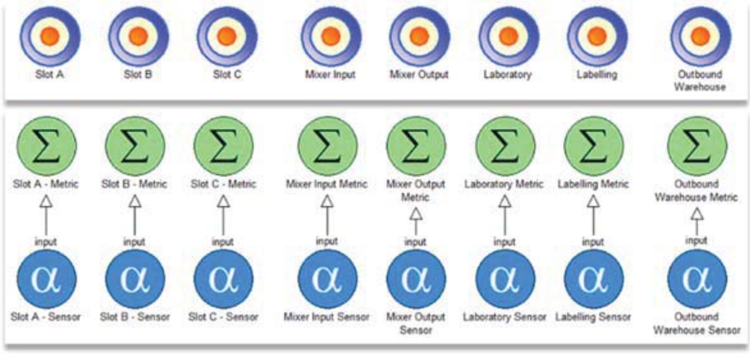

Figure 6: KPI (top) and Data Calculation (bottom) Models

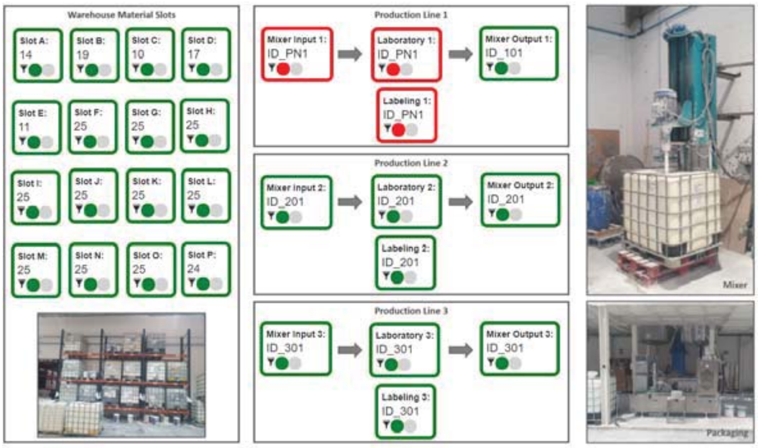

Figure 7: Real-time Monitoring Dashboard showing the Raw Material Warehouse and the Production Lines

The pilot case shows that the usage of models can pave the way for introducing digital twinning technologies in order to digitally optimize the paint production scenario. The remaining question is how to ease the transformation from conceptual and physical models towards industrial application cases not only for a specific case but in a company and product independent way.

The pilot case required different types of models (eg: BPMN models, physical models, KPI models, etc.) to create a common understanding among the diverse stakeholders, to identify digitization challenges, to develop an innovative optimization/transformation idea, to select the appropriate technologies and to test the approach before starting the implementation in the real world. Due to the different levels of abstraction and diverse stakeholder groups involved throughout this journey, the modelling steps leading towards an actual implementation were effortful and time-consuming. Therefore, the idea for future pilot cases is to identify patterns and afterwards reuse means of how to support companies with modelling. Starting with, the identification of digitization challenges and the selection of appropriate technologies in order to ease the journey from the first scenario assessment towards a digital transformation and optimization objective in an industrial application case should be guided.

5. Discussion and Reflection

Observations showed that digital transformation can unlock significant value, while posing challenges on companies having yet to walk through the journey of successful digital (business) transformation. In particular, for digital transformation technologies such as digital twinning, tremendous market growth is expected in the next few years, which creates a need for developing sophisticated approaches on how to introduce those technologies in an industrial context and guide the companies towards application scenarios in practice.

Based on a paint production pilot case in the European Horizon 2020 Change2Twin project, three concrete digitization challenges were identified: (a) the digitization of the raw material warehouse, (b) the digitization of the production processes, and (c) the digitization of the product information. By identifying these relevant digitization challenges in the OMiLAB Innovation Corner environment, light was successfully shed on different perspectives ranging from organizational considerations to business aspects. A physical proof-of-concept model allowed to ease the transfer from the conceptual digital innovation idea towards an industrial application case. The chosen model-based approach facilitated the industrial application case with respect to numerous aspects ranging from capturing the actual process models by BPMN modelling workshops to the establishment of a physical model towards enabling a better understanding of domain specific digitization challenges. The creation of a discussion platform based on a familiar association – the tea production sample –, eased paring up and knowledge exchange of stakeholders from different fields ranging from domain to technical experts. The usage of models allowed for a complexity reduction by means of abstraction and simplification. Those aspects eased the identification and extraction of information that is relevant for digital transformation/twinning as well as further on set the stage for the definition of requirements. The physical model in the OMiLAB Innovation Corner paves the way for an industrial application of the digital innovation idea by providing a secured testing environment to evaluate the feasibility within a simplified scenario before investing in digitization equipment for industrial purposes.

In general, heterogeneous companies require digital transformation support globally. However, it could be recognized that in industry, sophisticated transformation approaches are needed. Experiences throughout the sample pilot case show that there is a lack of awareness, experience and education with respect to digital transformation. In particular, science can help industry out with investigating in challenges beginning with questions such as:

- How to prepare, train and motivate companies/employees for digital transformation? How to change the mindset of people towards digital natives so that the way is paved for sustainable developments?
- How to create additional value and sustainable developments with digital transformation technologies that reach beyond a plain increase in competitiveness or efficiency? In which potential scenarios should digital transformation not be applied and why?
- What are the product-, company- and industry-independent challenges in digital transformation that every organization has to deal with? How can organizations from heterogeneous disciplines be guided through the selection of appropriate digitization technologies?
- How can digital twinning technologies assist organizations aside from typical production/manufacturing scenarios?

Beginning with, model-based approaches may be seen as one opportunity to tackle digital transformation in an industrial context as they may serve as means of knowledge sharing among diverse stakeholder groups.

6. Acknowledgements

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7. References

[1] World Economic Forum. Digital Transformation Initiative. Retrieved from http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/dti-executive-summary-20180510.pdf, slide 1 and 21.

[2] Tchana de Tchana Y., Ducellier G. and Sébastien R. (2019). Designing a unique Digital Twin for linear infrastructures lifecycle management. Procedia CIRP 2019, Volume 84, Pages 545-549.

[3] IoT Analytics. How the world's 250 Digital Twins compare? Same, same but different. Retrieved from https://iot-analytics.com/how-the-worlds-250-digital-twins-compare/.

[4] Change2Twin. Bringing Digital Twins to Manufacturing SMEs. Retrieved from https://www.change2twin.eu/.

[5] Woitsch R. (2020). Industrial Digital Environments in Action: The OMiLAB Innovation Corner, In Grabis J., Bork D. (Eds), The Practice of Enterprise Modelling, 13th IFIP Working Conference PoEM 2020, LNBIP 400, pp. 8-22, Springer 2020.

[6] Gartner. Digital Twin. Retrieved from https://www.gartner.com/en/information-technology/glossary/digital-twin.
[7] Gartner. Create a Digital Twin of Your Organization to Optimize Your Digital Transformation Program. Retrieved from https://www.gartner.com/en/documents/3901491/create-a-digital-twin-of-your-organization-to-optimize-y.
[8] Gabler. ABC-Analyse. Retrieved from https://wirtschaftslexikon.gabler.de/definition/abc-analyse-28775.
[9] OMG BPMN. Business Process Model and Notation, Version 2.0. Retrieved from https://www.omg.org/spec/BPMN/2.0/About-BPMN/.
[10] ADOxx.org. Change2Twin Development Space. Retrieved from https://adoxx.org/live/web/change2twin/downloads.
[11] OLIVE. OMiLAB Integrated Virtual Environment. Retrieved from https://www.adoxx.org/live/olive#fast_deployment.
[12] Greif T., Stein N. and Flath C. M. (2020). Peeking into the void: Digital twins for construction site logistics. Computers in Industry, Volume 121, ISSN 0166-3615.
[13] Hevner A., Chatterjee S. (2010) Design Science Research in Information Systems. In: Design Research in Information Systems. Integrated Series in Information Systems, vol 22. Springer, Boston, MA.
[14] MarketsandMarkets. Digital Twin Market. Retrieved from https://www.marketsandmarkets.com/Market-Reports/digital-twin-market-225269522.html.
[15] Deloitte. Industry 4.0 and the digital twin. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/cip/deloitte-cn-cip-industry-4-0-digital-twin-technology-en-171215.pdf.
[16] PwC. Industrial manufacturing trends 2020: Succeeding in uncertainty through agility and innovation. Retrieved from https://www.pwc.com/gx/en/ceo-survey/2020/trends/industrial-manufacturing-trends-2020.pdf.
[17] ADOxx.org. Meta Modelling Platform. Retrieved from https://www.adoxx.org/live/home.
[18] OMiLAB NPO. OMiLAB Digital Innovation Environment. Retrieved from https://www.omilab.org/.
[19] Gericke G. A., Kuriakose R. B., Vermaak H. J. and Mardsen O. (2019). Design of Digital Twins for Optimization of a Water Bottling Plant. IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society, pp. 5204-5210.
[20] Moser A., Appl C., Brüning S., Hass V.C. (2020) Mechanistic Mathematical Models as a Basis for Digital Twins. In: Herwig C., Pörtner R., Möller J. (eds) Digital Twins. Advances in Biochemical Engineering/Biotechnology, vol 176. Springer, Cham.
[21] Ruzsa C. (2021). Digital twin technology - external data resources in creating the model and classification of different digital twin types in manufacturing. Procedia Manufacturing. Volume 54, Pages 209-215, ISSN 2351-9789.
[22] Gartner. Create a Digital Twin of Your Organization to Optimize Your Digital Transformation Program. Retrieved from https://www.gartner.com/en/documents/3901491/create-a-digital-twin-of-your-organization-to-optimize-y.
[23] Lnsresearch.com. Forging the digital twin in discrete manufacturing. A Vision for Unity in the Virtual and Real Worlds. Retrieved from https://discover.3ds.com/sites/default/files/2019-04/forging-digital-twin-discrete-manufacturing-lnsresearch.pdf.
[24] Karagiannis D. and Kühn H. (2002). Metamodelling platforms. In EC-Web, vol. 2455, p. 182.
[25] Augustine P. (2020). Chapter Four - The industry use cases for the Digital Twin idea. Editor(s): Pethuru Raj, Preetha Evangeline. Advances in Computers, Elsevier. Volume 117, Issue 1, Pages 79-105, ISSN 0065-2458, ISBN 9780128187562.
[26] Parmar R., Leiponen A., and Thomas L. D.W. (2020). Building an organizational digital twin. Business Horizons. Volume 63, Issue 6, Pages 725-736, ISSN 0007-6813.
[27] Graphenstone. Retrieved from https://www.graphenstone.com/.
[28] BOC Group. Retrieved from https://www.boc-group.com/en/.
[29] ADOxx.org. DISRUPT – Industrial Business Process Management. Retrieved from https://adoxx.org/live/web/disrupt/industrial-business-process-management.