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AMPLIFY

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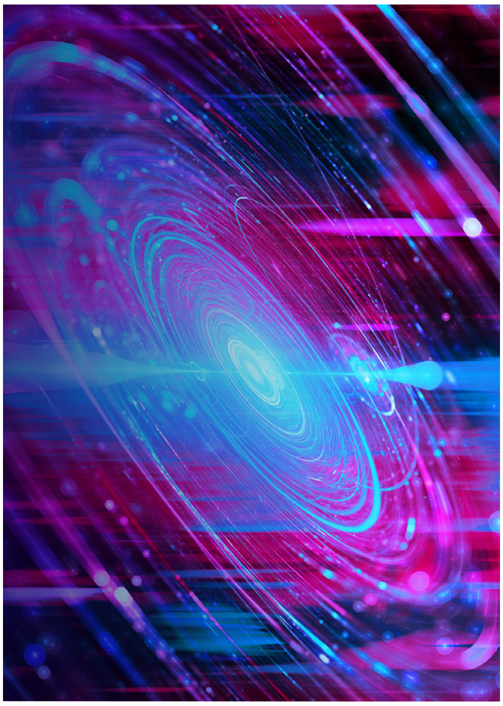
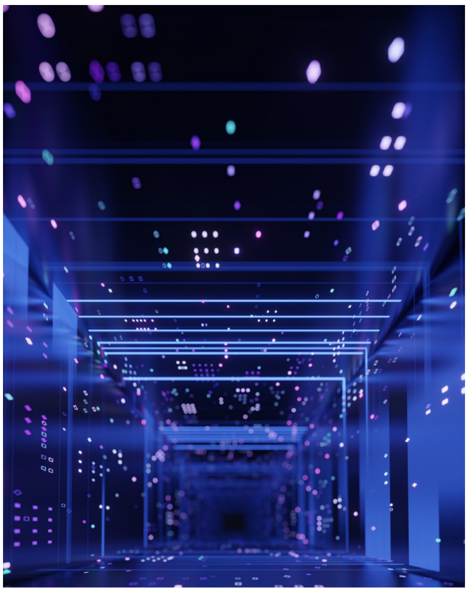
Anticipate, Innovate, Transform

Analytics: The Catalyst for Economic Value & Innovation

CONTENT





ANALYTICS: THE CATALYST FOR ECONOMIC VALUE & INNOVATION

BY DENIS DENNEHY, GUEST EDITOR

Analytics play a crucial role in generating economic value and fostering innovation by providing organizations with valuable insights (including information about customers, environmental scanning, and more) and data-driven decision-making capabilities.[1] It helps organizations identify trends, patterns, and opportunities that can lead to increased efficiency, cost savings, and revenue generation. By leveraging analytics, organizations can optimize their operations, improve customer experiences, develop innovative products and services, and gain a competitive edge.

Despite investment in analytics being a top priority for many organizations, a 2023 Statista survey found that only 37% of organizations said their efforts to improve data quality had been successful, highlighting an ongoing challenge faced by organizations across industries.[2] On average, between 60% and 73% of all data within an organization goes unused for analytics.[3]

In this issue of *Amplify*, we delve into the ways organizations are developing analytical capabilities that lead to valuable insights and create business value. We also explore the shift from being a data-driven organization to a data-centric one. The latter places data science at its core; data is a primary, permanent asset used as the starting point to determine organizational action.[4]

ORGANIZATIONS THAT EXPLOIT ANALYTICS TEND TO VIEW IT AS MORE THAN A MEANS TO AN END

As we explore this shift, it becomes evident that organizations that exploit analytics (and data in general) tend to view it as more than a means to an end — they harness it to create a data-centric culture, establish synergies within and across functions, and deepen relationships with myriad stakeholders.

IN THIS ISSUE

This issue of *Amplify* delves into the insights of organizations that have used analytics to generate economic value and foster innovation in products, processes, and services.

Bill Schmarzo opens the issue with a thought-provoking article about how companies can unleash business value and economic innovation through AI. Drawing on the seminal work of Adam Smith (author of *The Wealth of Nations*), Schmarzo explains that "the essence of economics is the creation, consumption, and distribution of wealth — or value" as a baseline for economic innovation. The author brilliantly balances his extensive industry experience and published works to highlight cultural empowerment as a way to foster an inclusive environment to demonstrate value. He identifies 10 critical characteristics of cultural empowerment in the context of leveraging AI and generative AI (GenAI) for economic innovation. Schmarzo also offers the "Thinking Like a Data Scientist" methodology to help business leaders maximize AI to create new sources of customer, product, service, and operational value. The article concludes with an example of integrating GenAI with the methodology to create an economic innovation force multiplier.

Next, Hossein Sahraei, Ramila Peiris, Luc Nguyen, and Olivier Moureau describe how global healthcare company Sanofi transitioned from reactive modes of data analytics (descriptive, diagnostic) to a proactive approach through prescriptive analytics. The authors, who are part of Sanofi's process data science team, provide a refreshing account of their experiences, challenges, and successes, beginning with an acknowledgment that digital transformation goes beyond adopting new technologies to fundamentally change how organizations operate, think, and innovate. They highlight the importance of developing a growth mindset, challenging established norms, and seeing uncertainty as a catalyst for innovation. The authors also explain how the organizational strategy prioritized practicality (an approach based on business needs and limitations), scalability (a framework that can be used in different areas with minimal effort), and sustainability (manageable execution, maintenance, and updates) in product design and deployment. The article reports on the economic value of empowering decision makers, along with benefits such as increased job satisfaction and helping workers maintain a healthy work-life balance.

In our third article, Antoine Harfouche explains how AI and big data analytics enable smart farming, focusing on the hydroponic forage market. With a current market value of more than US $5 billion, hydroponic systems that leverage technologies like AI, Internet of Things, satellite imagery, and data analytics can optimize environmental controls, improve resource management, and enhance crop resilience. He also outlines the advantages and disadvantages of several such technologies. By combining data, including genomic (epigenomics, transcriptomics, metabolomics), phenomic (plant height, leaf shape, angle, growth trajectory), and environmental (weather and soil, solar radiation, relative humidity), AI can enhance predictive accuracy and decision-making in breeding programs to enhance climate resilience. Harfouche explains the importance of the data value chain, which consists of data capture, data storage, data transformation, data analysis, data interpretation, and feedback. These stages are then instantiated into a framework to demonstrate how AI and big data analytics can be used to improve hydroponic cultivation and improve the sustainability of hydroponic farming. The article concludes with a call for increased collaboration among researchers, farmers, and policy makers to harness these technologies to create a sustainable and secure food production system for the future.

Next, Enjoud Alhasawi, Denis Dennehy, Yogesh Dwivedi, Guoqing Zhao, and Sean Coffey highlight a growing concern about how supply chain disruptions negatively impact both developed and developing countries. The authors provide insights from practitioners at four companies located in Ireland and Kuwait that operate in large, complex agri-food supply chains. They focus on understanding how AI enables resilience in agri-food supply chains. Building on the four dimensions of supply chain resilience (readiness, responsiveness, recovery, and adaptability), the authors show how the companies used robotics and expert systems to mitigate the threat of supply chain disruptions. Drawing on secondary data, they acknowledge that other functions of AI (machine learning, machine vision, natural language processing, and speech recognition) can be applied to various elements of the supply chain, including forecasting, optimization of processes, supplier selection, automation, and decision support for configuration, design, and planning. Anticipating that future supply chain disruptions will threaten the global agri-food sector, the authors call for concerted efforts between industry, the public sector, and academic researchers to build more resilient supply chains.

Finally, Daniel J. Rees, Roderick A. Thomas, Victoria Bates, and Gareth Davies wrap up the issue by examining the transformational impact that healthcare-related technologies (e.g., AI, wearable sensors, clinical and genetic data) have on the healthcare and pharmaceutical industries. These technologies can potentially transform healthcare business processes, resulting in faster, more efficient decision-making, human-error reduction, and accelerated product development cycles that can lead to faster product launches. The authors gained insights from 48 senior managers in healthcare and pharmaceutical organizations to both identify best practices and understand the challenges related to using healthcare-related technologies and data-centric decision-making to deliver value to stakeholders. Best practices, such as governance (memorandum of understanding), incentives (monetary and nonmonetary), scalability, and collaboration between pharmaceutical makers and technology companies, are identified as key enablers. Such practices enable stakeholders to mitigate challenges like culture (trust, reputation, time, risk aversion), governance (contracts), and scalability. The article concludes with recommendations to ensure the right individuals choose tools and processes that can lead to successful partnerships and transformational initiatives for the benefit of patients, society, and the wider economy.

Analytics is a powerful tool for driving growth, fostering innovation, and creating economic value in today's increasingly data-centric business world. We hope the articles in this issue advance your understanding of how organizations from various industries are identifying use cases for analytics as a catalyst for economic value and innovation and provide you with a blueprint for guiding your teams, organizations, and stakeholders to successfully navigate turbulent environments.

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About the guest editor

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Denis Dennehy is Associate Professor of Business Analytics and School Research Lead at the School of Management, Swansea University, Wales, UK. His research primarily focuses on the mediating role of technologies and its implications for teams, organizations, and society. He has worked on several industry-oriented research projects funded by UK Research and Innovation (UKRI), Enterprise Ireland, Science Foundation Ireland, Erasmus+, and Irish Aid. These projects have been informed through extensive engagement with various organizations, including Dell, Intel, Fexco, Leading Edge Group, Texuna, Kepak Group, and not-for-profit organizations in Kenya. Dr. Dennehy's research has been published in leading journals, including *Information and Management, Information Systems Frontiers, International Journal of Operations & Production Management, European Journal of Operational Research*, and IEEE. He is Co-Editor-in-Chief for *Communications of the Association for Information Systems*, Senior Editor for *Information Technology and People*, and has edited several special issues related to his field. Dr. Dennehy earned a master's and PhD in business information systems from University College Cork, Ireland. He can be reached at denis.dennehy@swansea.ac.uk.

UNLEASHING BUSINESS VALUE & ECONOMIC INNOVATION THROUGH AI

Author

Bill Schmarzo

In today's rapidly evolving technological landscape, discussions often pivot quickly to the financial benefits — particularly cost reductions — that new technologies like AI and generative AI (GenAI) can offer. For instance, senior executives are fascinated with how GenAI can improve productivity and reduce customer service costs; this viewpoint echoes a widespread corporate desire to equate technological adoption with direct financial savings. However, this perspective only scratches the broader, more impactful economic potential of these technologies.

As economist/philosopher Adam Smith illuminated in his seminal work, *The Wealth of Nations*, the essence of economics is the creation, consumption, and distribution of wealth — or value.[1] While financial metrics focus on the ledger, counting pennies saved or spent, economics paints with a broader brush, exploring how technologies like AI/GenAI can catalyze new forms of value creation. This value can take the form of innovative customer experiences, enhanced product features, streamlined service models, and/or operational efficiencies that elevate the economic standing of enterprises and societies alike.

"Economic innovation" refers to the introduction of new products, services, processes, or policies that enhance an organization's financial health, efficiency, or economic growth. For example, rather than a tool for reducing costs and increasing productivity, GenAI can be a pivotal technology that drives economic value creation across various sectors. It can catalyze business model creation and a variety of market opportunities, creating economic value.

As we delve into the economic impact of new technologies like AI/GenAI, we see that their true value lies in their ability to redefine markets, enhance competitiveness, and spawn new economic ecosystems. This article explores how shifting our focus from a financial to an economic lens (not just counting costs but generating value) can radically alter our appreciation and application of groundbreaking technologies.

> **ECONOMICS PAINTS WITH A BROADER BRUSH, EXPLORING HOW TECHNOLOGIES LIKE AI/GENAI CAN CATALYZE NEW FORMS OF VALUE CREATION**

CULTURAL EMPOWERMENT FUELS ECONOMIC INNOVATION

Centralizing innovation to a select few "experts" limits an organization's potential to benefit from capabilities like AI/GenAI. Everyone in the organization must have a stake in innovation, especially frontline workers engaged in customer service and operations.

These individuals have valuable knowledge about where and how to apply innovative technologies to create new sources of customer, product, service, and operational value. They should provide feedback on the effectiveness of the analytics used to optimize customer engagement and operational execution, and that feedback should be used to update and refine the AI models (known as "reinforcement learning from human feedback" or RLHF). If you want full adoption of AI results, start by involving these folks in the definition, development, deployment, and refinement of the analytics they will use in their daily interactions. Economic innovation starts with cultural empowerment.

Cultural empowerment fosters an inclusive environment that values everyone's contributions and equips them with tools for innovation. The critical characteristics of cultural empowerment, particularly in the context of leveraging AI/GenAI for economic innovation, include:

- **Exploration** — drives innovation, especially with emerging technologies like AI/GenAI, which require experimentation to realize their full potential. Encouraging curiosity and pursuing knowledge and solutions without fearing failure is crucial to exploration.
- **Intelligent risk-taking** — involves making calculated decisions to pursue potentially beneficial innovations despite uncertain outcomes. It is supported by data-driven insights and a deep understanding of the potential rewards and risks involved.
- **Continuous learning and adapting** — represents essential qualities that highlight the significance of learning new technologies, business strategies, and market conditions. In the context of AI/GenAI, individuals should regularly update their skills and understanding to keep up with technological advancements and their business applications.
- **Transparency** — fosters trust and inclusiveness, allowing individuals to understand the rationale behind decisions, including AI-driven ones. It encourages a collaborative environment where the potential and limitations of AI/GenAI are openly discussed, ensuring that all stakeholders are on the same page.
- **Empathy and human-centric design** — begin with understanding the human impact of AI/GenAI and designing solutions that address fundamental human needs. It is essential to ensure that technological innovation is aligned with improving the human condition, leading to solutions that are not only economically viable but also socially responsible.
- **An adaptive mindset** — is crucial to the ability to learn, unlearn, and relearn as circumstances change. In an AI-enhanced world, this means pivoting and adjusting strategies as new information and technologies emerge.
- **Inclusivity and diversity —** involve diverse voices in the development and deployment of AI/GenAI, which ensures that a broad range of experiences and perspectives are considered, leading to more innovative and equitable solutions.
- **Resilience —** the capacity to recover from setbacks and persist in the face of challenges is critical when working with emerging technologies. It ensures that organizations can sustain innovation efforts through the inevitable ups and downs of technology adoption.
- **AI literacy** — consists of understanding and interpreting data, which is increasingly vital in an AI-driven world. Cultivating data literacy across the organization enables more members to meaningfully participate in, and contribute to, AI initiatives.
- **Ethical consideration** — is the heart of AI/GenAI. As they become more integrated into organizational processes, the ethical implications of their use must be considered. A culture that prioritizes ethical considerations will navigate the complexities of AI/GenAI more successfully and sustainably.

Encouraging empowerment throughout your organization can unlock your employees' collective creativity and knowledge, leading to more ideas about where and how AI/GenAI can develop solutions to drive your organization's economic innovation. That means senior management must invest in cultural empowerment and create a culture that exploits the natural human characteristics of curiosity and imagination.

Imagine a path that represents the journey toward cultural empowerment and innovation. This path starts with a base of curiosity and ends with the peak of innovation (see Figure 1). Figure 1 shows how cultural empowerment can inspire human curiosity and exploration, leading to genuine creativity and economic innovation. To achieve this human-driven economic innovation, we must promote a culture that embraces AI/GenAI for innovation, including:

- **Curiosity.** At the start of the journey, curiosity represents the foundational attitude that drives individuals to question the status quo and seek knowledge. In the context of AI/GenAI, fostering curiosity in all team members ensures a constant search for data insights and innovative technology applications.
- **Imagination.** Building on curiosity, imagination allows individuals to conceptualize novel ways to apply AI/GenAI. It's about seeing beyond current applications to imagine future innovations.
- **Creativity.** This level represents the synthesis of curiosity and imagination, turning new ideas into tangible concepts. In AI/GenAI, this might manifest as inventive data models, unique algorithms, or original ways to integrate AI into products and services.
- **Innovation.** At the pinnacle, empowerment and encouragement of exploration, intelligent risk-taking, and continuous learning result in new AI-driven products, services, or operational processes that deliver economic value.

CULTURAL EMPOWERMENT FOSTERS AN INCLUSIVE ENVIRONMENT

THINK LIKE A DATA SCIENTIST

Having established the economic imperative of shifting our focus from cost-cutting to value creation, we now need a collaborative, design-centric, human-empowered framework that can help organizations leverage AI to create new sources of customer, product, service, and operational value. Welcome to the "Thinking Like a Data Scientist" (TLADS) methodology (see Figure 2).[2,3]

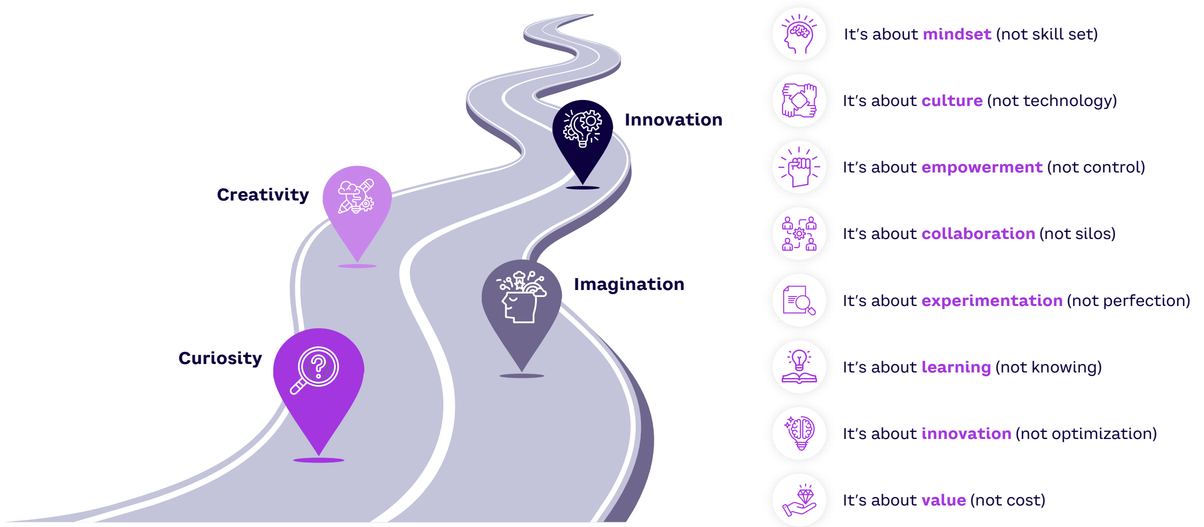

Figure 1. Path to cultural empowerment and innovation

Figure 2. "Thinking Like a Data Scientist" methodology

TLADS integrates design thinking, data science, and data economics to enhance decision-making and redefine how we perceive and capitalize on business opportunities. It is built on the following three fundamentals.[4]

1. DESIGN THINKING FUELS IMAGINATION & INNOVATION

With its core emphasis on user-centric problem-solving, design thinking plays a pivotal role in maximizing GenAI's potential. It prompts organizations to think beyond traditional boundaries, fostering an environment where innovation is encouraged and inevitable. By applying design thinking to AI development, companies can create solutions that are not only technologically feasible but also profoundly aligned with fundamental human needs and market demands. This alignment is crucial for developing AI-driven products and services that resonate with users and deliver sustainable economic value.[5]

2. DATA SCIENCE IS THE BACKBONE OF SCALING INNOVATION

Data science is central to unlocking AI's economic potential. The rigorous analytical processes and advanced modeling techniques in data science help businesses extract actionable insights from vast amounts of data. By systematically applying data science principles, organizations can predict trends, personalize customer experiences, and optimize operations — each an avenue for significant economic innovation. Moreover, data science ensures that AI initiatives are based on empirical evidence, enhancing their credibility in driving business value.

3. DATA ECONOMICS DRIVES SUSTAINABLE VALUE CREATION

Data economics provides the framework for understanding and quantifying data's value to business processes. In the context of AI, this means identifying how information assets can be transformed into economic gains. By applying data economics principles, organizations can measure the impact of data reuse, sharing, and innovation on their economic performance. This approach (1) helps maximize the ROI from data assets and (2) aids in crafting strategies that leverage AI for increased revenue and competitive advantage.

These fundamentals lay the groundwork for businesses to explore and navigate the complexities of deploying AI to deliver more accurate and meaningful outcomes. The synergy among these disciplines encourages a holistic view of AI's role within the business ecosystem, emphasizing sustainable value creation over short-term gains. This allows companies to adapt to the evolving economic landscape and drive forward-thinking innovations that redefine their industries.[6]

GENAI IS AN ECONOMIC INNOVATION FORCE MULTIPLIER

A force multiplier is a factor or tool that dramatically increases the effectiveness of an effort or system, enabling significantly more effective results with the same level of input.

Integrating GenAI tools such as ChatGPT with the TLADS methodology provides a force multiplier that can accelerate and expand economic innovation within organizations. By combining GenAI's cutting-edge capabilities with the structured, holistic approach of TLADS, organizations can unlock the creative potential of AI. This integration can transform economic innovation efforts in several ways:

- **Automated data exploration.** GenAI can automate the exploration of vast data sets, identifying patterns and insights that might not be immediately apparent to human analysts. This can accelerate the discovery and creation of machine learning (ML) features that are critical to building relevant, accurate AI/ML models
- **Predictive modeling and scenario simulation.** With GenAI, organizations can develop predictive models and simulate business scenarios with greater accuracy and less human bias. This capability supports more effective data-driven decision-making, which helps executives uncover new sources of customer, product, service, and operational value.
- **Rapid prototyping.** GenAI can generate prototypes of new products, services, or business models, allowing teams to quickly test and iterate. This highlights the importance of experimentation and validation in ensuring that ideas are innovative and viable.
- **User-centric design.** Leveraging GenAI in design thinking processes facilitates the creation of more personalized and adaptive user experiences. Organizations can continuously refine and enhance their offerings by integrating user feedback directly into the AI model training process, ensuring they meet evolving customer needs effectively.
- **Democratization of data and AI tools.** By making advanced AI tools accessible to non-experts, GenAI empowers a broader range of employees to engage with data science practices. This fosters a culture of innovation and collaboration that encourages a more inclusive approach to problem-solving.
- **Continuous learning and adaptation.** Integrating GenAI facilitates a culture of constant learning and adaptation, which is essential for staying competitive in dynamic markets. GenAI tools provide real-time insights and updates, enabling organizations to pivot quickly and efficiently in response to new information or market conditions.

By combining GenAI with TLADS, organizations can accelerate their current economic innovation efforts and expand their capacity to explore new opportunities for growth and value creation. This synthesis drives more effective and efficient innovation processes and embeds a sustainable, forward-thinking mindset across the organization.

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About the author

Bill Schmarzo is Customer Data & AI Innovation Strategist for Dell Technologies, where he is responsible for collaborating with strategic customers to facilitate cross-organizational alignment in their AI journeys. Previously, Mr. Schmarzo was CIO at Hitachi Vantara, where he spearheaded data science and co-creation initiatives, earning the prestigious Hitachi Limited's 2020 Solution Innovation Award for his pioneering work in data science and automated machine learning. As CTO at Dell EMC, Mr. Schmarzo played a pivotal role in creating a big data practice strategy, identifying target markets, developing solution frameworks, and leading analytics client engagements with his Vision Workshop. This innovative methodology aligns an organization's strategic business initiatives with supporting data and analytics to drive business growth.

He is author of *Big Data: Understanding How Data Powers Big Business*; *Big Data MBA: Driving Business Strategies with Data Science*; *The Economics of Data, Analytics, and Digital Transformation*; and, most recently, *AI & Data Literacy: Empowering Citizens of Data Science*. Mr. Schmarzo is a University of San Francisco School of Management Executive Fellow, Honorary Professor at National University of Ireland-Galway's School of Business and Economics, and AI Research Fellow at Coe College. He earned an MBA from the University of Iowa and a bachelor of science degree in mathematics, computer science, and business administration from Coe College. He can be reached at schmarzo@yahoo.com, @schmarzo on Twitter, and www.linkedin.com/in/schmarzo.

VISION INTO ACTION:

A REFLECTION ON SANOFI'S PRESCRIPTIVE ANALYTICS JOURNEY

Authors

Hossein Sahraei, Ramila Peiris,
Luc Nguyen, and Olivier Moureau

Proactivity isn't a choice in biopharmaceutical manufacturing; it's a fundamental need. The high costs associated with suboptimal process performance, which can result in significant delays or even a manufacturing halt, mean that continuing with outdated methods is no longer feasible. As a process data science team, our goal is to provide process scientists and production managers with the tools they need to proactively identify and address potential issues in vaccine production. By integrating prescriptive analytics into our workflows, we enable our scientists to take data-driven actions and effectively resolve challenges.

From a broader perspective, it's important to recognize that digital transformation goes beyond adopting new technologies; it's about fundamentally changing how organizations operate, think, and innovate. This shift requires moving away from traditional mindsets, questioning established norms, and seeing uncertainty as an opportunity for innovation. This is particularly important in process data analytics, where extracting useful insights from complex data relies on collaboration between data, process, operational, and quality teams. We need insights that align with scientific relevance and fit within operational constraints and quality expectations. This is essential since several parameters come into play, and correlations may occur by chance, rather than indicating causation.

Businesses understandably aim for predictability and control in the digital age, but the dynamic nature of manufacturing operations often challenges these rigid expectations. Thus, process variability, rather than being an anomaly, should be considered an inherent characteristic of the manufacturing landscape, providing a rich yet challenging environment for adaptation and progress. Recognizing the complexity of these operations, we have embraced the notion that process variability is not an obstacle but a resource to be harnessed for innovation, optimizing process performance and gaining insight.

This understanding has been the driving force behind our proactive approach to monitoring and troubleshooting manufacturing processes through the deployment of prescriptive analytics. Building on the pillars of product safety, quality, and efficacy, we aim to leverage data analytics not just to meet regulatory demands but to foster sustainable growth.

> **PROCESS VARIABILITY SHOULD BE CONSIDERED AN INHERENT CHARACTERISTIC**

In a previous *Amplify* article, we outlined the rationale behind transitioning from reactive modes of data analytics (namely descriptive and diagnostic analytics) to a proactive approach through prescriptive analytics.[1] We presented the main technical components of the solution (data contextualization, live analytics engine, and visualization/reporting) and emphasized the potential benefits of this shift, which included performing analytics at speed to reduce reaction times in process troubleshooting, faster recovery of manufacturing operations, and acting on data-driven insights to ensure process robustness, yield management, and predictable supply.

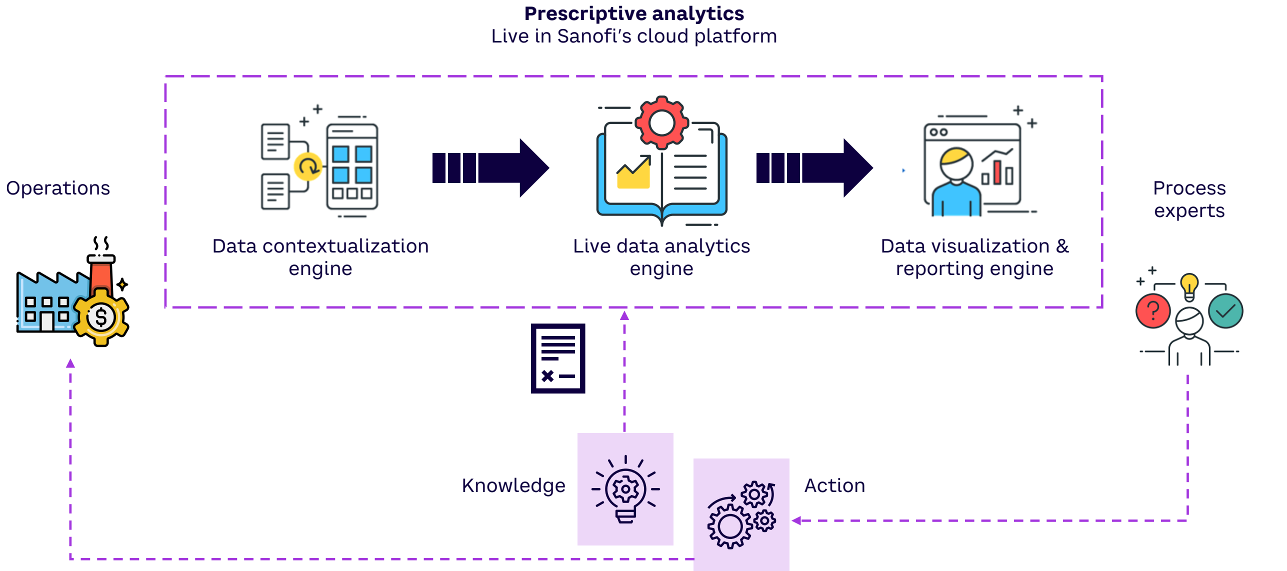

Figure 1. Sanofi's prescriptive analytics tool bridges operations and provides process experts with insights

This article is a reflection on our experiences, challenges, and successes during that journey, highlighting the transition from vision to action in adopting prescriptive analytics methodologies (see Figure 1).

VISION & STRATEGY

Our prescriptive analytics implementation was rooted in our vision to improve operational efficiency and product quality by shifting from reactive to proactive modes of operation. In short, we conceptualized a pragmatic digital capability that could be integrated with a new way of working to proactively identify and expediently resolve process-related challenges.

This vision translated into a primary objective: empowering stakeholders with rapid and live data analytics capabilities, enabling swift monitoring of the latest batches, and providing process-related suggestions to mitigate or avoid unfavorable process-performance situations. We aimed to detect anomalies and divergence in process performance while providing actionable recommendations to mitigate potential issues. To reach this objective, we formulated a strategy that prioritized practicality, scalability, and sustainability in product design and deployment (see Figure 2).

In designing the product, we took a practical, realistic approach that addressed the specific needs and limitations of our business environment. Numerous ideas were proposed, but we recognized the importance of simplicity and effectiveness in ensuring user adoption and decision-making support. We therefore focused on providing actionable information without requiring users to run models or manipulate data sets. This streamlined approach ensured that the tool remained user-friendly and streamlined decision-making.

Our strategy also placed a significant emphasis on scalability, striving to craft a general framework that could be adapted to various process areas with minimal effort. Embracing a product-agnostic approach facilitated rapid deployment, enabling seamless integration into new areas in a matter of days. By formulating a business knowledge and parameter-mapping database to collect product- and process-specific requirements for each area and generating generalized code for visualizations and insights, we laid the groundwork for a scalable solution capable of evolving alongside our expanding facilities and products.

To ensure sustainability, we paid close attention to managing the execution, maintenance, and updates of the product within existing resource constraints. Effectively balancing the workload of the new product with ongoing tasks, projects, and manufacturing support ensured its viability and efficacy. Our aim was not to add to the workload of our teams, but rather to streamline their processes and provide them with the tools necessary to make informed decisions.

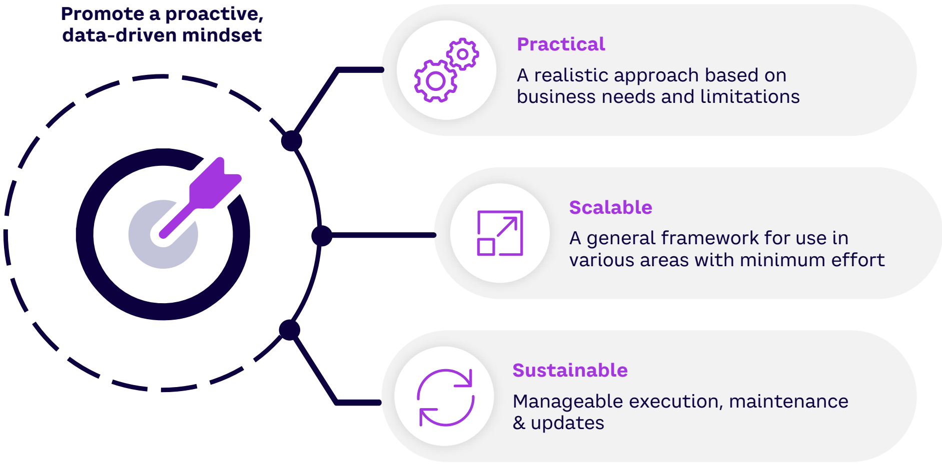

Figure 2. Designing and deploying the prescriptive analytics tool

PRODUCT LAUNCH

The unveiling of our prescriptive analytics solution marked a pivotal moment in our journey toward transforming pharmaceutical manufacturing at Sanofi. Our primary goal was to capture the attention of subject matter experts (SMEs) and end users, reassuring them that the tool was designed to complement their expertise rather than replace it.

To achieve this, we focused on ensuring that users understood the practical benefits of the tool and felt empowered to interpret its results. We spent considerable time on user training and support, guiding individuals through the application's interface and demonstrating its utility in real-world scenarios. By emphasizing the tool's role in enhancing decision-making and streamlining processes, we fostered enthusiasm and buy-in from frontline staff, laying the foundation for successful adoption.

However, the unveiling of the product presented challenges, particularly in engaging managers who were less familiar with the nuances of our previous workflows and data limitations. To maintain a balance between political correctness and a need for pragmatism, we focused on the tool's potential to address longstanding challenges and improve operational efficiency. By emphasizing the simplicity and user-friendliness of the interface, we sought to bridge the gap between technical complexity and managerial oversight, ensuring that all stakeholders understood the value proposition of the prescriptive analytics solution.

Successful user adoption in one area after another served as critical milestones in our journey, setting the stage for widespread acceptance and integration of advanced analytics into our manufacturing operations.

ITERATIVE REFINEMENT

We recognized early on the importance of ensuring a smooth, efficient user interface, particularly in contrast to existing tools with unfriendly navigation and lengthy computational times. We worked diligently to simplify the user experience, starting with familiar visualization formats and progressively integrating advanced analytics for deeper insights. This approach facilitated adoption and encouraged users to explore the tool's capabilities.

Initially delivered as a static PDF, the transition to an interactive application proved instrumental. This shift enhanced accessibility and generated significant interest from other areas within Sanofi, which were eager to replicate the success seen with our initial implementation. By incorporating additional features that facilitate rapid decision-making, we expanded the tool's utility, catering to diverse user needs and enhancing its overall value proposition. Through continuous iteration guided by user feedback, we ensured that the prescriptive analytics solution remained agile and responsive to evolving user requirements, ultimately driving tangible improvements in operational efficiency and product quality.

EMPOWERING DECISION MAKERS

A significant milestone in our implementation was the profound impact on decision-making processes within the data science team. By accelerating response times from days to minutes, our prescriptive analytics tool revolutionized the way critical insights were generated and acted on.

The dramatic reduction in response time provided decision makers with more time to perform in-depth follow-up analyses and facilitated resource reallocation. Freeing up valuable personnel to build more advanced models (e.g., mechanistic modeling programs) enhanced our analytical capabilities. The standardization of data analysis and reporting ensured consistency and reliability across the board.

The true measure of success lies in the intangible yet profound way our solution empowered process scientists and SMEs to swiftly analyze and respond to evolving situations. Achieving this cultural shift was not without challenges; it required collaboration with senior leadership to garner support and seamlessly integrate the tool into existing workflows. Amidst high-pressure scenarios, our solution provided these individuals with newfound clarity and insight into the dynamics within their areas, helping them swiftly make informed decisions.

Quantifying the impact of this transformation isn't simple, but its significance is undeniable. With faster analytics, decision-making has accelerated, letting the team swiftly return to expected process behaviors and avoid costs associated with production schedule disruptions. The reduction in investigation time led to tangible savings, including lead-time reduction, time savings during troubleshooting, and proactive intervention to ensure process robustness.

Moreover, having relevant analytics at hand alleviates stress during high-pressure investigations. This allows individuals to focus more effectively on the process and scientific aspects, enhancing learning through troubleshooting activities. This improved focus is beneficial to employees, contributing to job satisfaction and helping workers maintain a healthy work/life balance. In essence, empowering our team amplifies the output of our most valuable asset: our people.

LOOKING AHEAD

Looking ahead, our broad vision involves fostering a culture that values data-centric, proactive decision-making. Our current prescriptive analytics tool has played a pivotal role for three years, but its true significance lies in the cultural shift it has ignited within our organization.

Our mission is to empower people and drive meaningful change. As we evolve, our focus remains on sustaining this culture of innovation, ensuring that our commitment to data-driven insights guides our decisions.

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FROM LABOR-INTENSIVE TO SMART FARMING:

IMPACT OF BIG DATA ANALYTICS & AI ON HYDROPONICS

Author

Antoine Harfouche

The hydroponic forage market, which includes crops like barley, wheat, and maize, is experiencing significant growth. In 2023, the global hydroponics market was valued at US $5.2 billion. It's expected to grow at a CAGR of 8.5%, reaching $10.8 billion by 2032.[1] The hydroponic forage industry aims to provide year-round green forage for farm animals, reduce feed costs, improve production efficiency, increase profits, and create employment opportunities.[2]

Several companies in this sector are making substantial contributions to market growth with innovative, efficient hydroponic systems. For example, FodderTech offers systems that convert grains into green feed within seven days, greatly enhancing sustainability by providing a 98% reduction in water usage and a 99% reduction in land usage. The company says its systems can cut feed costs by up to 50% and reduce farmers' carbon footprint by up to 70%.

Another prominent player, CropKing, sells hydroponic systems that produce up to 210 pounds of fresh barley fodder daily. Its designs focus on maximizing space efficiency and minimizing water usage. Similarly, HydroGreen offers automated systems that produce fresh, nutritious livestock feed year-round, helping reduce labor and other costs.

Hydroponic cultivation of forage crops such as barley, wheat, and maize supports sustainable agriculture goals by providing significant cost savings while enhancing animal nutrition.[3] When AI and big data analytics are added, these systems not only boost production efficiency, they support the economic viability of small and medium-sized farms, making hydroponic farming an attractive option.[4]

This article explores the potential impacts of AI and big data analytics on hydroponic farming systems, focusing on the cultivation of barley, wheat, and maize as forage. Integrating AI into hydroponic systems can help farms optimize environmental controls, improve resource management, and enhance crop resilience.

SMART FARMING & SUSTAINABLE AGRICULTURE

Recent advances in AI and big data analytics have led to a new concept called "smart farming."[5,6] This concept, also known as "precision agriculture" or "digital farming," refers to the use of advanced technologies and data-driven approaches to improve agricultural productivity, efficiency, and sustainability. Specifically, it involves integrating modern technologies into traditional farming practices to monitor, automate, and optimize agricultural operations.[7] Table 1 describes the key farming technologies involved and their value to the smartness objective.

As Table 1 shows, advanced farming methods use technologies like AI, GPS (Global Positioning System), Internet of Things (IoT), satellite imagery, and data analytics to optimize crop management.[8] These technologies improve productivity, resource efficiency, and environmental sustainability by providing precise information for managing inputs like water, fertilizers, and pesticides.[9] They can also reduce costs, enhance crop yields, and minimize environmental impact, but they require a significant initial investment and strong technical and data management skills.[10]

In essence, big data and AI can integrate the social, environmental, and economic sustainability components of farming. This is crucial for realizing a holistic approach to sustainable agriculture. Social sustainability enhances farming and rural communities by developing shorter supply chains, fostering community involvement, and promoting youth development. Environmental sustainability focuses on mitigating carbon footprints, minimizing food waste, and enhancing food quality and security, primarily through lifecycle assessments and resource-recovery practices. Economic sustainability aims to reduce overall supply chain costs, boost productivity, and ensure long-term profitability by adopting strategies like short supply chains and the promotion of local food products.

Together, these sustainability components can lead to robust, resilient agriculture that not only supports economic growth but also protects the environment and enhances social well-being.

TECHNOLOGY		ADVANTAGES	DISADVANTAGES
Robotics & automation	Autonomous tractors	Ensures quality & reduces labor costs via driverless farming equipment	High initial investment cost; requires technical skills for operation & maintenance; potential job loss for traditional farm workers
	Harvesting robots	Use machine learning to identify & harvest specific crops, automating the harvesting process	High initial setup & maintenance costs; limited to specific crops & may require customization
	Robotic milking systems	Automate the milking process for cattle, enhancing efficiency & reducing labor needs	High initial investment & maintenance costs; requires adaptation by both farmers & cattle; dependent on technology, which may be vulnerable to failures
Connectivity & IoT	Sensors & devices	Collect data in fields on soil moisture, temperature & crop health	High initial setup cost; requires reliable Internet; potential data security & privacy issues
	5G	Supports vast number of IoT devices, enabling precise monitoring & control of farming activities	High infrastructure costs; limited coverage in rural areas
	Connected equipment	Monitors various aspects of agricultural operations in real time in, for example, flour mills, vineyards, cattle feed systems & livestock	High initial investment & operational costs; requires technical expertise for operation & maintenance; potential cybersecurity risks
AI & big data	Predictive analytics	Uses data from sensors & other sources to predict crop yields, pest outbreaks & optimal harvesting times	Requires large data sets & advanced analytics tools; high initial cost; technical expertise required; potential data privacy concerns
	Field-specific advisories	Provide insights on the right time for sowing, fertilizing & other activities based on real-time data analysis	Depends on accurate & timely data collection; requires investment in technology & training; potential resistance to change from traditional practices
Drones	Precision spraying	Apply pesticides & fertilizers precisely where needed	High initial investment & operational costs; requires regulatory compliance & training; limited battery life & payload capacity
	Aerial surveillance	Monitors crop health & field conditions from the air, providing valuable data for decision-making	High initial & maintenance costs; potential privacy & security concerns; weather-dependent
Blockchain technology	Traceability	Verifies origin & journey of agricultural products	High implementation & operational costs; requires collaboration across the supply chain; potential scalability & integration issues

Table 1. Smart farming technologies

THE DATA VALUE CHAIN

AI and big data analytics can optimize hydroponic systems for producing fodder crops like barley, wheat, and maize by focusing on light conditions, automation, and environmental controls.[11,12] AI has been shown to significantly improve water efficiency, plant growth, and yield consistency through smart automation, resulting in long-term economic viability, highly nutritional fodder, and improved environmental sustainability.[13]

AI and big data analytics can also accelerate the development of climate-resilient crops. By combining genomic, phenomic, and environmental data, AI can enhance predictive accuracy and decision-making in breeding programs to enhance climate resilience.[14]

There are six stages in the data value chain: data capture, data storage, data transformation, data analysis, interpretation/decision-making, and feedback:

1. **Data capture.** Vast amounts of data are collected from various sources, including environmental sensors, historical crop data, and market trends.
2. **Data storage.** The data is stored in a central database for further analysis. This stage involves storing and managing large-scale data sets while ensuring data reliability and availability.
3. **Data transformation.** The collected data undergoes processing and analysis using advanced AI algorithms. This step involves transforming and cleaning the raw data to ensure accuracy and relevance. The processed data is then analyzed to identify patterns, trends, and correlations that can inform decision-making.
4. **Data analysis.** The insights gained from the data analysis are fed into a decision-making system. This system provides actionable recommendations for optimizing hydroponic farming practices, such as adjusting nutrient levels, controlling environmental conditions, and predicting luminance frequency.
5. **Interpretation and decision-making.** The recommendations are implemented in the hydroponic systems. Continuous monitoring of the environment and crop health is maintained through sensors and IoT devices, ensuring real-time feedback and adjustments. The outcomes of the implemented strategies are evaluated to measure improvements in crop yield, resource efficiency, and overall sustainability. This evaluation helps refine the AI models and enhance decision-making processes.
6. **Feedback loop.** Continuous feedback ensures that evaluated outcomes are fed back into the data collection and analysis system, creating a cycle of improvement and optimization.

Figure 1 shows how AI and big data analytics can improve hydroponic cultivation. The integration of AI and big data analytics into hydroponic cultivation enhances the efficiency and productivity of forage crops and contributes to sustainable farming practices by optimizing resource use and reducing environmental impact.

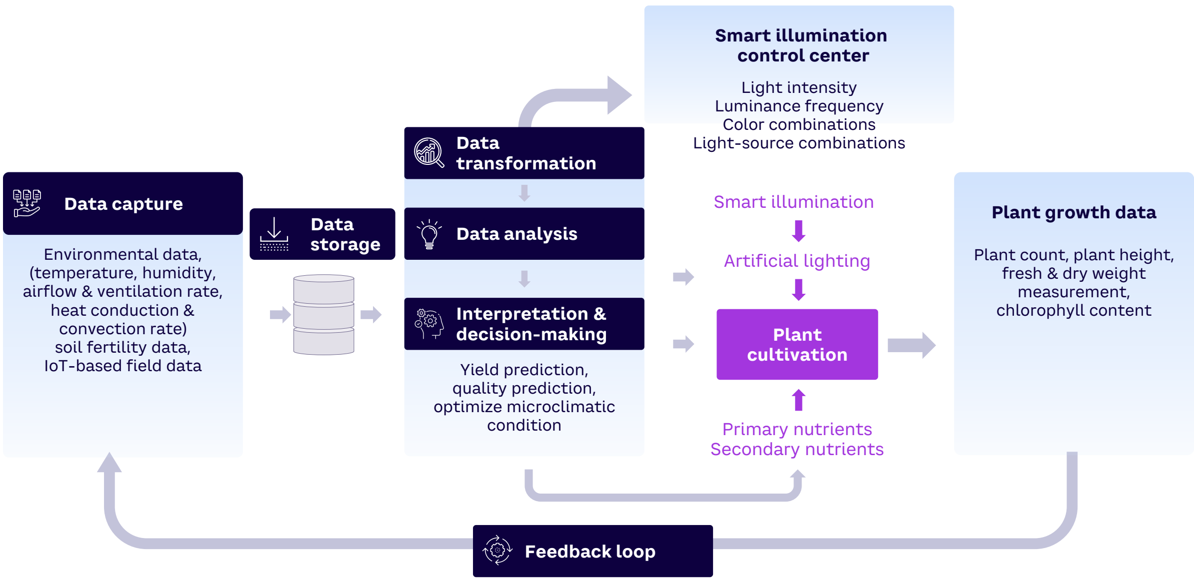

Figure 1. The six stages of using AI and big data analytics to improve hydroponic cultivation

CONCLUSION

The integration of AI and big data analytics into hydroponic cultivation of forage crops like barley, wheat, and maize is revolutionizing the agricultural landscape. This approach significantly enhances resource efficiency, crop resilience, and production sustainability. As the hydroponics market grows, with projections to reach $10.8 billion by 2032, these advanced technologies will play a critical role in addressing global food security challenges and environmental sustainability. Leading companies are driving this transformation by developing innovative systems that optimize water and nutrient usage, reduce labor costs, and ensure year-round production of high-quality forage.

> **THE ADOPTION OF AI & BIG DATA ANALYTICS BY HYDROPONIC FARMERS PAVES THE WAY FOR A SUSTAINABLE AGRICULTURAL FUTURE**

AI and big data analytics contribute to these advancements by enabling precise environmental controls, predictive analytics, and real-time decision-making, thus maximizing productivity and profitability for farmers. The six stages of the data value chain (data capture, data storage, data transformation, data analysis, interpretation, and feedback loop) demonstrate how AI can significantly improve the efficiency and sustainability of hydroponic farming. This includes:

- **Improved resource management.** AI-driven models optimize water and nutrient usage, reducing waste and improving crop yields.
- **Enhanced crop resilience.** The ability to predict and mitigate issues like nutrient deficiencies and pest infestations helps maintain healthy crop growth and improves overall resilience.
- **Scalability.** AI models can be scaled to larger hydroponic systems, making them applicable to both small-scale and commercial farming operations.

The potential of integrated systems extends beyond immediate economic benefits, promising a sustainable, resilient agricultural practice capable of adapting to climate change, conserving water, and minimizing environmental impacts. By fostering collaboration among researchers, farmers, and policymakers, we can fully harness the capabilities of these technologies to create a more sustainable and secure food production system for the future.

The adoption of AI and big data analytics by hydroponic farmers improves the efficiency and output of forage crops and paves the way for a sustainable agricultural future, addressing the pressing needs of our growing population and changing climate.

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HOW AI ENABLES RESILIENCE IN AGRI-FOOD SUPPLY CHAINS

Authors

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In recent research from *The Economist*, 63% of executives named macroeconomic uncertainty and geopolitics as major supply chain disruptors.[1] Other reports have found that supply chain disruptions are a drag on global activity and trade (including difficulties in the logistics and transportation sector and product shortages), have a negative impact on global production, and contribute to inflation.[2]

The volatile geopolitical landscape (Red Sea shipping disruptions, the Russia-Ukraine war, the Israel-Hamas war, and various economic trade wars), combined with the increasingly evident effect of climate change, is wreaking havoc on regional and global agri-food supply chains. Agri-food supply chain disruptions are no longer confined to farmers and food distributors — they can have serious repercussions in areas critical to the well-being of economies and societies in both developed and developing countries. For example, the Russia-Ukraine war is impacting global wheat, sunflower oil, and maize supplies, as well as food security and aid.[3]

In response, organizations and governments are looking at ways to leverage AI to safeguard and enable agri-food supply chain resilience. In this article, supply chain resilience refers to the ability to prepare and respond to disruptions, make a timely and cost-effective recovery, and calibrate to a post-disruption state (ideally, a better state than prior to the disruption).[4]

Resilience consists of four dimensions:[5,6]

1. **Readiness** — an organization's anticipation of a disruption, either by preparing for it or avoiding it.
2. **Responsiveness** — preplanned elements that mitigate the impact of a disruption while allowing the system to remain functional.
3. **Recovery** — repair of loss and the minimization of the time it takes to return to the original or desired state.
4. **Adaptability** — the capability to adapt to any operating changes in the environment.

In the context of agri-food supply chains, AI has the power to enable resilience by enhancing risk management and predictive analytics, enabling real-time decision-making and adaptability, automating problem-solving, and supporting long-term strategic planning.[7]

> **ORGANIZATIONS & GOVERNMENTS ARE LOOKING AT WAYS TO LEVERAGE AI TO SAFEGUARD & ENABLE AGRI-FOOD SUPPLY CHAIN RESILIENCE**

AI-POWERED RESILIENCE IN AGRI-FOOD SUPPLY CHAINS

AI can be applied to various elements of the supply chain, including forecasting, process and procedure optimization, supplier selection and evaluation, and automation and decision support for configuration, design, and planning.[8]

AI-powered systems provide organizations with the ability to process large, complex data sets in real time to enhance forecasting accuracy. Other benefits of AI-powered supply chain systems include real-time production tracking, prevention of order shipment delays, process optimization, and customer product prediction.[9]

Supply chain resilience also builds on elements of the smart factory, including the supplier quality management system, real-time data exchange, and predictive analytics to enable data-driven insights and actions.[10] Supply chain resilience requires proactive, prescriptive, guided risk mitigation, which involves organizational agility, rapid turnaround time to respond to planned and unplanned events, and flexible and dynamic connections between stakeholders in the supply chain ecosystem.

Our data analysis found that AI technologies can enhance each dimension of resilience to enable resilience in agri-food supply chains. In summary:

- **Readiness.** AI enables real-time data sharing, enhancing forecasting capabilities and enabling effective supply chain planning and dynamic inventory management.
- **Response.** AI-powered supply chain management tools support rapid reconfiguration of suppliers.
- **Recovery.** AI facilitates the effective management of human resources and improves process efficiency and productivity.
- **Adaptability.** AI improves the agility and sustainability of supply chains by providing actionable insights.

AI is increasingly being used by organizations for the procurement of short-term workers, which in turn increases resilience as supply chain managers seek innovative ways to mitigate the looming labor shortage.[11,12]

AI can also be leveraged to improve employee safety by using machine vision to monitor the use of personal protective equipment and verify that employees are adhering to the company's health and safety protocols and industry-wide standards. Companies can also use AI to process data from systems aboard company vehicles to monitor whether drivers are operating them safely.[13] AI can enhance adaptability by providing logistical solutions to minimize shipment lead times by coordinating important shipping documents, determining any missing documentation, and recommending actions to avoid risks proactively.[14]

RESEARCH METHODOLOGY

This article is informed by insights from practitioners at four agri-food companies located in Ireland and Kuwait that operate in large, complex regional and global supply chains. We also draw on secondary data sources (industry reports, academic articles). A description of the companies is provided below, and the profile of practitioners is presented in Table 1. Primary data collection included face-to-face interviews with a focus on understanding how the case study companies use AI technology to enable resilience in agri-food supply chains in their respective industry.

CASE STUDY 1

This indigenous Irish company serving international markets is one of Europe's largest meat groups. It has annual earnings of more than US $2 billion, employs more than 5,000 people, and works with more than 28,000 farmers. The company has 14 manufacturing facilities throughout Ireland and the UK; sales offices in Europe, the US, Asia, and Africa; and a presence in more than 43 countries.

The group processes more than 50,000 tonnes of meat annually, including 500,000 cattle, 1.7 million lambs, and 450,000 pigs. As a primarily B2B company, it offers a broad range of fresh and value-added meat products serving the food service and retail markets. The company has a portfolio of brands that are successful in the chilled convenience and frozen meat categories in various markets.

CASE STUDY 2

In operation for more than 75 years, this Kuwaiti company operates a vertically integrated business model encompassing food manufacturing, distribution, retail, wholesale, and contract services. It has operations in five other countries (Saudi Arabia, United Arab Emirates, Qatar, Jordan, and Iraq). It imports international brands into Kuwait and produces various Kuwaiti-based food brands. The company employs more than 8,800 in its food business and healthcare/consumer business combined. The food business line accounts for 69% of the company's total revenue, exceeding $582 million in 2023.

JOB TITLE	CASE STUDY	LOCATION	YEARS' EXPERIENCE
Director	1	Ireland	35
Factory manager	1	Ireland	30
Commercial director	1	Ireland	17
Group head of category & customer marketing	1	Ireland	23
Head of technology transfer & commercialization	1	Ireland	20
Demand manager	2	Kuwait	17
Procurement manager	2	Kuwait	14
Supply chain manager	2	Kuwait	14
Logistics manager	2	Kuwait	13
Commercial systems manager	2	Kuwait	13
Service delivery manager	2	Kuwait	11
Business systems manager	2	Kuwait	8
Production manager	2	Kuwait	8
IT manager	3	Kuwait	16
Farm manager	3	Kuwait	9
Operations manager	3	Kuwait	8
Head of international trade	3	Kuwait	6
Bakeries manager	4	Kuwait	16
IT manager	4	Kuwait	15
Procurement team leader	4	Kuwait	13
Procurement manager	4	Kuwait	10
Inventory manager	4	Kuwait	2

Table 1. Practitioner profiles

CASE STUDY 3

Established in 1973 in Kuwait, this company manages a fleet of giant ships for trading and transporting livestock and several types of meat for the local market and international exports. The company owns the largest feedlot in the world, with a capacity of 200,000 heads, and its factory is considered one of the most advanced meat-processing capabilities in Kuwait. The company has subsidiary units in the United Arab Emirates, Australia, and South Africa. It produces organic fertilizers that guarantee high-quality green vegetation for its livestock. The company recently achieved $70 million in annual revenue.

CASE STUDY 4

Established in 1961 in Kuwait, this company owns factories making macaroni, biscuits, vegetable oils, animal feed, and gluten-free products. It operates nine major bakeries located throughout Kuwait that provide high-quality products at competitive prices. It has two production lines that can produce 14,000 loaves of bread in one hour. Its net profit in 2023 exceeded $250 million, a 48% increase compared to 2022. The company employs just under 4,000 people.

INSIGHTS FROM PRACTICE

Each of the companies in our case studies applied several AI-based technologies to enhance resilience in their supply chains, which led to improved performance. For example, case study 1 used robotic process automation to perform repetitive administrative tasks in place of human workers. It eliminated more than 15,000 hours per year of tasks related to supply chain management, increasing resilience.

Case studies 2, 3, and 4 all used expert systems (i.e., SAP HANA, Oracle, ERP [enterprise resource planning], warehouse management) to simulate human problem-solving and create advanced planning solutions to optimize sales, develop dynamic forecasting processes, elevate operational planning in the supply chain, and improve relationships with suppliers and customers. Drawing on the insights provided by the practitioners, Table 2 shows how AI-based technologies enhance the four resilience dimensions.

DIMENSIONS OF RESILIENCE	CASE STUDY 1 QUOTES	CASE STUDY 2 QUOTES	CASE STUDY 3 QUOTES	CASE STUDY 4 QUOTES
Readiness	Forecasting tools put us in a place of readiness to serve our customers better and better, to speak to our farmers, to tell them what it is we're likely to want in the future. (Director)	The value of our systems is that the error percentage becomes less, which enables the planning team to do accurate forecasting. (Demand manager)	The system is excellent in helping know stock levels; following the quantity of livestock, animal feed, and animal drugs. Access to this data is essential for decision-making and planning. (Farm manager)	Through the system, we can identify the item's providence under three classifications: green (safe), orange (reorder level), and red (risk). Based on this information, we always have enough items to cover any shortage in the supply chain. (Inventory manager)
Responsiveness	We use AI in our retail systems. So, like Sainsbury's and Tesco, we get access to their platforms for supply chain. We're able to see order fulfillment, on-shelf availability, and how much we have sold in a given week. (Group head, category & customer marketing)	The responsiveness depends on the correct inputs into the system. (Procurement manager)	We use AI modules to study customer behavior and analyze individual experiences of customers using our app. (Operations manager)	The system helps us communicate with suppliers with a click and make notifications for all supply chain partners through the system in real time. (Procurement manager)
Recovery	Our Ag-Nav is a sustainability digital platform that supports individual farmers, wherever they are in the agri-food supply chain, to understand what they (at a local level) can do to mitigate climate emissions. (Head of technology transfer & commercialization)	Maybe a supplier can send the product on time, but other factors (e.g., freight and shipping company; clearance and documentation from supplier) all need to be worked out to get a product to recover. (Demand manager)	After COVID-19, we decided to make the forecasting process for longer term, which keeps us under pressure, but this should avoid risks related to filling demand. (International trade manager)	The company has big investments in employing a robust system for saving data, including the latest backup solutions in case we have an attempted data security breach. (IT manager)
Adaptability	Implementing AI takes out the cost of human intervention; it takes out specialist skills that people in today's climate don't really want to do. They find data mining and data crunching menial and laborious, not exciting. (Director)	The information availability in the system is helpful for following the stock. Like suppose if we have some stock near to expiry, you can take action to avoid problems. (Procurement employee)	The system helps in analyzing the latest market trends that enable us to adapt. (Operations manager)	Trend analysis is essential to adapt with the latest market trends. For example, when I notice a product category has an unusually high demand, I need to identify the reason behind this trend and adapt production. (Bakeries manager)

Table 2. How AI enhances resilience dimensions

In Figure 1, we conceptualize how AI technologies (i.e., machine learning, expert systems, machine vision, robotics, natural language processing, speech recognition) can be used in agri-food supply chains and how they can enhance resilience dimensions.

In addition to describing the benefits of AI in this context, the practitioners acknowledged that digitizing their supply chains using AI technologies was challenging (see Table 3).

LOOKING FORWARD

The global agri-food sector expanded from $8.28 trillion in 2021 to $8.67 trillion in 2022 and is projected to reach $12 trillion by 2027.[15]

The threat of further supply chain disruptions is likely, especially if geopolitical uncertainty and repositioning intensify in the coming months, and there is a high probability the market value of this sector will erode. However, such events should be viewed by business leaders and governments as an opportunity to redesign their supply chains with a future resilience mindset.

As the agri-food sector grapples with geopolitical tensions, population growth, technological advancements, and shifting consumer preferences, increased collaboration between industry, public sector entities, and academic researcher will be key to building both resilient supply chains and economies. As such, governments can no longer take a back seat role and simply wait for markets to fail before implementing interventions. Against this background and the increasing digitization of agri-food supply chains, the ability of organizations to adopt, adapt, and effectively use AI is more critical than ever.

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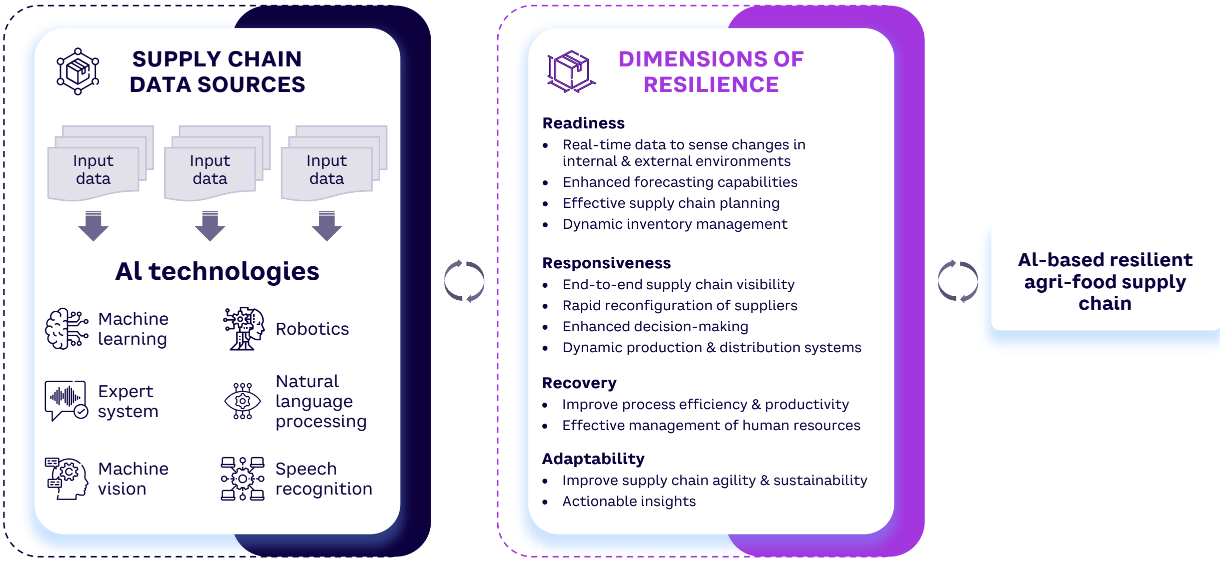

Figure 1. AI-enabled resilient agri-food supply chains

CATEGORY	CHALLENGES
Process	• Migrating large volumes of data from legacy systems to AI-based systems • Ensuring data accuracy • Creating unique item codes for each product, category, packaging paper, and size
Organization	• High cost of AI systems • Competition between supply chain partners instead of collaboration based on common approach to applying AI across the industry
People	• Need for tailored training programs in design and use of AI systems • Recruiting staff with advanced analytical and technical expertise • Resistance to adopting AI systems (or using them to their full potential) from stakeholders, employees, and farmers

Table 3. Process, organizational, and people-related challenges to using AI

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USING DATA TECHNOLOGY PLATFORMS TO DELIVER STAKEHOLDER VALUE IN HEALTHCARE

Authors

Daniel J. Rees, Roderick A. Thomas,
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The healthcare and pharmaceutical industries are witnessing a surge in digital data generation thanks to wearable sensors, electronic health records, and clinical and genetic data.[1] Simultaneously, the emergence of data-centric decision-making is set to benefit healthcare services in several areas.

These areas include:

- **Genomics and precision medicine.** This will enable targeted treatments for specific patient groups, potentially enhancing efficacy and leading to novel therapeutic avenues.
- **Remote care.** This will enhance healthcare accessibility, leading to patient needs being addressed earlier and the healthcare system potentially becoming more efficient.
- **Technology-supported self-management.** Patients will be able to better understand their condition(s), helping them more effectively manage their health and fostering improved behavioral and clinical outcomes.
- **Data.** This will serve as a catalyst for improving national healthcare systems' research and decision-making.
- **AI.** This could augment analytical capabilities for patient diagnoses, leading to more efficient triage and patient logistics management.[2]

The continued development of healthcare-related technologies, including AI, is transforming healthcare business processes, especially in medium-sized and large pharmaceutical firms, resulting in faster, more efficient decision-making. Other advantages include diminished human error and accelerated product development cycles, ultimately resulting in faster product launches.

MEANINGFUL METRICS

In recent years (and in large part because of the pandemic), governments stepped up pressure on the healthcare and pharmaceutical sectors, asking them to develop a more aligned, cohesive approach to the use of digital technologies and data management in decision-making to deliver greater value to stakeholders.[3]

Aligning healthcare interventions with outcomes that matter to patients is of paramount importance. Significant challenges arise when healthcare systems prioritize activity and inputs over outcomes, hindering adoption. For example, researchers found payer uncertainty about the value of investment in mental health treatments and showed the potential for this to impede the adoption of new treatments.[4]

> **THE CONTINUED DEVELOPMENT OF HEALTHCARE-RELATED TECHNOLOGIES, INCLUDING AI, IS TRANSFORMING HEALTHCARE BUSINESS PROCESSES**

Two other research groups demonstrated the criticality of aligning on outcome metrics to achieve value-based healthcare (VBHC).[5,6] Meaningful metrics and measurements serve as a guiding condition for innovation implementation, informed decision-making, quality improvement, and reduced costs.

A recent initiative spearheaded by the Welsh Government demonstrates the critical role of robust digital infrastructure in driving innovation adoption and realizing tangible outcomes. The Ibex Galen AI platform's analysis of prostate biopsies resulted in a remarkable 13% increase in cancer detection, and the platform is now being used at Betsi Cadwaladr University Health Board to examine suspected breast cancer cases.

Funded through the Welsh Government's innovation fund and supported by the Small Business Research Initiative (SBRI) Centre of Excellence, the AI tool uses a traffic-light system to classify digital images of pathology samples to indicate the likelihood of cancer, helping clinicians prioritize urgent cases. This is leading to faster diagnoses and is expected to reduce the need for additional biopsies and tests.[7]

RESEARCH METHODOLOGY

This article is informed by in-depth discussions with 48 leaders in senior management positions in healthcare and pharmaceutical organizations. The primary data was collected through a series of interviews, each lasting 45 to 60 minutes.

Each interview consisted of a series of questions related to collaboration activities between healthcare and pharmaceutical organizations and their use of technology platforms to deliver value to stakeholders. The questions sought to elucidate the best practices and challenges surrounding the collaborative use of emerging technology and data-centric decision-making to deliver value to stakeholders.

The interviews were recorded and transcribed in preparation for thematic analysis. Most participants held mid-level executive positions in their organization (n=37), with roles varying from managing director to division head and data lead. The remaining candidates (n=11) held roles such as supervisor, data analyst, and team manager (see Table 1).

MGMT LEVEL	DESCRIPTION	RESPONSIBILITIES	TITLES	NO. HEALTHCARE MANAGERS	NO. PHARMACEUTICAL MANAGERS
Executive	Top-level executives responsible for setting strategic goals & direction	Strategic planning, decision-making, overseeing organizational performance	President, CEO, COO, medical director, finance director	5	8
Middle	Mid-level managers responsible for implementing strategies & coordinating activities	Supervising teams, managing resources, communicating objectives	Department manager, regional manager, division head, team leader, digital/ data lead	11	13
Frontline	Supervisors, team leaders responsible for day-to-day operations & frontline employees	Directing tasks, ensuring productivity, resolving issues	Supervisor, data analyst, team manager	6	5
Total				**22**	**26**

Table 1. Profile of respondents

KEY BARRIERS

A qualitative data analysis was performed to surface themes related to developing an environment conducive to embedding technology platforms and data analytics for collaborative value provision (see Table 2).

The key barriers were each considered from a practitioner viewpoint to reveal themes (and contexts) and establish best practices (see Figure 1).

TRUST

Many participants viewed trust as critical for collaborations to flourish and noted that partners must take a consistent approach to developing strong relationships:

- Establish a common language.
- Understand the healthcare system.
- Align with others to create a shared agenda.
- Set clear shared objectives, including joint accountability.
- Name a champion for the collaboration.
- Establish alignment at all levels of an organization (leaders, managers, and subject-matter experts).
- Ensure experienced clinical champions are empowered and willing to take risks.

KEY BARRIERS	THEMES
Culture	**Trust** — the perception that potential collaborators might have a different agenda, such as being purely focused on sales or wishing to dominate a partnership **Reputation** — fear of backlash from colleagues and/or the public from working with partners outside the company's industry **Time** — expectation of fast outcomes and impact when partnerships require time to build trust and grow and learn together **Risk aversion** — fear of not being able to show a positive outcome/value
Governance	**Contracts** — issues around contracts being overly complex and/or slow to complete; concerns include data governance, IP, and funding mechanisms
Scalability	**Timeline** — fear of making a large investment in a new idea/program and not being able to scale it in a reasonable amount of time to realize the full value; reasons cited include fragmented systems and siloed organizations

Table 2. Key barriers to delivering value via technology for data-centric collaboration

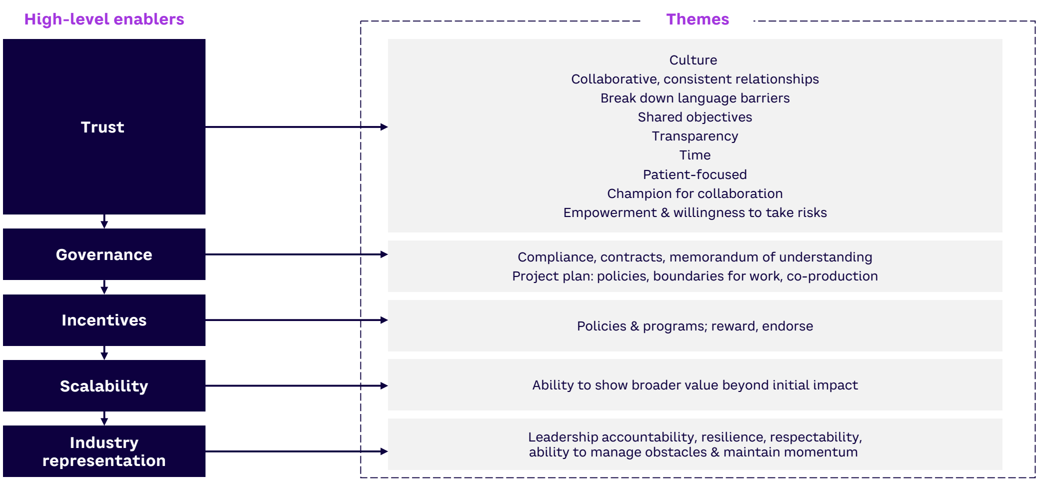

Figure 1. Best practices for delivering value via technology and data-centric collaboration

GOVERNANCE

Respondents said a memorandum of understanding is the best way to achieve strong, enabling processes. These documents should be co-created with legal experts from the outset and should include a requirement for a clear project plan, enabling SOPs (standard operating procedures), and ownership and financial boundaries.

Participants frequently expressed frustration with the intricate nature of contractual agreements, which can hinder the swift progression of collaborative initiatives. Delays in finalizing contracts not only impede project timelines, they exacerbate uncertainties surrounding data ownership, rights to innovations, and financial arrangements. Addressing these concerns requires a streamlined approach to contract negotiation and execution, one that favors clarity and expediency in addressing crucial aspects, such as data management, intellectual property (IP) rights, and financial obligations.

INCENTIVES

Performance management systems explore the interplay between monetary and nonmonetary incentives, resulting in policies or programs that reward the right collaborations and endorse and motivate individuals and teams. Susanna Gallani, the Tai Family Associate Professor of Business Administration at Harvard Business School, has examined mechanisms to align behavior, reward performance, and reduce burnout. A major part of her current work focuses on innovations in incentive models in healthcare.[8]

SCALABILITY

In this case, scalability means the ability to demonstrate from the outset how learnings might have value implications beyond initial impacts. For example, concerns around timelines stem from a fear of investing in new ideas/programs without the ability to scale them within a reasonable time frame due to fragmented systems and organizational silos.

INDUSTRY REPRESENTATION

As expected, the collaboration of healthcare systems with pharmaceutical companies is a key requirement in the successful integration of new data technology platforms. The pharmaceutical or technology companies' effort should be headed up by a senior executive who understands the system, is highly motivated, is willing to be held accountable for revenue generated (or not), is bold, and can manage the challenges associated with maintaining momentum.

RECOMMENDATIONS

With best practices/enablers established, the next step is to use the right individuals to choose effective tools and establish robust processes, as described below.

RIGHT TOOLS

Highly interoperative technology that allows safe data capture and robust data management is critical to ensuring data can flow from patients to clinicians and then across the total pathway of care.

RIGHT PROCESSES

When healthcare entities form partnerships, whether it's with pharmaceutical companies to explore new drugs/treatments or with IT companies to implement new data technologies, the contracting arrangements tend to be protracted due to their complexity.

Developing a consistent approach that is both robust and nimble requires careful co-development. The governance framework must account for resource and financial flexibility as well as:

- **Metrics and measurements.** The underlying principle of VBHC is delivering outcomes that matter to patients at the same or lower cost. Of course, understanding and evaluating existing or new interventions requires robust metrics that are focused on patient outcomes, rather than activity or outputs. It's also important to implement incentives, policies, or programs that reward the right collaborations and endorse and motivate individuals and teams to work together. These must be carefully designed to ensure the focus remains on value and doesn't get replaced by activity volume.

- **Pathway mapping.** Creating and evaluating interventions begins with understanding the entire cycle of care, not just the point in the pathway where a new intervention may have an impact. For individual patients, having choices at various points in the care pathway enhances their sense of empowerment and involvement in their treatment. This holistic perspective helps design interventions that are more effective and better integrated into the patient's complete health-care experience. In the health research sector, an understanding of the total care cycle leads to greater confidence in partnering with health systems and enables broader consideration of innovative services that create value (e.g., diagnostics, remote monitoring, and community services).

RIGHT PEOPLE

Many survey participants emphasized that in addition to a strong, knowledgeable leader, successful collaborations need a supportive environment. Many respondents expressed concern over the risk of relying on a single individual, potentially jeopardizing programs. It is crucial to have organizational alignment and support from skilled leaders who can manage new and complex partnerships. Additionally, having the right resources and skills from other team members readily available and deployed is essential. Here four key elements:

1. **Culture.** The culture must actively support collaboration, including leaders with a flexible mindset, an ability to embrace diversity of thought, and an understanding that successful strategic partnerships require time to develop. Every organization and industry has its own jargon, to the point where it's almost a language. Thus, each partner must spend time learning the "language" of the other collaborators.
2. **Functions.** Success is predicated on having a cross-functional team that includes individuals with clinical, financial, legal, and management expertise.
3. **Team.** The importance of diversity of thinking and skills was explicit in the interviews, from negotiating a collaboration and securing endorsement from the right leaders across the respective organizations to designing the program. The latter involves having the right clinical experts from the entire pathway, the right analysts to support evaluation, the right technology experts, the right compliance experts, and the right communications experts. This requires strong project management skills to ensure subject matter experts are engaged and included while avoiding management by committee, over-consultation, and/or program paralysis.
4. **Industry representation.** Strong leadership from pharmaceutical and/or technology companies is critical to the success of a collaboration. Our survey identified the following competencies as critical:
    - *Strategic vision* — understands the health-care landscape and aligns business vision and portfolios to create compelling proposals; turns ideas into actions; and has a proven track record of delivering successful outcomes
    - *Resilience and agility* — can shift priorities in response to the needs of customers or the organization; has an openness to learn from mistakes and take well-reasoned risks; finds solutions and makes decisions despite incomplete information; inspires others to engage through collaboration; demonstrates optimism; and guides programs forward in challenging circumstances
    - *Analytical thinking* — can identify areas of shared interest; can analyze appropriate data to formulate approaches; explores various options to deliver value for all collaborators; and sets out a clear process for reviewing outcomes
    - *Courageous leadership* — a driven, courageous leader who can manage obstacles and challenges while maintaining focus on the program's critical path; has the confidence to make decisions at a local level on behalf of the organization and, where necessary, to slow or accelerate activity
    - *Emotional intelligence* — creates a compelling vision; supports and builds strong internal and external stakeholder relationships; demonstrates an ability to engage other functions; and presents with confidence and gravitas

CONCLUSION

The healthcare and life science sectors are under increasing social and economic pressures locally, nationally, and globally. Merely increasing spending on healthcare is not resolving these issues. Harnessing new technologies and enabling data-centric decision-making will be pivotal for transforming how we deliver healthcare, and collaboration with pharmaceutical and technology companies will be essential to improving patient outcomes. We hope our findings will contribute to an evolving blueprint that leads to greater success in collaborative partnerships and transformational initiatives for patient, societal, and economic benefits.

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