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Communication and collaboration

in the context of smart engineering

PROSTEP

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Industry 4.0 offers enterprises great opportunities for growth but also presents them with new challenges. Without smart, connected products, there can be no digital factories and also no digital transformation of business process and business models. The development of smart products requires the intelligent linking of engineering processes across different enterprises and domains. That is what we mean by "smart engineering". A prerequisite for smart engineering is an overhaul of existing PLM architectures and end-to-end digitalization of the entire product lifecycle. This white paper describes the challenges posed by Industry 4.0 when it comes to PLM processes and systems and presents possible approaches for mastering these challenges. In a wider sense, Industry 4.0 means the intermeshing of the value chains in development, production, sales and service using state-of-the-art information and communication technologies. The force driving these changes is the increasingly rapid digitalization of workflows, which will have a major impact on our economic activity. It will fundamentally change the way we develop, manufacture and work in the future. First came steam engines, assembly lines, electronics and IT, now it is smart factories, smart engineering and smart services that are driving the changes which are also often referred to as the "fourth industrial revolution".

The white paper entitled "Smart Engineering: The Impact of Industry 4.0 on PLM" published by PROSTEP AG (Darmstadt) and presented here in a modified version takes a look at the impact that Industry 4.0 will have on future engineering and PLM processes and draws conclusions as to the further development of PLM.

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Smart engineering

Smart engineering is intended to provide support for the development of smart products and services, as well as a networked production setup that includes the associated production systems, over the entire product lifecycle. The objective is an end-to-end digital value chain.

The digitalization of business processes requires a complete digital product model that not only maps the development process but also the entire product lifecycle (digital master and digital

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By Martin Strietzel

How must a tool infrastructure be designed if it is to make possible smart engineering that truly satisfies the requirements of Industry 4.0? The author is of the opinion that expanding an existing IT backbone, such as PLM, into a "data hub" will only lead to the desired result if important steps in the direction of openness and agility are taken. A position paper on the prerequisites for an IT infrastructure that make the digital master and digital twin possible.

twin). Smart, connected products require interdisciplinary engineering. If it is to be possible for different development partners to work together on the system properties, a cross-discipline definition is needed. Model-based systems engineering closes this gap and makes possible a complete digital representation of a product over its entire lifecycle. Product data today is still managed in data silos in separate backbone systems that are only partially integrated if at all. What is needed is secure and efficient access to consistent and up-to-date product data over the entire product lifecycle. The Internet of Things (IoT) and Big Data allow data from the entire product lifecycle to be analyzed and utilized. Access to data relating to wear and tear, operating parameters, usage statistics and to service data not only enables predictive maintenance but also ensures fast feedback regarding customer benefits and expectations in the development process. This facilitates and accelerates product optimization in terms of functionality, cost and quality.

PLM and smart engineering

The IT systems referred to by the umbrella term "product lifecycle management" (PLM) play a crucial role when it comes to organizing a product engineering process that is geared to innovation. The PLM infrastructure, which has expanded greatly in recent years, is therefore a natural and powerful instrument for achieving the goals associated with smart engineering and Industry 4.0. PLM has a vital role to play in the digitalization of value chains and implementation of smarter engineering processes. If you look at today's development processes with a view to the challenges posed by smart engineering, you will see that mechanical, electrical/electronic and software development at many companies is still rooted in different organizational units. This often means that the same tasks, such as change management or functional modeling, are performed using different IT systems in different processes. This wide range of systems, in particular, is a challenge that can be met with modern PLM concepts. It is, however, important that the right course be set and the approach best suited to the individual circumstances be selected when designing the architecture. In general, we need strategic approaches which, where possible, reduce the complexity of the PLM infrastructure and make the dynamics of the changes involved in the restructuring manageable. They should also be capable of dealing with fuzzy future requirements and terms of reference. It can be assumed that process innovations will result in a significant increase in efficiency when developing, manufacturing and servicing smart products. If these opportunities are to be exploited and, at the same time, the risks minimized, the aim of creating new and more efficient PLM processes should be approached step-by-step. The following strategic PLM-related subject areas have been identified as areas of activity:

- Agile product development processes and modular PLM architectures
- Integration of ALM, PDM and ERP systems
- Systems engineering and model-based systems engineering
- Interdisciplinary variant, configuration and change management
- Collaborative PLM processes
- Implementation of the digital master model

Existing PLM solutions cannot be used to address these areas of activity or only with a high level of implementation and administrative overhead. Most PLM experts agree that what we need are federated systems with a modular, open architecture. A modular, multilayered architecture allows data to be linked across different systems. The creation of a digital workspace, which provides every user with the information and functions they need to perform their respective task in a uniform user interface, is a key prerequisite for making the growing complexity of the systems and processes involved in the interdisciplinary development of smart products manageable. Intelligent algorithms provide users with support here and allow fast, personalized access to information via role-based graphical user interfaces.

Agile processes and modular PLM architectures

The development of products and production systems that are linked via the Internet places new demands on how PLM processes are organized and what PLM system landscapes look like. The integration of not just the different engineering disciplines but also the development and manufacturing planning departments or the development and service departments is becoming increasingly important. In other words, PLM is becoming multidisciplinary. This is something that companies must take into consideration when formulating their PLM strategies. A modern PLM strategy must anticipate future changes; it must be proactive, innovative and flexible. Providing support for new, service-oriented business models requires, for example, the tighter integration of data from development and production with information relating to product utilization in order to support predictive maintenance and smart services. In this digital information loop, PLM is not always the owner of the information but it is the broker. The key objective of a PLM strategy, namely making uniform, binding and up-to-date product information readily available, must therefore be rigorously expanded – but not in the sense of a giant data store, where all the information is managed according to the same guidelines. Monolithic system architectures are not flexible enough to keep pace with dynamically changing requirements. The increasing complexity of interdisciplinary product development can only be handled by a modular overall architecture, comprising federated subsystems with intelligently linked information. A modular architecture creates scope for adapting and redesigning process and reduces the effort involved in doing this. Key requirements for the adaptability of this modular PLM architecture are openness and support for standards, as it is these standards that make it easier to exchange individual subsystems. When planning the new IT infrastructure, it is therefore important to always make sure that system suppliers and integrators observe the Code of PLM Openness (CPO). The transformation of existing system landscapes is a major challenge. Companies not only need to find the IT infrastructure best suited to meet their needs but also define a strategy for its gradual implementation. To achieve this goal, companies need a good overview of the solutions available on the market, on the one hand, and the integration know-how needed to incorporate them in their existing system landscapes and migrate existing information, on the other.

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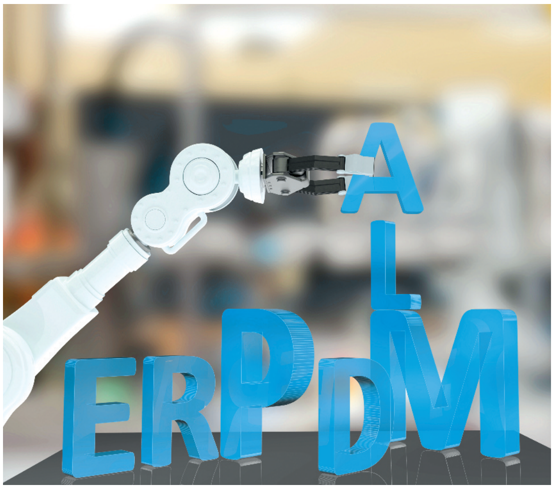
Integration of ALM, PDM and ERP systems

Today, a variety of different management systems are used to control the processes involved in mechanical and software development as well as logistics and production: ALM (application lifecycle management) for the software, PDM (product data management) for the mechanical systems and ERP (enterprise resource planning) for production control. The ability to access, at any time, up-to-date and binding information about a product has always provided the basis for making sound business, economic, technical and organizational decisions. Industry 4.0 and the digitalization of products make the end-to-end availability of information about a specific product crucial to, for example, being able to offer product-related services over the entire lifecycle of a product. The lack of data integration between systems, the departments in an enterprise and within value and supply chains is a major obstacle when it comes to establishing new business models. Responsibility for maintaining the data and managing the data logistics usually lies with the process owners in the respective organizational units. At the interfaces between development, production, service and maintenance, however, data passes between different systems and is thus represented differently and ownership of the data changes



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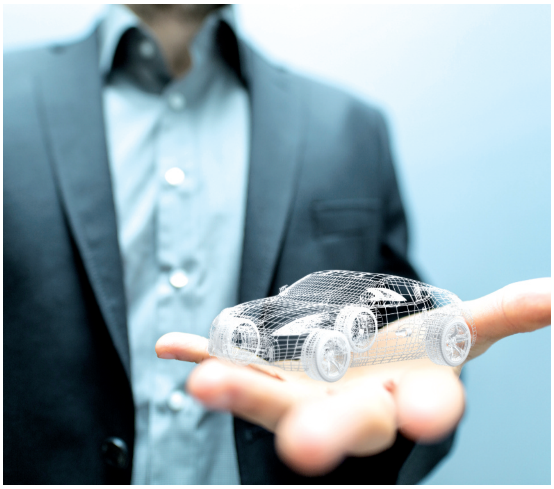
This has always resulted in the need for automated data transfer in both directions so that, for example, it is possible to identify those products in which a defective part has been used or which software version has been installed on a certain controller. The growing influence that software is having on key product characteristics gives rise to additional requirements regarding the integration of ALM, PDM and ERP, especially when it comes to the parallel handling of multiple product variants. This is a result of the different speeds at which mechanical and software development are performed. Mechanical parts require a long lead time before they can be used in practice, especially when they are manufactured using complex tools. Software allows for late changes, which however also have to be tested and documented. System integration must permit both read and write access and support search operations for documentation purposes, which gives rise to a need for data networking. The lightweight integration of multiple systems in a single cockpit (user interface with late aggregated data) is one of the attractive options. It must also be possible to manage data sovereignty despite the changing status of the information objects.

It would be an illusion to think that one of the management systems could be expanded to create a data hub.

This fictitious “hub” would not be able to meet the requirements relating to secure data management nor would it offer the flexibility needed for agile processes and innovation. The best solution is a network comprising ALM, PDM and ERP systems that allows the entire lifecycle of a digital product representation to be mapped. The integration of the data sources needed for the development and manufacture of smart products will be implemented by means of a powerful integration platform. It ensures the highly efficient linking of data without any need to overhaul the existing ALM/PDM/ERP landscape.

Systems engineering and model-based systems engineering

The development of smart, connected products is a highly interdisciplinary process. Not only must the engineering disciplines traditionally involved in mechanical, electrical/electronic and software development be integrated in the development process at an early stage but also new participants, so that their various requirements can be incorporated: the production planning department, which has to develop the appropriate systems, the service department, which will be offering the product as part of a service package, and external partners, with whose systems or platforms the products are to be connected. Domain-specific IT tools and methods provide little support for this interdisciplinary process. One recommended alternative is systems engineering, an approach used in the aerospace industry. It supports all the disciplines involved in development throughout all the phases of the product engineering process, independently of the procedural model being used – regardless of whether it is based on the well-known V model or on agile approaches. The requirements and functions of the system and its subsystems, as well as their interaction, are modeled, simulated and validated in abstract form on the basis of the analysis of who is actually involved in the product development process. A systems engineering-based methodology that is becoming increasingly popular in industry is model-based systems engineering (MBSE) with the help of SysML. MBSE formalizes the methodology employed for system modeling and system validation, making it easier for models to be exchanged with other participants in the process and reused. Although systems engineering methods and tools are already being used at many companies, their use generally takes place separate from the discipline-spe-



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cific development processes. On one hand, the challenge involves establishing a cross-discipline development process for smart, connected products and, on the other, integrating the tools and methods in the PLM processes in such a way that traditional functions such as version, change and configuration management can be used on the MBSE artifacts.

Model-based definitions and digital masters

Ever since the introduction of the first 3D CAD systems, development departments have been pursuing the idea of replacing paper-based documentation with an entirely digital product description. Thanks to powerful visualization tools, geometric models are today also available in digital form outside of the development and engineering departments and can be used to optimize other business processes when embedded in 3D PDF documents for example. When product data is transferred to the work preparation department, however, paper drawings are often still being used. The 3D master model provides the basis for end-to-end drawingless processes but confines itself to the geometrical and mechanical dimensions of a product. In the meantime, however, products that were primarily mechanical in nature now include an increasing number of software-controlled functions. They are perceived as being part of a system and must be developed as such. The production process is also undergoing a profound transformation brought about by Industry 4.0. Flexible production systems respond dynamically to external influences and control production quality autonomously. To do this, all the product parameters relevant to production must be available in digital form. The concept of a digital master takes the idea of a 3D master and develops it further, taking account of the new development and production requirements. A digital master is a complete, digital product model comprising all available product information. In addition to geometric and mechanical properties, this includes electrical components, embedded software, material properties relevant to production, process information for production and commercial information from the ERP system. The composition of the digital master changes according to the information relevant at any given point in time throughout the product lifecycle. The digital master provides the basis for the digital twin and supplies all the processes with the information they need. While the digital master represents the complete, digital description of a concrete product, the digital twin includes other information that is relevant for simulation, production and service. Purchasing processes, technical documentation, audit and approval processes, as well as the marketing department, can use the digital master as the main product model. The challenge for companies is identifying the business processes that will allow digital masters and digital twins to deliver their greatest potential benefit.

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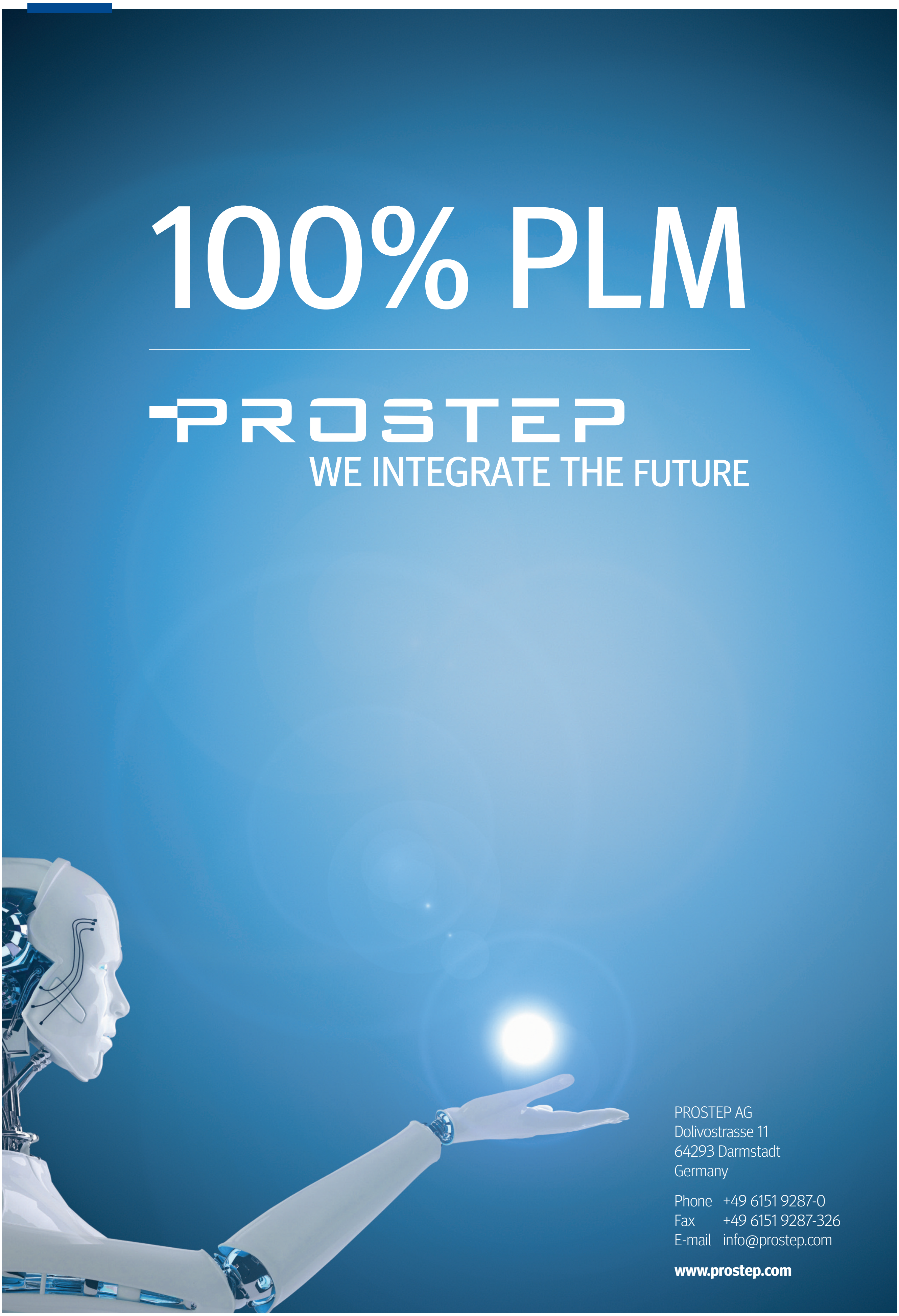
Interdisciplinary variant, configuration and change management

Coping with increasing product complexity and ever-larger numbers of product variants throughout the entire development process is one of the main challenges that needs to be addressed within the context of Industry 4.0. The methods used to do this must also be able to meet the requirements of smart engineering, such as agile processes, short development cycles, rapidly changing market conditions and consistently high demands placed on product quality. In the age of digitalization, mastering product and process complexity is thus a core competence when it comes to product development. Successful complexity management requires a suitable product model comprising a functional view and the product structure. If such a product model is to be made possible, the product architecture must be adapted accordingly and the product model created as a digital master. The digital master permits efficient monitoring and control of product complexity within the process. This involves mapping not only the product dependencies (engineering data, software, documentation, simulation data) and product characteristics in an appropriate manner but also all the variant information. With the help of suitable methods and tools, the digital master can be used as the basis for an extensive analysis of the consistency of the product description and characteristics and thus ensure quality. These methods and tools allow product variants to be monitored and controlled throughout the entire process, which significantly shortens the change cycles. In addition, these methods and tools permit flexible change management as the repercussions of changes can be seen immediately. Mastering complexity is thus of vital importance for a company's PLM processes and a prerequisite for the successful implementation of Industry 4.0 initiatives. It requires that product architectures be revised accordingly and that a digital master be implemented in cross-domain development processes in such a way that it maps the system properties for all the variants. At the same time, appropriate methods and tools must be deployed that allow all those involved in the process to cope with the product complexity reliably and with as little outlay as possible.

Collaborative PLM processes

Technological innovation in the context of Industry 4.0 is leading to greater collaboration across companies and domains. It is not only new partners but also completely new players that have to be incorporated in collaboration processes. Today's PLM systems are not designed for this, which is why a great deal of information is still being sent in unencrypted form, i.e. without any protection for intellectual property, via email. The option of using PLM in collaboration scenarios will become increasingly important in the context of Industry 4.0. This should be taken into account as early as possible when defining the focus of PLM strategy. Many industries will see the rise of innovative new companies that develop, manufacture and market products together. These companies will compete with established manufacturers. The partners to these companies assume responsibility for subprocesses in the product development process in a flexible manner and in changing constellations. This places increasing demands on the flexibility of the processes to be designed and creates a growing need for collaborative technologies and methods that can be implemented immediately. Incorporating external partners and suppliers that offer their services in the global network requires collaborative approaches that can be easily integrated in existing PLM systems. They must provide support for very different scenarios, from occasional collaboration with sporadic data exchange through to regular provision within the framework a long-term partner relationship or joint venture. Not only reliability but also data security and the protection of intellectual property play a key role in collaboration scenarios. Collaborative PLM processes are not, however, only a question of the technologies used, they also call for a holistic approach to organizational structures, technology and employees. The aim must be to design collaboration processes in such a way that the overall efficiency and effectiveness of people and systems is optimized. This is why current collaboration processes and future requirements must be analyzed closely before the relevant solutions are implemented.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