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WHITEPAPER

Building an intelligent, connected manufacturing enterprise with Closed Loop Manufacturing

After the Industrial Revolution in the 18th and 19th centuries, the manufacturing industry underwent a similar paradigm shift in the 2000s with the proliferation of digital technologies and the internet. Sure, there were a few breakthroughs along the way - like the assembly line, which enabled mass production. However, advancements in digital technology during the 21st century landed the manufacturing industry in an environment of continuous evolution.

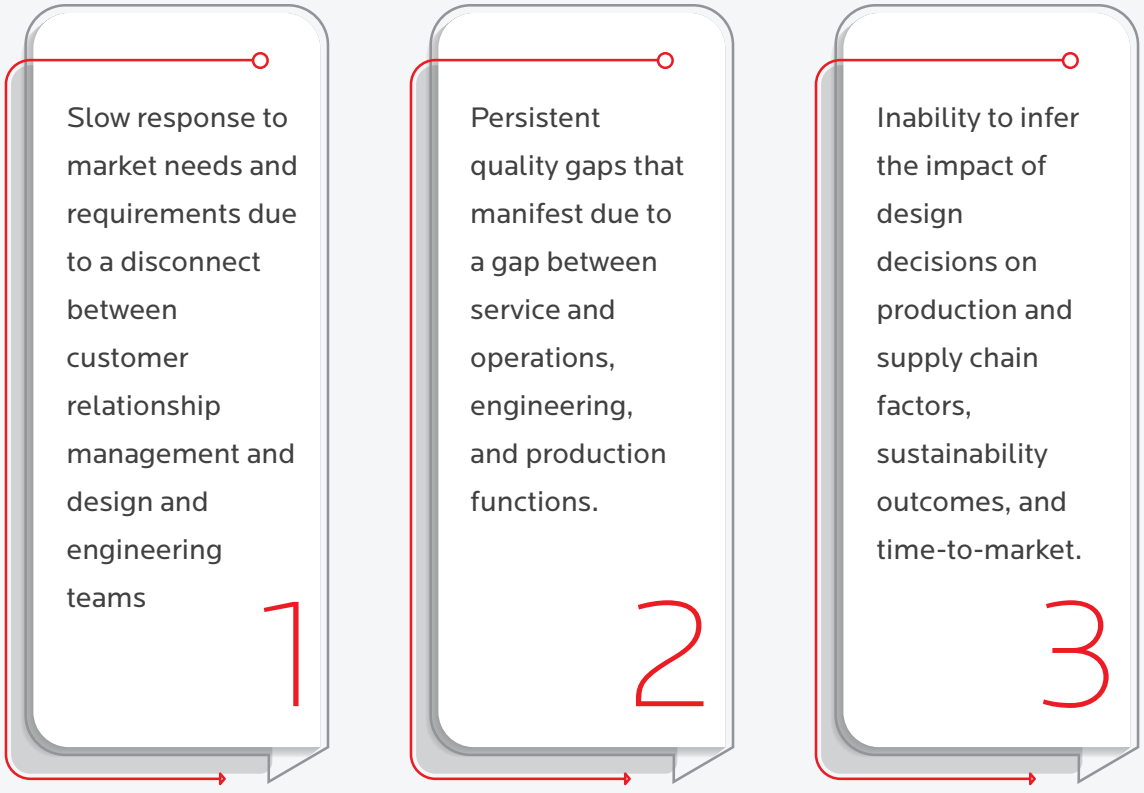
Today, Industry 4.0 is a globally recognized paradigm in manufacturing - and is being widely pursued by enterprises to gain a competitive edge. The adoption of sensor technology, ubiquitous connectivity, and targeted digital solutions has created a new currency in manufacturing – and that currency is data. And although a key promise of Industry 4.0 was to unleash new efficiencies and capabilities with data, 73% manufacturers are still struggling to gain actionable insights from their data.[1]

The key reason behind this challenge is the siloed transformation of manufacturing value chains. But these efforts have not been in vain. In fact, they have laid the groundwork for yet another breakthrough, which will be realized through cross-domain integration, facilitated by knowledge graph-enriched digital threads. By implementing a generative AI layer on top, manufacturers are looking at yet another frontier of evolution. Read how this transition can be achieved, and how it can be exploited in today's economic environment.

Despite Industry 4.0 advancements, product lifecycle challenges remain.

The manufacturing industry has recently emerged from the difficult economic and geopolitical conditions of the 2020s. However, macroeconomic uncertainty looms, and lead time for production materials remains 37% above the pre-pandemic levels.[2] In addition, persistent labor shortages, talent issues, and an unfavourable geopolitical climate indicate that the manufacturing industry is still far from exiting troubled waters.

These external challenges are inviting executives to look within - and find ways to mitigate their impact through innovative strategies. In this regard, a fragmented and disconnected product lifecycle has surfaced as a major shortcoming - and therefore, also an opportunity that is yet to be exploited. Here are a few ways in which it is manifesting:



Locating the fault lines

Ultimately, there is a single root cause of the above problems: the data pertaining to a single domain remains within it. A lack of cross-domain integration leads to suboptimal decisions and planning and coordination challenges.

Decision-makers are unaware of what data exists, where it exists, and how it can help them make better decisions. Ultimately, the cost of production remains a production problem, and high lead times remain a procurement problem. Similarly, customer feedback takes too long to reach the engineering teams.

[1]*https://d1.awsstatic.com/events/Summits/reinvent2023/MFG304-R_Building-a-knowledge-graph-and-AI-powered-manufacturing-digital-thread-REPEAT.pdf*

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[2]*https://www2.deloitte.com/us/en/insights/industry/manufacturing/manufacturing-industry-outlook.html*

The intelligent, connected manufacturing enterprise: foundational capabilities.

While manufacturing enterprises have relentlessly digitized their key functions, the systems they have implemented in the process, seldom talk to each other. As a result, the key phases of a product life cycle remain disconnected from each other. This further aggravates the gap between the market needs, and whether and how a product fulfils those needs.

The intelligent and connected manufacturing enterprise must address these three issues that exist in even digitally mature organizations today.

1

Breaking the silos across manufacturing value chains

The first step in this direction is to get various systems driving key phases of the product life cycle to talk to each other.

For instance, the decisions made at the design stage can have significant consequences - like the cost of the final product, or time to bring products to market. As a result, the systems driving these processes must talk to the ERP, MES, CRM, Supply chain control tower, SCADA systems, and other solutions in deployment. This is the key to facilitating collaboration across domains.

2

Creating context across the product life cycle

Once the digital systems across the product life cycle domains are integrated, it is now possible to create a context for key decisions in each value chain. This calls for an approach to build traceability using digital threads.

While digital threads are not exactly a novel strategy in manufacturing, its application has been limited by the difficulty of integrating data across domains. In the next section, we propose an approach to overcome this challenge using knowledge graphs.

3

Making insights discoverable to key stakeholders

Lastly, the context created through digital threads should translate into actionable insights that can improve the quality of decisions across the product life cycle. Moreover, these actions should enhance the outcomes for all stakeholders, from engineering, production, and service teams to customers, suppliers, and distributors.

How to build an intelligent, connected manufacturing enterprise.

In our work with our clients, we have seen that most manufacturers have already laid the groundwork for building an intelligent and connected manufacturing enterprise. Our approach exploits existing implementations and Industry 4.0 technologies to further the value of data that is now available within IT, OT, and ET systems.

Digital twins: the puzzle is half-solved, already

Currently, manufacturing enterprises are leveraging digital twins across three areas - design, production, and service and operations. The design digital twin enables engineers to pre-empt design issues and create flawless blueprints at the outset.

Similarly, the production digital twin mirrors the shopfloor conditions, offering insights into evolving bottlenecks, production efficiency, and machine output. Lastly, the service and operations digital twin maximizes the health span of the product by integrating maintenance, management, and service workflows.

Each of these digital twins conjures a comprehensive view of their corresponding domains and drives significant improvements in domain specific KPIs. However, they use different data definitions and models, making it difficult to facilitate data exchange between these domains.

The answer: multi-domain model integration with digital threads

This is where knowledge graph-enriched digital threads come into the picture. Multi-domain data model integration requires the harmonization of data models employed in the design, engineering, production, and operations digital twins.

Because this data is high-dimensional, knowledge graphs transform this dimensionality to context by enriching each node (product, part, process, or machine behaviour) with all the intricate ways in which it interacts with other elements.

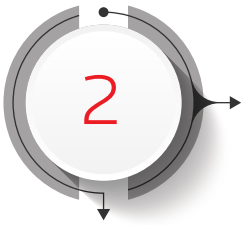
Digital threads enable traceability and transparency into the real-time and historical state of all domains by integrating with manufacturing digital twins. In addition, they also build forward visibility by integrating with the supply chain control tower, thus building true visibility across all manufacturing value chains. Implementing a generative AI layer on top of this architecture enables faster and easier discoverability of hidden relationships and insights.

This convergence of IT, OT, and ET systems synchronizes processes across the product life cycle. So, what does such a manufacturing organization look like on the inside?

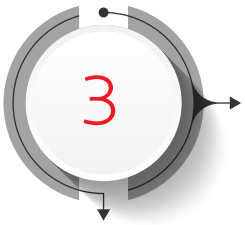
Closed-loop manufacturing: envisioning the endgame

With knowledge graph-enriched digital threads, organizations transition to closed-loop manufacturing and operations. Here are some capabilities enabled by such a solution:

Product design and engineering teams gain c**omplete downstream visibility** - in other words, lead time for part procurement, the impact of a production process on final costs, or service overheads of design decisions. Likewise, customer feedback reaches design teams quickly and continuously.



Insights become easily discoverable to all users. For example, a QA engineer can simply query the defect distribution by various criteria, like severity or cause. Similarly, service engineers can identify the root cause of a failure by querying traceability data for the product.



Connected and synchronized processes **lower the time to market.** By accounting for various factors like product complexity, QA processes, lead times, outsourcing strategies, and production schedules, digital threads can enable enterprises to bring products to market as quickly as possible.

Backward and forward visibility r**educes the gap between actual and projected costs**. Digital threads make hidden cost factors like expedited part shipping, supplier disruptions, or probability of recalls visible early on, thus enabling corrective actions.

Ultimately, digital threads power true collaboration between previously siloed functions, thus paving the way for synergistic outcomes. Moreover, digital threads can also be leveraged to accurately track the carbon footprint of a product throughout its life cycle.

Using this data, manufacturers can then identify the most lucrative strategies for minimizing GHG emissions of their products, thus enhancing their sustainability outcomes.

What next?

As manufacturers pursue continuous digitization to advance their strategic goals, knowledge graph-enriched digital threads present a viable approach to attain singularity in the manufacturing enterprise. It builds upon the adoption of design, production, and operations digital twins, and existing solutions in use to converge disparate, yet chronologically interrelated processes to desired business outcomes.

When manufacturing associations are defining the pathways to build a connected ecosystem through the Manufacturing X paradigm, businesses must first break the silos that remain within their own organization. Manufacturing X will undoubtedly unleash a new definition of resilience and operational excellence at a systemic level.

Early movers will stand to benefit significantly from this paradigm. However, these organizations will have to be at the peak of their digital maturity to participate in a connected manufacturing ecosystem. Knowledge graph-enriched digital threads augmented by a generative AI layer represents the latest stage of evolution in the Industry 4.0 paradigm. This transformation will gear businesses up for the cutting edge of the future while enabling them to realize peak performance in today's economic climate.

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