Is your PLM calibrated for the Internet of Everything Era?
Upgrade your product lifecycle management to PLM 4.0
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1 Executive Summary

In a dynamic world with ever-increasing complexity and uncertainty, firms have to develop approaches in order to cope with nowadays challenges. In this light, Internet of Everything (IoE) offers necessary capabilities connecting people, devices and services. This paper aims at presenting how the application of PLM for IoE solutions can exploit the potential of new products. The four PLM design domains PLM Strategy, PLM Process, Product Architecture, and PLM IT Architecture & IoE Data Analytics are aligned to solve potential struggles, implement the information flow and play an influential role for the overall organizational success.

For the realization of Industry 4.0 approaches a sustainable digitalization of the whole product lifecycle is needed. To demonstrate the importance of PLM in this context, the following three practical fields were identified for the purpose of this paper: The Automotive sector, the Healthcare sector and the Energy sector. More specifically, these fields were used to indicate how PLM allows for handling potential complexities. IoE devices have a huge potential but there are also several challenges that need to be coped with, especially when implementing the IoE devices into firms’ product lifecycle. Subsequently, for a better understanding of the product lifecycle management framework the four PLM design domains are described in detail. These four design domains are applied to the three use cases and presented in a matrix table in order to show how big the impact of particular PLM-Tools is on several sectors.

By implementing a Digital Twin into the production facility the information of products or systems can be reviewed and analyzed very fast. One advantage of this is the possibility to react very quickly in a short time in order to solve problems or conduct changes. Replication of physical assets combined with IoE will enable companies to simulate real world issues and have better control over their products.

In addition to the previously mentioned issues, this paper provides (practical) guidance for managers and executives. In terms of implementing IoE in their firms and the consequences such implementation may have for new product development and management in general. In following the guidance provided in this paper, top management members shall be enabled to achieve a variety of positive outcomes such as improved market fit, reduced costs and communicative advantages. More generally, the underlying paper is intended to convey a better understanding of the crucial product and service related topics relevant to the IoE market.

Keywords: Internet of Everything (IoE); Internet of Thing (IoT); Product Lifecycle Management (PLM); PLM 4.0; Product Development; Digital Economy; IoE platform; Digital Twin; Partnering.
2 Digitalization disrupts established product development & Management approaches

A rising complexity of products, an on-going digitization and an accelerated shift of market demands lead to a rapidly rising number of uncertainties in business and technology environments. These uncertainties make it challenging to successfully develop new products and services: development costs increase, implementations become more complex and finally result in more and more product flops. Information technology does more than simply support companies and their business - digital technologies and their intelligent application are decisive key factors, putting their stamp on products, service concepts and market strategies.

The definition of Internet of Everything and its market projections are characterized by huge volatility. There is not an agreed definition of the Internet of Everything (cf. Stark, 2015). While Internet of Things (IoT) relates to the enablement and management of interconnected devices logically associated with physical things, IoE extends this concept beyond things to include people, processes and the data supporting them. The individual components of IoT with various devices and other products have existed for many years. The concept of IoT emerged in the 1990s, although many companies didn't start to address the subject until later. The IoT and related Smart Products offer companies and their customers many potential benefits. At first glance there may not seem to be much in common between new product development as well as product lifecycle management (PLM) and the Internet of Everything. However, the two subjects are closely related, as the "things" are products. And the devices are also products. Since the inclusion of people is to be seen as necessary, we refer in this paper to IoE.

Since a couple of years the topic of IoE has impact on new product development as well as PLM which gains quite some attention from management science (in publications of J. Golovatchev and O. Budde, 2010, 2014, 2016). The detailed consideration and research on IoE and its impact on new product development (NPD) and product lifecycle management are still missing.

The IoE offers many potential opportunities and benefits to both manufacturers and users of products and services. Some benefits arise when the product is inside the company. Other benefits arise when the product is outside the company, from where the product can send data to the company's product developers, maintenance engineers, machine operators and sales force. No doubt, IoE is one of the buzzwords of 2017 – the term is omnipresent and surprisingly hard to understand for many people in the industry and most importantly for many customers across all industries. According to Gartner\(^1\) (2017) we will see 8.4 billion connected “things” in 2017, up 30% year over year and with 20.4 billion “things” existing in 2020. Likewise, Gartner says $2 trillion will be spent on IoT solutions in 2017. This estimate is underlined by the massive investments from big ICT players (e.g. Google, Amazon, Microsoft, Alibaba, Deutsche Telekom, Oracle, SAP etc.), as they’re investing heavily into IoT platforms, products and services. We see a similar development to the cloud computing business in its early stages – a trend which was primarily implemented and boosted by vendors. Perhaps the most significant difference and one focus point of this paper is the importance and power of start-ups who are...

\(^1\) http://www.gartner.com/newsroom/id/3598917
leveraging the IoE trend and building entirely new products designed horizontally across industries or tailor made for a certain vertical. The pace of IoE start-ups emerging is significant and mainly driven by dramatic drop in prices for sensors and computing power.

At the same time IoE encompasses an entire set of services from the internet and around products - and adds some new ones. IoE market trends show level of activity and change in this market as lightning fast and in its early stages shaped by many market uncertainties. On the one hand these IoE offerings derive amazing opportunities for clients to make their existing business better by cutting costs and driving revenues, but on the other hand they are bringing enormous complexity to their potential clients – mainly due to the generation of massive amounts of data, different PLM cycle speeds, data management issues and necessary process adjustments. In a nutshell, small IoE solutions can have big impact on customers – generating big opportunities, but in case of wrong PLM Management it can lead eventually to big risks. By applying smart PLM for IoE solutions, customers can leverage the potential of these new products with significantly less risks. Consequently, scholars as well as practitioners call for new perspectives that understand the challenges and opportunities of IoE for the product development and management from a management perspective. Simultaneously, companies should know their field of industry and the market to evaluate their own position in comparison with other companies and regarding their customers.

This also refers to the issue that IoE may be seen as a technical topic for engineers to play within their sandbox and not as a business subject requiring executive involvement. How will the project team find out where business value will be generated? How will real business benefits be measured and tracked?

Firms are in need of new approaches to deal with those issues and have to take a proactive step to develop the solutions and this paper has the ambition to give clients guidance in this new world.
3 PLM 4.0 required as orchestrator to cope with increasing integration of IoE devices

Despite the huge potential of IoE devices, there are quite a few risks and challenges that need to be managed when integrating them into existing product lifecycles. We identified three exemplary use cases in the sectors of Automotive, Healthcare and Energy to describe and assess these challenges and risks. The description of the future use cases is followed by an assessment of 23 PLM design elements and their impact on the PLM targets.

3.1 Automotive and Digital Twin – intelligent factories and autonomous driving

As already mentioned above, smart factories will be one of the areas, where IoE devices will have the biggest impact in the future. An almost perfect example for how to use IoE technology in the field of manufacturing and logistics is a smart glove that helps workers in logistics and manufacturing to work more efficiently. Based on Intel’s wearable-development module Edison, ProGlove is integrating technology into the natural movement of workers’ hands. As a business intelligence solution for production management, it combines RFID, motion tracking, sensors and automated scanning. ProGlove not only provides its users with useful information about products, processes and assembling instructions, but is also able to gather information, such as documentation about processes and workflow sequences, and send it back to a central storage. By applying the technology in production, tools are becoming intelligent and reduce complexity, as e.g. motion tracking is helping to avoid mistakes, in case of workflows are not sequenced in the right order.

The power of this solution gets enabled, when ProGlove is integrated in already existing production facilities and IT systems of an Automotive OEM. After having been implemented, the devices are able to send data which they gather during usage. The intelligent logic gets more powerful when more and more IoE devices from different vendors are being integrated in the IT landscape of the OEM. The chance for the OEM is, that all devices communicate with each other, information sent by these devices is gathered, logically combined and analyzed, so the manufacturer can benefit in a way, that e.g. development cycles can be shortened significantly thanks to real-live availability of the data.

However, the challenge on the OEM side is to align the technologies of all different IoE device vendors, software, updates and creating interfaces that enable smooth and timely docking of new components and technologies.

From either view it is necessary to have a holistic view on PLM’s four functional design domains: PLM Strategy, PLM Process, Product Architecture and PLM IT Architecture & IoE Data Analytics, as being integrated in the production at different OEMs, their requirements have an impact on product enhancements of the IoE device vendor, too. Meanwhile, the OEM has to handle the different development cycles, updates and upgrades of all used components. The main challenge is the interaction between the vendor and its different customers when it comes to developing the devices further. ProGlove will benefit from the data gathered while being used at the different customers, however they are challenged by integrating the fast development cycles of ProGlove.

In order to provide better quality and safety for the product cycle in an Automotive sector, a Digital Twin can be integrated into PLM. But what lies behind the term Digital Twin? There is no established definition among researchers. The term was first introduced by Dr. Michael
Grieves\textsuperscript{2} from the University of Michigan in 2002, based on the idea that the information of a physical object can be digitally linked to a twin.

A Digital Twin depicts real products or systems digitally to constitute an application of its physical twin and predicts traits and performance over the whole lifecycle. By using live data (e.g. sensor data) it enables a realistic replication of the physical twin. According to a study by Gartner\textsuperscript{3} from 2016, the Digital Twin is one of the top 10 strategic technology trends of 2017. Additionally, it is predicted in this light that within a few years numerous products and systems will be depicted by Digital Twins.

The process of a Digital Twin can be seen as following: the data of the physical object is transferred to the IoT Platform where it can be analyzed and classified. The IoT platform sends the evaluated data to the simulation platform which displays the physical object as a digital copy. The simulation outputs are transferred back to the IoT platform where they are evaluated regarding the processes and detection of problems. Finally, feedback goes back to the responsible person of the physical object. Due to the realistic representation, processes such as blowing processes or heat regulation can be exactly determined. With regard to failure measuring, around 30\% can be predicted by big data analyses. Digital Twins offer the opportunity to predict the remaining 70\% of failures. A Digital Twin offers many opportunities, especially for the Automotive sector e.g. for product development, logistic planning or quality management. It allows a faster adaption and implementation and improvement of operations. Thus, not only producer requirements can be met but also customer requirements. Another application field is early prototyping. By establishing of a test model in an early planning phase of the production cycle, weak points can be determined.

With regard to the collection and aggregation of new data, the implementation and usage of Digital Twins can be challenging. Hence, PLM solutions should be applied as for example PLM IT Architecture & IoE Data Analytics which ensures an efficient and intelligent data management.

Intelligent factories also play an important role in the context of Digital Twins. OEMs are facing the challenge of integrating more and more players and technologies into their production and service cycles. The full potential of intelligent factories only becomes a successful case if all parties agree to collaborate on a common system. Through the implementation of Digital Twins, the management of manufacturing steps could be easier. For example, the abrasion of machines or unused capacity could be more easily detected. Moreover, the usage of Digital Twins offers the opportunity to respond very fast to changes. The communication between the production plant and the product can be accelerated.

3.2 Pharma & Health – Personalized edible drugs and healthcare

A couple of challenges specifically arise in the sector of Pharma and Health. The average cost to develop and approve a new drug is roughly at $55m. Besides that, lots of sold drugs are not consumed by the patients but simply thrown away.

\textsuperscript{3} http://www.gartner.com/smarterwithgartner/gartners-top-10-technology-trends-2017/
IoE devices found their way in, as RFID tags were used to equip drug packages. This was quite a step forward in improving inventory and drug counterfeiting. It also gives pharmacies and retailers the chance to store data (e.g. information for the patients on how to use the drugs) on the chips and provide useful information to the customers.

Nowadays, as technologies have been developed further, some companies have even been able to create eatable IoE devices. This groundbreaking technology makes it possible to embed devices in the medication itself and thereby to gather data about medication regiments, health issues, miss-use or even drug black markets.

Especially pharma companies and insurance companies would benefit from the usage of such technologies. Pharma companies would benefit in the case of improved drug testing, tracking of side effects and shortened development cycles. Insurance companies would gain deep knowledge by gathered data of how their customers live and take (or not take) their medicine. This is a great opportunity for them to customize individual products and services.

The biggest advantage in this scenario is to be seen for the medicine manufacturers. IoE devices would be the key connector between consumers, insurance companies and medicine manufacturers. Especially they can profit from the data by making it useful through analytics and in the end to improve their development cycles. This will have a real cost impact during their R&D and approval phase. The challenge, however, is to analyze the insights drug manufacturers learn from the shortened feedback cycles and to incorporate it into their R&D cycles and product lifecycles. A powerful PLM Architecture can serve as the enabler for the Pharma industry for improved drug testing and development.

3.3 Energy & Utilities – Smart grids & connected homes

The Energy sector is facing two major challenges: Firstly, it has to cope with the energy turn-around and secondly it is facing the process of digitalization. In order to survive on the market, companies have to profitably cater themselves to the transformation and build new business models in the digital world.

As the conventional energy business is significantly hit by decreasing profits, the digital transformation implicates massive changes in the business logic of almost all industries. Telecommunication, media and retail companies have been the first to be affected by the pressure to innovate that internet companies such as Skype, Google and Amazon have caused.

The transformation and digitalization pushes companies to extend the product portfolio drastically in the direction of Smart Energy products. Although those companies have already faced an increasing level of complexity in the past (e.g. complex pricing models for B2B clients), these new challenges will push them to new limits. They have to embrace the new innovation dynamic in the market, therefore they have to make the right decisions in a timely manner. This means, that companies have to transform from a nowadays one-fits-all product company with a limited product spectrum to a Full-Service-Provider offering customized solutions as Smart Energy Products (cf. Golovatchev; Budde, 2016) by the means of mass production.

Consumers or B2B customers stand at the end of a definable value chain and network. The entire value creation is directed towards the satisfaction of those customer needs which grants a special role to the “translation” of the own product to the needs and experience of customers. Companies that have distinctive capabilities in the field of innovation, service quality (“Cus-
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tomer/Service Experience”) and market entry are particularly successful in taking up this interface position and hence manage customer relationships. In times of social media, Big Data and the Internet of Everything, the management of information and innovations become two key success factors.

IoE devices have already been the enabler for innovation in the field of smart grid. The intelligence of these devices is able to transform conventional grids to smart, data driven, grids. The implementation opens up new opportunities towards business models for both existing and also new stakeholders such as utilities and network operators, ICT companies and last but not least the customers.

Households could benefit from smart grids as well. Being equipped with smart metering devices, already by today, it is possible to measure and track consumption, control heating remotely, and source energy efficiently. Smart metering brings multiple major advantages for the customers. While consumption can be tracked instantly, billing can be done more transparent. Instead of estimates based on the forecasted consumption, real-time usage can be calculated. These data can also be used by the customers to radically reduce their bills, since up-to-date information of their consumption allows them to manage their energy use and supply more efficiently. This of course also will have a significant effect on the pricing. Usually, the pricing of electricity is embossed by supply and demand and thereby peaks at certain points in time, whereas lows could attract customers to source energy at better prices. As market prices would be more transparent, customers will rethink their consumption habits and thereby save both energy and money.

Remote control of energy consuming devices at home also shows an interesting scenario. With washing machines, dishwashers, heaters, etc. being connected, mobile control would allow customers to switch them on and off whenever they want. They could react to changing market prices and make use of intra-day lows.

In order to cope with the challenges energy providers are facing, the firms have to leverage the opportunity that lies in digitalization in form of new, significantly more complex business models. Those will be realized through partnerships across industries, very close customer relationships and with the aid of digital technologies. An example for such an innovation is the emerging market for intelligent household appliances which is typically known as “Smart” or “Connected Home”. Companies from different independent industries, such as energy, telecommunication, building engineering work together to launch such products and solutions. Other markets with similar constellations that are expected to become relevant for energy providers are cities or regions with intelligent infrastructures and civic services (“Smart Cities”). Moreover, facility and energy management including energy services as well as the expansion of decentralized infrastructures and prosumer solutions become highly relevant in the upcoming years.

As a consequence of the growing demand for tailored products and the dynamics of technological developments, the range of added value services offered by power provider companies will grow and become more complex. Having brought some light into the Smart Energy product definition, the question arises why complexity is an important issue for energy industry that

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needs to be managed adequately. Providers must be prepared to handle the ever-increasing complexity. If they are to master the related organizational and technical IT challenges, they will have to develop a holistic product lifecycle management approach which will enable them to adapt their product portfolios quickly.
4 The four design domains of PLM 4.0

On the way towards PLM excellence, which describes the state of lean products and services offered at the best market price, product quality, process quality, costs and time to market (cf. Golovatchev, J. et al, 2010b), 23 PLM design elements have been identified, that indeed have an impact on the four PLM design domains (see Figure 1). Amongst these 23 elements, some have more, some have less impact on the four design domains. We have analyzed the three use cases intensively and would like to highlight a few of them, which we find are very relevant. The developed PLM framework can serve as a basis for further evaluation of the impact of the IoE on the product development and management. The detailed description of the design and target elements can be found in Golovatchev, J. et al., 2010, p.22 ff.

The conducted evaluation phase has revealed that the designed approach can be applied to a diverse set of product and service related problems and seems specific as well as adaptable enough to be helpful in different business settings. In combination, these four factors provide a framework for development and management of complexity of the products in the era of the IoE.

As for PLM Strategy, PLM Process Variants and Customer Need Management have the biggest impact across all three sectors. Network-based product service systems have replaced long-lived products with limited variance. With the usage of modules and new devices, product lifecycles change and interdependencies between components and network infrastructures have to be taken into consideration. A PLM Strategy also has to be designed towards the market needs of ever changing customer demands and expectations. Feedback, demands and expectations have to be monitored and integrated in the development process. Individual solutions will be the mass production of the future.

The usage of IoE devices will affect products and services in a way, that they become more virtualized and service-oriented as they are by today. Thus, product model and product data have to be aligned more and better than ever. A structured mode based on an information
network needs to be applied across the entire organization to provide the reference data model, which makes further integration possible.

Value-Adding Partners will have the biggest impact on the PLM Process itself. Partnering is a great opportunity for penetration of new markets, access to new technologies and customer satisfaction. Nowadays partnering is indispensable since companies are forced to develop and implement new ideas. Nevertheless, the challenge will be to include all partners in the development processes. As products will become more and more complex, standardized processes are required. Not only the integration, but also the manageability of these value-adding partners has to be organized. The bigger the difference in size and scale of all involved companies is, the more challenging it is to keep them aligned. Through partnering the use of IoE devices can get more complex and the abundance of data more incomprehensive. Thus, partnering should be managed through partnership’s entire lifecycle. PLM IT Architecture & IoE Data Analytics can help to organize and structure the data flows with the aid of the Workflow, Document and Product Data Management System. It is important to note that the scale of partnering can and will differ strongly between industry verticals and inside them it strongly depends on the company size as well as strategic directions (make or buy decisions). However, we do see for midsize to large organizations partnering important in order to integrate innovative PLM solutions driven by deep technology as helpful to move fast.

With respect to the IT Architecture domain, three design elements show similar degrees of impact in all three cases. PLM in its entirety also needs to cover the IT domain of decision support systems. This is one of the most critical parts, especially taking into consideration that with the implementation of connected, data generating devices, Extended Collaboration Tools need to ensure a continuous data provisioning for controlling and product portfolio analysis. Thus, those tools shall make collaboration across different departments throughout the own organization, as well as with outside partners, possible.

By having IoE devices implemented, more and more data is gathered. In order to benefit from this immense amounts of data, Data Management processes and tools need to be set in place, because unstructured data is useless data. Without the huge amounts of data being structured, it cannot support decision making in a satisfying way. The design element of Data Management itself can be separated into three different aspects: data visibility and role-based access to information, harmonized data sources and data consistency, and versioning of product-related data. All of these them shall support availability, accuracy, timeliness and completeness of information towards achieving transparency for making the right decisions at the right time. Additionally, Cognitive Systems should be applied in order to analyze and review the data and to use for better understanding of customer requirements.

In order to benefit in the most efficient way, PLM IT Architecture & IoE Data Analytics needs to be in line with all other systems like CRM, OSS, BSS or finance. Only a full integration of a PLM application, for example, makes it possible to track and analyze financial data from both, a customer-related and a product-related point of view (cf. Golovatchev, J. et al., 2010).

In 2010 the authors composed a comprehensive study about PLM in the telecommunication industry for which they analyzed 50 communication service providers with regard to existing PLM structures. In 2013, this PLM approach was adjusted to the energy and utility industry.
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The results show that an integrated product lifecycle management enables companies to control the increasing complexity such companies are facing. The companies in the Industry 4.0 and during the digital transformation are faced with similar challenges as a result of the increased complexity which makes both problem settings quite analogous. The model proposed in the following section shows that through the structural similarity, problem-solving approaches can be adapted to the current challenges of the Industry 4.0 in the context of IoE implementation. The dimensions of an integrated PLM and the related design elements can be derived from the integrated management principles. The framework encompasses the four dimensions of PLM Strategy, PLM Process, Product Architecture, and PLM IT Architecture & IoE Data Analytics and should be used from companies as an orientation for their processes and products in the future (see Figure 2).

This PLM approach provides companies’ management with best-practice management tools that are collectively exhaustive and mutually exclusive in the four design domains — enabling management to evaluate and to integrate the right components within their organization according to the specific complexity level of the company. It is essential for any organization to do an in-depth internal PLM Audit executed from a carefully picked interdisciplinary team across the company and with external resources. The existing PLM has to be analyzed and evaluated very honestly and systematically. The design elements give in this paper help to structure the Auditing process along that logic. The strengths and opportunities inherent in such a PLM approach can be summarized as follows:

- It is holistic in a sense that it reflects all fields for action from a management perspective.
- It provides a wide range of best-practice management tools that simply need to be configured according to a company’s individual complexity level.
- It safeguards the business-to-business alignment as PLM is a collaborative process which includes the coordination of departments within a company, as well as the management of external parties.

Figure 2: Next Generation PLM Framework in the Era of the IoE
It spans the entire product lifecycle starting with the early phase of innovation management, through launch and market management all the way to the retirement phase.

The following tables in the next subsections (see Figures 3-6) aim to validate the elements on the three respective use cases. The size of the Harvey Balls thereby indicates the degree of impact for the customer of the IoE solution (e.g. Automotive OEM, Pharma companies, Energy provider). Design elements with a bigger impact have to be adapted more intensively, when keeping the virtualizing and service-oriented effect of implementing IoE devices in mind.

4.1 PLM Strategy – Understand and leverage the Holy Grail

The purpose of the domain ‘PLM Strategy’ is the alignment of the innovation and marketing strategy with the overall PLM Strategy to allow for a synchronization of the product development, market management and retirement processes. In order to do so, a strong link to customer needs management has to be ensured, as well as the safeguarding of lifecycle-oriented product and project portfolio management – controlling and monitoring the innovation and product pipelines. A strategic PLM Process management defines the cornerstones of the PLM Process by introducing PLM Process variants according to innovation level and by implementing consistent PLM Process reporting. What we have seen along our research is the importance of looking into the long term future, which we define in a 5 – 10 Years scope. This is a profoundly difficult task given the fact that fundamental technological and fundamental shifts make it hard to predict what will happen next. The baseline of this future outlook must be shaped by larger underlying trends and factors, which create a fundament for these long term projects (e.g. the spread of Artificial Intelligence, Robots, Cyber Attacks, and Autonomous Systems). The technological trends must be sidelined to projected changes in the particular market and most importantly the change of customer demand of the company. External support especially on the technological side by domain experts is highly recommended.

In particular, for the IoE companies the design of PLM Process variants and agile processes play a very important role by the development of various innovations. For example, the development of an energy tariff, as incremental innovation, requires a completely different product development process design as the introduction of new innovation complex products and services in the context of e-mobility (cf. Golovatchev, J.; Budde, O. et al, 2010b).
A successful product management for a complex product requires an active Customer Experience Management (CEM). CEM is based on two new innovative approaches that are increasingly important for the IoE industry: Customer Experience Design (CED) and Design Thinking. Using these approaches, it may be possible to constantly check and continuously improve customer interaction points during the customer journey. We are convinced that customer centricity will be more important than ever. Spending enormous amount of time by observing very carefully, deeply and analytically the customers and reviewing how customer requirements have changed in the past will help to outline the future. From change of customer demands it is recommended to literally work backwards and define alongside the Product strategy alongside PLM. One practical example of future customer patterns that we observed is the demand for being very fast in practically anything: new features, customer service, buying and servicing processes. Slow-moving product development cycles will not be very attractive anymore in the market.

PLM Strategy

![Figure 3: Impact of IoE on design elements in the domain PLM Strategy, own illustration]

4.2 PLM Process – Make collaboration and flexibility a core competence

Since PLM plays a crucial role for the organizational success in such highly complex and competitive markets as the utility industry, the relevance of an adequate PLM Process is self-evident. As indicated in the earlier section, the requirements on such a PLM Process have changed. Long-living products with a limited variance in their product structure along their lifecycle are becoming less and less relevant. Those products have been replaced by a new type of product-service-system that is characterized by the fact that it consists of a bundle of components/modules, each with a different lifecycle and a high variance and functionality.

As part of the definition of the functional integration, the organizational interfaces between the different departments and with the external value chain partners involved should be clearly defined.
4.3 Product Architecture – Organize complexity for efficiency

Many present quality deficiencies in the product development across all industries originate from a diffuse definition of products as well as from the inconsistent view on the object “product”. The right Product Architecture leads to simplification, cost optimization and sustainability of “product and service engineering” through the re-use of the production and service modules, shorten “time-to-market”, avoiding overlaps in development and reduce technical variance, availability of the product modules ranges of all service lines (factories) for all division of the companies.

The problem of building a modular product structure can also be solved by an appropriate Product Architecture. A product modelling on the performance level (market perspective), process level (service view) as well as the physical product level (material goods and network) is required. In addition, for modelling in these dimensions, a clear production view (data model) on an appropriate level of information technology, should be assured. For example, for e-mobility, the properties of the available plugs in the charging stations should be taken in the consideration (cf. Budde, Golovatchev 2011).
4.4 PLM IT Architecture & IoE Data Analytics – Make data a key asset

Finally, appropriate IT support Architecture and IoE Data Analytics are necessary for the efficient PLM Process implementation and for data management. For the companies in energy industry such a PLM IT Architecture must support the PLM Process in the dimensions: (1) Decision support, (2) Operational support and (3) integration of supplemental business applications. We suggest to rely on a PLM IT Architecture and IoE Data Analytics that re-uses, respectively customizes existing IT- components as far as possible. For the product-service-systems (PSS) mainly the systems for the project and workflow management are essential. In the IoE world the integration of supplemental business applications will play the very important role to ensure the effective product management. IoE Data Analytics is necessary for the understanding, evaluation and management of data. Through the three parts of it, Sensor Data Analytics, Machine Data Technologies and Cognitive Systems, the huge amounts of data flows can be structured and analyzed to create an additional value of the gained informational insights.

From future perspective, the amount of data will continuously arise. In this respect Machine Learning, Data Science and Big Data are common buzzwords. Machine learning applied to a PLM solution can help to evaluate and orchestrate the data in a self-organized way. Machine learning algorithms was developed to learn constantly and to optimize the outcomes and is regarding Gartner (2016) for the next 10 years one of the top disruptive technologies. It is an inexorable trend. We can clearly see this on Jeff Bezos (Amazon CEO) open letter to shareholders “These big trends are not that hard to spot (they get talked and written about a lot), but they can be strangely hard for large organizations to embrace. We’re in the middle of an obvious one right now: machine learning and artificial intelligence.” While Machine Learning is about predicting the data, Data Science is more about getting of the knowledge from data and processing of data. This is the part where PLM IT Architecture & IoE Data Analytics come into play in order to manage this information. And finally Big Data is the high amount of collected information which is very complex and too big to be analyzed with standard data processing tools. PLM IT Architecture & IoE Data Analytics is the key element to cope with challenges which may occur by the data overload. Along the years, companies moved from simple PDM

Figure 5: Impact of IoE on design elements in the domain Product Architecture, own illustration

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5 http://www.gartner.com/newsroom/id/3412017
Is your PLM calibrated for the IoE Era?

**PLM IT Architecture & IoE Data Analytics**

[Table and diagram depicting impact levels of IoE on various PLM systems across Automotive, Healthcare, and Energy sectors.]

*Figure 6: Impact of IoE on design elements in the domain PLM IT Architecture and IoE Data Analytics, own illustration*

systems that would store only CAD models and some meta-data to complete PLM solutions that can store the whole development process such as documents, pictures, videos and references. It is essential to spend time and closely conducting a technology analysis encompassing big trends and its implications on PLM systems.
5 Focus for success: Top 8 recommendations to get started

This paper pointed out the importance of PLM 4.0 in the era of IoE. Through a rising complexity and uncertainty companies are facing many challenges in business and technology environment. Digital technologies have to be seen as a big opportunity in order to perform well in the age of digital transformation. IoE offers companies as well as their customers many benefits through interconnecting devices which are logically associated with physical objects. Simultaneously, IoE entails a huge complexity due to the high amounts of data or different cycle speed. PLM helps to find solutions for these issues, because companies are in need of new concepts to handle potential problems.

In the following, 8 top recommendations will be presented in order to provide implications for managers and executives. The implications are composed from our wide knowledge and experience base which builds on collaboration with clients in various sectors.

5.1 Cooperate with experts – Leverage your learning curve through experience sharing

The right team needs to be set-up that will guide your PLM refreshment in the IoE era that consists of internal and external teams, a cross-functional future PLM transformation team with the clear goal to do assessment of internal infrastructure and PLM set-up as well as a look outside into market and technology. Involve experts to get an outside-in view on your PLM frameworks and also engage your suppliers to review it, towards achieving operational excel-
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...ence that lasts. Through the know-how of experts, it will be easier to plan and realize affordable actions. Besides, a professional conduction of PLM implementation will lead to long lasting and advantageous process according to the specific complexity level of the company.

5.2 Technology analysis and future proofing – Understand and explore the latest trends

In the next step a technology analysis should take place. Understand and explore the latest trends and tools in IoE Hardware and Software, Data Science, Big Data and Machine Learning. Apply the impact and potential partnering opportunities of those each of the four PLM Design domains. New trends and positions can arise in the value chain with regard to orchestration, operators of ecosystems or Big Data administration. Machine Learning delivers methods to predict a huge amount of data. It is ideally suited for PLM IT Architecture & IoE Data Analytics. The question that arises for managers is not if a PLM system will have Machine Learning features. The real question is: how to develop and deploy machine learning features applied to a PLM solution? Data Science will be the heart of new PLM systems. Together with Machine Learning, managers can find anomalies on the development process, analyze sentiment of documents, find trends on part number and release date curves. To manage Big Data, companies require complete PLM solutions that can store the whole complex development processes. Are PLM systems going to use Hadoop, Spark, Hive to access this huge amount of daily generated data? Or are they going to stay with old technologies? Explore, if Digital Twin technologies can be impactful in your development process – a digital representation of physical products combined with the possibilities of IoE can enable your company to constitute real world objects and have larger control over your company’s processes and manufacturing.

5.3 Carry out an extensive industry and market analysis

It is important to understand how your competitors manage IoE in their product lifecycle management. Probably there is a something to learn from them or gives an orientation on the maturity of peers inside your industry. Have a look on your current position across market analysis, trend analysis and scouting. Which position does your company have compared with other companies when it comes to adapt IoE to their products? Make sure to highlight which trends in the market and industry result in IoE and how will data generation, analytics and intelligence influence yourself, your competitors and customers. Find the risks, challenges and chances caused by IoE on your business model. Reflect if you already integrate real time information of customers in order to use this information for improving your products and developing your offerings. A further important element is to take a look at the PLM solution landscape: which new PLM solutions exist? Are there dramatically new and different approaches by established or nascent players?

5.4 Internal PLM & IoE audit

Analyze in-depth your existing PLM Framework and Strategy – is it up to the mark? How deep has your field of business been saturated by IoE and industry 4.0 so far? Proof which areas of the value chain might be affected by IoE and how your PLM can be influenced by the changes or most probably is already heavily impacted. Understand your main cost drivers, analyze sectors in your company where more information would help you to make smarter decisions. Check your PLM approaches in order to estimate required implementations. Think about which solutions the most innovative players in your industry are already applying. Evaluate and plan according to your demand.
5.5 Future customer – What are customer expectations of tomorrow

Find out how future customer requirements in the digital era change the way you develop and manage products. Obsessive customer centricity will have an even higher importance in the future. For a better understanding of it you should step into the customer’s shoes. Take into account customer's expectations for the design and application of your product but also for your product strategy alongside PLM. Through intensive quantitative and qualitative observations and analysis of customer requirements, future trends of his behavior can be anticipated. Nowadays, fast-moving product and development cycles are in demand such as new features coming on the fly as a product evolves (e.g. Software Updates), customer service or buying processes. An intelligent method also can be to take existing recent trends and just extrapolate them into the future: what effect has the on-demand economy like Uber already and how can it look like in 5 years? What is the future experience and design of software updates? What is accelerating product shipment already and how can that look like in the future (drones, self-driving trucks etc.). In sum, smart PLM solutions should be defined by future customer needs as its most important driving factor.

5.6 Extreme use cases

Develop in your future PLM transformation team three potential high-impact IoE Use Cases applied on your products or on products in your industry and simulate, how it would impact the four PLM Pillars in the way they are designed at your company today. How an extreme use case should look like? It should face the future opportunities combined with a high relevance for your sector. If your company is in the Automotive sector your extreme use case could comprise a case of a self-driving car with the opportunity to design the interior in a completely different way – more space due to the elimination of handlebars and circuit, car seats might become unnecessary and will be replaced by beds. This exercise makes it easy to look into the future from a user experience and product point of view and work backwards and it will be a healthy eye-opener and stress test for your existing PLM framework.

5.7 Formulate a PLM 4.0 Strategy that looks to the next 10 years for your company

A PLM Strategy 4.0 should be developed for realization of your company’s vision and is based on the findings you have conducted in the previous steps. Investigate the next transformation phases and identify the necessary steps and experts. The usage of IoE devices has consequences for products and services therefore product model and data should be coordinated. A PLM Strategy should prevent your production from bottlenecks. Integrate your products, sensors and data in PLM 4.0 and understand PLM 4.0 as a comprehensive and highly critical function for IoE with potential gains across your whole enterprise. Address PLM 4.0 in an integrated and holistic fashion and achieve sustainable competitiveness and market success. The PLM strategy should have a scope of 10 years.

5.8 Carefully execute the Strategy and monitor your progress

If you start adopting and experimenting with IoE solutions, we strongly recommend to review your existing PLM framework and carefully assess the impact IoE solutions will have. As already mentioned PLM comprises four PLM design domains which help you to cope with challenges on various process levels: PLM Strategy, PLM Process, Product Architecture, and PLM IT Architecture & IoE Data Analytics. Evaluate your PLM Strategy, master the most important design elements and put yourself in the pole position towards PLM 4.0.
6 Conclusion

The key goal of this paper was to understand hot product/service related topics, business- and go-to-market models of the participants inside the IoE market and trying to understand how these new emerging IoE players will change the PLM. Especially customers, e.g. large enterprises who are picking up to adapt and test these new IoE. To do so, the paper aims at integrating knowledge from the diverse fields into a comprehensive, practical approach for the development and implementation of the products and services using IoE technologies.

The research results show that it is generally feasible to establish a general management perspective on development of products and services within IoE. Furthermore, new areas of research could have been identified by focusing on practitioners’ challenges within IoE and new product development that have not been investigated by recent literature. Moreover, a future outlook across selected key sectors (with IoE product related issues in Healthcare, Automotive, and Energy) is also a focus of this analysis.

This paper focused especially on the needs and challenges of innovation and product managers who have to find ways to cope with rising uncertainties and the problem of increasingly complex business environments and digitalization. Therefore, this paper presents first learnings that guides practitioners through implementation of industrial IoE and its impact on new product development and management. It gives them guidance on how the company’s IoE project could be linked with its new product development initiatives. Ideally, managers are able to achieve improved product market fit, save costs due to early problem identification and enjoy a wide range of communicative advantages by using the results of the paper.
7 Reading on


8 The Authors

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9 The Company

Detecon International is one of the world’s leading management consulting companies, one which combines classic management consulting with outstanding technological expertise. This approach of thinking in terms of these two areas simultaneously will determine the future performance of every company.

Our business is consulting, our strengths are digital technologies and networks. For more than 30 years, we have been supporting companies and telecommunications providers around the globe, helping them to improve the sustainability of their competitiveness and performance capabilities along the entire value chain with the aid of innovative technologies. Moreover, we offer our clients solutions in all fields of classic corporate consulting: strategy, organization, processes, and HR management.

Digitalization has advanced to become today the overriding challenge of a globalized economy cutting across the boundaries of industries and sectors. Digital technologies are in our world no longer the vicarious agents for the business side – IT is becoming the core of products, business models, and processes. Broadband networks create the fundamental platform for a networked world. The consultants at Detecon help their clients to rethink business models, to digitalize procedures and processes, to network customers with companies, and to build the platforms for customers, companies, and products. Our unique selling proposition is the combination of technological expertise, business know-how, and transformation experience acquired by our consultants during more than 20,000 successful projects in Germany and abroad, from San Francisco to Beijing. We understand the processes and business models of our clients and know how they can exploit technology to gain a decisive and sustained lead over their competition. We build the bridge between the business and the ICT perspectives. These are the skills which enable us to guide our clients through digital transformation. Detecon is a subsidiary of T-Systems International, the key account brand of Deutsche Telekom.

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