



RESEARCH SPOTLIGHT

Artificial Ingredients

How Generative AI Transforms Six Key Value Streams in Manufacturing



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Introduction

Imagine if you had the key to unlocking a technological revolution in the world of manufacturing with an impact as powerful as the Programmable Logic Controller (PLC). You have been told that this key could cause both great harm and good. Would you use it?

Generative Artificial Intelligence (AI), including powerful tools known as Large Language Models (LLMs) like [OpenAI's ChatGPT](#), [Google's Bard](#), and [Microsoft 365 Copilot](#), represents an exciting frontier with immense potential to transform how we design, create, and innovate in manufacturing. Generative AI comes in multiple flavors; an LLM is a way to generate text and is the technology that we will evaluate in this report. Other variants can generate images, music, and video. As you will see in this LNS Research Spotlight, generative AI is here to stay, and forward-thinking manufacturers are actively using it. From product design to production processes, it is reshaping the industry.

To make this Research Spotlight interactive and ensure a deeper understanding, we have included example prompts for you to try out using your favorite generative AI tool. Engaging with these prompts will give you a first-hand experience of how generative AI operates. However, please remember not to input any personal or confidential information into any AI tool unless you fully understand the terms of service and trust the provider.

If you need an explanation of the terms used in this Spotlight, please see the "decoder ring" at the end of the report.

*So let's embark on this journey together,
exploring the new realms made possible by
this cutting edge technology*



Generative AI and the Business of Manufacturing

To put things in context, we would like to introduce you to LNS Research's Industrial Transformation (IX) Framework (Figure 1). Certainly, manufacturing does not exist in isolation; it is part of a business and is there to serve the interests of that business.

Our first recommendation, whether you are using generative AI or not, is to make sure that you know your primary business objectives, break down those objectives along the value streams of your business, and build a strategy map (Figure 2). Then, you can identify the initiatives you want to implement to improve your business performance and reach your goals. Few things are worse than spending resources to achieve a goal that does not matter.

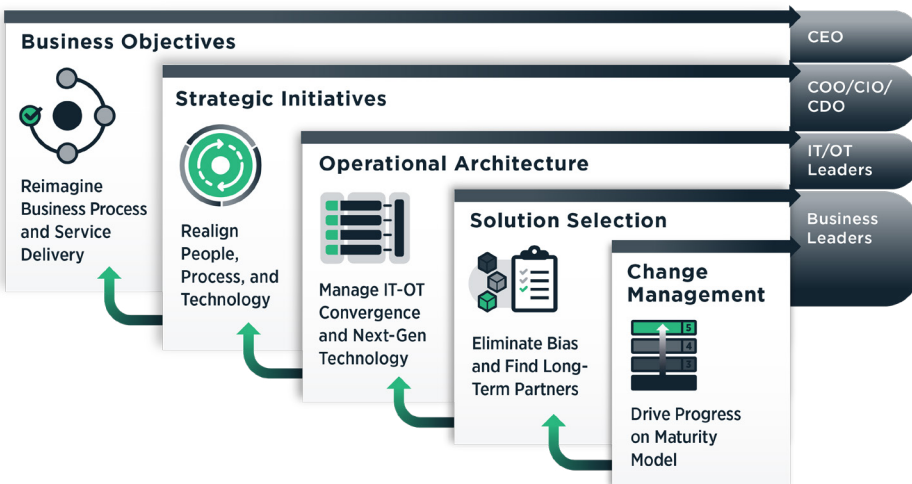


FIGURE 1 - The Industrial Transformation (IX) Framework

	OBJECTIVES	MEASURES	INITIATIVES
Financial <i>How should shareholders see us?</i>	INCREASE REVENUE → INCREASE PROFITABILITY ← REDUCE COSTS	net sales, net income, return on capital, stock price, ...	new financial systems, governance, risk and compliance (GRC), integrated reporting, ...
Customer <i>How should customers see us?</i>	SOLUTION PROVIDER → GLOBAL LEADERSHIP → SUSTAINABILITY	new customers, market share, new product revenue, service revenue, net promoter score, ...	product as a service, sustainable products, customer-centric selling, geographical expansion, brand awareness, ...
Operations <i>What processes should we excel at?</i>	NEW PRODUCT INTRODUCTION → INCREASE EFFICIENCY → ASSET OPTIMIZATION → REDUCE RISK	operating margin, Overall Equipment Effectiveness, Return on Net Assets, time to market, on-time delivery, ...	operational excellence, operational risk management, energy management, accelerated innovation, digital transformation, ...
Learning and Growth <i>How should our organization learn and improve?</i>	WORKFORCE ENGAGEMENT → IMPROVE TECHNOLOGY → LEARNING ORGANIZATION	workforce engagement, learning outcomes, knowledge deployment, systems cost, ...	training, leadership development, learning management system, enterprise IT revamp, ...

FIGURE 2 - Strategy Map

While it is essential to understand your business objectives before implementing generative AI, you can bootstrap the process by using it to understand your strategy's key elements.

We know that a lot of the readers are likely to have tried ChatGPT before, but if you have not, then try the following two prompts:

- "Summarize Tesla's business strategy."
- "Explain the strategy to a process engineer."

You will see an example of how ChatGPT can summarize complex information and tailor the result to an audience.

We have now covered the basics of the Industrial Transformation framework. We know what our business goals are, we have broken these goals down to KPIs related to our value streams, we know how to measure our progress, we have identified our initiatives, and we have used generative AI to summarize a strategy. Let's get back to looking at the general state of generative AI.



The State of Generative AI

Unexpected and Unrivaled Rapid Adoption: According to a study by UBS, by January 2023, two months after the launch of ChatGPT, the generative AI service reached 100 million active users. This active user adoption is four and a half times faster than what TikTok experienced and 15 times faster than Instagram. Recent usage data shows a slowdown in adoption likely caused by the increased use of other generative AI tools with fewer restrictions.

There are many reasons for this rapid adoption, one of the most significant being the technology's unparalleled accessibility. Anyone with a web browser can visit the ChatGPT website and start a conversation; typing on a keyboard is the only prior skill required.

There has been a fair amount of skepticism around generative AI. One of the biggest concerns is that generative AI is hallucinating. At the core of the issue is that generative AI cannot think; it is not intelligent; it just serves up a very good illusion of intelligence. Large Language Models (LLM) build a sentence structure based on a probabilistic estimate of the words that come next.

Generative AI is suffering from the same GIGO (garbage in = garbage out) issue we see in other AI systems. As such, it is critical to train the model on the facts you trust, not the general opinions of the internet. If you want to confirm this yourself, conduct this simple experiment.



Exercise

Open a new tab in your web browser with ChatGPT in it and paste the following text into the prompt: "It was a warm summer day. We were sitting under a tree and looking out over the green field."

You should see something like this...



It was a warm summer day. We were sitting under a tree, looking over the green field.



The sun lazily drifted across the sky, casting dappled shadows through the leaves of our sheltering tree. A gentle breeze carried the scent of freshly-cut grass and wildflowers. Sarah looked up from her book and sighed, a smile curling on her lips.



"It's perfect out, isn't it?" she said.

I nodded, taking a sip of my iced tea. "Yeah, almost too perfect."

Just then, the tranquility was broken by a distant rustling sound, growing louder. A deer emerged from the edge of the woods, cautiously stepping onto the field. Its eyes met ours briefly before it continued grazing.

It was a simple, magical moment that neither of us wanted to end. Yet, as we would soon discover, that field and the coming summer held more than just idyllic afternoons. The tranquility masked an underlying tension, a secret the small town had kept for years, waiting for the right moment to surface.

And that moment was rapidly approaching.

Observe how ChatGPT responds. It will continue to write an essay based on your opening words. You did not even ask it a question; it just strung the words together to create a new hallucination with no roots in reality and with the same level of confidence as the fact-based Tesla strategy. You can experience the probabilistic behavior of ChatGPT by asking the same question again and experiencing a slightly different result.

Generative AI in Manufacturing

So, let's focus on generative AI in manufacturing. At LNS Research, we like to evaluate software from the perspective of how it adds value to the value streams (Figure 3) that are necessary for the manufacturing business.



FIGURE 3 - Value Streams

Each value stream has activities that are being improved using technologies like generative AI.

Certain generative AI capabilities are common across all value streams. These include:

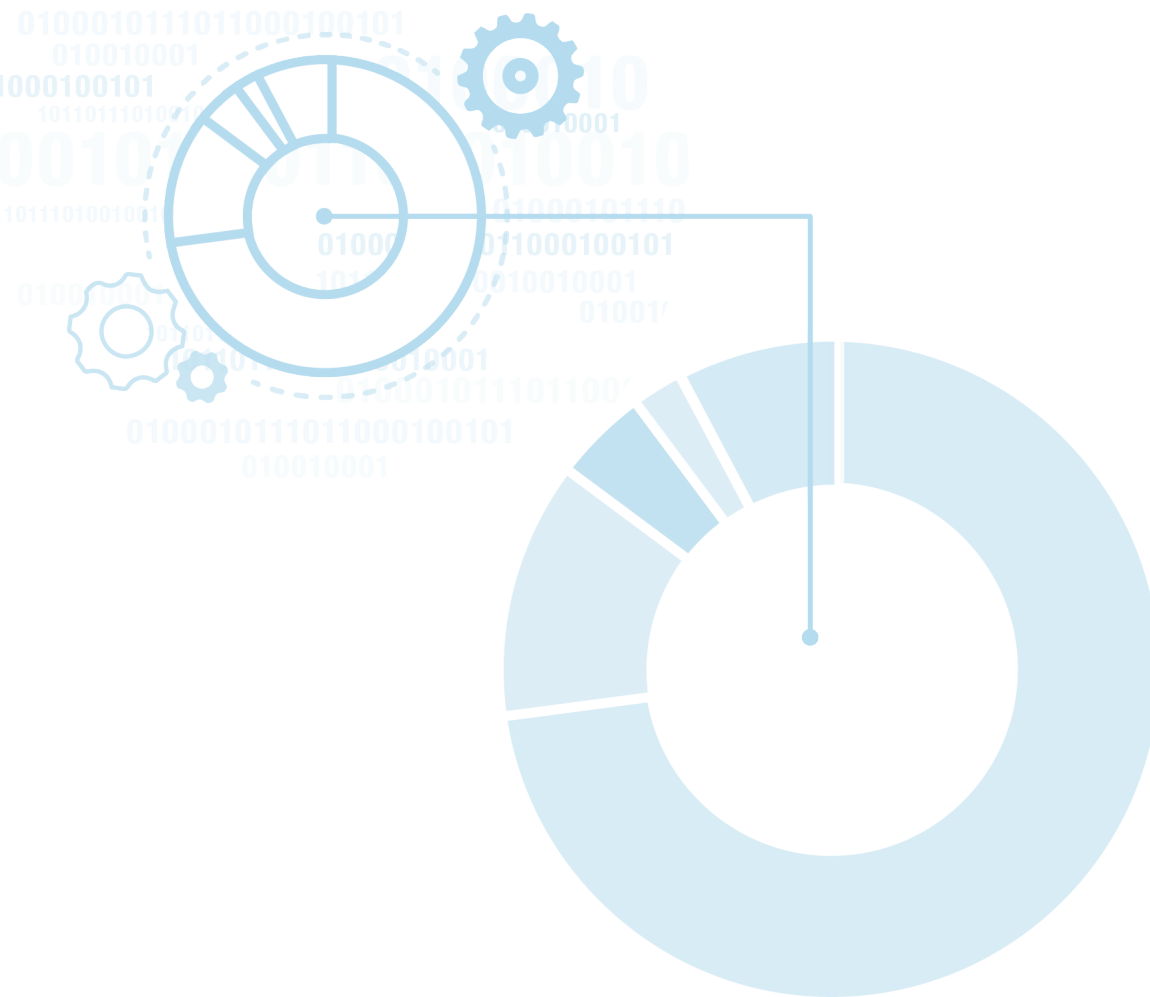
- 1. Assisted learning:** Once a user becomes familiar with how to frame the conversation, it becomes like having a friendly co-worker at your side who relentlessly tries to answer all your questions. One of the most inspiring stories told about generative AI in education comes from Sal Khan, the founder of the Khan Academy. In a TED talk called, [How AI Could Save \(Not Destroy\) Education](#), Khan shared how a ChatGPT-empowered system can enable everyone to have their own highly skilled personal tutor, which would level the playing field for less privileged students. In March 2023, Khan Labs introduced Khanmigo, an AI guide for education that tutors learners and assists teachers.
- 2. Assisted troubleshooting:** You can describe a problem you are observing and ask for help identifying the root cause and how to fix it.
- 3. Summarizing text:** Summarization is a task that is much more predictable than text expansion, as the full truth is stored in the original documents. You likely have already seen this if you have tried using ChatGPT; if not, we suggest you try the prompt for the Tesla strategy shown previously.

Let's dive into the manufacturing value streams.

1. Engineering

Engineering is one of the areas where generative AI is making an early impact:

- **Code Generation and Troubleshooting:** Generative AI can generate code, even for specific tasks like PLC ladder logic for Rockwell ControlLogix or creating a spiral staircase in the Dassault Systèmes SOLIDWORKS CAD program. This capability also extends to troubleshooting faulty code.
- **Code Explanation and Testing:** Generative AI can provide detailed comments to explain your code or even create code based on descriptive comments. It can also generate unit tests for your code, which is typically a time-consuming task.





Exercise

Ask the model to generate a simple piece of code in a programming language you are familiar with. If you're an engineer with coding experience, provide the model with a code snippet and ask it to debug and fix it.

You should see something like this...

🌟 GPT-4 ⓘ

 Using Python, write the code to connect to a source of the S&P500 index and analyze the results. Include charts.

 To fetch and analyze S&P 500 index data using Python, you can use libraries like `yfinance` for data retrieval, `pandas` for data manipulation, and `matplotlib` for plotting charts.

Firstly, you'll need to install the required packages if you haven't already:

```
bash Copy code
pip install yfinance pandas matplotlib
```

Here's a basic example:

```
python Copy code
import yfinance as yf
import pandas as pd
import matplotlib.pyplot as plt

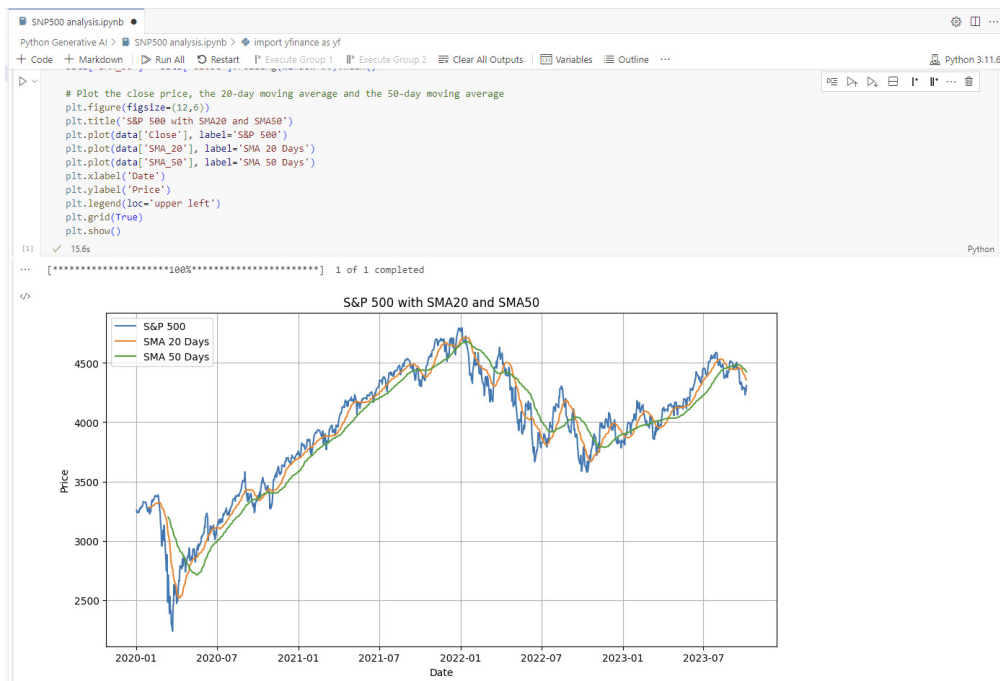
# Fetch S&P 500 data
ticker = "^GSPC"
start_date = "2020-01-01"
end_date = "2023-01-01"
data = yf.download(ticker, start=start_date, end=end_date)

# Simple moving average (SMA)
data['SMA_50'] = data['Close'].rolling(window=50).mean()
data['SMA_200'] = data['Close'].rolling(window=200).mean()

# Plotting the data
plt.figure(figsize=(12,6))
```

If you want to run the code, you need to install Python and other developer tools (it is beyond the scope of this exercise).

Here is what the results look like when running in VS Code with Jupyter Notebook...



The second part of this exercise is to give the model a piece of code and ask it to explain what the code does. Alternatively, describe a function in plain English and ask the model to create code that matches your description. For a challenge, ask it to generate a unit test for a piece of existing code.

Generative AI, combined with image recognition, (e.g., convolutional neural networks), can be trained to recognize and classify information that can be hard for humans to comprehend, such as large Piping and Instrumentation Diagrams (P&IDs) and Process Flow Diagrams (PFDs). The upstream and downstream dependencies can be used for input into failure mode analysis necessary for operations, asset management, and supply chain execution.

These are just a few examples of how generative AI can be utilized in the field of engineering. However, it's crucial to note that while generative AI can generate impressive results, it is not infallible. Always inspect and verify the text that AI has produced.

2. Procurement

Generative AI can be used to speed up supplier correspondence. It can draft documents to communicate findings, collect data requirements from partners, and summarize meeting notes. It can even be used to power chatbots for vendor collaboration.

3. Operations

Generative AI can navigate, identify, and summarize vast amounts of information. One of the common challenges in operations is finding the correct information, even if that information is readily available on the corporate SharePoint server. The traditional search techniques require exact word matches, and they are unable to compose answers that go across multiple documents. Generative AI solves this issue and can help train and guide operations personnel through complex tasks.

Generative AI can be integrated with Connected Frontline Workforce (CFW) Applications that guide operators through complex tasks. Voice-enabled chatbots will remove the need to dig through information in disconnected systems; it will finally be possible to have a conversation with the manufacturing plant, the machines, and the systems.

4. Asset Management

Asset Management is often a manual process based on a long learning process, human interaction, and hand-typed notes. Generative AI, combined with Natural Language Processing, shines in this area. The maintenance and troubleshooting manuals can be used to train the model, and human-entered information can be processed, cleaned up, and summarized. Data that has been processed and cleaned by generative AI can be put into a format that can be used for further analysis.

Generative AI can go way beyond interacting with humans for asset management. It is ideal for systematic methods, such as Failure Mode and Effects Analysis (FMEA). A properly trained model can assist an FMEA professional with predictive analysis, automated documentation, and risk prioritization. The model can even be proactive and recommend mitigation strategies and process optimizations.

5. Supply Chain

AI has been heavily used to optimize inventory levels and manufacturing activities based on analyzing supply and demand signals. Not all implementations have been equally successful, and no supply chain AI model predicted the shortages created by COVID-19 or that the "Ever Given" container ship would get stuck in the Suez Canal. However, a model trained with the FMEA approach can identify the blockage of a major shipping route as a failure mode and prepare for alternative routing plans.

Generative AI will be able to solve some of the problems that EDI has struggled with for decades. For example, it can act as a "human interface" to planning and scheduling systems so that it will be possible to ask, "When will the Widgets-R-Us order be delivered?" and "Which orders will be delayed if purchase order XYZ is delayed by five days?" These types of applications will require plug-ins that we see being developed for ChatGPT – these plug-ins can perform specific tasks that go beyond what generative AI can achieve by itself.

6. Service

With generative AI, we may finally get the chatbot that consumers prefer to interact with. Imagine a chatbot that can understand and assist you better than a human – a chatbot that is fully informed about the product you bought, including its manufacturing process and usage history. A customer service chatbot based on generative AI would have the full history of all other conversations that you've had previously; it would automatically detect your frustration and escalate to a supervisor based on the tone in your voice; and it would gather all the information that you provided as feedback to product management.

Generative AI: Fact, Fiction, Failure?

You have likely been around the block a few times and have seen enough shiny objects to know they are not all gold.

That said, we believe generative AI is real, and we are seeing industry implementations that prove its value, but we also have to be realistic about what it is. It is important not to become blinded by shiny objects. Every new technology must earn its right to be used, and we must test and challenge each of these technologies to ensure that it is in our best interest.

This is why we challenge every reader of this Spotlight to learn from reliable sources and try generative AI to understand both its strengths and weaknesses. It is critical to understand the limitations of these technologies so that we can act in ways that counter those limitations.

What Could Possibly Go Wrong?

There are many reasons your generative AI implementation may fail. Here are a few:

- **You believe that generative AI is intelligent:** It is not. The moment you think the model is intelligent, your guard will go down, and you will trust the model in ways it should not be trusted.
- **You use generative AI to reduce the need for skilled labor.** The reality is exactly the opposite; generative AI can help you increase the skill set of the company associates. Generative AI is not a substitute for knowledge but an enabler of knowledge. Using AI does not relinquish you from the responsibilities of actions, even if they are based on the recommendation of AI.
- **You fail to protect yourself.** Make sure that you understand the legal impact of using a public generative AI or a model that is trained on public data. You must understand what you should share and what you can use.

- You forget that garbage in = garbage out.** Again, generative AI models are not intelligent; you must feed them with the information they use for their results. Be prepared to build your own model and feed it the books and subject matter expertise that you want the system to act on. Remember that it is OK to feed the system college textbooks as long as you do not break copyright law. Generating valuable content requires interviewing your subject matter experts and documenting what they know. This step is critical as your model will fail if you do not provide the right information.

Keep in mind that you likely will encounter many of the same challenges as we see in Advanced Industrial Analytics, where our research shows that the top two issues are data quality and gathering buy-in from the organization (Figure 4).

Top Challenges Facing Analytics Initiatives

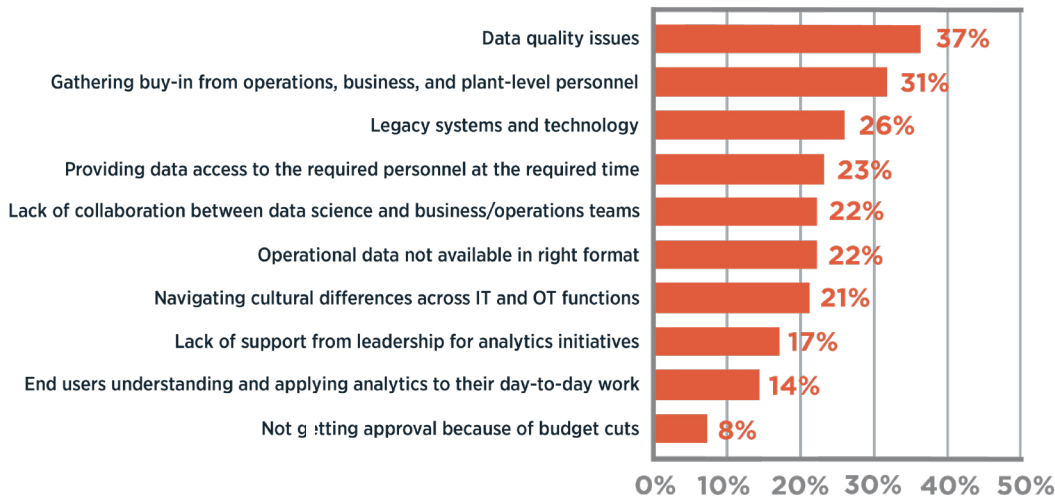


FIGURE 4 - Analytics Challenges

The Opportunity Beyond "Just" Generative AI

"You can think of generative AI as the end of your beginning. In essence, it's the starting point for a much richer journey using a combination of AI technologies," says Ron Norris, Director of Operations Innovation at Georgia-Pacific. Norris and Michael Carroll, Vice President of Innovation at Georgia-Pacific, have established their organization as a thought leader in AI for manufacturing and supply chains.

As previously stated, generative AI is not intelligent; it cannot reason and think. As an analogy, look at how different students learn:

- Some students have a photographic memory, can read and absorb, and can combine related data sets.
- Other students derive information from first principles. They learn the basics and the rules of the system. Using this information, they can extend their reasoning beyond what they have been taught.

Generative AI is like the first set of students; causal AI is the second set. Great power appears when doing both.

Georgia-Pacific is one of the world's leading manufacturers of tissue, pulp, paper, packaging, building products, and related chemicals. They have built an AI model that is not only trained on the best college textbooks and industry whitepapers about pulp and paper, but they also interviewed subject matter experts and fed several lifetimes of domain knowledge into the model. The result was a change in procurement and blend optimization, with a pilot implementation generating significant percentage savings in raw materials spending. It was an amazingly small amount of work for such an impactful result.

In addition to changing procurement, Georgia-Pacific has produced a successful proof of concept for customer order management that increased touchless orders on a 10X scale, a step change in creating a frictionless business.

Next Steps for Manufacturers

If you followed the exercises of this Spotlight, then we have hopefully whetted your appetite enough to make you interested in generative AI. As you take the next steps, it is essential to remember that manufacturing is not about technology; it is about creating business value.

IX Journey: Five Stages of Transformation Maturity

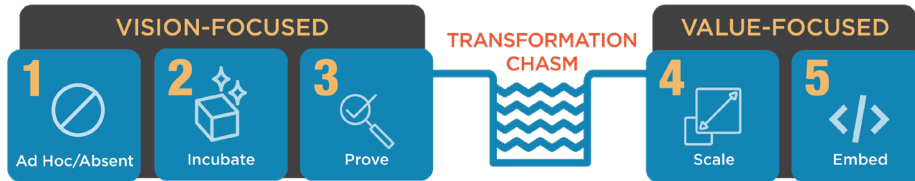


FIGURE 5 - The Five Stages of Transformation Maturity

Executives and functional leaders of manufacturing companies need to challenge themselves to identify opportunities for step changes to cross the Transformation Chasm and create value (Figure 5). Generative AI may be a technology that can enable step change if it is used wisely.

Here is an actionable list in two phases:

Phase 1: Follow the Industrial Transformation (IX) Framework

1. If you have not done so already, identify business objectives and decompose them into KPIs for business areas and functional value streams in manufacturing.
2. Create a list of the most critical problems you want to address; don't limit the list to problems that generative AI may solve.
3. For each problem, identify the success criteria and how much solving it would improve the KPIs.

4. Starting with the most crucial problem, evaluate the technologies you believe could provide a solution; don't limit yourself to generative AI. Run a thought experiment where you rate each solution against the criteria identified in point 3 and the expected effort to solve the problem.
5. Choose the problem and technology that provides the most value for the effort, independently of whether the technology that you choose is generative AI. This may seem counterintuitive in an article about generative AI but remember that manufacturing is part of the business. It is not about technology; it is about creating value.

Phase 2: Do this if only your analysis identified generative AI as a good technology to solve the problem

6. Generative AI is likely a new technology for you. It is essential that you become proficient in understanding the capabilities and constraints. Create a Pathfinder project for the business problem that you want to tackle. Also, it is essential to be deliberate and select only a few projects you can track – do not select hundreds of projects. Create a cross-functional task force and set aside a budget for how much you are willing to spend to find a path forward.
7. Iteratively learn and try. Based on your budget, you may be able to hire industry professionals and engage with world-leading universities like Georgia-Pacific did, or you may take online training classes to get your internal team up to speed.
8. Train the system. Choose trusted sources of information and gather domain knowledge from the subject matter experts to train the model. These sources can be both internal and external. The important part is that they represent the truth you want the model to know. This step is critical.

9. Constantly measure the results of your work against the business objectives. You must ask the question, "How did generative AI change our efforts and the outcome?" Communicate successes and failures to your organization so everyone can learn from each other. The goal is not to deploy shiny new technologies but to transform your business for the better.
10. When you have found a path that proves the value, then it is time to benefit from the economies of scale and scope. Roll out your findings for the selected functional area to the broader organization and expand the Pathfinder scope to new functional areas. It is time to accelerate and pivot to value.
11. You will know that you have successfully used generative AI the day it is embedded in your daily operations. It will no longer be a technology that gets all the attention; it will just be one of the many tools that get the job done.



Recommendations

It takes a while to understand and use generative AI. Therefore, we recommend digging deeper to experience the possibilities before you put generative AI into action.

Indeed, you need to be in the driver's seat to make decisions that are right for your company. While generative AI is exceptionally accessible, the time to understand and master it is significant. Larger corporations, such as Georgia-Pacific and its parent company, Koch Industries, have the resources, whereas small and medium businesses likely need to collaborate with industry peers and suppliers. Georgia-Pacific is not alone; most large corporations are testing or using generative AI. Some notable examples include Pfizer (for drug development) and Kellogg (to reduce waste and boost sales).

Generative AI is here to stay, and it is already changing our lives. However, generative AI is still in its infancy. It will continue to evolve, and future benefits will likely far exceed what we see today. The value growth will be exponential as new technologies will stand on the shoulders of the technologies we have today. Therefore, you must start exploring now; you will have no funding available if your competitors get ahead and take your market share.



Appendix

Recommended for Further Knowledge

- [LNS Research IX Framework](#)
- [Harvard - GPT-4 - How does it work, and how do I build apps with it? - CS50 Tech Talk](#)
- [Sal Khan Ted Talk](#)
- [OpenAI Prompt Engineering class](#)

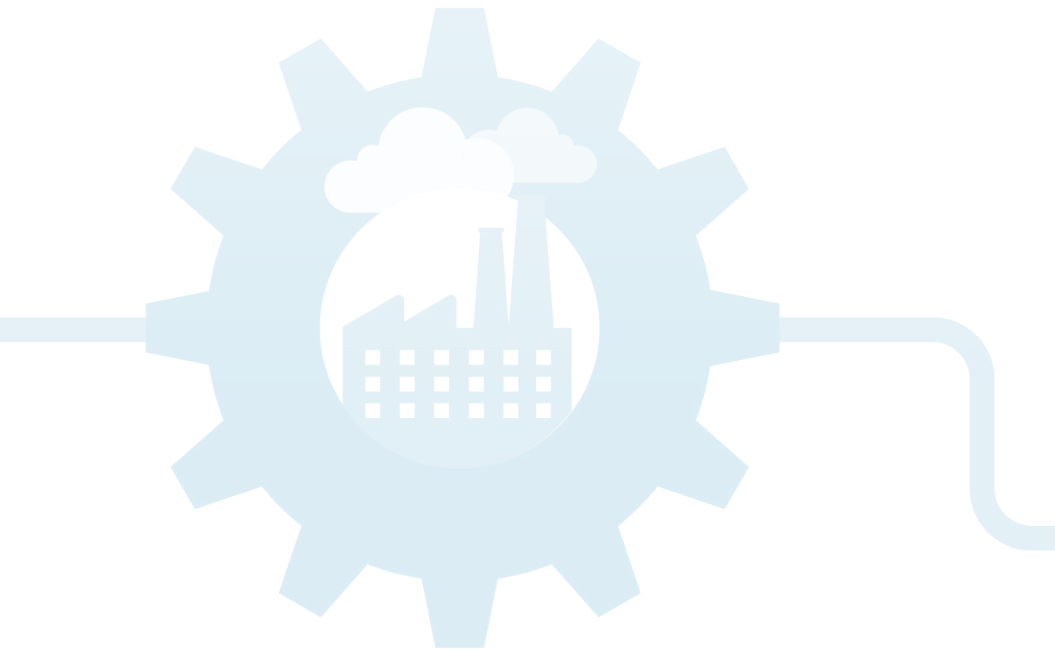
Definitions/Terminology

This Research Spotlight uses several terms that may need additional explanation:

- **Artificial Intelligence (AI)** refers to the simulation of human intelligence processes by machines, particularly computer systems, to learn, reason, perceive, and adapt.
- **ChatGPT** is an AI conversational model developed by OpenAI that generates human-like text responses based on user inputs.
- **Computer-aided Design (CAD)** is a technology used for creating precise 2D or 3D models and designs in various fields, such as engineering, architecture, and graphic design.
- **Causal AI** is an advanced form of artificial intelligence that focuses on understanding and modeling cause-and-effect relationships to make better predictions and suggest effective interventions.
- **Generative AI** refers to the subset of artificial intelligence that empowers a model to generate creative output, such as images, music, or text, by learning patterns from input data.

- **Generative Pretrained Transformer (GPT)** is an AI language model using machine learning to produce human-like text based on input.
- **Harvard CS50** is an introductory computer science course at Harvard University that provides a broad foundation in the principles of programming and computational thinking.
- **Large Language Model (LLM)** is an artificial intelligence model that utilizes extensive data training to understand and generate human-like text.
- **Programmable Logic Controller (PLC)** is an industrial digital computer designed to control manufacturing processes, such as assembly lines or batch processing, by monitoring inputs and making decisions based on its programmed logic and writing to outputs.

This Research Spotlight was written in collaboration with OpenAI's ChatGPT-4.



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