



NAC Executive Insights

Artificial Intelligence and Complexity

Key Points

- Artificial Intelligence (AI) and complexity are deeply interconnected.
- AI interacts with complexity in multiple ways.
- AI alleviates complexity through automation, pattern recognition, optimization, and predictive modeling.
- Uncertainty plays a crucial role in complex systems.
- AI helps mitigate uncertainty in three key ways – reducing decision uncertainty; real time adaptability; and simulating uncertain outcomes.

Introduction

Artificial Intelligence (AI) and complexity are deeply interconnected, with AI both responding to complexity and creating complexity in various domains. Let's break this down into different facets while also exploring the critical role of uncertainty management in each.

Understanding Complexity in Relation to AI

Complexity often arises in systems, decision-making, and problem-solving, due to large-scale interdependencies, unpredictability, and dynamic environments, such as we encounter in Large Complex Projects (LCP). AI interacts with complexity in multiple ways:

- **Data Complexity** – Large volumes of structured and unstructured data require AI to sift, process, and extract insights.
- **Computational Complexity** – Some problems are difficult to solve due to the exponential growth of possible solutions; AI helps optimize solutions.
- **Cognitive Complexity** – Decision-making involves numerous variables, unknowns, and adaptive behaviors, making AI valuable for reasoning.

Artificial intelligence thrives in dealing with complexity because of its ability to handle vast amounts of information and identify patterns that would be infeasible for humans to process manually.

Role of Artificial Intelligence in Managing Complexity

AI's role in managing complexity emerges from its abilities in automation, pattern recognition, optimization, and predictive modeling. Crucially, AI mitigates uncertainty in three ways: reducing decision-making uncertainty, enabling real-time adaptability, and simulating multiple uncertain outcomes. Artificial Intelligence (AI) and complexity are deeply interconnected.

Some core ways AI addresses complex challenges include:

- **Automation of Complex Processes** - AI eliminates repetitive and error-prone tasks, streamlining operations. We see this in industries such as manufacturing, healthcare, and finance. It enables autonomous decision-making in multi-agent systems where thousands of interacting components must operate efficiently (e.g., logistics optimization). Approaches and solution sets developed for other industries are analogs for the planning, delivery and subsequent operation of LCPs.
- **Managing Uncertainty through Data Analysis & Prediction** - Uncertainty is a major challenge in complexity, as it hinders precise decision-making. AI tackles uncertainty through predictive analytics:
 - Machine Learning (ML) models detect patterns in chaotic systems, allowing business and project teams to forecast trends, risks, and anomalies.
 - Probabilistic Models (such as Bayesian inference) allow AI to reason under uncertainty by quantifying likelihoods instead of relying on absolute truths.
 - Generative AI refines insights when data is incomplete by simulating potential outcomes and generating realistic scenarios.

Bayesian inference is a powerful framework in probability and statistics for updating beliefs in light of new evidence. At its core, it's about learning from data and refining what we know.

- **Optimization of Complex Systems** - In real-world decision-making, AI applies algorithms that optimize solutions in complex and unpredictable environments:
 - Neural Networks analyze intricate patterns where traditional statistical methods fail.
 - Reinforcement Learning adapts AI behavior over time, navigating unpredictable conditions (such as autonomous robotics or dynamic pricing models).
 - Graph-Based AI Models untangle highly interdependent systems like financial networks, social connections, and supply chains.

AI's Role in Managing Uncertainty

Uncertainty plays a crucial role in complex systems. AI helps mitigate uncertainty in three key ways as previously outlined:

- **Reducing Decision Uncertainty** - AI algorithms improve decision-making by eliminating cognitive biases that might distort human reasoning. Risk assessment models predict the likelihood of events, providing more reliable guidance for decision-makers.
- **Real-Time Adaptability** - AI adapts dynamically to changing conditions, unlike rule-based automation, which requires static instructions. Systems like self-learning AI models analyze new inputs continuously, ensuring adaptability even in volatile environments (e.g., financial markets, climate science).

- **Simulating Uncertain Outcomes** - AI creates alternative scenarios using simulations, allowing organizations and project teams to test multiple possibilities before taking action. This approach is vital in disaster management, urban planning, and resource allocation, where decisions must be made despite incomplete information.

AI actively transforms how we perceive and engage with complex problems and systems. It reduces uncertainty by enabling faster analysis, more accurate predictions, and adaptive learning models, ensuring more informed, strategic decision-making in everything from medicine to space exploration.

This relationship between complexity and AI continues to evolve. As AI grows more sophisticated, it doesn't just solve existing complexities—it redefines the limits of what is manageable, bringing entirely new possibilities into the equation. Hyper-personalized project analytics is now possible.

Quantum-enhanced AI could dynamically adjust task priorities based on live data. For hyper-personalized project analytics, quantum-enhanced AI can rapidly analyze live data to dynamically adjust task priorities, tailoring decisions to specific project needs in real time. This leads to smarter resource allocation and more efficient project management.

Real-Time Decision Systems in Project Management

AI-driven real-time decision systems can be used to form a responsive, interconnected feedback loop enabling continuous adaptation to emerging project conditions.

- Real-time decision systems use AI, IoT¹, and edge computing² to enable adaptive, data-driven decision-making. This ensures that projects react dynamically to unfolding events. Specific uses include:
 - **Dynamic Project Tracking & Adjustments:** Real-time AI-driven dashboards monitor thousands of project parameters and adjust priorities autonomously:
 - **Live Resource Tracking:** AI identifies inefficiencies in real-time and redirects resources accordingly.
 - **Instant Bottleneck Alerts:** If delays occur in one part of a project, AI suggests alternate workflows instantly.
 - **Recommended Tools:**
 - Microsoft Project with AI capabilities can dynamically track progress, predict project risks, and adjust timelines. Similar tools use real-time data analytics for more responsive decision-making.
 - Jira, offers AI plugins for agile project management, enabling dynamic adjustments based on real-time inputs. Jira is purpose-built for agile teams and excels in environments where iterative development, collaboration and flexibility are key.

¹ The Internet of Things, or IoT, refers to the network of physical devices connected to the internet, collecting and sharing data. This includes everything from smart home gadgets to industrial sensors.

² Edge computing, on the other hand, is about processing data closer to where it's generated, like on the IoT devices themselves or local servers, instead of sending it all to a central cloud. This leads to faster decision-making and reduced data transfer.

Use Cases:

1. *Smart Factory Deployment - A manufacturing company rolling out an automated factory could use real-time AI dashboards to track machinery installation. If an unexpected delay occurs (e.g., a supplier shipment is late), AI instantly updates schedules and redirects workers to alternate tasks, keeping progress on track.*
 2. *AI-powered IoT devices can monitor heavy construction equipment, predicting maintenance needs and efficiently allocating resources to prevent breakdowns, thus boosting performance and minimizing downtime. Caterpillar's CAT Connect is a real-world example, using IoT and AI to monitor equipment health, optimize performance, and reduce downtime through predictive maintenance in construction.*
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- Predictive Maintenance & Risk Mitigation - Real-time AI systems can predict potential failures before they happen:
 - Sensor-driven Predictive Maintenance: AI-powered IoT devices in industrial projects detect equipment failures before they cause downtime.
 - Hazard Avoidance: AI analyzes weather patterns, material stability, and worker fatigue on construction sites.
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Use Case: High-Speed Rail Construction - A project to build high-speed rail infrastructure could use real-time IoT sensors on bridge construction materials to detect structural weaknesses before they become safety hazards—preventing costly delays.

- AI-Driven Decision Making in Agile Workflows: AI-based real-time decision systems help project managers reconfigure plans on the fly:
 - Adaptive Budgeting: If market prices for raw materials fluctuate, AI redesigns budget distributions automatically.
 - Workforce Optimization: AI balances workload across teams, preventing burnout and ensuring high-efficiency productivity.
 - **Recommended Tools:**
 - AI-driven decision-making in Agile workflows can be seen in tools like JIRA and Trello, which use machine learning for adaptive budgeting and workforce optimization, balancing workload by predicting project risks and resource allocation.

- Companies like IBM and Microsoft offer such solutions, with real-world cases in construction and software development. For workforce optimization, AI aids in distributing tasks based on team capacity and skills, boosting efficiency.

Use Cases:

1. *Large-Scale IT System Overhaul - A major bank undergoing a full digital transformation could use AI decision systems to reallocate developer efforts dynamically—redirecting workforce instantly if security vulnerabilities arise in new software deployments.*
 2. *AI-enabled Agile project management has been employed by tech companies using AI for software testing and predicting code issues, which streamlines the testing phase and reduces time.*
 3. *In construction, AI-enabled Agile project management has been used to schedule activities, allocate resources, and monitor progress, minimizing delays and budget overruns. One case study highlighted the use of AI-based tools in construction management to efficiently schedule tasks and reduce budget overruns. AI also optimizes design, predicts risks, and enhances resource allocation, with companies like Autodesk leading the charge in this space.*
 4. *Autodesk's Generative Design used in the Shanghai Tower project employed AI-enabled solutions for construction management, optimizing design, reducing costs, and enhancing efficiency.*
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Real-time AI systems excel in:

- Dynamic workflow adaptation
- Predictive failure mitigation
- Agile corporate & industrial deployments

AI combined with quantum computing enables project managers to gain unprecedented control over uncertainty while accelerating efficiency beyond traditional planning methods.

Application in the Engineering & Construction Industry

The engineering and construction industry can benefit immensely from advanced technologies such as AI to enhance efficiency, risk management, and real-time decision-making. Real-time AI decision systems can optimize performance in the engineering and construction industry in several ways. Recommended tools are intended to be illustrative.

- **Real-Time AI Decision Systems for Engineering & Construction:** AI-powered real-time decision-making boosts agility by adapting workflows, detecting issues, and preventing costly setbacks.
 - **Smart Project Tracking & Workforce Management** - AI dashboards track labor force productivity, material usage, and real-time deadlines, adjusting schedules instantly when delays or supply issues arise.
 - **Recommended Tools:**
 - Procore AI-Powered Construction Management platform leverages AI for smart project tracking and workforce management, optimizing labor planning, scheduling, and real-time tracking. It provides insights to optimize

workforce allocation, enhancing efficiency and reducing downtime, ultimately driving more effective project execution.

- Monitors project phases in real time
- Automatically shifts schedules based on weather, permits, or delays
- Uses AI-driven insights to reallocate workforce efforts dynamically

Use Cases:

- 1. High-Rise Building Construction - If an unexpected supplier delay occurs, AI immediately updates workforce priorities, assigning teams to alternate tasks while waiting for materials.*
 - 2. The Hudson Yards development in New York City, where Procore's AI-powered construction management platform was utilized. The platform streamlined coordination, risk management, and communication among various stakeholders across this massive, complex project.*
 - 3. Renovation of Sacramento's Golden 1 Center used Autodesk's PlanGrid platform to streamline project tracking and improve collaboration among contractors and stakeholders, showcasing its capabilities in efficient construction management.*
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- PlanGrid, now part of Autodesk Construction Cloud, is a comparable platform in the engineering and construction industry. It offers smart project tracking, real-time collaboration, and workforce management tools, enhancing project efficiency and oversight.
- ALICE (Artificial Intelligence Construction Engineering) is a cutting-edge platform designed to revolutionize how large-scale construction projects are planned, optimized, and executed. It's particularly powerful for infrastructure, energy, and commercial developments where complexity, risk, and resource constraints are high

ALICE specializes in generative scheduling and simulating construction sequences, Procore offers comprehensive project management with AI enhancements, and PlanGrid, now under Autodesk, focuses on digital blueprint management and field collaboration. Each serves different aspects of construction management, making them complementary in some cases.

- **Predictive Maintenance & Equipment Optimization** - AI-powered IoT sensors ensure machinery doesn't break down unexpectedly, preventing downtime and cost overruns.
 - **Recommended Tool:** Siemens MindSphere IoT Platform³
 - Monitors equipment wear and tear
 - Predicts failures before they happen using sensor data
 - Ideal for heavy equipment in large infrastructure projects

³ Siemens MindSphere is a cloud-based, open Internet of Things (IoT) operating system designed to connect industrial assets and harness data for smarter decision-making and operational efficiency. At its core, MindSphere enables companies to collect, analyze, and visualize data from machines, systems, and sensors across global operations. It supports a wide range of industries—from manufacturing and energy to transportation and infrastructure

Use Case: Underground Metro Construction - AI-driven sensors detect excavator wear & tear before failure, preventing expensive downtime in tunnel excavation projects.

- **Live Hazard Detection & Site Safety Management** - AI can analyze safety risks in real time, identifying potential accidents before they occur.
 - **Recommended Tool:** Smartvid.io AI-Based Construction Safety
 - Scans site footage for safety violations
 - Predicts worker fatigue & equipment hazards
 - Reduces insurance risks for engineering firms

Use Case: Oil Refinery Construction - AI flags worker safety violations - such as missing helmets or fatigue indicators - reducing accident rates significantly.

For the engineering and construction industry, combining quantum computing for predictive modeling with AI-driven real-time decision-making transforms operations into high-efficiency systems.

Recommended Approach

Best practice may be considered to consist of:

- AI Decision Systems for real-time workforce adjustments, predictive maintenance, and safety compliance.
- Integrate IoT Sensors & AI Dashboards to detect supply chain delays, optimize workflows, and monitor structural health.
- Quantum Computing for large-scale scheduling, risk simulations, and material performance analysis.

Summary

The convergence of Artificial Intelligence (AI) and complexity heralds a transformative epoch in project management and industrial operations. As shown in this Executive Insight, AI's intrinsic capabilities—ranging from automation and pattern recognition to predictive analytics and optimization—enable organizations to effectively navigate the multifaceted challenges inherent in large-scale, complex and dynamic projects. AI not only alleviates complexity by streamlining processes, enhancing decision-making, and fostering real-time adaptability, but it also mitigates the uncertainties that characterize complex systems. This dual role positions AI as an indispensable tool for managing the interdependencies, unpredictabilities, and rapid changes typical of today's projects.

The integration of AI with emerging technologies such as IoT sensing and quantum computing amplifies its potential, facilitating unprecedented levels of project control, risk management, and resource allocation. Case studies in construction, infrastructure development, and industrial automation illustrate how AI-driven solutions—such as predictive maintenance, real-time decision systems, and generative design—yield significant improvements in efficiency, safety, and cost-effectiveness. As AI continues to

evolve, its capacity to redefine project boundaries and operational paradigms will only expand, pushing the limits of what is achievable.

In embracing these advances, all stakeholders must remain cognizant of the ethical, operational, and technical challenges that accompany the deployment of AI in complex environments. Strategic investment in intelligent systems, coupled with adaptive management practices, will be crucial to harness AI's full potential responsibly and effectively. Ultimately, AI's integration into complex project management is not merely a technological upgrade but a strategic imperative that promises to unlock new horizons of innovation, resilience, and sustainable growth.

For Further Reading – Other Executive Insights

- Complex Projects
- Impacts of Artificial Intelligence on Management of Large Complex Projects
- Large Complex Programs as Open Systems
- Systems Thinking in the Construction Industry
- Organizational and Management Considerations in the Adoption of Artificial Intelligence in Engineering & Construction Organizations
- Use of Artificial Intelligence in Construction Safety
- Proper Reliance on Artificial Intelligence in Project Management
- Human Factors in Large Complex Projects

Other References

- Evolving Artificial Intelligence (AI) Challenges and Risks in Construction; Construction Management Advisor; CMAA; January 2024
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- Prieto, R. (2024). Measurement of Complexity in Large Complex Projects, PM World Journal, Vol. XII, Issue IV, April 2024.
- Prieto, R., Hajiya, A. (2024). Managing Complexity in Large Complex Projects, PM World Journal, Vol. XIII, Issue XI, December.
- Caterpillar CAT Connect
- IBM Corporation, *IBM Quantum Risk Analytics*
- Procore Technologies, *AI-Powered Construction Management*
- Siemens Digital Industries Software, *MindSphere IoT Platform*
- Autodesk Inc., *Generative Design for Construction*
- Smartvid.io, *AI-Based Construction Safety Solutions*
- Microsoft Corporation, *Project with AI capabilities*
- Atlassian, *Jira Agile Project Management with AI Plugins*
- Atlassian, *Trello*
- Autodesk Inc., *Autodesk Construction Cloud*
- ALICE Technologies, *ALICE Construction Engineering Platform*

About the Author

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