# _Digital Thread

Connecting Service, Engineering and Eco-Design from the perspective of the organizational change management


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# _Digital Thread: Connecting Service, Engineering and Eco-Design from the perspective of the organizational change management

The digital thread concept is the foundation of digital transformation and provides access to always up-to-date, reliable and extremely valuable data collected and aggregated from the entire development process, including the service area. This is very important in the context of today's ecological requirements. Access to data also provides incredible opportunities related to its use by AI analytical algorithms. However, building a digital thread poses a huge challenge not only technically, but also organizationally. The article explains what a digital thread is and how it is built, and also presents a practical example that allows you to properly plan its implementation and maximize its positive impact on the organization.

## _Introduction

The product lifecycle management (***PLM***) paradigm, in its essence, covers the entire product lifecycle, from the initial idea to end-of-life activities (recycling, refurbishment, disposal, etc.). However, when it comes to systems implementing the concept, the greatest progress over the past 25 years has been in the area related to product development management, i.e. CAD data management, product configuration, configurable product management (options and variants) and related processes (e.g. engineering change management). Systems supporting the equally important area of Field Service Management developed at the same time, but largely in isolation from ***PLM***. In other words, while systems supporting product development, which are part of ***PLM***, were developing, Field Service Management systems were developing in parallel, but their level of integration with ***PLM*** is usually limited. As a result, although valuable data is acquired from products in use, companies use it to a limited extent because this data is not exposed between functional silos. The consequences of this are twofold – service data cannot be used in the design of the next generation of products, and engineering data cannot be used in the service area.

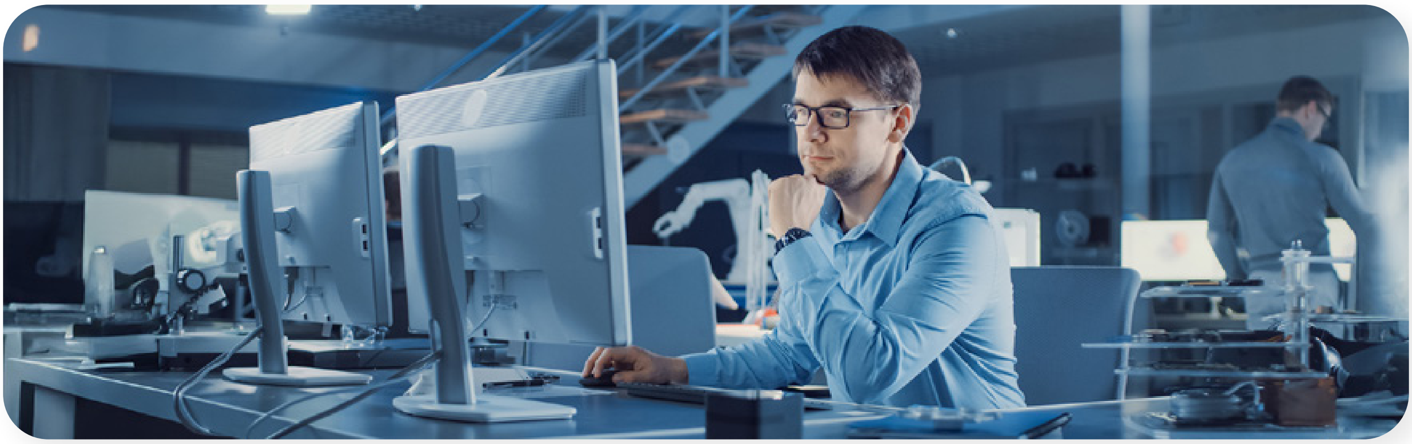
## _Challenges to overcome

Fragmented data systems

Limited service-to-design feedback

Environmental design challenges

Although there are advanced platforms for managing data in individual areas, only some of them are integrated with each other. Often, data related to requirements, system architecture, product development, maintenance, operation of intelligent products and service management are stored and managed in separate systems and operate on different, incompatible data models (interoperability is not ensured between them). This prevents insight into complete product data and traceability. For example, in the case of the need to replace a component in a product delivered to the customer 10 or 15 years ago (e.g. in a high-power transformer), the service employee needs to use the design documentation, but they only have the serial number of the component and the name and serial number of the product the component is part of. How and in what system (database) should they search for technical documentation, considering the fact that they work in a service branch in a country other than the one in which the product was designed and manufactured? Another example is when a selected product component regularly breaks down, and the problem concerns a given generation of the product. The service performs regular repairs of this component. Does the design department have the possibility to use the information recorded by the service and on this basis can redesign the product so that the problem will no longer occur in the next generation? Let's examine another example, this time related to the issue of ecology. It is indisputable that products today should be increasingly environmentally friendly. To ensure this, they should be designed in accordance with ecological design principles. However, this is currently hampered because design teams have a very limited ability to use data extracted from the current generation of products that are in use. This means that they are unable to effectively calculate the actual values of a product's environmental impact categories and make changes to new products and manufacturing processes on this basis (e.g., use different, more environmentally friendly materials or optimize manufacturing and supply chain processes).



## _The way it should work

Let's assume that the solution to these problems can be an integration platform that allows, with relatively little effort, for integrating solutions from the product development area with the ***PLM*** system acting as a data backbone and with systems from other areas, e.g. manufacturing, sales, etc. The ***PLM*** system ensures the integration of product structures built at the product development stage, i.e. from the mechanical and electrical design activities (MCAD and ECAD), through developing the engineering and manufacturing product structure (EBOM and MBOM), to the service structure (SBOM). ***PLM*** also supports product design using systems from multiple suppliers (xCAD), as well as the product diversity management paradigm, so it provides the ability to easily generate product variants (which is particularly important in the case of highly configurable products, such as modern cars or office chairs). It also provides support in the creation of assembly and service instructions based on engineering data, and these in turn are used to develop parts catalogs. The integrated structures evolving over the product life cycle are shown in Figure 1.


**Figure 1.** Integration of product structures built at the product development stage in PLM system

Although modern ***PLM*** systems are excellent at the tasks for which they were designed, after the analysis so far, their limitations become apparent. Therefore, a company that wants to achieve a smooth and seamless flow of data throughout the entire product lifecycle and across all its business units (which is the path to realizing a digital factory) must overcome this limitation.

Solutions such as the aforementioned standardized integration platforms provide the ability to go beyond the boundaries of standard ***PLM*** and integrate with domains upstream in product development (requirements management and system architecture), with the supply chain and manufacturing systems (ERP and MES), as well as streamline two-way data exchange with post-production phases, i.e. the field service management domain. A schematic diagram of the unified integration platform is shown in Figure 2.

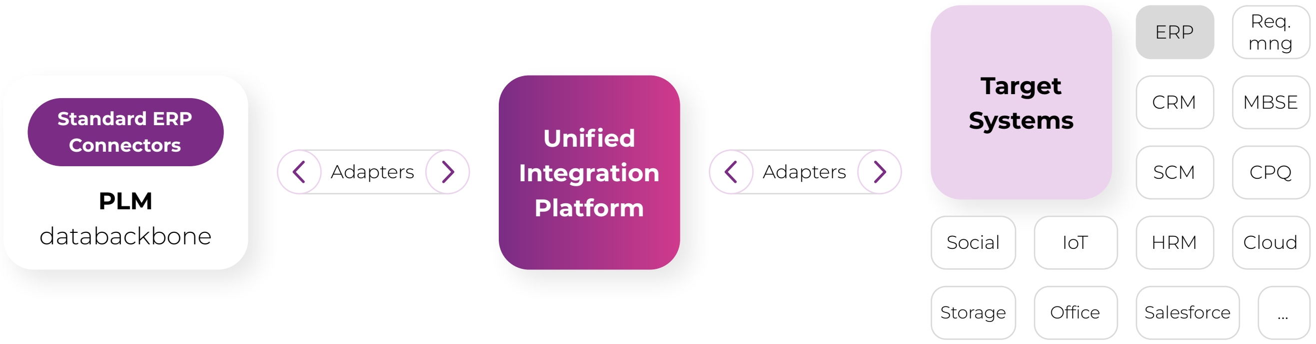



**Figure 2.** Unified integration platform providing access to many domains

Including field service management area into the digital thread provides access to valuable service data on the one hand and supports service activities on the other. Typically, service personnel (especially those who support products on-site when they break down, as happens with transformers, elevators, or trains) do not have easy access to technical documentation.

If they want to order the necessary components, they may need to see the complete technical documentation for this purpose. If the system they use is integrated with the ***PLM*** system, this problem does not exist at all.

Having access to complete data obtained through the integration of domains throughout the entire life cycle can successfully feed solutions for designing environmentally friendly products (a concept referred to as Eco-Design) and serve as the basis for calculating the environmental impact of designed products.

The collected data – especially that are obtained from production machines and products in use, as well as service data – can be used as data sets to train analytical models (e.g. artificial neural networks using deep machine learning), which enables automatic optimization of the operation of machines and devices (e.g. to reduce energy consumption) or prediction of product failure states.

## _Let's build it

Although many theoretical digital thread examples can be found in many scientific studies, access to complete examples based on actually existing and integrated applications is not widely and easily available. Let's use the PTC application ecosystem as an example of overcoming the challenges discussed. Starting from the beginning of the product lifecycle, Codebeamer acts as a comprehensive platform for application lifecycle management (ALM), including requirements management (in this case, for the entire product, not just the software). Assuming we are considering a complex intelligent product or product-service system, ***PTC Windchill Modeler*** supports a systems approach by providing the ability to design complex systems using the SysML language (this approach to systems design is referred to as Model-Based System Engineering, MBSE).

Moving further along the product lifecycle path, we have the stage of building 3D models using many different varieties of computer-aided design techniques (mechanical, electrical, hydraulic, etc.).

## 01

PTC Creo Parametric is a comprehensive solution for mechanical design, and ***PTC Windchill*** acts as a platform for building and managing the engineering structure of the product integrating CAD structures created in the design tools.

## 02

If, however, we additionally want to use electrical design tools, EPLAN – although not part of the PTC portfolio – may still be a great solution. This system can be integrated with the ***PTC Windchill*** system, enabling us to build and manage a multidisciplinary product structure consisting of both MCAD and ECAD objects.

## 03

When we want to build an overloaded structure of a configurable product in order to then generate product variants, the ***PTC Windchill*** system module called Options and Variants supports this approach.

Once defined, the engineering structure can be easily transformed into one or more production structures (if it is necessary to include multiple factories) and supplemented with elements that do not have a graphical representation but are part of the bill of materials (e.g. grease, glue, oil, etc.). Based on the manufacturing structure, also in the ***PTC Windchill*** system, a manufacturing processes structure is created. 3D data generated in the design tools are directly used here to build visualizations of manufacturing operations in the PTC ***Creo Illustrate*** tool. Operations related to assembly or packaging of the product are defined in a similar way. The final effect in the form of dynamically generated complete manufacturing, assembly or packaging instructions is prepared in the PTC ***Arbortext*** package and is associative with the elements of the product structures to which they refer (***Creo Illustrate***, ***Arbortext***, and Windchill are integrated with each other). In other words, full data traceability is ensured within the ***PTC Windchill*** system. This is of great importance in the case of complex processes that require complex and multi-aspect (requiring consideration of many criteria) impact analyses. The best example of where this is critical is in the engineering change management process. To illustrate this, imagine that the system automatically informs the process engineers responsible for preparing assembly or work instructions about a change introduced by the designer in the technical documentation in the CAD system. All this is thanks to the associativity between the structures within the ***PTC Windchill*** system. The presented structures are also the starting point for subsequent transformations to the service structure or for generating a service parts catalog, for which ***PTC Windchill*** SIM is used. This is done in an almost identical manner. It is worth noting that the features described here provide even greater benefits for complex, configurable products where the complexity of the data and associated business processes is much greater.

When a product leaves the factory, tools from the middle of the product lifecycle come into play. The first of these is the ***PTC ThingWorx IoT*** platform, which provides the ability to collect data from sensors placed in the product. This gives insight into the actual operation of the product and serves as the technical basis for building advanced analytical solutions in the field of digital twin.

This data can be used anywhere in the digital thread, but it is particularly important in three areas:

- Quality assurance
- Designing subsequent generations of the product
- Business analytics

This allows not only to draw conclusions for the future from the analyzed data, but also to act actively – in the case of using artificial intelligence models, it gives the ability to ***predict unfavorable events*** (e.g. malfunction or failure) and take preemptive actions. Such knowledge gives it the ability to act in advance and eliminate downtime.

This brings us to the maintenance stage, or more precisely, field service management, for which the PTC ServiceMax solution is responsible. With access to product structures and technical documentation, service personnel can operate effectively, and engineering teams can benefit from service data. With access to product engineering data (such as the history of what materials were used and which processes were performed to design, build, and maintain each product), service planners can better plan for resource needs or parts availability to support the predicted maintenance requirements in the field. Execution-focused stakeholders, such as service technicians, can benefit by gaining better insight into the product parameters and service specifications attached to the product to more effectively diagnose service situations and apply appropriate parts or work instructions. This maximizes their efficiency, which is crucial in times of increasing product complexity and limited service resources.

At the highest level is the ***ecoPLM*** solution, which uses the complete data provided by the digital thread to assess a product's environmental impact. What is extraordinary is that while such an assessment is usually made after the fact, the ***ecoPLM*** system – having access to data related to the product's impact on various aspects of the environment and based on the EF 3.0 method developed by the European Commission – allows for the prediction of this impact. Thanks to this, products can be optimized from an environmental perspective at the design stage.

As a result, the negative impact of the product on the environment is minimized before it actually occurs. Although ecological design methods (referred to as Eco Design) have been known and used for a long time, what is revolutionary in this case is that – thanks to the use of a digital thread – ecological design is supported by data collected from the entire extended product lifecycle. And this is not even the end of the possibilities. This only opens the door to the use of artificial intelligence methods or further integration via blockchain with a digital product passport.

The whole is complemented by an integration toolkit that bridges the connection and exchange of data with a digital thread built using systems from PTC's portfolio of many other systems, such as ERP, CPQ, SCM or MES. Analytical, or ***IoT*** or CAD tools from other vendors that cannot be integrated with ***PTC Windchill*** in a standard way are also supported. In this way, the flow of data can go in multiple directions, allowing the ecosystem built in this way to be treated as a kind of digital enterprise implementation.

The described ecosystem of PTC solutions that includes digital thread, taking into account the integration toolkit and assuming that the process is carried out in accordance with product sustainability, is illustrated in Figure 3.

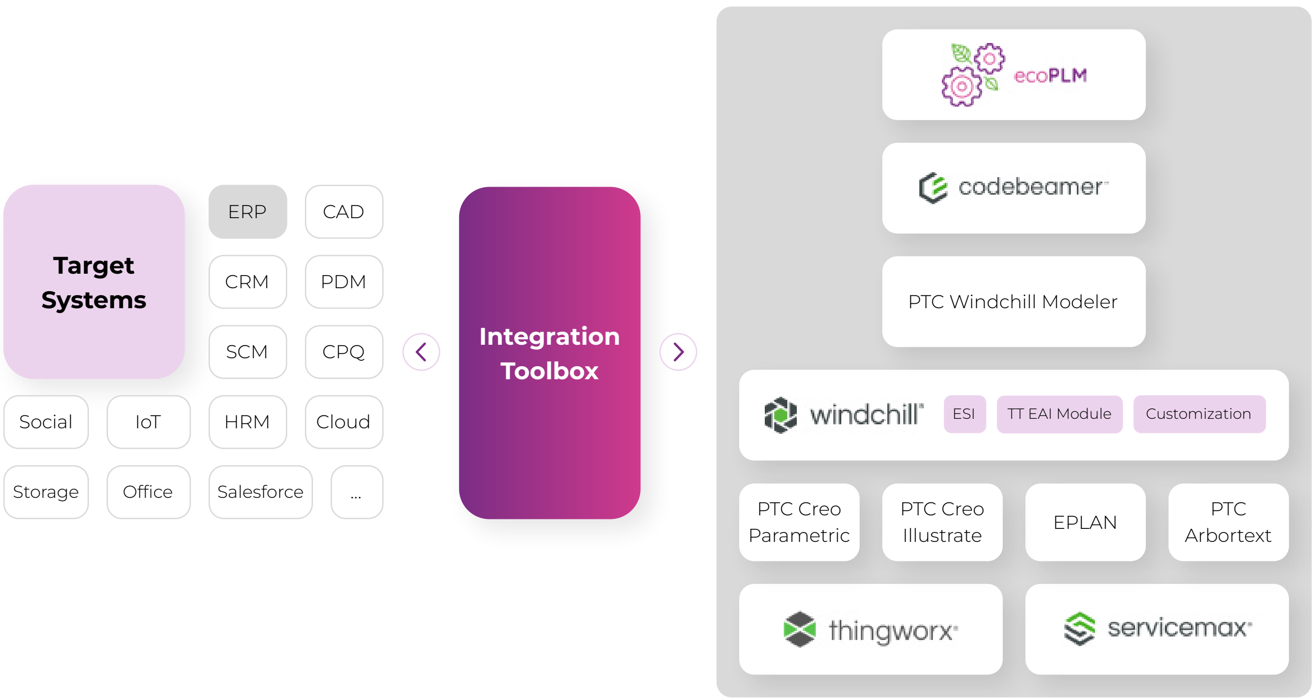



**Figure 3.** Ecosystem of PTC solutions comprising the digital thread

By fostering collaboration between teams such as the technology vision task force, this integrated ecosystem ensures a robust and future-ready digital enterprise strategy.

# _Consulting as a competency of the future

Implementing and integrating IT systems with such complex architecture requires not only sophisticated and advanced technical skills, but also close cooperation at every stage between the supplier of the solution, the customer and the end users. It is generally believed that the most important stage for the success of the entire initiative is the stage of building and implementing the final solution. In the case of digital transformation, the planning stage of the entire initiative, project management, as well as adoption and maintenance are extremely important. This requires a high level of mutual understanding between the ordering party and the solution provider – not only at the management level, but also between experts. In all this – in addition to experience and technical skills – soft consulting skills play a key role. It should be remembered that digital transformation projects are not just IT projects, but constitute a major organizational change, the subject of which is people. The company's operational activities should be disrupted as little as possible by the implementation, and once the implementation is complete, the implemented solution should bring the anticipated benefits as soon as possible.

That is why an extremely important and often overlooked issue during the implementation and subsequent adoption of innovative IT solutions is the role of business consulting.

**The two most important areas** in the **context of implementing the advanced IT solutions** discussed here are:

## 1 Proven implementation methodologies

The availability of proven methodologies for implementing innovative IT solutions that can be used across a wide range of manufacturing companies with different business profiles. Currently, many concepts and very innovative IT solutions are developed by software providers and are the subject of research in academic centers, but a large part of manufacturing companies struggle to overcome the difficulties associated with their implementation, adoption by employees and full production use. Projects aimed at implementing new, very innovative technological solutions are often of a research and development nature, which means that both the supplier and the ordering party of the solution gain detailed knowledge about the implemented system only during the project implementation, and work methodologies are developed together – the company responsible for the implementation (referred to as the Global Solution Integrator, GSI) has often not had the opportunity to gain practical experience beforehand, and in addition may also face a shortage of highly qualified experts and consultants. Often, after the project is completed, the system implemented in a manufacturing company is more of a prototype and before it reaches full operational efficiency and begins to be a source of measurable benefits, further work on its development is necessary. Being aware of this state of affairs, many companies unfortunately consciously abandon (or postpone) the implementation of innovative technologies, fearing substantial financial expenses with no guarantee of return in the foreseeable future. Examples of technologies whose implementation poses the greatest challenge for enterprises include digital twin, digital thread, or metaverse. Although there are many scientific studies on these technologies, their implementation and practical use still constitute a small percentage compared to more mature technologies, such as CAD or ***PLM*** systems. The development of repeatable and sufficiently general implementation methodologies of this type of IT solutions so that they can be used in a wide range of manufacturing enterprises with different business profiles is currently a very big challenge.

## 2 Integrated training effectiveness

Currently used methods of conducting workshops and training often lack effectiveness because they focus on selected domains (e.g. CAD design, PDM system, engineering change management), and are also focused on slow learning of the new system by users. Due to the fact that the development of current information systems is moving towards domain integration, the boundaries between classes of systems are blurring. This is particularly evident in the case of companies producing complex smart products (such as electric cars or drones). Current systems supporting product development increasingly include not only the CAD and PDM systems that have been successfully used for a long time, but also project management, after-sales service management (including service support), ***IoT***, AI, or system design. IT solutions supporting the design of environmentally friendly products are also gaining popularity very rapidly, which requires members of the new product development team to consider the entire product life cycle. Therefore, training for employees learning systems used in the product development process should be created in a way that takes into account new work models, e.g. product development in a project environment (including 3D modeling, project management and PDM), or cooperation in an integrated digital thread environment. Participants in such training should learn to use the entire spectrum of data provided by the integrated environment. This means that consulting services should evolve at the same pace as IT systems have been evolving for many years, and training programs should reflect the level of integration of the systems for which they were prepared. Providing access to data alone does not ensure full success – what counts most is the ability to use them effectively in practice. Additionally, IT system implementations are being carried out at an increasingly rapid pace, which means that training should also enable the maximum reduction of the adoption time while maintaining its effectiveness. This is especially important for companies that are rapidly moving from a low level of digital maturity to a much higher one, which is based on future operating models that use advanced and innovative IT technologies and tools.

# _Digital transformation as an organizational change

In the discussion so far, we have analyzed the technical and consulting perspectives. Let's now look at the process of building a digital thread from the point of view of a complex organizational change that needs to be consciously and deliberately managed, and treat it as an element of the broader concept that is digital transformation.

To begin with, let's answer the question of what, in fact, is organizational change? In a general sense, change is a permanent feature of human development, especially in the current turbulent environment and globalizing world. Organizational change, on the other hand, is a process in which an organization goes through modifications to its structure, strategy, processes, technology, culture and other aspects of functioning.

Change in an organization can be caused by various factors. These can be external factors, such as:

- The need to adapt to changes in the external environment
- Developments in technology
- Changes in customer preferences
- Changes in regulations

and internal factors, such as improving operating efficiency or increasing competitiveness

Knowing what organizational change is, let's now consider what organizational change management actually is. This term refers to the totality of approaches, tools, techniques and measures used to identify, plan and carry out the transformation of an enterprise from its current state to a target, desired state. It usually also encompasses the enterprise's environment and the stage of consolidating the effects of change.

In terms of digital transformation and the implementation of complex information systems, organizational change involves changing the way digital technologies are used to forge a new business model in the organization that supports the creation of added value and increasing the efficiency of its production. In other words, it's about **moving from partially digital data processing to fully digital**.

Given the above, the digital transformation process, in the most general sense, is divided into three main parts:

## 1 Digitalization phase

This is the process of encoding analog information about physical objects and processes into a digital format that can be stored (archived), transferred (shared, such as in digital libraries) and transformed by computers. Typically, digitalization includes internal and external documentation, but does not flow into value-creation activities within the organization. Examples of the benefits of moving to working with digital data include: access to documents from any device and at any time, easier sharing of documents, environmental friendliness, cost-effectiveness, greater security, easy organization, and protection of documents from destruction, crucial for customer service.

## 2 Digitization phase

Once an organization has moved to a model that relies on the use of digital data, the digitization phase can begin. Digitization means using advanced information and communication technologies to change existing business processes. It allows the creation of new online or mobile communication channels, enabling a new form of interaction between the organization and the customer, changing the distribution process, or managing business relationships digitally. IT plays a key role here, enabling the optimization and effective coordination of existing business processes to create additional customer value in a more creative and efficient way. Noteworthy, digitization does not just focus on savings, but primarily streamlines processes.

## 3 Digital transformation

The final step involves changes throughout the organization, leading to the creation and development of new business models that lead to a significant advantage in the market. The use of IT leads to fundamental changes in existing business processes and procedures. This also enables cross-border interactions with suppliers, customers and competitors. Therefore, **digital technologies** can help **achieve competitive advantage by transforming organizations** to use existing core competencies to develop new ones.

With regard to systems for managing the product lifecycle, particularly the digital thread, the scale and pace of organizational change associated with digital transformation depends on a number of factors, key among them being the organization's current level of maturity and the target level it wants to be at, and the timing of this transition. However, regardless of the scale of systems implementation and integration, any change related to changing IT tools (and especially as important as systems that support development and product lifecycle management) greatly affects employees. To trace the impact of this change, let's use the widely recognized Kübler-Ross model, which allows us to trace the progression of change over time and its impact on employee motivation and performance.

For employees, the change begins when the plan and scale of implementation of a new system (for example, the implementation of a ***PLM*** system and the development of a digital thread concept) is announced. Implementation and development of such large systems means a radical change in working methods and the need to adapt to work in a completely new environment. This causes shock in employees, which in a fairly short time turns into denial. These negative effects can be further compounded by insufficient information on how to implement the system communicated to employees.

From this point on, employee productivity and motivation begin to decline. Intensive implementation work related to the ongoing project begins, disrupting the previously established work rhythm. Employees begin to feel the effects of the changes. Inadequately managed change can, at best, lead to a big drop in motivation and slow down project work, and at worst, in extreme cases, can cause the project to fail completely or be stretched out over time, even for years. On the other hand, properly guided communication and adequate support in the form of design workshops and properly designed and conducted training will make the negative effects much less severe. Employees will more quickly accept new work tools and stop being afraid of them, allowing them to move smoothly into the stage of discovering and experimenting with new tools. The place of anger and denial will be taken by fascination with new technologies and the amazing possibilities they offer. For this to happen, however, a high level of awareness among change leaders is essential, and the support of an experienced technology partner is key.

The comparison of the change process associated with the implementation of complex IT solutions implemented in the traditional way with the process supported by an experienced solution provider is shown in Figure 4.

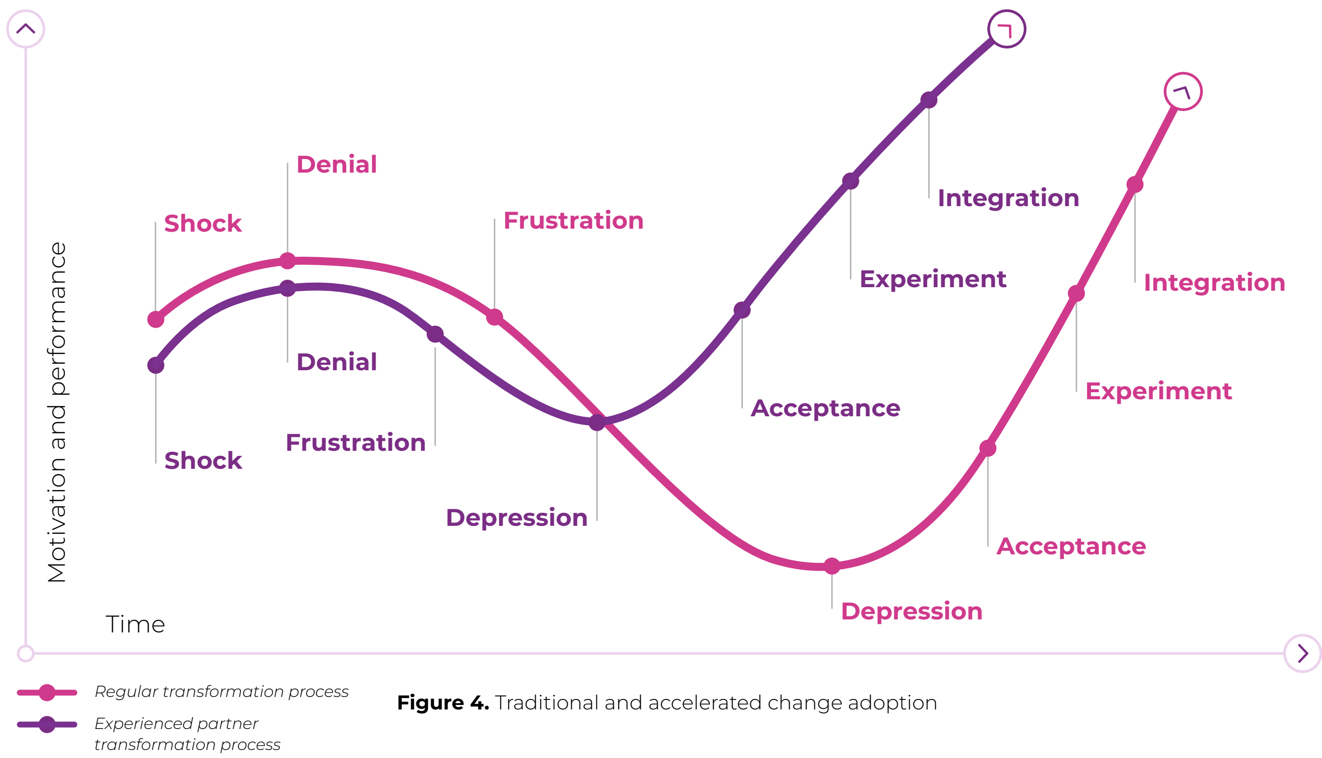
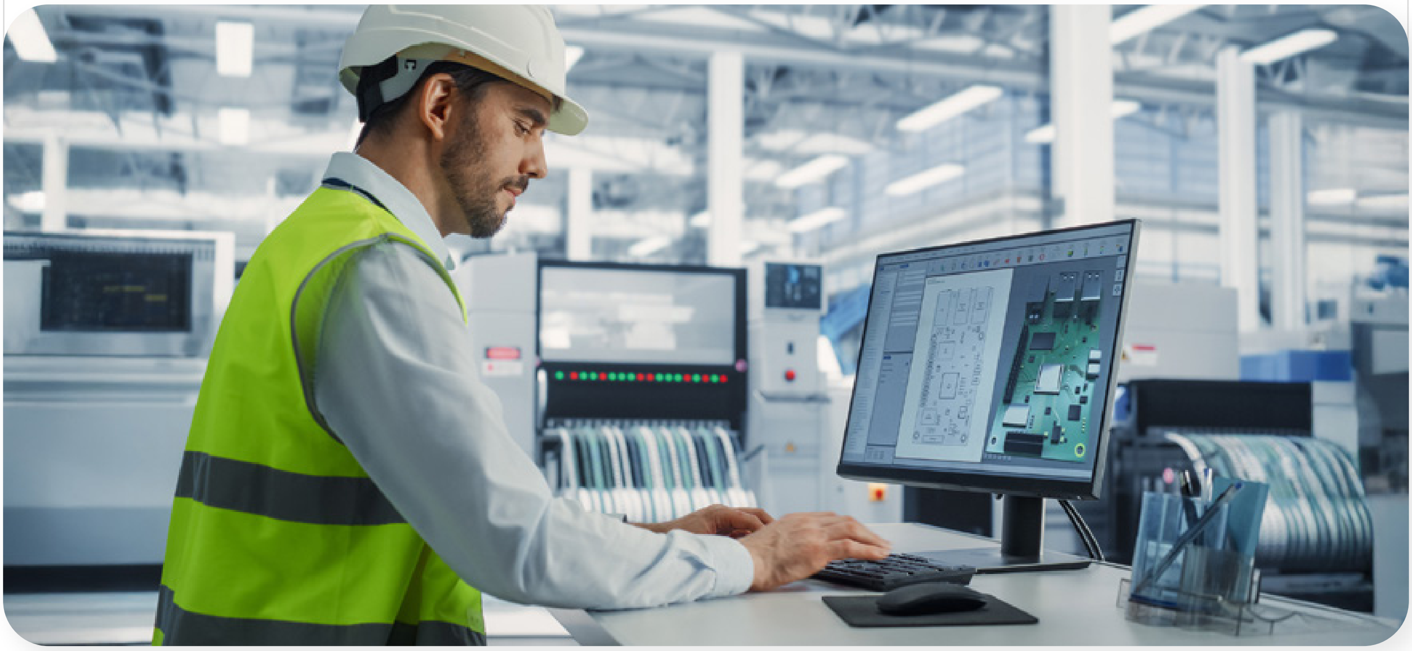



**Figure 4.** Traditional and accelerated change adoption

# _Conclusions

Based on the reasoning presented, we can outline a model of a company capable of guiding an organization through the entire process of a complex organizational change, such as digital transformation, in particular the design and implementation of solutions that make up the digital thread.

A provider of such highly complex IT solutions should support the organization at every stage, starting with the identification of needs, through the development of a roadmap and the various stages of system implementation and enablement. The ability to provide support in organizational change management is as important here as technical competence and capabilities.



The company responsible for the implementation project should have both technical and consulting expertise, sufficient human resources, and a deep understanding of the processes and phenomena that occur during significant organizational changes like digital transformation and implementation solutions as complex as digital thread. These resources should be committed long-term, as digital transformation projects often span several years, and the stability of an experienced project team is crucial. Beyond resources, the development of transferable standards and implementation methodologies is equally vital. Implementing one system and training a single group of users is vastly different from implementing and integrating multiple complex systems. It becomes even more challenging when training diverse user groups who may use the solutions in varied ways across an international business environment.

In the context of digital transformation and future operating models, organizations often face time pressures, alongside the need to learn new systems and fundamentally alter established, proven work methods. As a result, it is crucial to not only organize and conduct efficient training sessions but also ensure these trainings are effective, enabling users to handle real-world scenarios competently. This ensures a higher level of digital maturity, leading to a swift return on investment and realizing the anticipated benefits of these digital initiatives.

**_Do you have any questions?**

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