DELMIA

UNLEASHING SUPPLY CHAIN RESILIENCE USING AI AND VIRTUAL TWINS

DASSAULT SYSTEMES

INTRODUCTION

In the previous eBook on supply chain resiliency, we discussed the different stages of evolution that an organization goes through in its journey towards a resilient supply chain. In this eBook, we discuss how supply chains can truly transform from a digital supply chain to an autonomous supply chain. We also discuss the role played by AI, Optimization and Virtual Twin Experiences in achieving an autonomous supply chain.

Managing a supply chain is a complex challenge which has only grown more intricate in recent years due to globalization, a volatile geo-political landscape, technological advancements, and the increasing demands of consumers. The complexity arises from a multitude of factors which make Artificial Intelligence (AI) and Machine Learning (ML) essential tools for effectively addressing the challenges in modern supply chain management. Economic uncertainty, poor visibility, demand uncertainty, and ESG concerns are just a few factors that contribute to the health of the supply chain network.

From a purely mathematical standpoint, supply chain management presents a complex and dynamic set of challenges, and optimizing these variables while considering the associated constraints is a formidable task. AI and ML algorithms can efficiently process and analyze this extensive and highly dimensional data to derive insights and solutions that humans struggle to identify due to the sheer scale of variables involved. The real-time capability of AI and ML is particularly noteworthy. This real-time adaptability ensures that supply chains remain agile and resilient: capable of navigating unexpected disruptions, surges in demand, or alterations in market dynamics.

WHAT IS THE COMPELLING NEED FOR AI AND ML IN SUPPLY CHAIN PLANNING?

Supply chain optimization is fraught with mathematical complexity due to a range of internal and external challenges:

External challenges include extreme weather, financial crises, trade disputes, pandemics, climate change, cyber-attacks, terrorism, supplier bankruptcy, and other uncertainty factors.

Internal challenges include issues like lack of visibility, collaboration, agility, increasing complexity, manual processes, digital discontinuity, and competing business goals (e.g., sustainability vs. profitability).

The mathematical complexity of supply chain optimization can be staggering. Consider the following statistics:

Combinatorial Explosion

The number of possible combinations for optimizing decisions in a complex supply chain can easily run into the billions or more. Traditional methods struggle to explore these vast solution spaces efficiently.

High-Dimensional Spaces

Supply chain optimization problems often involve high-dimensional spaces with numerous decision variables, constraints, and objectives. Solving such problems analytically becomes increasingly difficult as dimensions grow.

Real-Time Adaptation

In dynamic supply chain environments, decisions must be made in real-time to respond to changing conditions. AI and ML algorithms easily process large volumes of real-time data and adapt decisions accordingly.

Uncertainty Modeling

Mathematical models must incorporate uncertainty stemming from external factors like demand fluctuations, supply disruptions, and market volatility. Stochastic optimization techniques are employed to handle this uncertainty.

Large-Scale Linear and Non-Linear Programming

Supply chain optimization often involves solving large-scale linear or non-linear programming problems. These require specialized algorithms and computational resources to find optimal or near-optimal solutions.

Integer Programming

Many supply chain decisions involve discrete choices, such as selecting suppliers, transportation routes, or production quantities. Solving integer programming problems adds an additional layer of complexity.

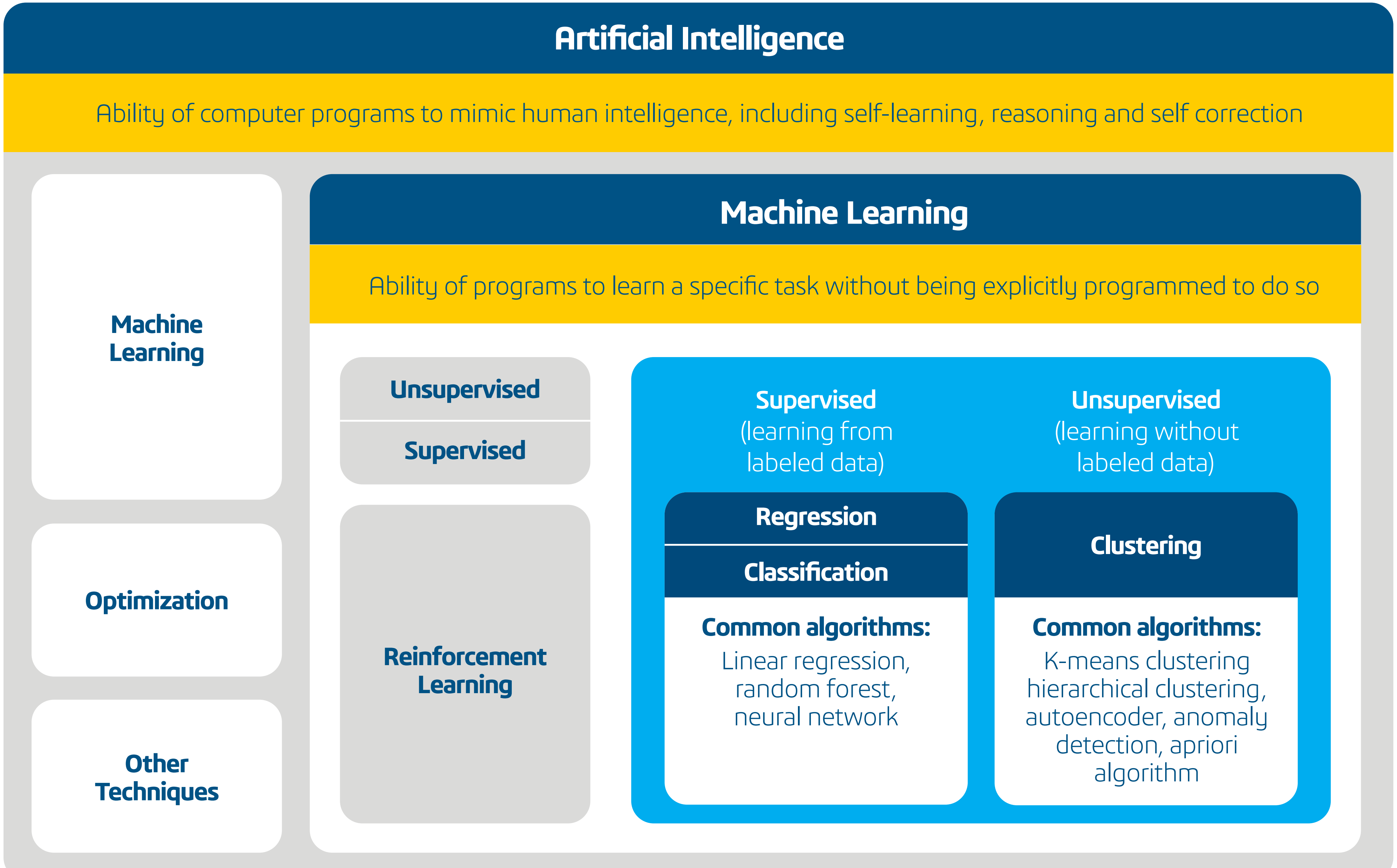
Multi-Objective Optimization

Balancing multiple, often conflicting, objectives (e.g., cost minimization and service level maximization) necessitates the use of multi-objective optimization techniques which introduce more mathematical complexity.

To address these complexities, AI and ML employ advanced mathematical and statistical methods, such as linear programming, mixed-integer programming, dynamic programming, and machine learning algorithms like neural networks. These techniques allow for efficient optimization, data-driven decision-making and real-time adaptation in supply chains. Companies can no longer address supply chain challenges with manual or spreadsheet-based processes and the need for advanced optimization is now critical.

UNDERSTANDING ARTIFICIAL INTELLIGENCE

Although the terminology may seem complex, it is possible to understand how optimization works in different ways:



The hierarchy between the terms mentioned in the context of AI can be understood as follows:

1. **AI (Artificial Intelligence):**
AI is the overarching field that encompasses all the subfields and techniques listed below. It refers to the simulation of human intelligence in machines that can perform tasks requiring human-like reasoning, learning, and problem-solving.

2. **ML (Machine Learning):**
ML is a subfield of AI and focuses on the development of algorithms that allow computers to learn from data and improve their performance over time without being explicitly programmed. There are several different types of machine learning approaches, each with its own characteristics and applications.
The main types of machine learning are:

   - **Supervised Learning:** The algorithm is trained on a labeled dataset, which means that each input is associated with the correct output. The algorithm learns to map inputs to outputs, making it suitable for tasks like classification and regression.

   - **Unsupervised Learning:** This involves training algorithms on unlabeled data. The goal is to discover patterns, structures, or relationships within the data without explicit guidance.

3. **Optimization:**
Optimization is a mathematical technique used in ML and other AI subfields to find the best possible solution among a set of feasible solutions, often involving complex variables and constraints.

4. **Heuristics:**
Heuristics are mathematical techniques that use rules of thumb or practical approaches to find approximate solutions to complex problems, especially when an exact solution is not feasible or computationally expensive.

In summary, AI is the broader field, and ML is a subfield of AI. Optimization and heuristics are problem-solving approaches that can be used within the context of AI to find efficient solutions to complex challenges. While AI encompasses a wide range of techniques and applications, ML is specifically focused on learning from data to make predictions or decisions.

SCOPE OF AI IN SUPPLY CHAIN

Artificial intelligence (AI) is poised to revolutionize the scope of supply chain management, moving us beyond the era of digital maturity into one defined by "intelligent autonomy." Over the past nearly three decades, the focus has been on digitizing supply chains, employing computers, software, and the internet to streamline operations and enhance transparency.

1

This digitization has already yielded remarkable benefits in terms of efficiency and transparency. However, as markets grow increasingly dynamic and unpredictable, the need for a more adaptive and forward-looking approach becomes evident.

2

Imagine a supply chain that operates with the sophistication of a highly intelligent robot. It doesn't merely follow predefined plans; it possesses the ability to predict future events, make real-time decisions, and continuously optimize itself. This shift represents a game-changing leap, transcending digital upgrades and ushering in a new era of supply chain management.

AI USE CASES IN SUPPLY CHAIN

Supply Chain Optimization

- Demand Forecasting
- Inventory Optimization
- Warehouse Management
- Demand Sensing
- Demand Segmentation
- Real Time Order Tracking
- Capacity Planning
- Route Optimization
- Supplier Relationship Management
- Network Design Optimization
- Dynamic Pricing
- Supplier Risk Management

YETQL (Yield-Energy-Throughput-Quality-Labor)

- Quality Assurance Automation
- Energy Consumption Prediction
- Production Yield Optimization
- Labor Demand Forecasting
- Energy Efficient Logistics
- Quality Predictive Analytics
- Labor Task Allocation
- Route Optimization
- Throughput Maximization
- Workforce Performance Analytics
- Energy Efficient Equipment Selection

Predictive Maintenance

- Equipment Health Monitoring
- Conditions Based Maintenance
- Predictive Failure Analysis
- Predictive Asset Reliability
- Anomaly Detection
- Sensor Data Fusion
- Network Design Optimization
- Prognostic and Health Management
- Failure Mode Identification
- Cognitive Diagnostics
- Predictive Maintenance Alerts

AI's role in supply chain planning is all about mathematically optimizing variables to enhance predictive maintenance, production efficiency, and overall supply chain optimization. It is akin to having a mathematical wizard that fine-tunes the complex attributes of the supply chain to make it more efficient, cost-effective, and adaptable to changing conditions. When it comes to keeping the supply chain running smoothly, AI is crucial in predicting when machinery or equipment might need maintenance. This is done to minimize downtime and costs. In mathematical terms, it boils down to Machine Health (MH) and the Maintenance Schedule (MS). AI here simply optimizes MS based on MH data. Similarly, AI tackles the nitty-gritty of production and operational efficiencies. AI applications within YETQL are all about optimizing these variables, both individually and together, to boost production efficiency. Finally, in the broader spectrum of supply chain management, AI helps optimize several critical variables like demand, inventory, transportation, and various costs. The goal here is to minimize expenses and maximize efficiency throughout the supply chain process.

When it comes to planning business operations, we usually have two approaches: tactical and strategic. Tactical planning helps us with day-to-day issues, while a strategic approach takes a longer view, helping a company stay competitive in the long run.

In supply chain planning, it's important to remember that while tactical fixes can solve specific problems, they might cause new issues. The supply chain is like a puzzle, and tweaking one part without looking at the whole picture can lead to unintended consequences. Let's explore this with some examples.

Use Case 1: Yield Improvement at Machine Level

Let's consider an example: A bottling plant employs ML to enhance the efficiency of an articulated robot arm. The ML model analyzes historical data and fine-tunes the machine's settings, leading to an 8% increase in its production output.

Scenario 1:

The improvement is localized and not integrated into the supply chain

At first glance, this appears promising. However, this isolated improvement doesn't automatically translate into a proportional supply chain-wide benefit. The reason is the intricate nature of supply chains. To realize the full potential of this 8% output increase, every element of the supply chain must adapt, from inventory management to distribution logistics. Without this synchronization, the additional output will lead to excess inventory, creating challenges in adapting to the change.

Yield improvement of machine leading to inventory build up

Scenario 2:

The improvement is synchronized into the supply chain

In the second scenario, the company embraces a holistic approach. Machine learning is seamlessly integrated into supply chain planning. When the ML model predicts an 8% yield improvement, the entire supply chain quickly adapts. Workforce planning adjusts to meet the increased demand, scheduling is optimized, factory planning is coordinated, and logistics planning ensures timely deliveries. This synchronization guarantees that the ML-driven enhancement translates into tangible benefits for the entire supply chain.

Yield improvement getting translated into real benefits

Use Case 2: Throughput Improvement at Plant Level

Shifting the focus to plant-level efficiency, we can explore how machine learning impacts a larger scale and how synchronization differs.

Scenario 1:

Isolated Plant-Level ML Improvement

In this case, ML is deployed at the plant level to improve overall efficiency. Imagine a manufacturing facility using ML to optimize its entire production process. Through advanced predictive maintenance and production scheduling, the plant's efficiency increases by 10%. While this substantial improvement is noteworthy, it must be recognized that it doesn't automatically translate into seamless integration with the broader supply chain. Without synchronization, this boost in plant efficiency may result in inventory surpluses and logistical challenges across the supply chain.

Throughput improvement of plant leading to inventory build up

Scenario 2:

Synchronized Plant-Level ML Improvement

In the second scenario, ML is deeply embedded in the DNA of supply chain planning. When the plant-level ML predicts a 10% efficiency gain, it triggers a coordinated response across the supply chain. Workforce planning adapts to increased production, scheduling is optimized to meet demand, and logistics planning ensures efficient distribution. This synchronization ensures the plant's efficiency improvement translates directly into substantial benefits for the entire supply chain.

Here, the key distinction lies in the magnitude and scale of improvement, with the larger-scale plant efficiency enhancement requiring more extensive coordination within the supply chain. In Scenario 2, this coordination leads to maximum efficiency gains across the entire supply chain, making it a different challenge and opportunity compared to machine-level improvements.

Throughput improvement at plant resulting in faster and on-time deliveries to end-users

Use Case 3: S&OP Planning

Let's elaborate on the two scenarios of ML-based cost prediction, highlighting the difference in outcomes when it is not integrated into S&OP versus when it is fully integrated.

Fig: The decrease in variance between the estimate and actual cost is helpful only when the insight is timely integrated into S&OP decisions

Scenario 1:

Standalone ML-Based Cost Prediction

In this scenario, ML algorithms significantly reduce cost prediction errors by 80%, providing valuable insights into future expenditures. However, these enhanced predictions remain disconnected from the Sales and Operations Planning (S&OP) process, resulting in untapped potential and limited actionability. As a result, the organization misses opportunities to make data-driven decisions related to sourcing, procurement, and inventory management.

Scenario 2:

Integrated ML-Based Cost Prediction with S&OP

In this scenario, the organization takes a more strategic approach by fully integrating ML-based cost prediction into its S&OP framework. Despite achieving the same impressive 80% reduction in cost prediction errors, the key difference lies in the application. These precise cost predictions now directly inform S&OP discussions and decisions, providing actionable insights into sourcing, timing, and quantity considerations. As a result, the S&OP process iterates to optimize sourcing strategies, production schedules, inventory levels, and distribution plans. This strategic integration translates the enhanced cost predictions into tangible cost savings, contributes to a more resilient supply chain, and enhances overall operational efficiency.

THE DELMIA ADVANTAGE

Fully Integrated Approach

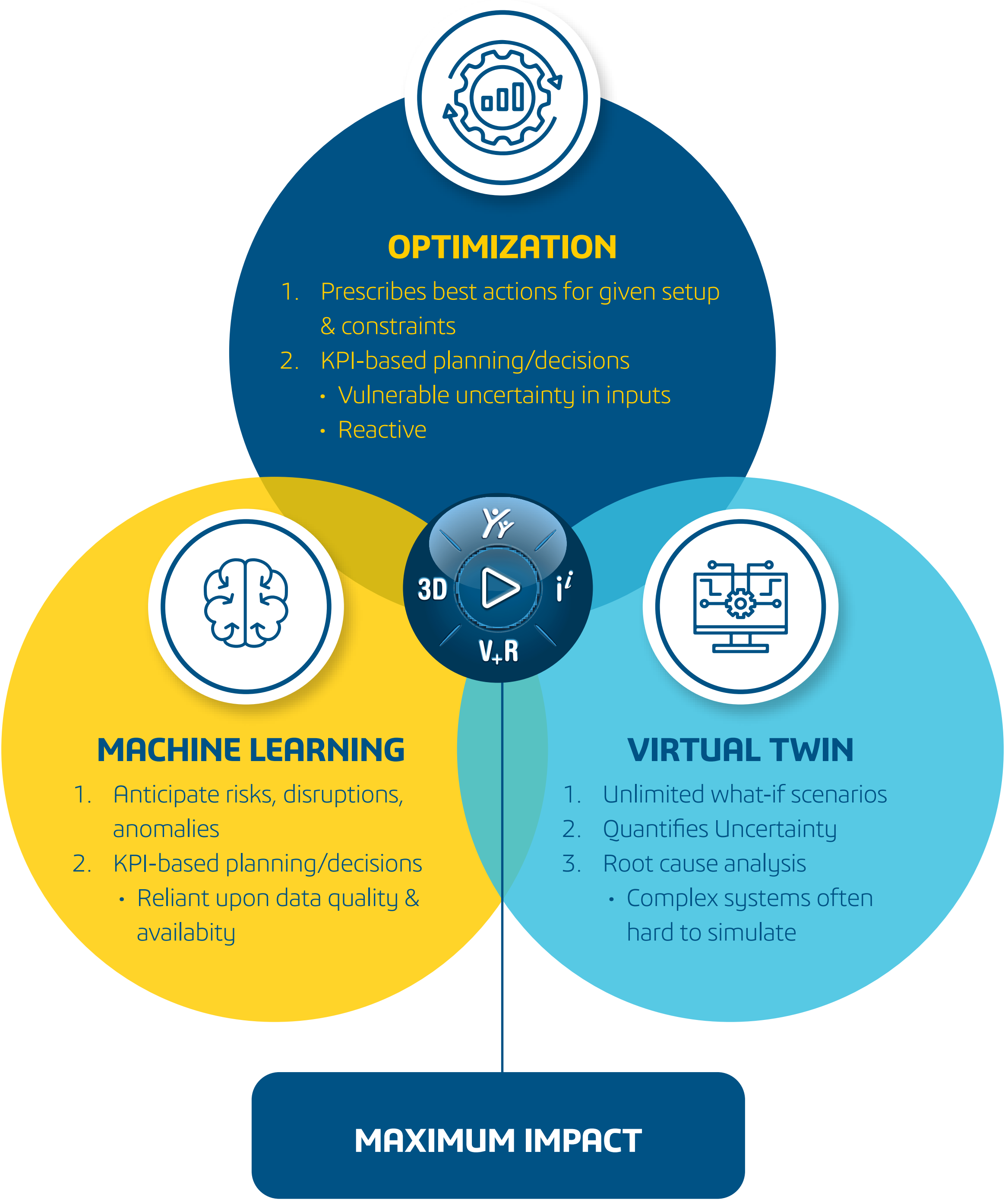
While AI can provide valuable insights and predictions, it still falls short in two critical aspects:

- Understanding and interpreting the intelligence generated by AI is not always intuitive for users
- Taking actionable steps based on that intelligence can be challenging

This is where DELMIA has a unique approach and value proposition: It combines AI-enabled optimization with Machine Learning (ML) and Virtual Twin technology, creating a comprehensive solution to address these challenges effectively.

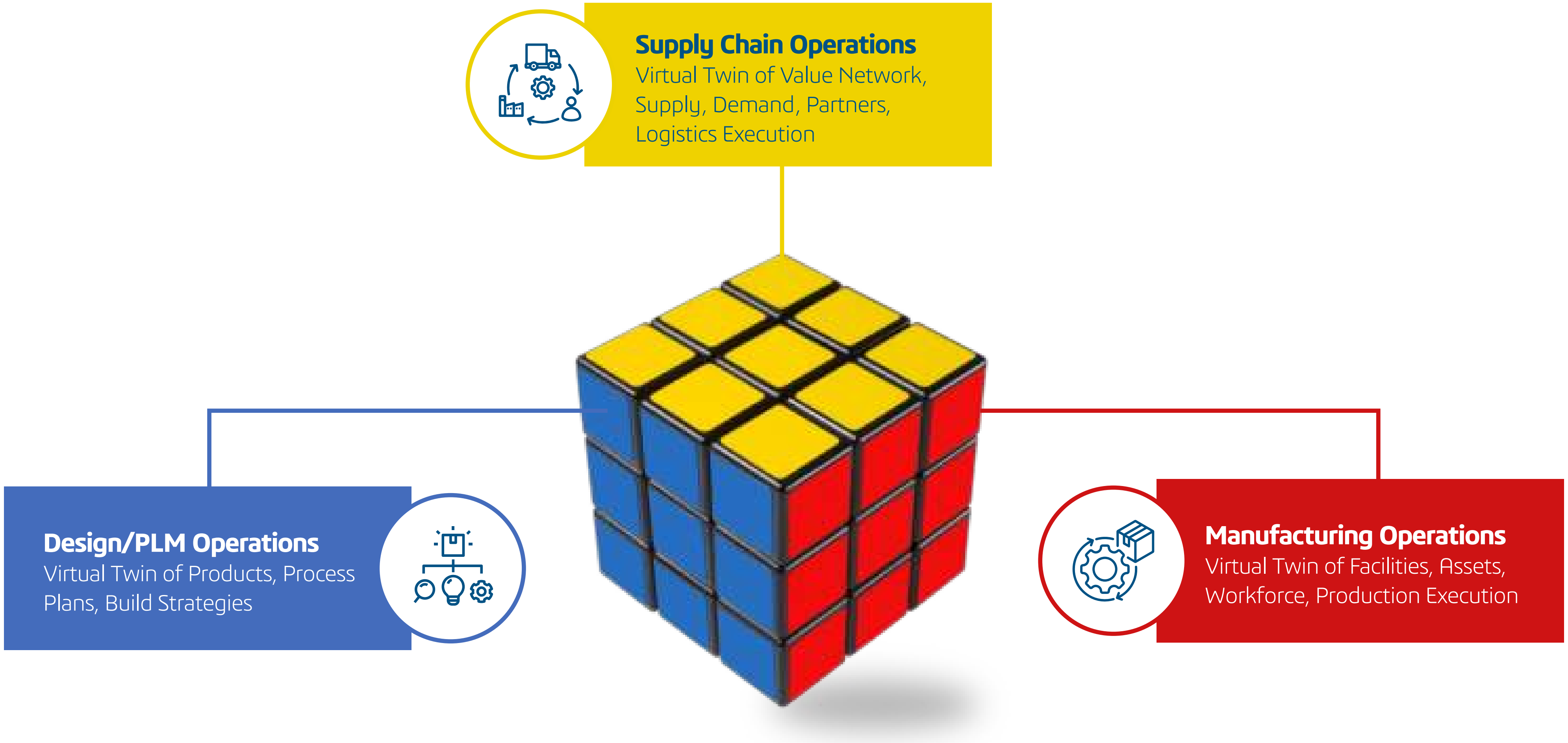
With DELMIA's integrated approach, users gain a deeper understanding of the AI-generated intelligence. The combination of AI and ML enables the system to continuously learn and improve from the data it processes. This self-learning capability enhances the intelligence, making it more accessible and actionable for users.

The Virtual Twin technology further enhances the user experience by creating a digital representation of real-world processes and systems. This virtual twin mirrors the actual operations and can simulate various scenarios. As a result, users can experiment with different strategies, identify potential issues, and make informed decisions without disrupting real-world operations.



Execution-oriented Philosophy

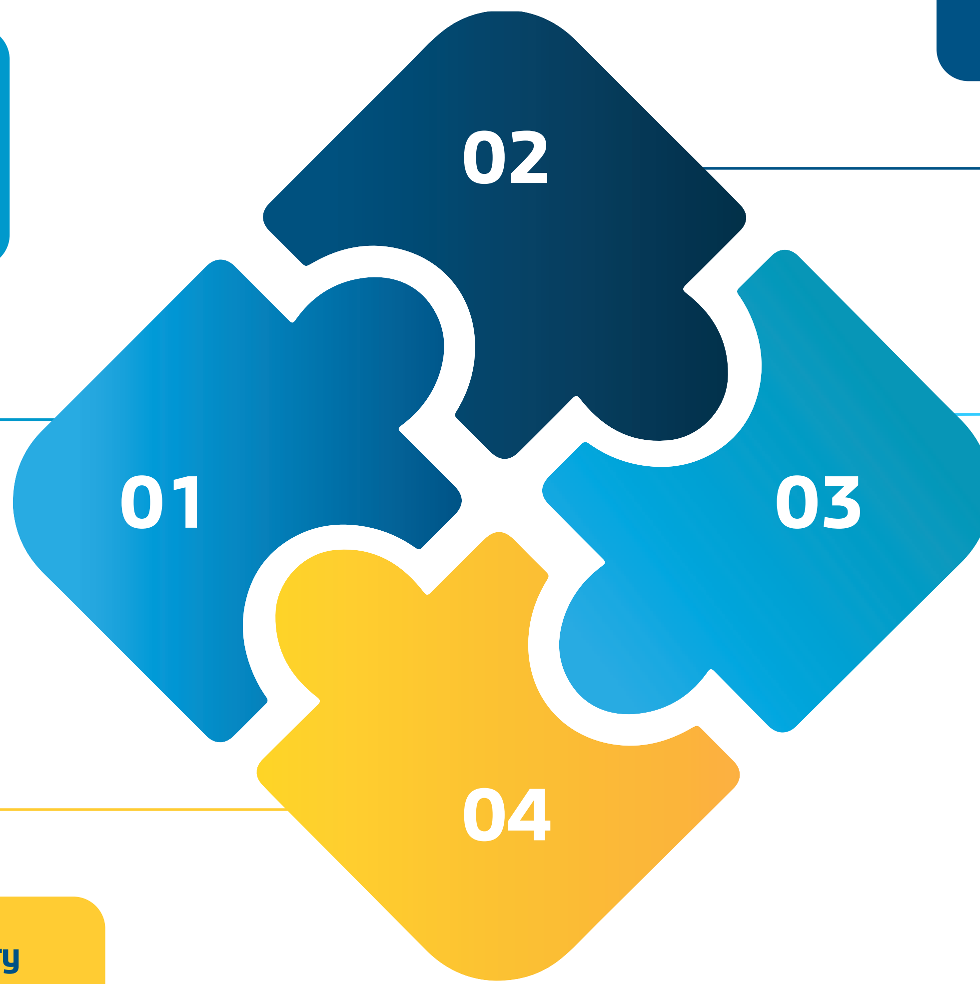
A study was conducted by the research organization, Tech-Clarity, aiming to identify the common denominator among companies that were top performers in four key parameters: revenue growth, time-to-market, EBITDA, and innovation. One factor that consistently stood out among these top performers was collaboration across manufacturing, design, and the supply chain. The findings are rather intuitive: product specifications and process capabilities form the foundation for supply chain planning, and manufacturing plays a central role in all these aspects. However, implementing this seemingly straightforward solution is extremely complicated.



The Rubik's cube analogy illustrates the complexity of optimization across different disciplines and how they often pursue goals in isolation rather than collectively. Achieving this level of synchronization is nearly impossible without a collaborative platform of integrated applications. The **3D**EXPERIENCE platform provides organizations with a holistic, real-time vision of their business activity and ecosystem. It connects people, ideas, data, and solutions in a single collaborative environment, empowering businesses to innovate, produce, and trade in entirely new ways.

Deep Industry Expertise and Best-in-Class Technology

DELMIA



Holistic and Native AI Integration

Seamlessly embed AI into every facet of operations

Best-In-Class Optimization

Fine-tune every aspect of manufacturing and operations for efficiency and effectiveness

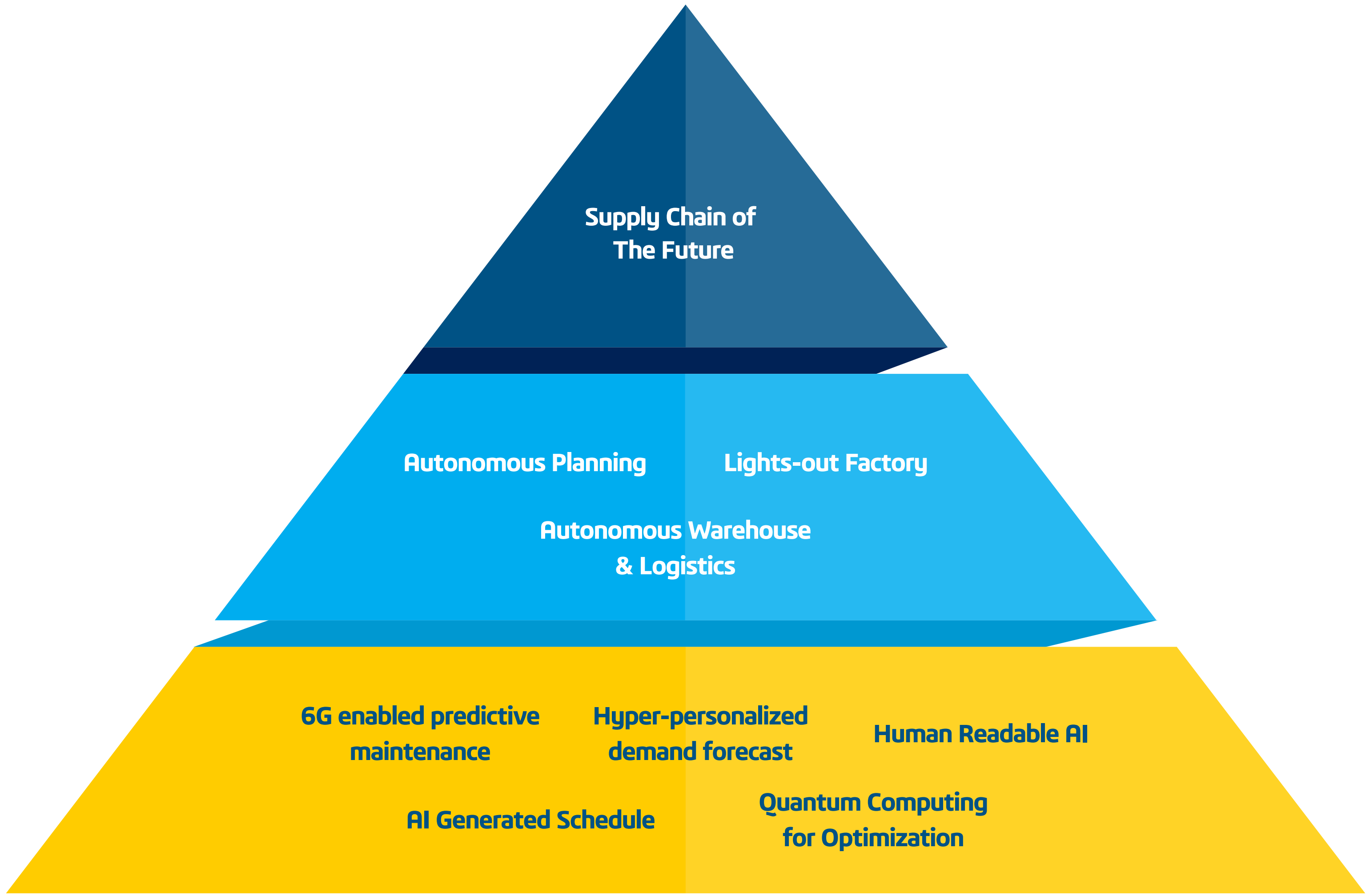
Knowledge and Experience

Draw from a deep well of knowledge and experience from various sectors

Best-in-Class Industry Experience

Finely tailored solutions for the unique challenges of industries

WHAT DOES THE FUTURE LOOK LIKE?

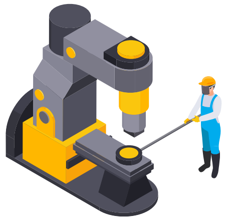


The supply chain of the future will feature autonomous planning driven by AI and quantum computing, optimizing every step from procurement to delivery. Factories will operate with minimal human intervention, integrating advanced robotics, 6G connectivity, and AI-driven maintenance. Warehouses and logistics centers will become autonomous hubs, offering real-time personalized responses. Human-readable AI will facilitate swift, informed decisions, while quantum computing will solve complex problems efficiently, adapting to changing circumstances for enhanced sustainability. This future supply chain will act as a dynamic, self-adjusting ecosystem, becoming a strategic asset for businesses in an ever-changing world.

VALUE AND BENEFITS TO CUSTOMERS

DELMIA has helped its customers transition into an era of efficiency and adaptability. Autonomous planning algorithms, AI-driven supply chain, and cutting-edge technology have optimized every aspect of their supply chain. This transformation has resulted in more agile and responsive supply chains, reduced downtime, and enhanced sustainability, ensuring that businesses can thrive in an ever-changing world.

Some examples of how we have helped our customers:

	**Leading Metals Manufacturer**	Optimization maximize business KPI's vs customer service levels & regulatory requirements	• Over **50% reduction** in order backlog • Up to **50% reduction** in lead times • **25% and 20% reduction** in inventory and work-in-progress, respectively
	**Global Beverage Producer**	Machine learning **reduces sourcing** costs based on historical data	• **$8 million reduction** in sourcing costs • Improved profitability • Improved fulfillment
	**World Leader in Energy & Telecom**	Improved S&OP stakeholder workflow with enhanced forecasting	• **30% forecast accuracy** increase • **~€0.5 million reduction** in inventory in pilot phase • Paradigm shift from volume to value-based planning

Some of our customers:

3B fibreglass company, AIRBUS Defence & Space, Bridgestone, BHP, CARVANA, Dassault Aviation, Eurostar, Flinders Ports, FINNAIR, green cargo, GLENCORE, Gatwick, Herbalife Nutrition, IMERYS, JUMBO, Lindström, Lavigne, Morrisons, Marathon, mcpp, PANDORA, RosaMaria, Speed Group, Smithfield, sij group, SKF, TRESPA, Tribotecc, Sydney Trains, TÖNNIES, virgin atlantic

CONCLUSION

In conclusion, the pervasive influence of Artificial Intelligence (AI) in supply chain management is undeniable. AI's innate ability to process vast amounts of data, predict outcomes, and optimize operations makes it a perfect fit for the complex and dynamic world of modern supply chains. The value it brings in terms of increased efficiency, adaptability, and resilience is significant.

THE NEED FOR AI IS NOW CRITICAL

Understanding what it is, helps identify how to apply it

AI IS PERFECTLY SUITED TO SUPPLY CHAIN CHALLENGES

Opportunities in supply chain are extensive

ADOPTION OF AI WILL TRANSFORM YOUR SUPPLY CHAIN

Value is significant, especially when orchestrated with Manufacturing & Engineering

IMPLEMENTATION REQUIRES EXPERIENCE

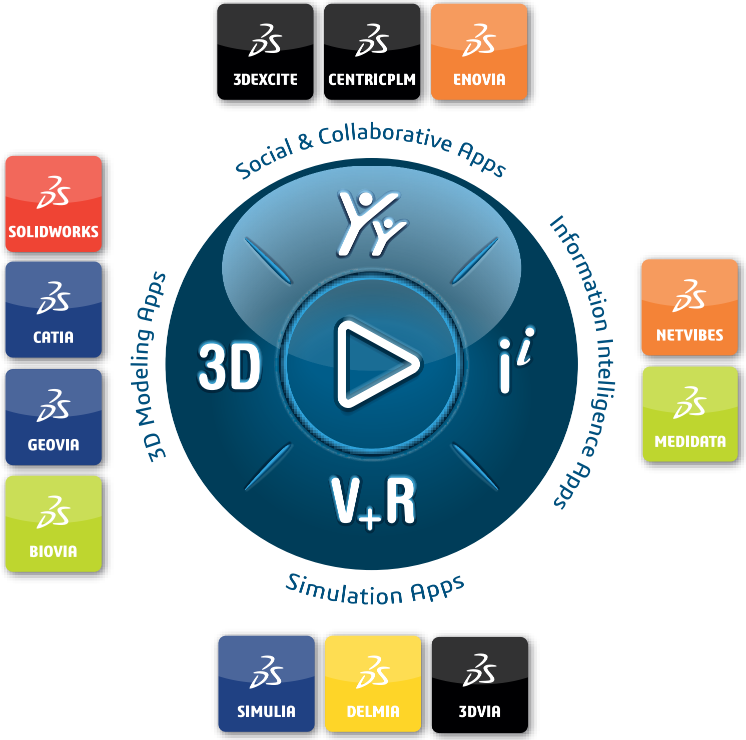
It is critical to know how and when to apply - work with a trusted vendor

However, it's not just about adopting AI but also about knowing how to implement it effectively. Choosing the right partner with a deep understanding of industry nuances and a commitment to integrated solutions, is paramount in harnessing the full potential of AI in reshaping the future of supply chain management. DELMIA helps customers embrace this transformative technology to help them thrive in an increasingly competitive and ever-evolving business landscape.

Our **3D**EXPERIENCE® platform powers our brand applications, serving 12 industries, and provides a rich portfolio of industry solution experiences.

Dassault Systèmes, the **3D**EXPERIENCE Company, is a catalyst for human progress. We provide business and people with collaborative virtual environments to imagine sustainable innovations. By creating virtual twin experiences of the real world with our **3D**EXPERIENCE platform and applications, our customers can redefine the creation, production and life-cycle-management processes of their offer and thus have a meaningful impact to make the world more sustainable. The beauty of the Experience Economy is that it is a human-centered economy for the benefit of all –consumers, patients and citizens.

Dassault Systèmes brings value to more than 300,000 customers of all sizes, in all industries, in more than 150 countries. For more information, visit **www.3ds.com**.



DASSAULT SYSTEMES | The **3D**EXPERIENCE® Company

Europe/Middle East/Africa
Dassault Systèmes
10, rue Marcel Dassault
CS 40501
78946 Vélizy-Villacoublay Cedex
France

Asia-Pacific
Dassault Systèmes K.K.
ThinkPark Tower
2-1-1 Osaki, Shinagawa-ku,
Tokyo 141-6020
Japan

Americas
Dassault Systèmes
175 Wyman Street
Waltham, Massachusetts
02451-1223
USA