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The Digital Transformation of the Product Management Process: Conception of Digital Twin Impacts for the Different Stages

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Abstract: In this paper the potential impact of digital transformation in general and digital twin applications on the Product Management Process (PMP) in particular will be investigated. The object is to figure out the potential benefits of digital twin utilization. Methodologically, a conceptual and analytical approach are applied in using statistical data, surveys, latest literature and logical conclusions. Thus, the approach is twofold: from the conceptual point of view the different types of digital twins are introduced; from the analytical point of view different applications in different stages of the PMP will be subject to investigation. So, this paper can be categorized as conceptual paper based on an extensive literature research. The findings of research revealed that the digital transformation can offer various benefits for the PMP. It can be summarized that in all phases of the PMP potential benefits can be identified. The most important is saving time and money, avoiding waste of physical resources and simultaneously raising quality, reliability and competitive advantage. Regarding the originality value it can be stated that this is the first comprehensive examination of the entire PMP with regard to digital transformation in order to identify sources of potential benefits.

Keywords: Digital twin, Digital transformation, Digitization, Innovation, Value management, Product management

1. Introduction

Even Henry Ford thought that everything that is done can be made even better. This guiding principle is also important for companies, because only those who work continuously on improvements will have long term success. Improvements, however, often include change. In order to implement this, companies have to constantly adapt to current developments and technical progress. The same applies to the different tasks in companies, such as product management. In the following, the potentials for the improvement of the product management processes triggered by the digital transformation will be examined.

The importance of the digital twin for companies is shown in figure 1. The data collected by PwC for the study "Digital Factories 2020" shows, on the one hand, the actual implementation in companies for the year 2017. In addition, the company representatives were also asked for an outlook for 2022. When comparing the two figures, it is noticeable that the increase within only five years is considerable in all areas of digital twin. Almost half of the companies surveyed indicate that by 2022 digital twins will be used in production and as a virtual copy of the product.

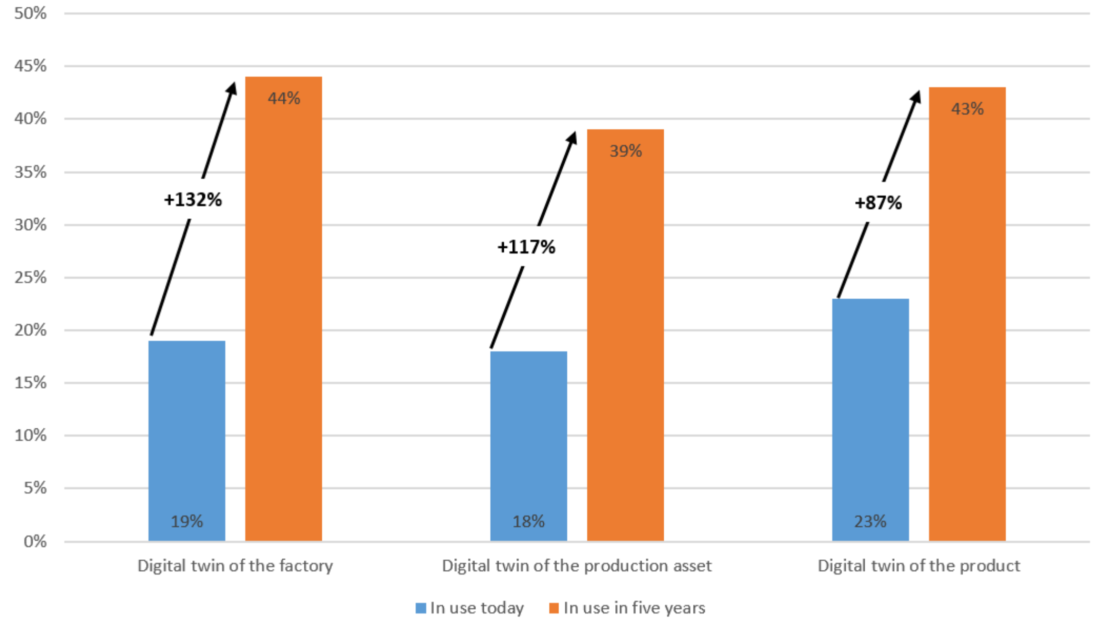


Figure 1: Digital Twin (own graph, based on Data from PwC 2017)

For this reason, the importance of the topic of digital twin should increasingly be brought into focus.

2. Terminology

2.1 Digital transformation

For the concept of digital transformation, there is still no standardized definition. Frequently, the digital transformation is equated with digitization, which currently does not also have universally valid definition. By analysing different definitions of the Digital Transformation, it is possible to identify certain key elements on the basis of which a valid definition for this publication can be drawn up: Digital Transformation is the integration of technological developments in digitization into different areas of companies. Here, business processes or entire value chains may be optimized by new technologies and on the basis of collected data, and business units, customers and other stakeholders are networked with each other [Schallmo 2016, p. 4 and p. 7]. Thus, the two terms differ: Economic aspects are considered in digital transformation, but digitization also includes society [BMWi, 2015, p. 3]. The digital transformation is thus a subarea of digitization.

2.2 Digital twin

The concept of the digital twin is increasingly being discussed, as this topic is currently relevant for many companies and is becoming increasingly important. A Digital Twin is a virtual image of a physical product. Both are networked and able to communicate with each other. The physical twin can be finished products as well as individual components, entire production plants or processes [Grieves, 2018, p. 67 and Schonschek, 2018, p. 42].

A Digital Twin consists of three parts: One is the physical product itself, which is also called physical twin. On the other hand, there is the virtual twin, the digital image that reflects the physical twin. And last but not least, there is a communication between the physical and the virtual twin, which enables the transmission of data and information [Grieves, 2018, p. 67]. This principle is shown in Figure 2.

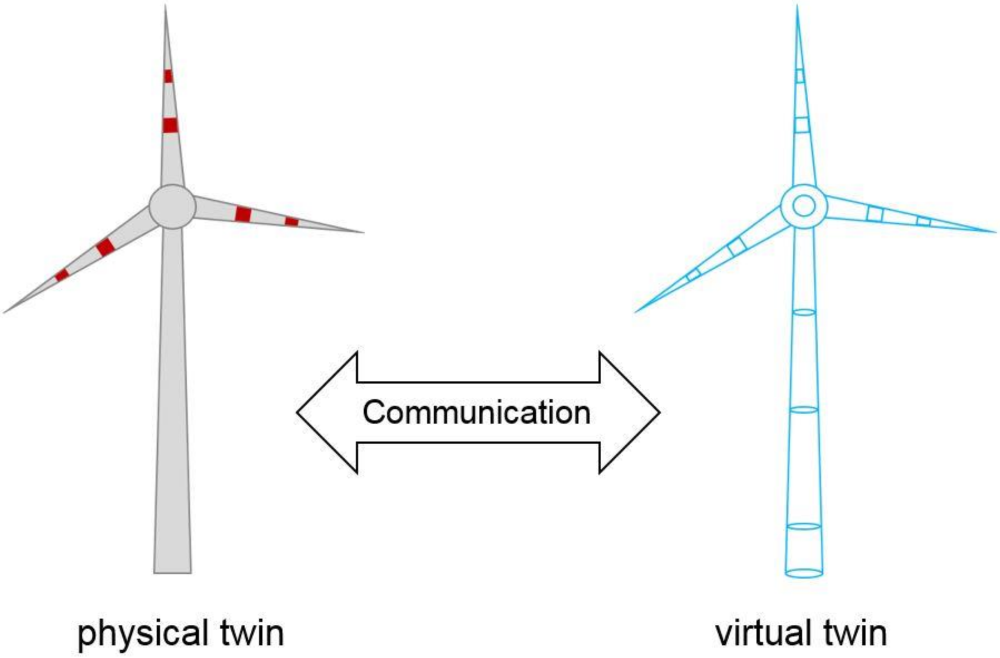


Figure 2: Digital Twin

There are three basic different types of Digital Twins, the DTP, DTI and DTA. These three kinds are shown in Figure 3.

DTP is the Digital Twin Prototype, which is an image of physical products in the prototype phase. The special feature here is that the virtual twin is created before a physical twin is produced. This allows tests and simulations to be performed on the virtual twin until it has optimal design and behaves as desired throughout its lifecycle. If so, the physical prototype can be produced. The use of Digital Twin Prototypes is particularly useful for products with high complexity [Grieves, 2018, p. 68]. The second type of Digital Twins is the DTI, the Digital Twin Instance. In this case, a specific physical product is assigned to the virtual twin, which maps over its entire lifecycle. This type of Digital Twin is used, for example, to transmit information about necessary maintenance work [Grieves, 2018, p. 68].

The third type of Digital Twins, the Digital Twin Aggregate (DTA), is the collection of multiple DTIs of products. The DTA does not itself collect data, but collects the data of the DTIs, in order to bundle and analyse them, so as to give an overall view of the performance of a particular product in its individual embodiments [Grieves, 2018, p. 68].

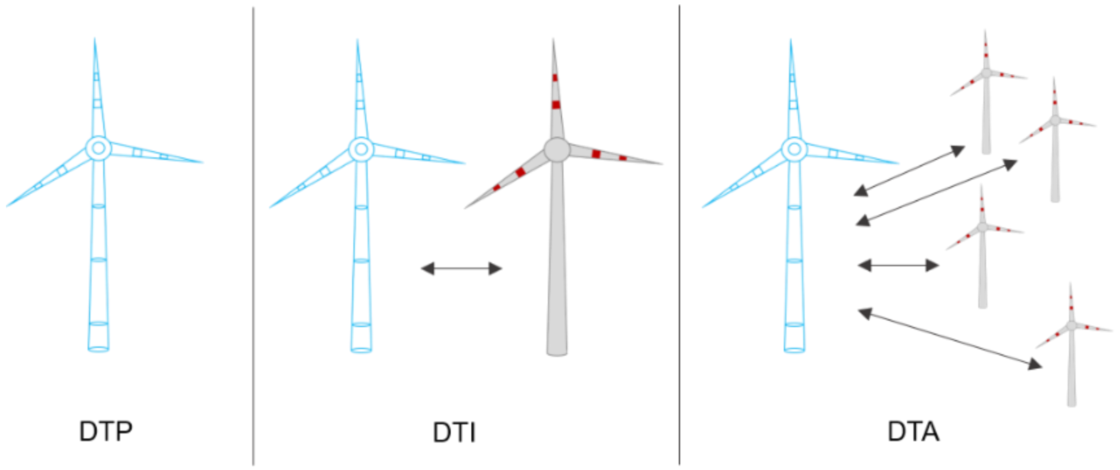


Figure 3: Types of digital twins

Besides these three main types of Digital Twins, there is another type that occurs in the field of artificial intelligence, the Intelligent Digital Twin (IDT). Not only does this digital twin mirror information, like the types of Digital Twins we've already introduced, it's also capable of making predictions based on data we collect. The use of intelligent digital twins could predict how this product will behave in the near or distant future based on the current state of a product. This would avoid errors in advance and simulate the complete lifecycle of a product [Grieves, 2018, pp. 67-69 and Tao, 2018, pp. 3564-3567].

3.Influence on The Product Management Process

3.1 Product management process

The analysis of this publication is based on the product management process shown in Figure 4, which represents a shortened version of Hofbauer's product management cycle [Hofbauer/Sangl, 2018, p. 340]. The process consists of six phases, each of which involves specific activities. These activities are influenced or can be optimized by the digital transformation.

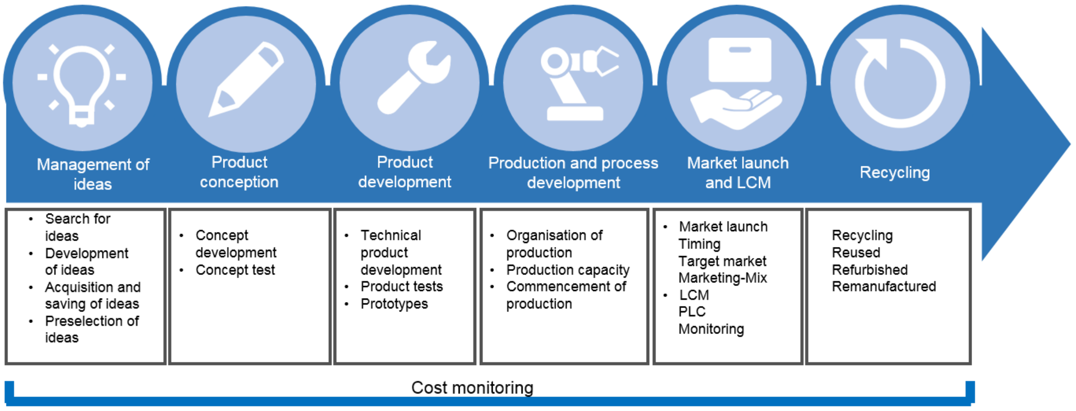


Figure 4: Product management process

3.2 Phase 1 - Idea Management

The idea management phase benefits a lot from the possibilities of digital transformation. Digital techniques allow a significantly larger number of people to be involved in the idea generation process than it was previously the case. For example, open innovation approaches, such as idea contests or crowdsourcing, can be pursued.

Crowdsourcing is about finding solutions to a problem with the help of many contributing specialists. These people can be experts, but also potential customers or lead users. There is a distinction between in-house and outside crowdsourcing. In-house crowdsourcing primarily involves employees, but it can also involve external people. If crowdsourcing takes place outside the company, dedicated platforms are usually used [Hofbauer/Sangl, 2018, pp. 369-371]. In addition to company-owned innovation platforms, non-company platforms are also used. For example, the InnoCentive platform is successful, with more than 300,000 members, which made up of more than 200 countries [Hofbauer/Sangl, 2018, pp. 369-371].

Idea competitions also work with the knowledge of a large crowd. External or in-house people gather ideas on specific topics. In most cases, idea competitions are limited in time and the best idea is ultimately selected by a jury or by users. This type of involvement of contributing people in the innovation process is particularly useful in the initial phase of idea management, when it comes to collecting the widest possible variety of ideas [Knöchel, 2018, p. 19 and Brening, 2017, p. 32]. Mostly idea competitions are internet-based over certain platforms [Piller, 2017, p. 80].

In addition, there are potentials through the integration of customers in the form of Virtual Community Integration (VCI). Here, customers are integrated via the internet into the innovation process. The advantage is that not only a dialogue takes place between the customer and the company, but also between the different customers. The company can follow this communication and get further insights or ideas from it [Ankle, 2018, p. 27]. Later, in the evaluation phase, customer involvement is also very useful. A major benefit of integrating open innovation approaches into idea-gathering and development is that it allows to work internationally to come up with solutions, thus involving a significant larger number of people and experts than it would be the case at the national level. As a result, international companies can already receive input from different cultures in brainstorming. In addition, open-innovation methods can reduce time-to-market and increase market acceptance [Piller, 2017, p. 69].

Also interesting for idea management is netnography. Here, the topics that potential or current customers discuss on the internet are surveyed. This includes comments or even reviews from users of relevant websites, such as topic-specific blogs or even social media channels. The advantage is that it raises the genuine feelings and thoughts of the users, which in turn can help the company in generating ideas and also in the selection of ideas. In addition, important information about customers are collected, such as buying behaviour, product preferences or even reviews of current products. From this, product policy measures such as product differentiation can be derived [Hofbauer/Sangl, 2018, pp. 372-373 and Knöchel, 2018, p. 13]. The subject of reverse engineering is also affected by digital transformation. So far, this has mainly been related to physical products, but currently software reverse engineering is becoming increasingly important as well [Aabidi, 2017, p. 1].

In addition to approaches to generate and gather ideas, the digital transformation also offers potential for capturing and storing ideas. By using digital solutions, such as idea management databases, ideas can be stored long-term, assigned to specific categories or checked for redundancy. In addition, it makes sense to capture the ideas already digitally, since this can reduce the processing effort. An example of such an idea management tool is the software Idea and Request Management (IRM) [XWS, n.d.].

3.3 Phase 2 – Product Conception

Starting from the product conception phase, the use of Digital Twins is recommended, which was already explained in chapter 2.2. If a company wants to integrate digital twins, this should be done as soon as possible from the beginning of the product conception phase. This is because the data collected in the respective phase forms the basis for the subsequent phases, so that the Digital Twin is enriched with more and more data in the course of the process until it is finally possible to offer a promising new product [Boschert, 2016, pp. 68-69]. For the product conception phase, data from past product developments are also relevant, since they can be used to quickly create the basis for the digital twin. This newly created Digital Twin is then filled with initial information regarding the design and operation of the product for which a concept exists. If it is decided to further develop the product concept, in the subsequent phase, the product development, the previously fed data can be specified and extended. Thus, as the amount of data increases, the visual image of the virtual twin also grows in the course of the development process [Boschert, 2016, p. 70]. In the later stages, the virtual twin is complemented by its physical twin, thus entering the real world.

For the phase of concept testing itself, the use of digital twins offers additional advantages. For example, with the help of Digital Twins different design variants of a product can be created. As a result, concepts can already be tested at this stage, without producing a prototype. The Digital Twin makes it possible to do simulations of the product concepts as well as to make predictions about their respective performance [Maplesoft, 2018]. At the product design stage, Digital Twin Prototypes (DTP) are relevant, because there is no physical image yet. Further advantages can be gained through the use of virtual technology models. These models form the basis for various design and contain design principles and technical specifications such as minimum cross sections. This makes it clear even at the product conception stage whether a concept can actually be implemented in a physical product or whether the implementation is not feasible. Since this happens without having to produce a prototype, there is a high potential for savings in terms of product development costs. In addition, technology models allow a better prediction of costs, since they usually contain the most expensive components [Braess, 2016, p. 1267-1268].

In addition to technology models, Digital Mock Ups (DMU) can also be used. These, like the technology model, represent products or components virtually. Digital mock ups can also be used to run simulations that replace tests with real prototypes and even expand their capabilities. Thus, simulations can already be created in the early phase of the product conception in order to be able to sort out concepts that perform poorly at an early stage [Riascos, 2015, p. 356]. Thus, bad investments are avoided. Digital mock ups can also be combined with technologies such as augmented reality. This considerably simplifies the operation for the user and expands the possibilities of action [Riascos, 2015, p. 359f]. Furthermore, technologies such as augmented reality and virtual reality also offer new possibilities in concept testing in general. Thanks to these technologies, product concepts can be visualized in their early stages and thus are better valued [Winkelhake, 2017, p. 95]. The evaluation of concepts can also be facilitated by software solutions. Another advantage of using special software is that it often also allows the storage of the rejected product concepts, so that they are not lost and can be viewed again at later times, if their relevance may have changed [Jetter, 2005, p. 148].

3.4 Phase 3 – product development

Digital transformation has changed the way how product development works. As a basis for the technical development and the construction of the products are assistances such as CAD. By means of CAD technical drawings can be made digitally, which serve as basis for the prototype production as well as the succeeding production. With the help of this virtual product development, the development time can be partially reduced by half [WiGim, 2017].

There are also advantages for prototype development. For example, in addition to physical prototypes, digital prototypes can also be used. These make it easier to carry out technical investigations such as the performance of crash tests [Disselkamp, 2012, p. 50]. In addition to the term digital prototypes, the term virtual prototyping is often used [Gausemeier, 2012, p. 19]. Physical prototypes can be made faster through high-performance computing systems and additive manufacturing processes. This fact also reduces product development time and enables the compatibility of various parts to be quickly tested. This is well-known as rapid prototyping [Hofbauer/Sangl, 2018, p. 482]. In order to produce prototypes by means of additive manufacturing processes such as, for example 3D printing, however, digital prototypes are initially required which contain the data necessary for production [IAV, 2013, p. 229]. Prototype development also makes use of augmented reality (AR). AR only requires half the number of physical prototypes since tests and simulations can be performed digitally [Winkelhake, 2017, p. 95].

The use of digital twins plays a major role in product development. If their use was carried out consistently in the previous product management process, the virtual twin in the form of the DTP already contains the data developed in the previous phase and can now be used as the basis for further product development. First of all, it makes sense to execute developments on the DTP and to carry out simulations until it has an optimal design [Boschert, 2016, p. 67]. Thus, different variants can be tested and the future performance of the product can be predicted [Tao, 2018, p. 3568]. Once this is done, a prototype can be made based on the data generated. If both a physical prototype and the digital mirror image are present, this is a Digital Twin Instance (DTI). With this, the virtual twin can communicate through the utilization of sensors [Schonschek, 2018, p. 43]. The data of the simulations of the Digital Twins can be used for the product development itself, but also for subsequent phases. This is the case for example when it comes to carrying out maintenance work, or when the production planning and the production of the new product starts [Klostermeier, 2018, p. 300 and Boschert, 2016, p. 72]. In addition, simulations using digital twins offer advantages over simulations without them. The results of the simulations behave like virtual sensors of the twin. The advantage here is that they can be placed anywhere. This makes it possible to obtain measurement data from locations involving the integration of a physical sensor, e.g. would not be possible due to space limitations. Through this combination of virtual and physical sensors, more comprehensive data can be collected than would be possible otherwise [Gebhardt, 2017, pp. 26-27].

3.5 Phase 4 – Production and process development

Production and process development is strongly influenced by the effects of digital transformation. As for the processes of the previous phases, technologies such as virtual reality or digital mock ups play a major role in production planning. This allows production processes to be digitally simulated and optimized. For example, the manufacturing process can be simulated in different variants of the spatial arrangement, so as to find out which arrangement allows the most time-saving production. Even within individual production cells, the process can be optimized in this way [Hofbauer/Sangl, 2018, pp. 503-504].

In addition to the digital representation of individual production areas, the digital factory is also of particular importance in this phase. This is a complete digital model of a real factory. This consists of several individual models that are linked together. As a result, for example, the entire material flow within the factory can be tested in advance and optimized, or entire factory processes can be simulated. This helps, for example, to determine the optimal lot sizes or the optimal distribution of personnel resources and arrangement of machines and plants. Simulations of traffic and personal movements can also be carried out for optimal planning of traffic in and around the company premises, the building and also the escape routes. Further potential for digital factories is provided by the use of mobile devices, as information such as three-dimensional factory models can be retrieved from any location or GPS can be used for material flow analysis. Virtual and augmented reality can also be integrated into the digital factory. VR can virtually commit the planned factory, which, on the one hand, improves spatial perception and, on the other hand, creates new potential for optimization, for example by analyzing the light incidence in the various rooms. This would not be possible with two-dimensional models. Augmented reality makes it possible to display additional components such as systems in existing factory halls or to provide information about machines visually [Hofbauer/Sangl, 2018, pp. 510-515].

For the use of digital twins, it is important to equip them with appropriate sensors. Because this, as well as the connectivity via the internet, makes it possible that the respective individual products can communicate with their virtual mirror image [Schonschek, 2018, p. 43]. As a result of the data collected, faulty products can be quickly identified and valuable information on the efficiency of production collected. If a large number of such products is manufactured, each of these individual products can serve as a DTI. Through the introduction of a DTA (Digital Twin Aggregate), which brings together the collected information of the DTIs, statements about the overall performance of the production can already be made during production [Grieves, 2018, p. 68].

In addition to the use of digital twins of products, digital twins of entire factories are also used in production and process development. These are usually found in the context of so-called smart factories. In a smart factory, the individual products, machines and plants as well as the entire factory environment are networked digitally via the internet. This enables the use of digital twins in production, which can reflect current processes and data in real time. By using digital twins of processes, machines or entire factories, manufacturing flexibility, efficiency as well as speed can be increased and time-to-market reduced [Daimler, 2018]. Digital twins of factories provide the monitoring of the real factory, because the fact that a communication between the virtual and the physical twin takes place, the virtual image can also intervene in real processes and thus, for example, machines are switched on. The same thing works the other way around. If, for example, machines are activated in reality, the virtual twin also reflects this change in real time [Fraunhofer, 2017]. The advantage is also that occurring problems can be recognized immediately and thus a fast adjustment is possible. The cause of the problem can be more easily determined, and whether this is due to a particular component or it is due to faulty processes [Rougoor, 2018].

3.6 Phase 5 – Market introduction and lifecycle management

Market introduction and the lifecycle management (LCM) are also influenced by the digital transformation. There are new options for the marketing mix of the introductory phase. These are new products that may become relevant through technological developments. For sales support, options such as digital product configuration via websites and virtual reality have emerged. Furthermore, technologies such as virtual reality are integrated even in stationary sales. In terms of communication policy, products can be advertised over the internet in the form of online advertising, blogs, influencers or websites. Here, the advertising individually tailored to the customer, is an important topic. Even in the real world, product communication is influenced by digital technologies, such as augmented reality in retail spaces. There are also potentials for the entire lifecycle management. With regard to the marketing activities in the individual phases of the product lifecycle (PLC), the same developments apply as explained above. In general, monitoring product performance has become much easier. The amount of data available in larger numbers helps. Insights can be drawn with the help of big data methods [Gebhardt, 2017, p. 27].

The use of digital twins is also important for lifecycle management, because it helps them track the condition of a product throughout its lifecycle. This can intervene in case of abnormalities in the performance of a product before it fails. This is particularly important for industrial goods, but can also be found in durable goods. This basic principle is called predictive maintenance and can also be used without Digital Twins. However, the quality of the prediction increases, the more data is available and the better the current state of the respective object can be monitored [Schlotmann, 2018, p. 38 and Klostermeier, 2018, p. 307]. For example, predictive maintenance could reduce product outages by 70% and reduce maintenance costs by 25% [Gebhardt, 2017, p. 27]. Another advantage of the Digital Twin is that the data collected over the lifecycle is not stored in different locations, but all collected by the Digital Twin [Michels, 2016, p. 253]. The collected data on product performance and product use by the customer are also valuable in relation to upcoming product developments, as they can provide information regarding optimization potential [Boschert, 2016, p. 73 and Gebhardt, 2017, p. 27].

In order to be able to optimally support lifecycle management, sometimes even supplemented with the previous phases, the use of special PLM software may be worthwhile. These enable the management of the products from development to disposal [Günnel, 2017]. An example of such a software solution is the Teamcenter program from Siemens, which, in addition to lifecycle management, should also facilitate communication between the individual areas and companies involved [Siemens, 2018].

3.7 Phase 6 – Recycling

In terms of recycling, there are also optimization potentials that already start during the development and product manufacturing. Often the problem occurs that recycling companies do not know which materials are actually contained in products. This information problem has to be solved in the future. Here, for example, technologies such as sensors can help [Wiltz, 2017, p. 5]. In this context, digital twins could also offer benefits to the products. The fact that waste management companies know which materials are contained in a product is a basic prerequisite for the recycling of valuable materials [Reckter, 2018, p. 1]. Furthermore, a digital twin of a product that can no longer be used, can provide information about the state of the product and whether it has any potential to be reused after its revision [Daniel, 2017].

4. Practical Example

Industrial robots, which are controlled by software and perform many tasks efficiently and reliably are widely known. Within the concept of digital twins, this robot does not only physically stand at the factory’s floor, it also exists as a virtual model that reliably describes all the functionality of the robot. Such digital copies are referred to as digital twins, because processes can be simulated with them as described in chapter 3. Since these models consist of data and algorithms only and have no physical-material components, they can be used in many places inside and outside the company to improve the device itself, or for the further development of the manufacturing process.

Some companies like Siemens, General Electric, Dassault, etc. already use the digital twin in their operations, mostly for manufacturing practice. A physical and virtual twin of an assembly armature unit is displayed in figure 5 as an example.

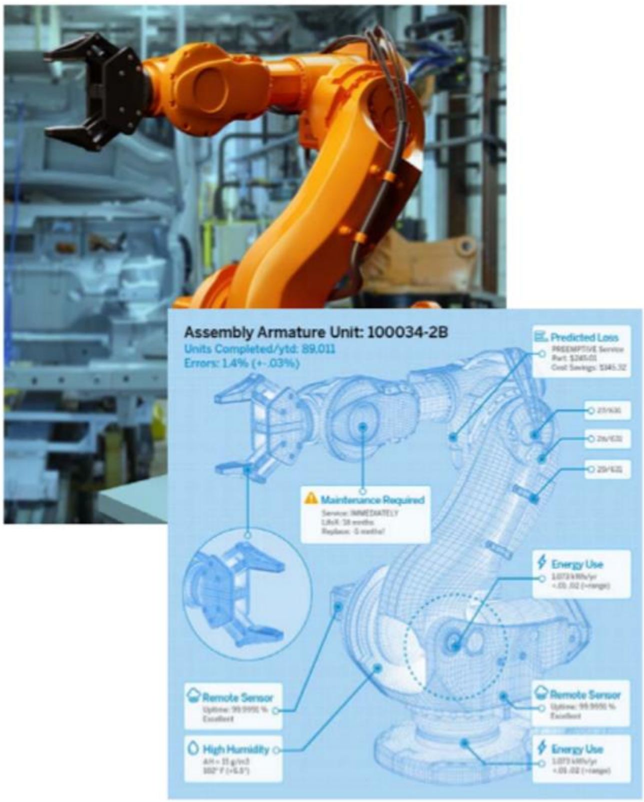
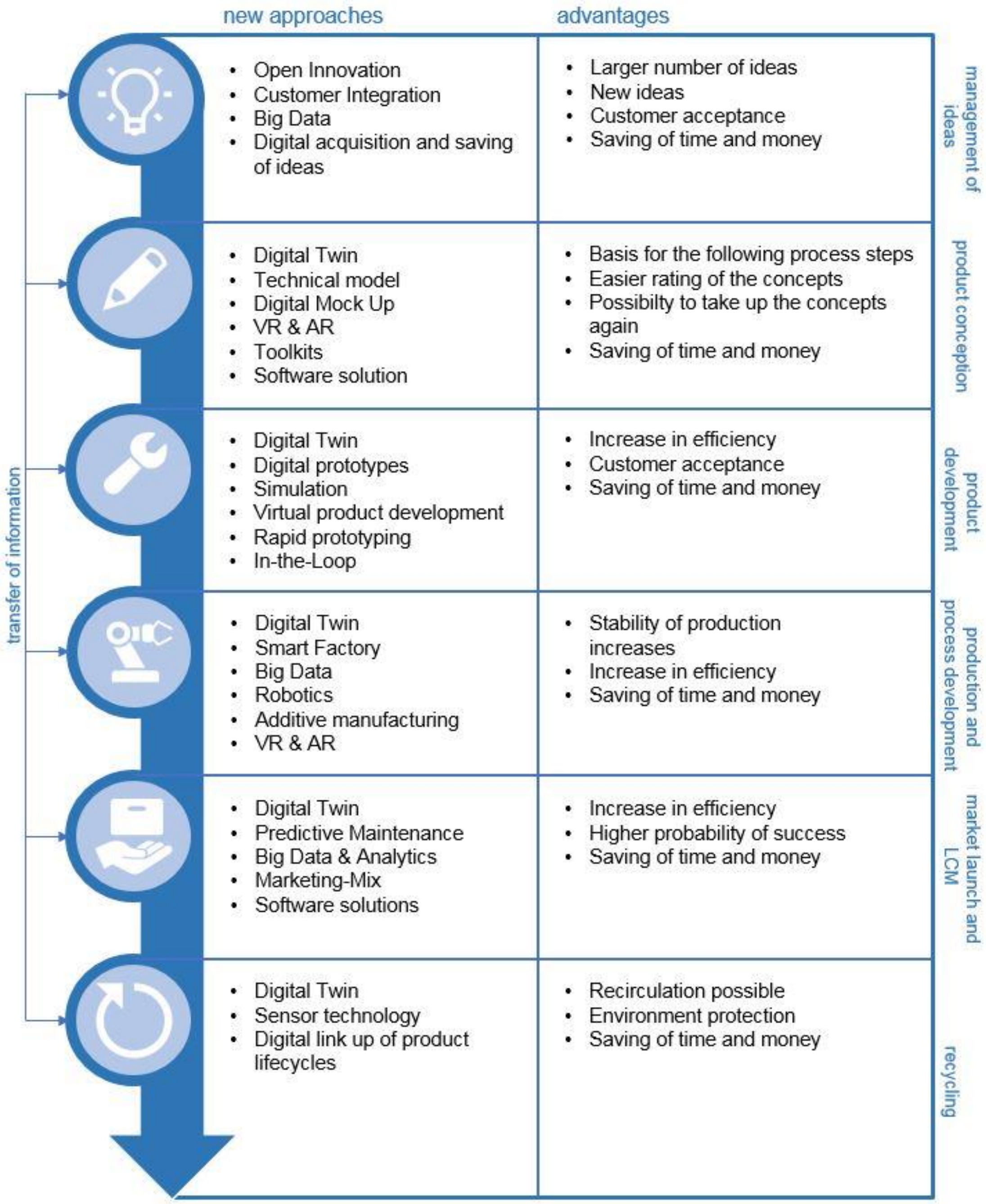


Figure 5: Example (source: intelligence, SAP AG, Walldorf)

5. Conclusion

This article shows that digital transformation can offer many potentials for product management. Costs and time can be saved for each of the six analyzed phases. Even an increase in effectivity and efficiency can be realized. Benefits such as better customer acceptance or the ability to be more sustainable can also be achieved more easily. Another goal could be to partially parallelize the individual steps in order to further shorten the development time and consequently time-to-market. Simulation and optimization can be executed without the need of investment in physical equipment. Some of the technologies presented are already implemented or in implementation, others are still in their initial phase and will be further developed, such as the Digital Twin concept. Figure 6 shows a summary of the results, partially supplemented by further changes for the respective phases.



new approaches	advantages	
• Open Innovation • Customer Integration • Big Data • Digital acquisition and saving of ideas	• Larger number of ideas • New ideas • Customer acceptance • Saving of time and money	management of ideas
• Digital Twin • Technical model • Digital Mock Up • VR & AR • Toolkits • Software solution	• Basis for the following process steps • Easier rating of the concepts • Possibilty to take up the concepts again • Saving of time and money	product conception
• Digital Twin • Digital prototypes • Simulation • Virtual product development • Rapid prototyping • In-the-Loop	• Increase in efficiency • Customer acceptance • Saving of time and money	product development
• Digital Twin • Smart Factory • Big Data • Robotics • Additive manufacturing • VR & AR	• Stability of production increases • Increase in efficiency • Saving of time and money	production and process development
• Digital Twin • Predictive Maintenance • Big Data & Analytics • Marketing-Mix • Software solutions	• Increase in efficiency • Higher probability of success • Saving of time and money	market launch and LCM
• Digital Twin • Sensor technology • Digital link up of product lifecycles	• Recirculation possible • Environment protection • Saving of time and money	recycling

Figure 6: Digital Transformation in Product Management

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