Leveraging Data-Driven Digital Twins to Accelerate Industry 4.0

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What are Digital Twins?

Implementing digitization in a streamlined manner is one of the greatest challenges facing companies today, thanks to limited time, resources, and an aversion to disrupting current workflows. As Industry 4.0 initiatives advance businesses across the globe, digital twins have become essential tools for efficiency analysis and process optimization, providing risk-free virtual environments in which to test the effects of change.

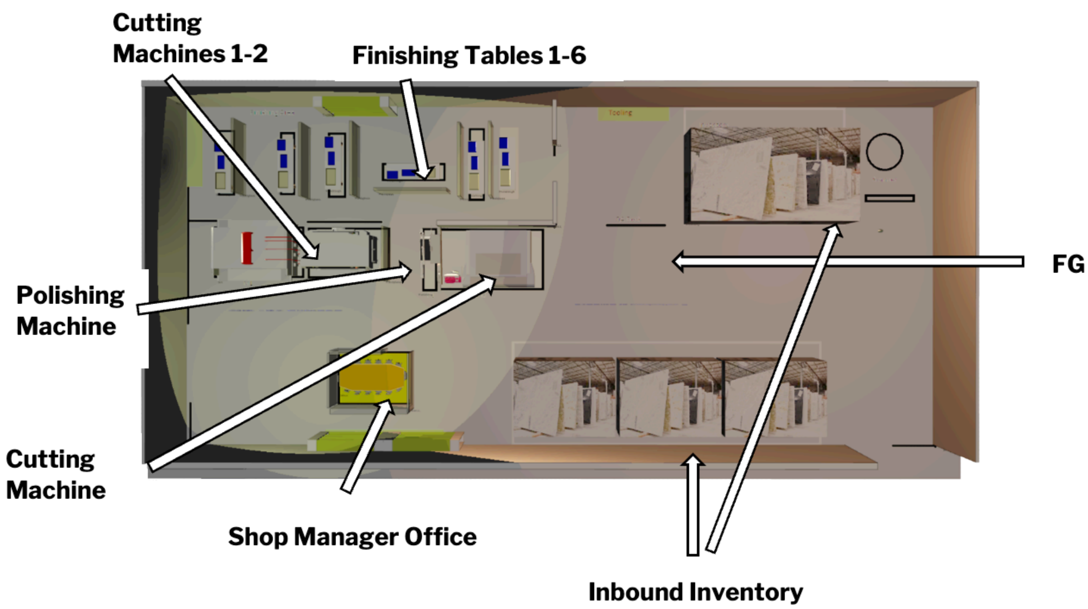
While the most basic digital twins provide not much more than a nice animated visual of a facility, more powerful models leverage machine learning and predictive analytics to take the time and guesswork out of projects like bottleneck analysis and growth projection. Industries like healthcare, warehousing, logistics, and manufacturing can use these digital twins to track the current state of their operations, and prepare for the future with models that learn from data and constantly look ahead.

There are four main types of digital twins, each varying in their complexity and cost to implement. Each have their advantages, and each twin builds on the one before it, adding functionality and an extra level of detail in their representation capabilities. They are:

1. The Visual Twin
2. The Randomized Twin
3. The Data-Driven Twin
4. The Learning Data-Driven Digital Twin

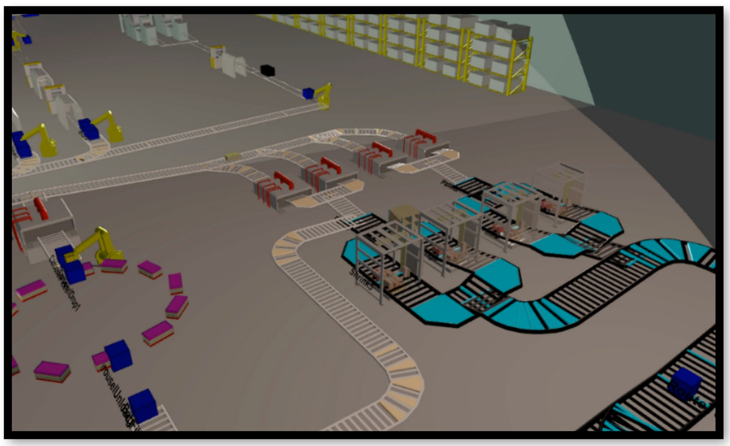
The Facility: Use Cases

To better understand how these twins are implemented, we'll look at a small factory that handles granite, marble, and other types of stone for home applications. This is a build-to-order environment that handles raw material with manual and automated manufacturing processes, multiple types of equipment and machinery, and a flexible work force on a department level. Materials processing is based on customer demand and work orders, while flow and equipment use is determined heavily by the types of material being used.



1. The Visual Twin

The most basic digital twin available is the *visual twin*. Like any digital twin, visual twins offer some way to visualize the total environment, and that can be in either 2D, 3D, or VR. Elements of the facility like conveyors, materials, and robots are represented with a high level of detail, and the model as a whole can mirror your facility accurately.



While a visual twin is slick, at this phase, it is nothing beyond an animation, so the advantages stop there. A visual twin is great for conveying *how* your operation performs, but the model is not actionable. In other words, the visual twin offers no insight as to how you can optimize or improve.

2. The Randomized Twin

A step up from the visual twin is the *randomized twin*. The randomized twin begins with the same polished animation of the visual twin and begins to incorporate data analysis. Data can be used to perform simulation runs and see where things are backing up, for instance. One using a randomized twin might perform a time study, perhaps, and want to feed the results into the model. Those data will tell the model how to behave.

The limitation of the randomized twin is that when done, the randomized twin takes your data and does what its name suggests—randomizes data by fitting them to distributions. The randomized twin provides a window into your operation, okay for basic forecasting and analysis, but that window is what it is—a window, limited by the data off of which it operates.

The randomized twin is ill-suited for making tactical decisions, as there can be very little in the way of forecasting or prediction. The randomized twin cannot simulate changes in workflow, scheduling, or availability of material because the simulation run represents only what is in the collected data. For better analysis, a Monte Carlo simulation method is required, and even then, the randomized twin is only looking in the rear-view mirror, simulating how things ran over the course of the distributions it received, thus optimization solutions are never as certain as they could be.

“*Should we purchase another cutting machine?*”

Ask the randomized twin, and it may reveal an answer over the course of a single simulation run. The result, however, could be just whatever the randomized data happened to indicate, and it would not be safe to assume that distributions always indicates what’s best for the operation. When data changes, answers change in turn, and this is the limitation of a randomized twin.

3. The Data-Driven Twin

The *data-driven twin* is where a digital twin becomes a tool for identifying the current state of your operation and predicting future states of readiness, without requiring much additional user effort. The data-driven twin builds on the randomized twin by connecting to data from systems like ERP, MRP, PLCs, and Barcode scans. Here, the data-driven twin is loading real data sets, and tying in data from multiple sources to teach the model how to behave as accurately as possible. Processes in the model do not behave according to a distribution, but rather according to the operation itself.

In the case of the factory, connecting to your own data systems, like work orders, is key for modeling the processes and workflows of the facility. Processes like cutting and finishing are based on real-life constraints, like material, color, edge type, linear feet, all defined by the work order data fed into the model. Equipment and product routing data also come into play, as the data-driven twin takes into account the time required for different cutting stations to cut different materials, as well as the setup time and optimal route different materials should take so they pass through the machines best suited to handle their type.

All these data determine how the digital twin will behave, and because the data driving the model are much more comprehensive, the results of the data-driven twin will be much different than those of the randomized twin. The model represents your actual operation and starts to provide clearer answers to what-if questions and plans to expand into the future.

After leveraging a data-driven twin, the factory identified congestion caused by their receiving procedures. Rather than pulling in all their inventory at the beginning of the day, they assigned different pull rates in order to streamline traffic and reduce the impact of inventory in the staging area, which in turn freed up space for finished materials when it came time for them to be shipped out for installation.

4. The Learning Shadow Twin

The *learning shadow twin* places the data-driven twin into a live environment, where the digital twin monitors the operation in real-time, and reacts to changes and disruptions in lockstep. By wrapping together data sources and pulling from them on a continuous basis, the learning shadow twin will start to understand how your operation works, and can constantly look forward to identify delays and areas where performance can improve. The learning shadow twin does this not only day-to-day, but hour-by-hour and minute-by-minute.

The learning twin takes as much data as you can throw at it; the more data, the better. The learning twin lends itself to a web interface, as it is a tool to be accessed by everyone in an organization who wants a snapshot into the operation, not solely those leading an optimization initiative.

In the factory, workers can use the learning twin to get a view of the current state of operations. With RFID data, each slab, cart, and piece of material handling equipment is tagged, identified, and associated with the paperwork for the order. The system will automatically create an association between an order and the cart in its proximity, and displays its movement through the operation. A dashboard displays order numbers and shows when they were started, which ones are in production, and which have been finished. The learning twin uses this data to forecast future orders with expected lead time, making the data available to all members of management.

The learning twin also incorporates live feedback in the form of machine data, where workers can view the status, utilization, and efficiency of equipment like blade saws, while keeping track of remaining blade life, water usage in gallons per hour, any error codes that come through, as well as the equipment's expected upcoming maintenance. These are all identified by the learning system, analyzing data through a neural network and learning the intricacies of the operation to generate forecasted, actionable data.

Conclusion: The Path to a Digital Twin

There are three crucial steps for an organization in selecting a digital twin:

1. **Define your goal**

   What are your organization's goals? In other words, why are you implementing a digital twin? Do you want only visualization or basic operational analysis? What about implementing IoT 4.0, planning for expansion or automation, or optimizing scheduling in real time?

2. **Identify your target**

   What are the milestones you need to hit? For visualization and basic operational analysis, choose a visual twin or a randomized twin. For everything else, choose a data-driven twin.

3. **Develop your plan**

   What's the next step after implementing a digital twin? Explore your options and figure out the best course of action. Can you increase capacity? Change your layout? Will seasonality impact your operation? Connect your ERP systems, or take it a step further with RFID and identify how things work. Data-driven twins will always give you forecasting and analysis while also showing you the current state of your operation.

There is a lot to consider when choosing and implementing a digital twin. Whether you just want a fancy 3D model of your facility, or want to turn that model into a true shadow, digital twins have proven themselves as indispensable tools for industries looking to advance to 4.0. Learning data-driven digital twins empower that advancement by learning from the past and looking ahead to the future, ensuring your organization is always ready for what comes next.

References

Adra, Hosni, & de Vries, Jim. (2021, July 20). *Createasoft digital twin demo* [Webinar]. Enhance International Group.