A Practical Approach to the

Machine Builder Digital Twin

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Improving Engineering, and more, with the Digital Twin

Digital Twin Potential

Machine builders must continuously raise the bar to compete in today's dynamic, global markets. How are they leveraging digital twins to improve how they quote, design, produce, install, and commission more complex, smart, connected, flexible, and tailored equipment than ever? Further, how can they extend their digital twins to improve installation, commissioning, and service?

Increase Digital Twin Maturity to Drive Value

Digital twin improvement opportunities span the product lifecycle and offer significant new business value from bids through service. Our research shows that top-performing manufacturers use more advanced, mature digital twin capabilities.[1] But few machine builders have tapped the full potential.

Continuous improvement through a comprehensive digital twin spanning the lifecycle is valuable, but it is a journey. There is plenty of room for most manufacturers to improve and drive increased profitability, but they can't do it all at once. Instead, they can implement the basics and find ways to expand the value through higher maturity at each step. This eBook introduces four areas where machine builders can improve their digital twins, sharing a combination of first steps and more advanced actions to drive business value and increase profitability.

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Recognize the Potential of the Digital Twin

The Growing Need for Machine Digital Twins

Machine builders face increased challenges, including increased equipment complexity, greater market complexity, and new demands for sustainability. These issues impact their operations and their operators, driving additional engineering requirements such as increased machine automation, monitoring, and the need for remote service.

Extend Digital Twin Value over the Product Lifecycle

Comprehensive digital twins allow equipment manufacturers to innovate and experiment in the virtual world to get unique machines right the first time. Virtual design helps them improve machine design cycles, quality, performance, configurability, and sustainability by allowing all disciplines to collaborate starting as early as equipment requirements on a holistic, contextualized product model. Lastly, running digital twin simulations enable them optimize designs virtually before building them.

But the value doesn't end in Engineering. Machine digital twins incorporating manufacturing operations and quality data allow them to produce equipment faster and more efficiently with higher first-time quality. Machine digital twins extended to the operating environment can speed up commissioning, ensure equipment runs the first time, improve performance for machine operators, and enhance operator training. Twins can also enhance service through service transformation, including machine monitoring and analytics. Finally, they can help in product retirement by enabling circular thinking where equipment can be brought back, refurbished, or harvested for valuable components.

Making Progress Toward Your Digital Twin

Choosing a Starting Point

For many companies, the improvements described on the previous page sound like rocket science. In fact, it is. Industries like aerospace have proven the value, and the potential is nearly limitless. But adoption can be intimidating, especially for manufacturers that haven't fully achieved the value a holistic digital twin can offer to Engineering.

What should machine builders do now? Each manufacturer needs to define what the digital twin means to their business, assess their current capabilities and then make tangible, incremental steps to improve their maturity and associated business value. Digital twin initiatives should have rapid ROIs, providing value right away and making progress toward a fully mature future state. The value will be different for each company, but we've identified a number of improvements for companies to use as a starting point based on their goals and maturity.

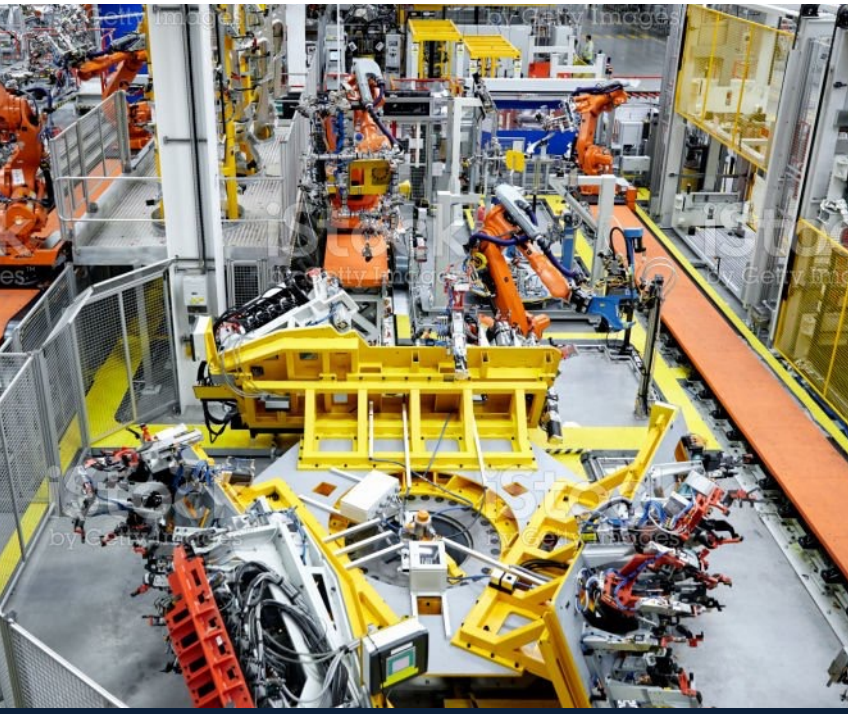
Create a Value-Driven Strategy

It's essential to develop a practical plan based on what would be the most valuable to the company. Find practical problems and use the digital twin to address them. The challenges may relate to quality, speed to market, or supporting additional configurability without compromising quality. Or, they may be supplier collaboration challenges. For some, they could be sales enablers to let potential customers experience how configured equipment will behave in their environment using high-fidelity simulations.

We recognize that each company is different in their starting point, what will drive the most value, and the practical sequence in which they can implement changes. It's time to identify ways to get started, create a customized plan with first steps to drive business success, extend the value, and expand on the competitive advantages achieved. Let's look at some opportunities.

Our definition of the digital twin:
The digital twin is a **virtual model of a physical item**. The model represents a specific product, configuration, pieces of equipment, plant, city, or other physical asset with enough fidelity to predict, validate, and optimize performance and behavior. It's connected and kept in sync with its physical twin over its lifecycle to collect, aggregate, and analyze actual field data to monitor performance, gain intelligence, and close the loop between designs and the real world.

1) Design in Full Product Context



Top Performers are achieving superior levels of performance with higher digital maturity, including increased adoption of digital twins.[1]

Getting Started

A foundational step to gaining value from the machine digital twin is developing a comprehensive product model that's accurate enough to reflect, and predict, reality. Most machine builders can design and simulate mechanical components in 3D. Their models represent a digital mockup of the machine and typically include wire harnesses and routings to prevent clashes. Engineers can also typically design and validate hydraulics and motion paths based on models.

Extend

To move to the next level, companies must expand their models to include other domains. The machine digital twin should go beyond the mechanical representation to model electrical components such as chips, boards, and sensors in context. It should also incorporate software and controls. Extending the digital twin across disciplines allows engineers to start early, work in parallel, and collaborate more effectively to understand how decisions in one domain impact others, prevent conflicts, reduce errors, and drive innovation.

Expand the Advantage

As maturity grows, machine builders can adopt more systems-level thinking. They can adopt a systems design process to design system and software architectures, engineer network communications, and develop embedded software with their digital twins. The systems design process should start with requirements and flow through validation. Finally, digital twins should expand beyond Engineering to include more operational factors, including cost, materials, suppliers, and sustainability, to allow designers to evaluate options and design alternatives comprehensively. Developing in this context encourages collaboration and design integration from early concept through detailed engineering.

2) Embrace BOMs / Configurations / Variability

Getting Started

Another fundamental step in improving engineering and downstream processes with the digital twin is to contextualize product models with the proper configurations. Few complex machines are identical. They may require simple component or subassembly selection from an "overloaded BOM," more complex engineering calculations, or possibly custom parts. Product models must reflect this complexity, and as our prior research shared, "The equipment digital twin should manage BOMs and engineering changes across configurations to provide digital continuity across the product's lifecycle."[2]

Extend

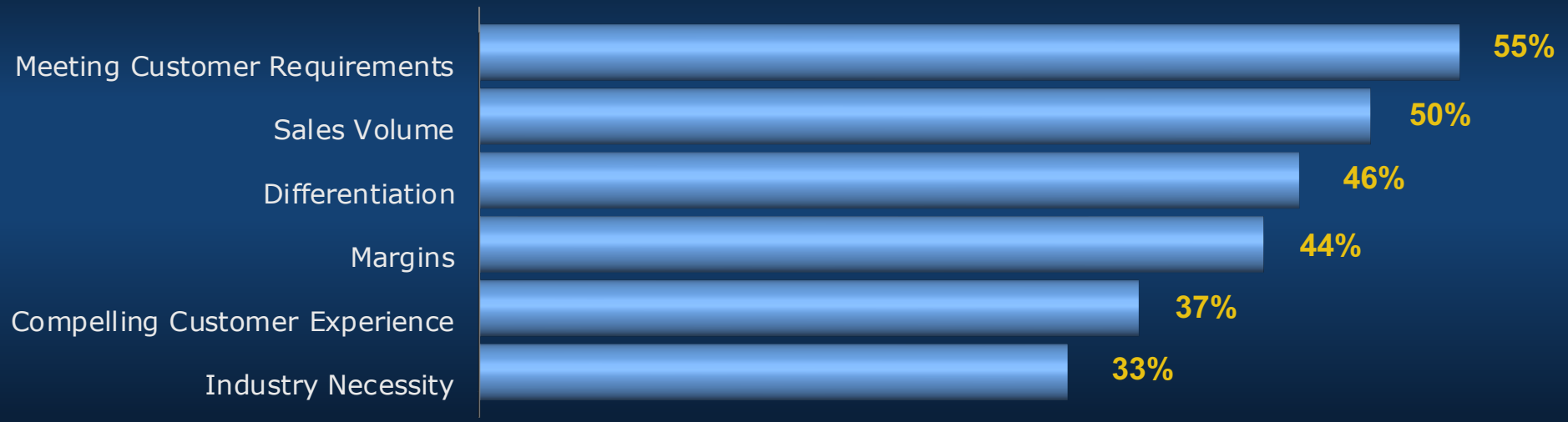
To raise the value of the digital twin, companies can capture variability early and incorporate it throughout the lifecycle of the serialized machine. This helps companies embrace complexity and make tailorability a competitive advantage.

Further, associating the model to the customer order allows manufacturers to develop and share tailored, realistic digital twins with kinematics and behaviors. This allows the customer to experience the machine in the virtual world to gain confidence that the machine will meet their requirements.

Expand the Advantage

Finally, as maturity grows, companies can extend digital twin usage to manage as-built and as-maintained machines. Keeping an up-to-date BOM that matches equipment in the field allows them to better support aftersales and replacement activities. This also sets the stage for them to maintain a live IoT connection with equipment to understand its current state and leverage the configured digital twins to service and maintain equipment. This improves service profitability and customer relationships. See *A Practical Approach to Improve Machine Builder – Operator Collaboration*[4] for more.

BENEFITS OF CUSTOM-ENGINEERED PRODUCTS[3]



3) Simulate / Optimize / Virtually Validate Equipment

Getting Started

Machine builders with an accurate digital twin can improve designs by predicting real-world behavior and improving performance in a virtual environment. They can leverage machine and control systems digital twins to visualize and animate specific configurations to aid sales and find issues earlier to prevent rework. Most machine builders use some form of simulation. Simulating the configured digital twin allows them to validate design decisions using tools like FEA and structural analysis for mechanics, thermal analysis, CFD for hydraulics and airflow, 1D planning, and more. This allows them to validate and optimize designs and explore new ideas.

Extend

Companies can extend the advantage of simulation by adopting multiphysics to optimize factors such as machine noise and vibration. Leveraging the multidiscipline digital twin, they can simulate movement, mechatronics, and operation of the equipment integrated with controls. These forms of simulation allow them to improve operator and operations experience by improving sightlines, safety, and ergonomics in the context of the machine's digital surroundings. They can also improve operational performance by modeling and optimizing energy. Machine builders can push value further by modeling more advanced digital twins that include components like batteries and sensors or adopting advanced simulation that incorporates AI and ML techniques.

Expand the Advantage

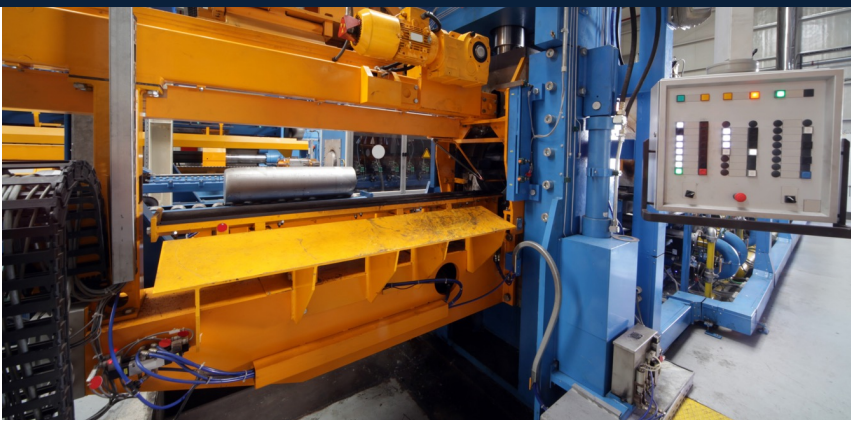
To further extend the advantage, companies can close the loop by providing real-world information from testing and operation back to engineering to improve the digital models. This allows them to gain more value from their digital twins through continuous improvement, improving designs based on real-world feedback collected via the IoT. Our research concludes, "Correlating expected and actual performance from the digital and physical twins provides much more accurate performance predictions and further helps close the loop to improve performance."[5]

> "The value of the digital twin expands as it extends beyond simply modeling the product. A comprehensive digital twin allows engineers, distributors, and customers to experience the equipment virtually. It can also enable predictive performance engineering, which, according to our research, allows companies to unlock new levels of innovation and performance while simultaneously improving efficiency and reducing cost."

"Increasing Equipment Design Velocity"
TECH-CLARITY

4) Expand Further Down the Lifecycle

Manufacturers can extend the value of the digital twin beyond engineering to improve downstream functions, including manufacturing, operations, and service. Establishing these additional views of the digital twin provides a comprehensive model of the machine from requirements through operations **to better manage and reuse company knowledge and experience** as experienced operators and technicians leave the workforce.



Getting Started

Machine builders increasingly recognize that the digital twin applies beyond Engineering. This can begin with modeling and capturing additional information, for example incorporating GD&T and quality data, in the digital twin to directly leverage it for quality inspections. It can also extend to the machine's operating life, for example incorporating the machine digital twin into customers' virtual environments to validate physical spacing in their facility.

Extend

Beyond viewing machines in customers' virtual facilities or BIM (Building Information Management) models, companies can use the digital twin to visualize equipment in the context of the virtual production environment, including inventory, material handling, machine tools, other equipment, cobots, and operators. They can collaborate with operators by leveraging the digital twin to conduct discrete event simulation and machine emulation to optimize throughput in context of the customers' equipment and automation. This allows customers to improve performance by using the digital twin to evaluate different implementation options or provide operator training and operating instructions, perhaps leveraging AR/VR. Machine builders may also turn their digital twins into a product by offering the digital twin as a deliverable or service to customers.

Expand the Advantage

Lastly, equipment manufacturers can further expand the value of digital twins in their machine lifecycles by adopting virtual commissioning. First, they can bring software into the loop to simulate and validate machines and controls virtually by using emulated PLCs. They can also virtually validate HMI and SCADA to drive quality and standardization. Finally, they can bring hardware into the loop using real PLCs to test controls. Machine manufacturers can dramatically speed up commissioning time, drive first-time quality, and reduce downtime by finding errors by effectively connecting the digital twin of the machine with a digital twin of the automation equipment in the digital world.

Get Started

Start Small, then Expand

The opportunities are expansive and potentially overwhelming. Remember that every company is different in where they start and what will drive the most value. Don't try to do too much at once or skip maturity steps. Focus on the tangible steps that add value to your business. But, keep the big picture in mind to ensure that early successes can be built on to reach a higher vision.

Focus on People and Process

The end goal is a better way of doing business, an integrated design and development process supported by the machine digital twin. To achieve this vision, make sure to get key people and departments aligned with the vision and the transformation. Help them understand the big picture, the steps to achieve it, and how it will help them in addition to helping the company.

Enable the Transition

New ways of working require the right tools. It's essential to evaluate your current software solution portfolio to ensure they are sufficient for the job. An effective machine digital twin requires support from a variety of engineering solutions, including CAD, multiphysics CAE, software design, and PLM. It also requires industrial and factory automation solutions, including CAM, MES, HMI, SCADA, virtual commissioning, and the IIoT. Depending on maturity, it may also require asset lifecycle and service management solutions (ALM and SLM).

Get Started

Think Holistically

It's important to consider more than individual tools. Evaluating how solutions work together to support the digital thread across the lifecycle is crucial. The machine digital twin is best served by a platform of solutions that work together. The platform should provide a central data model, the digital twin backbone, kept in configured context. It should be able to be acted on from different angles so everyone can contribute and get what they need in a secure, collaborative environment. Together, these product innovation platform capabilities support the machine digital twin.

It's essential to acknowledge, though, that no single platform will support every need. It's critical that the platform is open to allow integration and offers the capability to develop new applications that pull information together for specific purposes, ideally in a no-code or low-code environment.

Let’s Get Started

There are many options and a lot to do, but the value should come fast and be extended over time. Let's get started.

Acknowledgments

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About the Author

Jim Brown founded Tech-Clarity in 2002 and has over 30 years of experience in the manufacturing and software industries. Jim is an experienced researcher, author, and speaker and enjoys engaging with people with a passion to improve business performance through digital enterprise strategies and supporting software technology.

Jim is actively researching the impact of digital transformation and technology convergence in the manufacturing industries.

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Tech-Clarity is an independent research firm dedicated to making the business value of technology clear. We analyze how companies improve innovation, product development, design, engineering, manufacturing, and service performance through the use of digital transformation, best practices, software technology, industrial automation, and IT services.

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