The Lean Digital Twin Guide

The recent rise in interest in digital twins for industrial applications reminds of medieval seafarers navigating unchartered waters in search of fame and fortune. Their charting maps showed “Here be dragons” at the edges which meant dangerous or unexplored territories, in imitation of a practice of putting illustrations of dragons, sea monsters and other mythological creatures on uncharted areas of maps where potential dangers were thought to exist.

Industry analysts like Gartner, Forrester, and the ARC Advisory Group who survey a broad spectrum of the industrial market, all agree that digital twins will proliferate over the next couple of years.

Digital twins have attracted wide-spread attention and are considered to be the key to smart manufacturing and other industrial applications that are embracing large scale digital transformation initiatives.

In this guide, we will present a methodology to create digital twins using a simplified, systematic and problem-to-solution approach.

The Challenge and How Do We Want To Solve It?

Because digital twins are digital representations or software design patterns, we look to software development practices and approaches for guidance.

There are multiple different software development approaches and our aim is not to review all the alternatives to determine best fit. We will focus on applying the principles that are used by many software startups that have vague requirements, limited resources and funding, and first need to find “product/ market” fit. The approach used by many of these startups is described as “The Lean Startup”.

The Lean Startup Methodology

Silicon Valley entrepreneur Eric Ries first introduced the term Lean Startup in 2008 and published his best-selling book titled The Lean Startup: How Today’s Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses in 2011.

The initial concept was aimed at helping startups take an agile and customer-centric approach to product development. The Lean Startup Methodology has since been widely adopted by startups, government organizations and global enterprises as a framework for creating innovative products and business models. For example, GE FastWorks launched 100 projects globally by using the Lean Startup approach. The results GE has achieved include: half the program cost, twice the program speed, and products selling over two times the normal sales rate.

In the following section, we’ll cover the elements of the Lean Startup Methodology that are most applicable to creating Digital Twins:

Minimum Viable Product

Eric Ries defines a minimum viable product (MVP) as a version of a product that enables you to learn enough to test your current assumptions with the least amount of development effort.

A common misconception about building an MVP is that it is simply a paired down version of the ultimate solution you aim to create. This approach overlooks the philosophy underpinning the MVP concept, which is to aid in validating your assumptions as fast as possible by getting user feedback.

In our experience, designing high-fidelity mockups and interactive prototypes have been powerful tools for generating the initial MVPs for digital twins. Because there is no development involved in this initial phase of experiments, we are able to rapidly turn around revisions of the prototypes and get multiple rounds of feedback.

Validated Learning

The Lean Startup approach draws on the Scientific Method by recommending that practitioners conduct falsifiable experiments to inform their decision making. This is in stark contrast to the traditional approach of creating a comprehensive one-off plan before embarking on the development phase of a project.

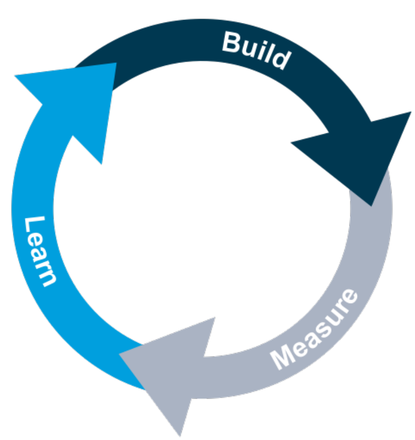
For most industrial companies, creating digital twins is still uncharted territory. This is why an approach originally designed for startups can be useful in navigating the process of innovating in the midst of uncertainty.
By running small experiments with measurable outcomes, you are better able to make constant adjustments based on real user feedback, rather than on your initial assumptions (which are often incorrect).

Using the rigorous Validated Learning approach prevents the misfortune of perfectly executing a plan that produces an obsolete solution.

Build-Measure-Learn

The Build-Measure-Learn feedback loop is a core element of the Lean Startup methodology. It consists of turning your ideas into an MVP, getting feedback from users and then making decisions based on what you learned.

Eric Ries emphasizes the focus on minimizing the total time to complete a cycle of the Build-Measure-Learn loop. This is particularly relevant to industrial organizations, who operate in hyper-competitive environments where innovating faster than the competition can have large-scale impact.



In our experience working with customers in asset-intensive industries, we've seen the outsized impact that digital twins can have. When you work on a scale where one hour of downtime equates to hundreds of thousands of dollars in revenue loss, even small-scale digital twin projects can produce enough ROI to fund additional development.

A large, multi-national Oil & Gas customer has seen a reduction of $8m in costs & production losses in a 6-month period by using a digital twin of an oilfield to optimize maintenance and regulatory inspections.

A mining customer is using a digital twin of their underground conveyor system to reduce downtime by detecting one type of failure mode with results of $3m+ additional revenue per annum.

In this guide, we've extracted and applied the most-relevant elements from this well-adopted approach to help industrial organizations create Digital Twins that solve real challenges and don't take months to architect and develop.

A Practical Approach To Lean Startup

In 2011, veteran software entrepreneur, Ash Maurya, expanded on the work by Eric Ries and released Running Lean: Iterate from Plan A to a Plan That Works.

In the book, Ash provides a practical and systematic process for applying the Lean Startup Methodology. In his work since then, Ash has built on these concepts and created the Continuous Innovation Framework. The framework consists of three key steps:

Model

The first step is to document your initial assumptions in a lightweight format. In the Continuous Innovation Framework, practitioners often use an adapted version of the Business Model Canvas developed by Alex Osterwalder and Yves Pigneur in the book Business Model Generation.

Prioritize

Before you start creating your MVP, understanding what to build should be a key step in your Digital Twin project. Finding the right problem to solve can be challenging.

We have developed a Digital Twin Ranking Matrix that enables cross-functional teams to rapidly brainstorm potential digital twin use cases and prioritize them based on factors like business impact and technical feasibility.

Test

Once you know which problems are worth solving, you can move on to defining the MVP and testing your assumptions using rapid experimentation.

A good experiment optimizes for speed, learning and focus. It has a goal, a falsifiable hypothesis to test, a defined timeline and one key metric to keep track of.

Example Experiments

#	Goal	Hypothesis	Timeline	KPI
1	Confirm that we are solving the right problem	Problem interviews will validate that cyclone pumps are responsible for 30 hours of downtime	1 week	# Positive responses
2	Validate which features to build into the cyclone pump digital twin	Lightweight mockups will validate that a digital twin will reduce cyclone pump downtime	2 weeks	Feature Priority Ranking
3	Validate that we can get the real-time data required to solve the problem	Developing an initial solution will validate that we can get access to the required data in real-time	2 weeks	Seeing live data in the application
4	Confirm that we can improve the operational metrics	Deploying the digital twin to one site will reduce cyclone pump downtime by 30%	12 weeks	Hours of downtime
5	Scale the improvement in operational metrics to more plants	Deploying the digital twin to 3 new sites will produce $3 million ROI	12 weeks	$ value of reduced downtime

The key is to run rapid experiments that build on each other and provide you with more learning and validation as you progress.

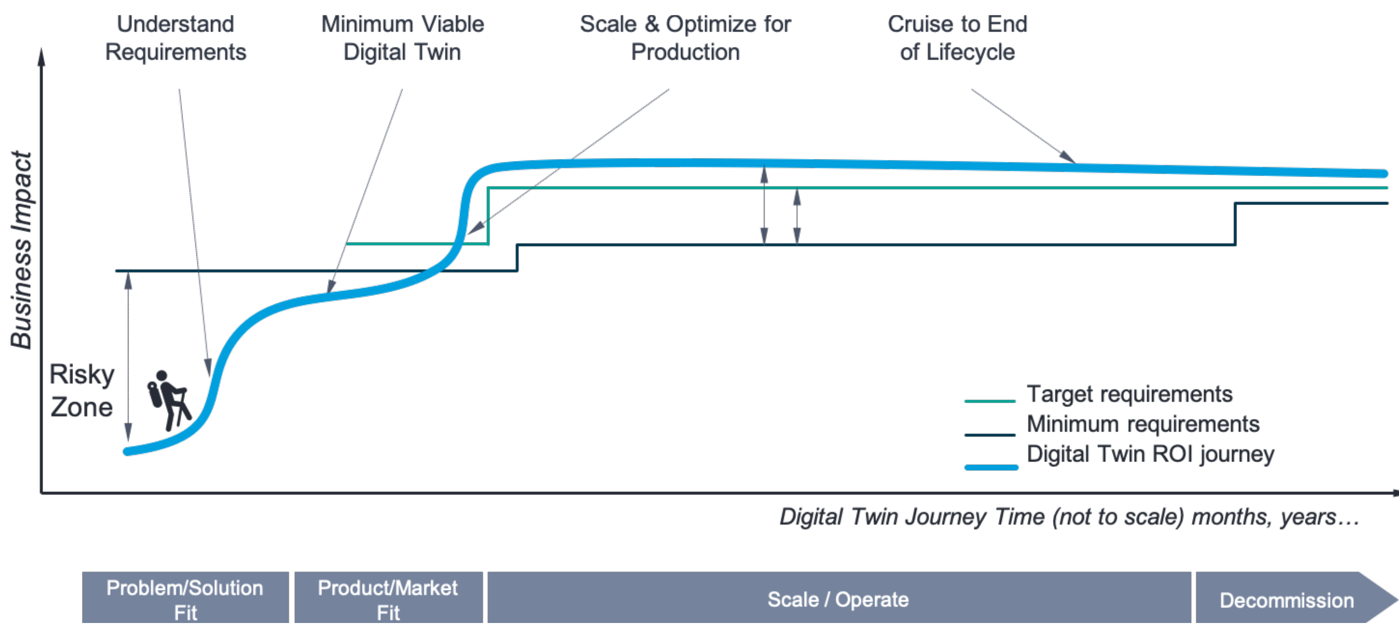
Applying a Lean Startup Approach to Digital Twins

We've adapted the principles of the Lean Startup Methodology and the practical tools from Running Lean and the Continuous Innovation Framework to help industrial companies innovate like startups in the uncharted Digital Twin arena.

Benefits of using a Lean Approach for Digital Twin Development

The Lean Digital Twin focuses on addressing a key business value metric with a defined financial benefit that can be verified in a short period of time. It provides short-term return on investment that can be used to fund the development of more advanced production twins.

This removes the cost and risks associated with projects where a lot of time is spent on requirements definition, product specifications, architectural designs and waterfall style development cycles. The cost and risks of this approach are significantly reduced as the initial phases to validate product/market fit are typically measured in days and weeks rather than months and years. The journey to develop digital twins is still uncharted, but by building on the Lean Startup approach you can create a clear path to success in the midst of uncertainty.



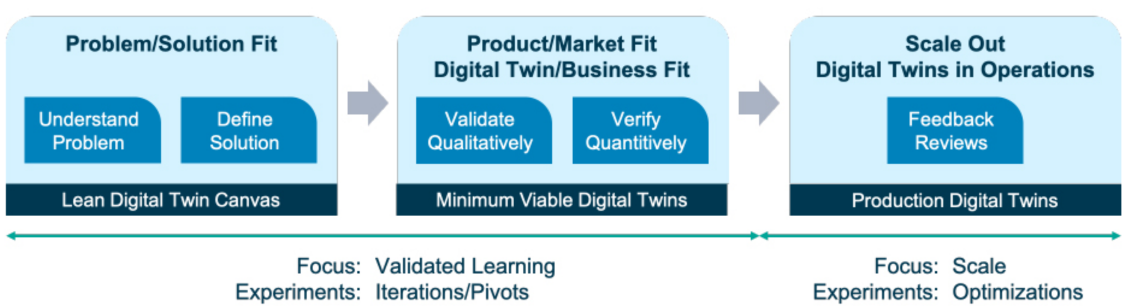
The Lean Digital Twin Process: Lean Startup Applied to Digital Twins

In the previous section, we described the fundamentals of the Lean Startup approach and how it can be applied to creating digital twins. Now we'll look at the practical application of this approach to develop a Lean Digital Twin.

The first phase of the approach minimizes development effort as it focuses on identifying key business issues that can be addressed with a digital twin by describing the overall solution in an easy-to-understand manner. It is referred to as the problem/solution fit phase of the Lean Startup methodology.

The second phase of the approach defines a minimum viable digital twin (MVDT) based on the problem/solution statement from the previous phase. The MVDT is used to validate and verify assumptions and hypotheses made during the problem/solution assessment. The MVDT may undergo multiple iterations to demonstrate a digital twin/business fit. This is derived from the product/market fit in the Lean Startup approach. This is best accomplished with agile development tools that allows subject matter experts to quickly change elements of the MVDT.

Once an MVDT hypothesis has been validated and verified, the digital twin can be scaled for full production applications and lifecycle.



These first two phases are focused on validated learning based on iterations and potentially pivoting the digital twin application as new learning emerges.

It is best to construct the lean digital twin in a series of consecutive steps that are outlined below.

Step 1: Find a problem worth solving (Understand the Problem)

The prioritization approach described here is used in two iterations to 1) rank multiple initiatives in an organization that could benefit from Digital Twins, and then 2) rank assets or processes that collectively operate as a system where use cases for the system are ranked. The first prioritization exercise focuses on prioritizing which system to focus on. The latter exercise provides guidance on the prioritization of use cases for an asset grouping that could be serviced by a single digital twin. Examples include a packing line in FMCG (fast moving consumer goods), a well in Oil & Gas, a robot assembly cell in manufacturing, a main line conveyor in materials handling or a processing plant in mining (the example we use later). Both exercises follow the same approach and the initial prioritization matrix can be omitted if the business is clear on the system that could benefit from a Digital Twin. It is, however, recommended to do the initial prioritization exercise to ensure that the real business challenges are addressed. It is the authors' experience that organizational biases often influence the selection of Digital Twin candidates and the Prioritization Matrix approach assists in identifying impactful projects.

The objective is to establish a falsifiable hypothesis to test around the business problem that the digital twin will address. "Cyclone pumps are responsible for 30 hours of downtime per month" is an example of such a hypothesis that can be tested in product/solution fit interviews and workshops.

The prioritization process assesses both business impact and technical readiness of a Digital Twin project.

The high-level business outcomes in the prioritization framework are the basis for scoring and agreeing on the business impact of a specific use case. The prioritization process starts with a list of potential Digital Twin use cases and ranks them based on their business impact for each desired business outcome. The business impact metrics are chosen to align with the strategic objectives of the organization. These are often referred to as the business drivers in digital transformation programs.

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Use Case Prioritization

		Business Impact					Economic	Technical Feasibility							
#	Use Case/Scenario	Safety	Downtime	Throughput	Quality	Cost	Value/year	Automation	IT Systems	Analytics	Environment	Project	B Rank	T Rank	Impact
1	Use Case 1	Medium	High	High	High	High	> $10m	High	High	Medium	High	High	6	3	2
2	Use Case 2	Low	Low	Medium	customer satisf	High	> $10m	High	High	Low	High	High	7	6	2
3	Use Case 3	Low	Low	Low	Low	Low	> $1m	High	High	Low	High	High	3	7	1
4	Use Case 4	Low	Low	Low	Low	Low	> $1m	High	High	Low	High	High	8	8	2
5	Use Case 5	Low	Medium	High	Low	Medium	> $10m	Medium	High	Low	High	High	8	4	3
6	Use Case 6	Medium	Medium	Medium	Medium	Medium	> $1m	High	High	High	High	High	6	2	2
7	Use Case 7	Low	Medium	Medium	Medium	Low	> $1m	High	High	High	High	High	4	3	1
8	Use Case 8	Medium	Medium	Medium	Medium	Medium	> $10m	High	High	High	High	High	7	3	2
9	Use Case 9	Medium	High	High	High	High	> $1m	High	High	High	High	High	4	8	1
10	Use Case 10	High	Medium	Low	High	Low	> $1m	Medium	Medium	Medium	High	High	7	4	2

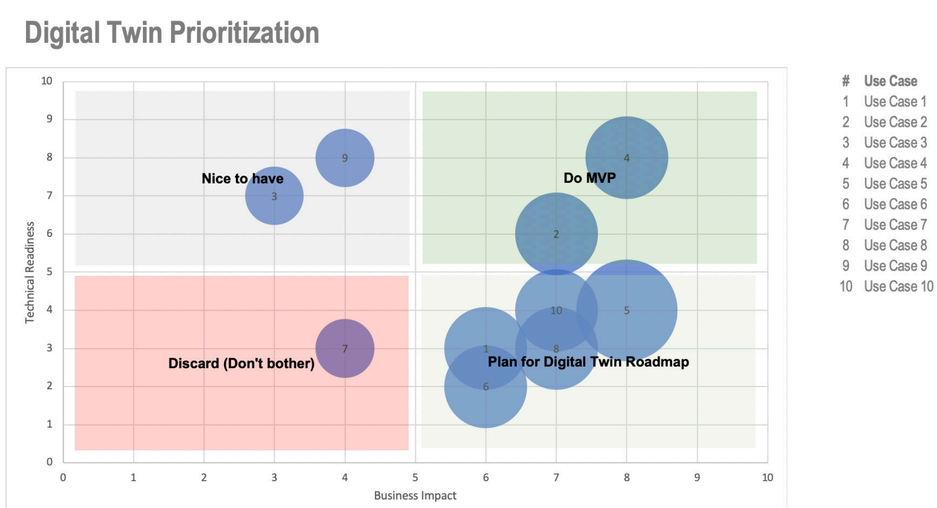
To avoid analysis paralysis a simple high, medium, and low scoring methodology is used in setting up a ranking matrix. This is best done with the business (operations), IT and OT representatives in a working session. Once the business impact is scored for each scenario the technical feasibility (or complexity) is assessed for each scenario, again without over-analyzing or getting into too much technical detail. It is a top down approach and even though information from reliability engineering practices like FMEA can be helpful indicators, it is important to guard that this becomes a technical feature or requirements design session. The impact assessment is done based on the strategic drivers of the business such as Safety, Down Time, Quality, Throughput, Cost etc.

In this example, the following technical assessment criteria is used: (1) OT complexity, (2) IT complexity, (3) analytics, (4) system complexity, and (5) project readiness. Technical assessment criteria can be adjusted to fit the requirements of the business, but for this example the criteria are for a typical industrial installation.

OT and IT complexity are described in terms of availability, accuracy, latency, and geographical location. Analytics is described in terms of maturity, sophistication (predictive and cognitive analytics) and application of business rules or physical models. System complexity is based on deployment infrastructure (edge, local, and cloud) and geographical constraints. Project readiness is assessed based on availability of subject matter experts and technical resources.

It is generally useful to define "order of magnitude" financial measures to agree on the high-level impact of each new state or scenario. The objective is not to be accurate in estimating the value of a business case, but to get high-level agreement between the different stakeholders on the potential impact of each scenario. In this example a scale of (1) greater than $100k, (2) greater than $1m, or (3) greater than $10m is used.

This "order of magnitude" is visually represented in a bubble chart with the business impact and technical readiness scores as the two major measures. The weighted average values of each of the measures are placed on the graph which is divided into four quadrants. The size of the bubble is determined by the value of the economic impact. The four quadrants represent the business readiness for each of the Digital Twin scenarios. The "Do Now" quadrant represents high business impact and a high level of technical readiness. Opportunities on the far right of the quadrant with the biggest bubble size often represent Digital Twin projects with the highest likelihood of success for all stakeholders.



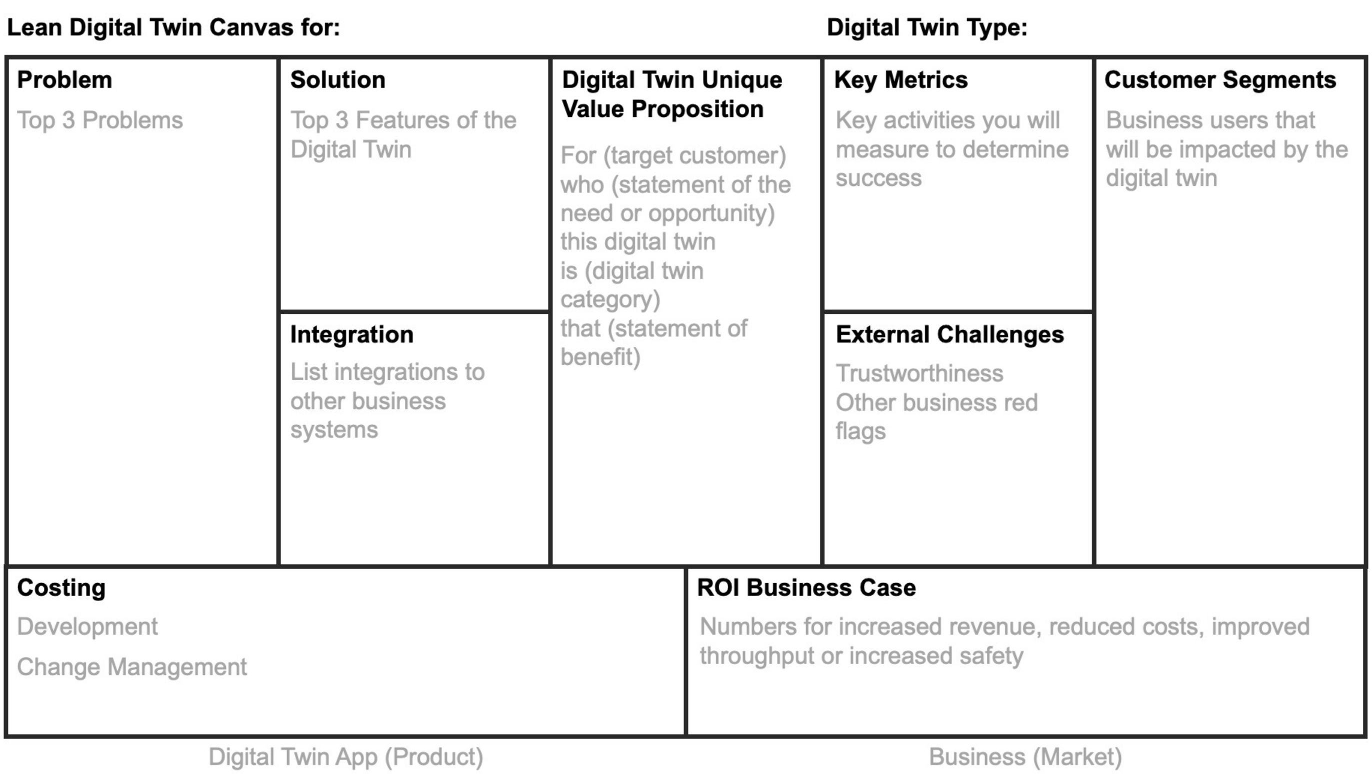
This approach provides a common understanding of the expected business outcomes and potential technical challenges in achieving this goal. It provides the basis for more detailed analysis of those projects with a high likelihood of success. A downloadable copy of the Prioritization Matrix is provided in the Lean Digital Twin Resource Kit. In using an iterative approach where Digital Twin scenarios are first done at an overall business level, the ranking will provide guidance on the highest priority process or system that in turn gets broken down into sub-systems, components or assets that are ranked based on the same process.

In an FMCG scenario the initial ranking may be done for business areas such as raw materials handling, production processes, filling and packing, and shipping. If filling and packing is identified as the best "Do Now" opportunity then the follow-on exercise could rank digital twin scenarios for filling/sealer, labelling, cartooning, packing, and palletizing. This will identify digital use cases with the highest likelihood of successfully addressing pressing business issues.

These sessions should be limited to 90min as more detail will be required in later analysis, but the objective is to be lean and reduce waste. The outcome of step 1 is a prioritized list of Digital Twin scenarios for problems worth solving.

Step 2: Document The Plan - Lean Digital Twin Canvas (Define the Solution)

Once one or two digital twin candidates are identified, a single page solution description is created for each candidate. This single page solution description is based on the Lean Canvas described in the section on the Lean Startup approach. The canvas is adapted for the Lean Digital Twin process and is referred to as a Lean Digital Twin Canvas. It describes all the key elements of the problem/solution fit.

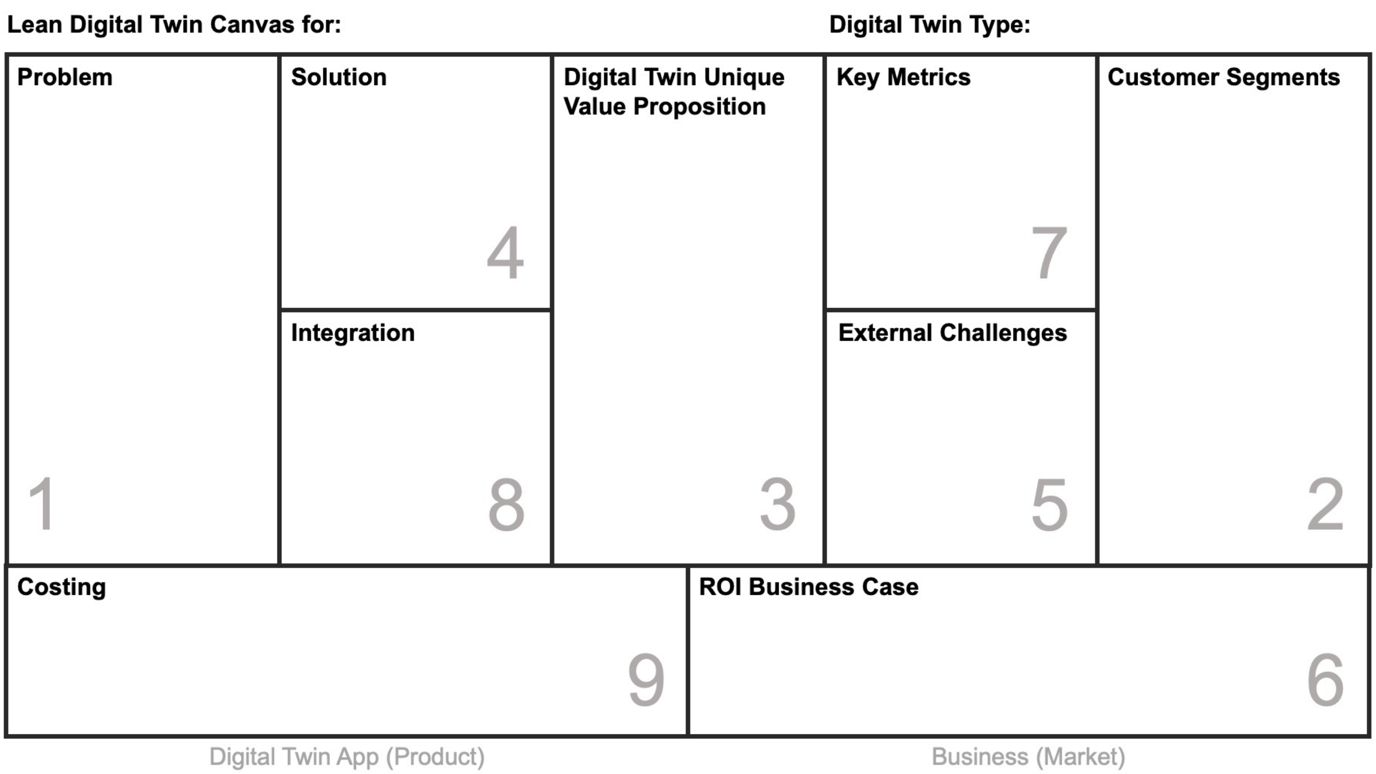


The proposed sequence for completing the Lean Digital Twin Canvas is described below. It is recommended to do the initial draft in a 60min session following the prioritization ranking exercise.

Sequence for completing the canvas in a workshop session:

1. (Problem) Define top 3 problems that your twin will address based on the prioritization matrix.
2. (Customer Segments) Who are the target users that will benefit from the solution? (digital twin)
3. (Digital Twin UVP) What makes this digital twin different from what you are already doing?
4. (Solution) What are the top 3 features of the digital twin? (AI, real-time, decision support etc.)
5. (External Challenges) What are the external red flags for the digital twin? (security, data access, connectivity)
6. (ROI Business Case) How will this digital twin deliver ROI?
7. (Key Metrics) How will the digital twin be measured (quantitatively)?
8. (Integration) What are the key integrations required to make it work?
9. (Costing) What is the projected costing?

It follows a logical sequence that starts with the problem and the users rather than jumping to product features. This holistic approach considers all aspects required to deliver a successful digital twin project.



The initial workshop session is aimed at completing as much as possible, but the Lean Digital Twin Canvas is updated continuously (versioned) as we test, validate and learn. One major benefit of the canvas is that it is easy to complete in a workshop session and it provides a one-page business plan for the digital twin that is easy to communicate to both end-users and project sponsors. It is presented as a single slide in sponsor meetings.

The completion of the Lean Digital Twin Canvas concludes the product/market fit phase of the Lean Digital Twin approach. The next phase focuses on validating and verifying your hypothesis and assumptions. This is done by developing a minimum viable digital twin or MVDT similar to the product/market fit phase of the lean startup methodology.

Step 3: Decide what goes into V1 of the Minimum Viable Digital Twin (MVDT)

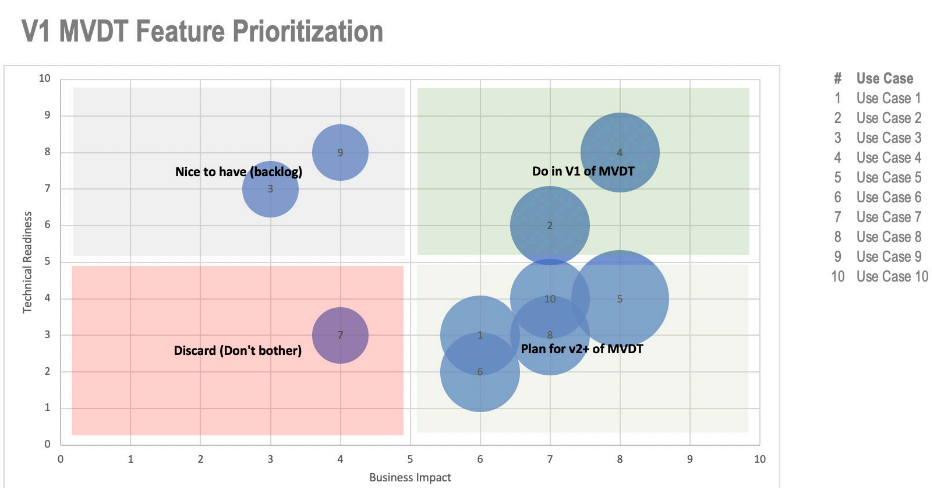
The same prioritization process that was used for choosing MVDT candidates is used to determine what features to include in the initial release or MVDTv1. The only difference is that digital twin features are now assessed on business impact and technical feasibility rather than business applications of the Digital Twins.

Typical features in an industrial application include, but are not limited to:

- real-time equipment data from sensors and devices
- time series data from historians and automation systems
- machine learning algorithms such as anomaly detection
- predictive algorithms such as classification and regression models
- production data from enterprise systems
- physics-based or engineering models that describe equipment behavior
- simulation models

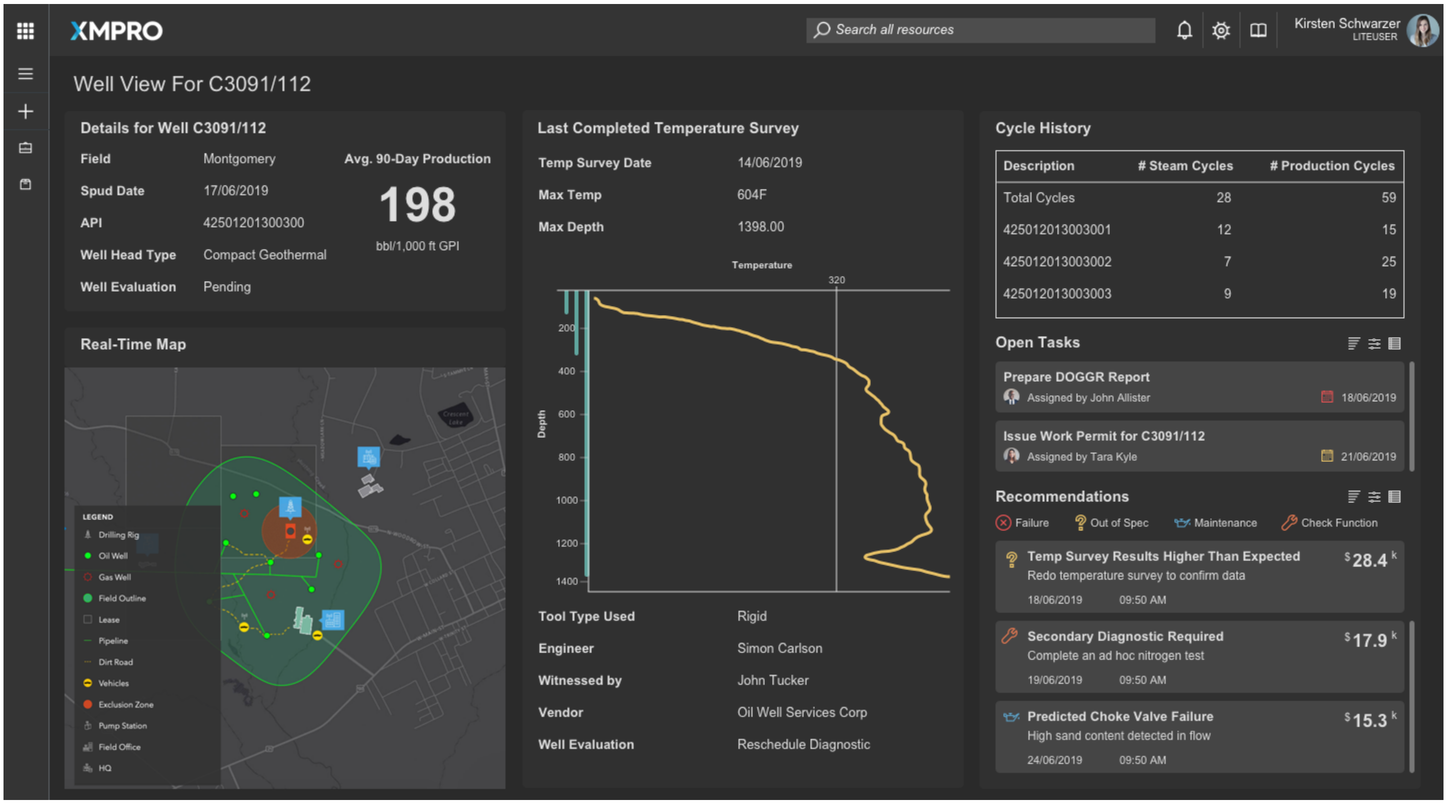
Digital twins are typically composed of combinations of the above features. Ranking these features in their ability to address the problem statement and solution identifies the two or three key features in the "Do in V1" quadrant.

This approach identifies key capabilities in the initial release that will provide the best guidance on validating and verifying the solutions capability to address the business challenge. It is important to note that the minimum viable digital twin features are still implemented as fully featured solution components, but the scope of the overall MVDT is limited to the two or three features identified in this process.



Step 4: Create lightweight MVDT to validate hypothesis

Mocking up an MVDT that includes the three features chosen in the previous step provides a basis for validated learning.



This mockup for a proposed well digital twin uses real-time event information for reservoir data from a subsurface data store, a well location map from a GIS data source, and production data from an operations database. The information is not yet integrated to the real-time data, but the mockup provides a realistic view of the lean digital twin and the decision support that it will provide users including operations data, recommendations based on descriptive and prescriptive analytics, and open tasks associated with this entity. Digital twin application tools that support an agile approach have this capability built in, but these mockups can also be done in simple tools such as Microsoft PowerPoint.

The mockup typically goes through multiple iterations during a two-week period of review by users and stakeholders. Mini presentations and interviews with stakeholders provide immediate feedback that is easy to incorporate in the mockups. The outcome of this process provides a validated basis for creating a live version of MVDT that will be used to verify that it solves the problem that it set out to do.

Step 5: Create an operational MVDT

Once the mockup is agreed upon, the actual MVDT is built out, preferably in agile development toolset, and integrated to operational data sources. This can range from a few days to 3-4 weeks depending on the tools that are used. Watch this on-demand webinar to learn how to build a Digital Twin with the XMPRO platform.

The benefit of using a Lean Digital Twin approach is that the feature set is limited which means users can be trained in a relatively short period of time to use the digital twin application. The objective of this step is to verify the assumptions and hypotheses made along the way and to identify areas where the MVDT must be improved or changed. This can be done for between 4 and 12 weeks based on the complexity and impact of the solution.

This phase is also used to validate and clean up data sources, verify algorithms, and check calculations to improve the quality of the decision support the digital twin provides. The results from this step concludes the product market fit review and serves as the basis to deploy and scale the digital twin to production.

Conclusion

The Lean Digital Twin approach is well suited to organizations that are starting a digital twin journey and want to use an iterative approach to discover requirements in a systematic way while demonstrating business value at the same time.

The approach requires top-down support and bottom up commitment. It is a collaborative approach that provides the guardrails for managing the process as it is not prescriptive. It does, however, require multiple iterations or pivots to find the best digital twin/business fit.

About the Author

I'm Pieter van Schalkwyk, the CEO of XMPRO. I'm an experienced engineer and technologist focused on helping asset-intensive companies improve situational awareness, process efficiency and decision making with the XMRO Application Development platform.

I started my career as a plant engineer and accrued ten years of engineering experience before making the switch to IT. I've since led the development of business performance management solutions for more than twenty years. I hold a Bachelor's in Mechanical Engineering and a Master's in Information Technology.

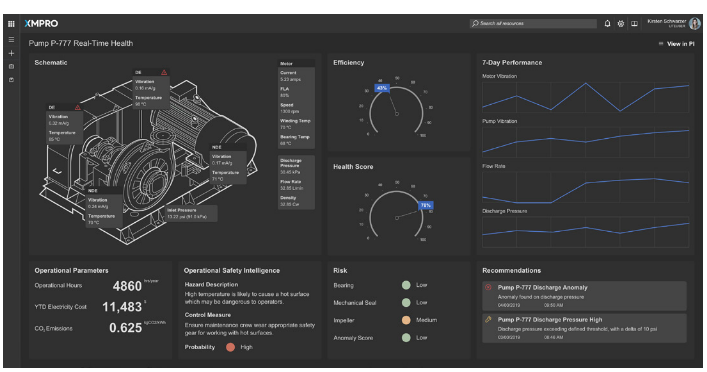
I'm currently the Digital Twin Consortium Natural Resources Work Group chair. And I served as co-chair of the Industrial Internet Consortium (IIC) Digital Twin Interoperability Task Group chair for four years. In February 2019, I received the IIC Technical Innovation Award.

My passion is helping industrial companies solve the challenges of operating in a world of real-time data. I hope this guide gives you a clear roadmap of how to create digital twin applications that deliver real value to your organization.

About XMPRO

To stay competitive and maximize opportunities in the new digital world, companies in asset-intensive industries need to respond to critical events in real-time. XMPRO's Application Development platform enables subject matter experts, like engineers, to build sophisticated apps in days.

Whether you're creating digital twins, event intelligence applications or digital business processes, with XMPRO, you can combine disruptive technologies into apps that help your team make better decisions.



Founded in 2009, XMPRO has a proven track record of helping organizations in industries like Mining, Manufacturing, Oil & Gas, and Energy/Utilities improve operational excellence.