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Impacts of Artificial Intelligence on Management of Large Complex Projects[1]

Key Points

- The management of large complex projects is entering an era of unprecedented challenge and one which warrants further attention and examination.
- The specific challenge this Executive Insight focuses on arises from the increased incorporation of artificial intelligence (AI) of all forms (machine learning, natural language processing, and others) into the various elements of project execution as well as the broader corporate frameworks in which these projects reside.
- This Executive Insight highlights the extent and breadth of AI development in the engineering and construction field and the challenges the industry and profession must address.

Brief Background on AI

AI makes it possible for machines to learn from experience, adjust to new inputs, and perform human-like tasks. Examples are computers learning to play chess or *Jeopardy*™ using AI, for intelligent assistants (Siri; Alexa), or for self-driving cars.

Big data and AI are interlinked. Data are being generated at an exponential rate. Analyzing these large sets of structured and unstructured data requires that self-learning computers recognize patterns using concepts like deep learning, machine learning, and neural networks. Big data and AI go hand-in-hand: one will not be useful without the other and the two reinforce each other.

Although most think AI is driven by big data analytics, the scope of the technology under the umbrella term that is AI falls into three distinct categories: big data, vision, and language. In essence, vision and language are related to machines being able to imitate and enhance human perception capabilities, while big data is related to how machines can analyze large amounts of data much quicker and more accurately than humans, find correlations, and even make predictions of how systems will behave in the future.

[1] For a more detailed discussion on this subject see: Prieto, B. (2019). Impacts of Artificial Intelligence on Management of Large Complex Projects. *PM World Journal*, Vol. VIII, Issue V, June.; https://pmworldlibrary.net/wp-content/uploads/2019/06/pmwj82-Jun2019-Prieto-Impacts-of-Artificial-Intelligence-on-Management-of-Large-Complex-Projects.pdf

AI encompasses a wide range of core technologies, but this Executive Insight is focused primarily on:

- **Machine learning** (ML) type of AI that involves using computerized mathematical algorithms that can learn from data and can depart from strictly following rule-based, pre-programmed logic.
- **Deep learning (DL)** is a form of ML that uses the model of human neural nets to make its predictions about new data sets.
- **Natural language processing (NLP)** enables computers to understand human language as it is spoken and written and to produce human-like speech and writing.
- **Computer vision (CV)** attempts to identify images of objects that can be seen. It also can include attempts to use the same technology to identify patterns in data, such as seismographic readings, that humans cannot readily see.
- **Machine reasoning (MR)** attempts to simulate human thought processes by using a computerized model of language to acquire knowledge and then make decisions. Expert systems are designed to build the model's own understanding of the world based on the relationships between words and concepts.
- **Strong AI,** also referred to as artificial generalized intelligence (AGI), attempts to simulate general human thought processes.

Extent and Breadth of Potential AI Use Cases

The rate of technology adoption is accelerating. This will have a broad impact on the projects that we do and how we do them. We are only at early stages of big data monetization, where only one percent of data is stored and analyzed, and only eight percent of companies have deployed machine learning beyond the initial testing phases. This will have a range of medium- and longer-term implications for industry (a sampling of those that the engineering and construction industry will face is shown in Table 1.)

The extent and breadth of AI use cases in the engineering and construction industry is shown in Table 2. Project management will be challenged with ensuring the veracity and quality of results derived from AI enabled activities.

Table 1 Implications for Engineering & Construction from Growth in Use of AI	
Medium Term	**Longer Term**
With the rapid evolution of technology, there will be an increased need for engineers to research, create, and test AI systems.	History has shown that technological advances in the past have helped create new jobs. This will be especially relevant for those in the engineering community.
Engineers have an enormous opportunity to showcase their creativity in response to advances in AI.	AI literacy/proficiency will be a prerequisite for survival.
New types of experts will increasingly be in demand in response to the new types of work created by AI technology.	Existing business model will be replaced by value-added business models (in part).
New developments in AI will enable engineers to complete their work more efficiently and solve a wide range of problems.	Risk of new entrants to business grows.
Exemplar AI use cases become mainstream. First movers accrue competitive advantage in winning work and executing work	Technology partnerships important but also increasingly transitory (*techceleration* hollows out, then current technology advantages occur at an increasing rate).
Existing labor time business model put under stress.	Continuous innovation and process improvement are prerequisites for survival.

Table 2 Potential AI Use Cases in Engineering & Construction		
Use Area	**Potential Use Case**	**Potential Use Case**
Business Development		
Marketing		
	Marketing Analytics	Visual search
	Marketing Personalization	Third-party data analytics to understand existing and target clients (including sentiment analysis)
	Neuromarketing for pre-testing (test content in private for desired effect)	Content generation
	Context aware marketing	Crowd sourced market research
	Static image recognition, classification, and tagging to improve discovery	
	Social media optimization (channel, audience, message, timing)	
	Social analytics and automation (stakeholder applications also)	
	Website personalization	
Sales		
	Pricing optimization	Sales content personalization
	Sales forecasting	Sales contact analytics
	Sales data input automation	Intelligent CRM systems
	Predictive sales/lead scoring	
Data (to support AI)		
	Data preparation platforms (extract, transform, load (ETL) platforms)	Data integration and transformation
	Converting paperwork into digital data	Data management and monitoring
	Data cleaning and validation platforms	

Analytics		
	Employee empowering analytics platforms (problem and insight identification)	Data visualization
	Client supporting analytics services	Real time analytics
	Geo-analytics platforms	Image recognition and visual analytics (inspection; safety)
	Business analytics platforms	
Financial		
	Fraud detection	Billing and accounts receivable automation
	Financial analytics (project performance and spend; overhead spend)	Tax filing and processing
	Credit scoring (client; subcontractors and vendors)	Agent-based simulations for decision making
	Expense reporting and management	
Legal		
	Legal and regulatory compliance	Contract Lifecycle Management (CLM)
Project Health		
	Project manager selection	Project execution discovery and modeling
	Project data analytics	Real time predictive analytics
	Project risk modeling, mitigation and management	Automated report generation
	Project mitigation and recovery plans	
Human Resources (HR)		
	Candidate identification and screening	HR analytics
	Performance management	HR services
	Retention management	

Information Technology		
	Cybersecurity prediction and analytics	Knowledge management
	Autonomous cybersecurity systems (prevention against cybersecurity threats)	Design recognition library
	Autonomous code development	Innovation support and prioritization
Engineering & Design		
	Planning	Design checking; validation; verification
	Stakeholder Management	RFI automation
	Estimating	Resident engineer/construction inspection
	Design automation and optimization	Continuous improvement
	Generative design	Evolving skills
	Project staffing	
	Design compliance (contract; specifications; codes and standards)	
Operations		
	Back office automation	Predictive maintenance
	Facilities management	Operating project analytics
Supply Chain		
	Supply chain	
Logistics		
	Automated logistical truck services	Object detection and classification – avoidance and navigation
Construction		
	Construction management	
	Construction safety	
	Construction quality	
	AI assisted construction	
	AI robot assisted construction	
	Automated report generation	
	Post-disaster assessment	

Barriers, Threats, Risks

Barriers

Several barriers to AI adoption exist within the engineering and construction industry and analogs will exist for other industry segments. These include:

- A lack of understanding
    - Engineers do not fully understand how AI-predicted outcomes were derived. This not only raises trust issues, but also creates potential legal and liability issues.
    - Data analytics are developing at a rapid pace, making it difficult to keep up with technology advancements and the benefits associated with them.
- A lack of resources
    - Many companies simply do not have the in-house IT infrastructure and expertise to successfully harness big data.
- A lack of willingness to change.
    - Having already invested heavily in legacy software systems, many executives may be hesitant to invest in new software solutions.

Threats

AI does not come without some risks. Algorithms are being designed to emulate what a human would do as closely as possible. Hence, algorithms can introduce human biases. While AI is useful for unstructured datasets, automatic classification, and forecasting and prediction, it is not ideal in understanding the reasoning in decisions, especially when many external factors are involved.

AI could help rejuvenate overall productivity, but the technology has to become much easier to use.

AI must overcome many ethical issues; it mandates thorough due diligence and impact assessment.
Some specific AI threats might include:

- Highly believable fake videos that impersonate prominent figures to manipulate public opinion
- Automated hacking
- Finely-targeted spam emails using information scraped from social media
- Exploiting the vulnerabilities of AI systems through adversarial examples and data poisoning
- Crashing fleets of autonomous vehicles
- Turning commercial drones into face-targeting missiles
- Holding critical infrastructure for ransom

Risks

AI creates three specific risks. First, intelligent machines often have hidden biases, not necessarily derived from any intent on the part of the designer, but from the data provided to train the system. For instance, if a system were to learn which job applicants to accept for an interview by using a data set of decisions made by human recruiters in the past, it may inadvertently learn to perpetuate racial, gender, ethnic, or other biases. Moreover, these biases may not appear as an explicit rule, but rather be embedded in subtle interactions among the thousands of factors considered.

A second risk is that unlike traditional systems built on explicit rules of logic, neural networks deal with statistical truths rather than literal truths. That can make it difficult if not impossible to prove with complete certainty that a system will work in all cases, particularly in situations that are not represented in training data. Lack of verifiability can be a concern in mission-critical applications (such as controlling a nuclear power plant or aircraft) or when life-or-death decisions are involved.

A third risk is that when machine learning systems make errors, diagnosing and correcting the precise nature of the problem can be difficult. What led to the solution set may be unimaginably complex and the solution may be far from optimal if the conditions under which the system was trained happen to change. Given all this, the appropriate benchmark is not the pursuit of perfection, but rather the best available alternative.

Impacts on Engineering & Construction Companies

Artificial Intelligence will become a factor at all stages of the project life cycle impacting not only how companies do business, but also the business they do, the services they deliver, and the mix of skills they will require.

Planning

Planning transformation can be thought of in two dimensions. The first revolves around the changed planning process on the public sector side, while the second is in the execution of planning activities themselves.

The public sector planning system is ripe for machine-learning. Initiatives include:

- AI customer-facing interface to answer general planning inquiries, from the status of applications to various other queries. It will retrieve and present any information that people are likely to need via computer or phone.
- A validation process with AI validating applications and then saving and checking all documents before placing them in the planning database.
- Public consultations are also set to be transformed through AI. For example, passersby with smart phones can virtually see design proposals for a vacant lot as they stand at the site itself.

In executing traditional planning activities, we tend to limit the number of scenarios considered given their complexity and often non-deterministic nature. AI enables seeing deeper correlations and hidden constraints and couplings, suggesting solutions outside of what otherwise may have been considered.

Design

A search of ASCE[2] papers shows the industry is not standing still on AI. A number of potential use cases have been described and researched. These discrete and very specific use cases represent the immediate future of AI in the civil engineering profession while the medium and longer term aspects covered in this Executive Insight are accelerating towards us.

The use cases to date stop short of addressing the broader issues on how the design process needs to change and how maximum industry leverage can be obtained. The importance of performance-based standards must be called out as an enabler of innovation broadly but the enablement of broad AI adoption specifically.

AI aids the design process but also modifies it[3]. Research into AI has produced:

- Software systems that design artifacts
- Software systems that provide assistance to designers (for example by critiquing design choices or suggesting other alternatives)
- Theories about how designers reason
- Studies and analyses of actual design activities
- Models and descriptions of natural categories of design activity (for example, routine parametric design)
- Guidance about how to apply existing AI techniques to design problems

The field has progressed to functional reasoning and creative design, and from solo designers to teams.

While AI affects the design process indirectly in a myriad of ways including categorization of types of knowledge, new tools and new processes, it can also affect the design process directly. Some examples of direct impact include:

- Agent learning
- Methodology generation
- Planning

Many examples of task-based uses of artificial intelligence can be found in civil engineering design.[4]

AI can help guide the design process. As a result, what we design will be different than what we might otherwise have done. Similarly, new tools allow some of what we previously have designed, investing engineering time and talent in, to be adequately handled by artificial intelligence.

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[2] American Society of Civil Engineers

[3] Chapter 6, *AI for Design Process Improvement*; David C. Brown; Worcester Polytechnic Institute

Procurement/Supply Chain

Digital transformation is poised to change the supply chain more profoundly than any other functional area and more dramatically than at any point in its history in terms of driving efficiency and resiliency to disruption. In the context of the challenges facing supply chains, it becomes clear the old ways of working will not suffice and even best-in-class performance today is unlikely to be good enough in the future. The supply chain must become a "thinking" supply chain, one that is intimately connected to all data sources, enabled with comprehensive and fast analytics, openly collaborative through cloud-based commerce networks, conscious of cyberthreats, and cognitively interwoven.

If we broadly assess the typical supply chain, two major gaps emerge. The first is an analytics gap, whereby available analytics and even AI capabilities are not keeping up with the growth and diversification of data and data sources. If a supply chain is to be best in class, or even above average, available data must be fully leveraged—whether it is traditional structured data that is easily searchable by basic algorithms or unstructured data more akin to human language. Unstructured data doesn't fit nicely into relational databases, and searching it based on traditional algorithms ranges from difficult to impossible. Then there is dark data, broadly defined as data that is not visible or not yet visible to an organization. Regardless of the nature of data, however, the thinking supply chain must have access to the data and be able to analyze it for value in real time.

The second gap is one of attention and knowledge. Supply chain organizations have pursued cost reduction and traditional lean practices to the point that there are fewer people in the organization than at any time in the past, and as baby boomers retire, they take with them knowledge and practical experience that is not replaced by the millennials who succeed them. While this may be productive in the short term, as data analytics capabilities invariably grow in the supply chain, there likely will not be enough "eyeballs" available to act upon the resulting insights. Thus, the role of AI and machine learning becomes critical.

The imperative exists, therefore, for a digitally-enabled thinking supply chain that can manage, in real time, massive amounts of structured and unstructured data from both internal and external sources, including data sets that might previously have been elusive. Imagine a thinking supply chain that could aggregate data across regions to both anticipate future demand accurately and manage current replenishment or that could manage asset, inventory, and shipments through real-time tracking and optimization and then configure and change orders even in the middle of production—all done automatically without direct human intervention. This supply chain would not replace people necessarily—they would have oversight, of course—rather, it would enhance and augment the decision-making process. A thinking supply chain could iterate decisions far faster than any human could.

How does the project manager’s role and oversight responsibilities change?

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[4] Artificial Intelligence in Civil Engineering; Pengzhen Lu, Shengyong Chen, and Yujun Zheng; Hindawi Publishing Corporation; Mathematical Problems in Engineering; Volume 2012, Article ID 145974, 22 pages doi:10.1155/2012/145974

Construction
From automotive robots that can “see” what to weld, AI is extending into construction.

Business Implications

AI has direct impacts on the business models, driving both companies that do projects as well as the business of projects. AI impacts the skills we need and the tools we use.

Business Model
AI has the potential to unlock new business models for companies. These business models can be described as “AI First” business models. The “AI-First” business model is about using data and algorithms for three main things, all of which contribute to category leadership:

1. Create better products/services, thereby becoming leaders in product/service adoption.
2. Optimize processes by augmenting humans, thereby becoming leaders in product/service pricing.
3. Reduce costs by replacing humans, thereby becoming leaders in workforce efficiency.

Importantly, the value added created by AI does not lend itself to value capture through charging for work-hours. New pricing models will be required in the industry. In developing these new models it is important to recognize that along certain dimensions, the firm and by extension its projects are becoming an AI supplier and thus needs to understand the predominant strategies and business models for AI firms.

Three potential business models include:

1. Bolt-on
2. Enhanced process
3. Letting the machine stand alone

In the third AI business model, the AI technology changes an entire workflow by introducing an AI-infused, better-way-to-complete-a-business-process. AI “owns” the experience end-to-end, with little human-required assistance, giving algorithms the full control over the experience. What is the role of the project manager?

Changing Skills
Part of the AI mindset is a shift in the way we approach problem-solving. AI must learn through mistake-making and in various iterations of a task over time while gathering information from a larger data set. Shepherding this process requires visionary talent with a relatively high tolerance for both risk and failure. This will challenge project managers and their need to reliably deliver project outcomes.

AI professionals need the creativity to imagine how the technology can be applied, paired with the analytical acumen to measure results and determine success over time. They must be willing to take risks and perform experiments while being resilient enough to fail fast and move on faster. Talent like this can only succeed within the right organizational culture. Projects and project management practices may be seen as a drag on AI adoption. This must be recognized and reconciled.

Agility is a required skill.

Tools We Use

Much can be written about individual tools, but this is not the focus of this Executive Insight. Tools that the project manager will increasingly use include AI as well as a set of inter-related tools:

- Cloud computing
- Data analytics
- Data mining
- AI
- Augmented Reality (AR)

Impacts on the Profession

Three broad sets of challenges exist for the profession. These include:

- **Resources**
    1. Access to quality training data
    2. Access to limited pool of talent
    3. Reskilling workforces

- **Big Data**
    - Significant time required for data cleaning and processing, ensuring data integrity.
    - Lack of interoperability across protocol, device types, data types, and data sets.
- **Standards and Regulations**
    - Lack of algorithmic standards
    - Unclear ethical standards
    - Unchartered legal/liability and regulatory questions or standards
    - Uncertainty around compliance with existing regulations
    - Risks of explainable algorithms and compliance in highly regulated industries
    - Lack of industry-specific best practices

Skills Requirements

Effective delivery teams will be essential to succeed in an environment of techceleration and expanding AI. Teams will need to have access to a wide variety of skills and experiences. They will need to be collaborative, seamlessly synchronized, and able to fully leverage the advantage of their collective intelligence and capabilities—both human and artificial. They will need to be able to efficiently share information through a widely distributed communications system. The teams and the team composition will need to grow and adapt to a rapidly changing working environment. Project managers have a leadership role.

AI will present unique opportunities for the profession, but for those opportunities to be fully realized we will have to carefully understand and appreciate AI applications' strengths and limitations. The AI environment will not be static by any means. Existing AI applications will evolve and new applications will rapidly merge both from commercial off-the-shelf and internally developed sources. Project managers and engineers will need to not only effectively use existing AI applications, but also actively seek applications to address specific engineering and management challenges.

Adaptability will be a key characteristic as the obsolescence of past practices will take on an accelerating pace to match *techceleration* advancements.

Future needs will require project teams to:

- Understand neural networks and multi-layer data abstraction, empowering analysis and utilization of data.
- Comprehend and differentiate between theoretical concepts and practical aspects of machine learning.
- Master and comprehend advanced topics such as convolutional neural networks, recurrent neural networks, training deep networks, and high-level interfaces.
- Understand major applications of AI across various use cases, including analogous use cases in various fields.
- Implement classical AI techniques, such as search algorithms, mini-max algorithms, neural networks, tracking, and robot localization.
- Apply AI techniques for problem-solving and explain the limitations of current AI techniques.
- Formalize a given problem in the language/framework of different AI methods (e.g., as a search problem, as a constraint satisfaction problem, as a planning problem, and others).

How the Project Manager's Role May Change

In the near term, AI will likely replace tasks rather than jobs. It will also create new, higher value tasks to be undertaken given the power of the new tools. The union of AI and engineering, for example, should create AI engineering dealing with invention, innovating, designing, building, maintaining, research, and improving structures, machines, tools, systems, manufacturing processes, components, materials, processes, solutions, and organizations. The project manager's role will evolve to reflect these changed execution capabilities and approaches.

As AI further enables the various execution activities, it will drive changes in traditional roles as well as create new ones. Traditional roles will increasingly incorporate AI and many steps in the overall work process. The importance of assumptions made including constraints imposed will take on increased importance. The ability to draw a direct line from the assumptions made to the resulting design or analysis may no longer be possible. AI will rely on larger data sets than a discrete engineering or other task would likely consider today. AI will consider many possible optimization scenarios as well as analytical models to employ.

Tomorrow's AI-enabled engineer and project manager will require familiarity with how AI is being employed, the veracity and robustness of the assumptions made, and importantly any potential biases that may be reflected in the training data used to create the embedded AI algorithms. Sensitivity to assumptions including constraints will also take on increased importance, and assumption migration will need to be closely tracked.

Optimization parameters reflected in AI-enabled analysis must be closely understood.

Checking of AI-enabled designs will present new challenges as well validation and verification of AI-derived analyses and designs. Will the resultant outputs be the result of an automated process, a product if you will, produced by a tool or a professional work product? How do project management oversight and capabilities need to change?

In the short- to medium-term, AI enablement will be task-focused around valuable use cases. AI-aware engineers will be required to identify, define, and test prospective high value use cases. Data scientists who understand the existing and prospective big data in this domain will be required to assemble clean and well categorized data sets to train new AI algorithms. They will be supported by data engineers and data analysts. Approaches to validation and verification will be essential, especially in any scenario where formal certification that AI tools have been adequately validated and verified is required.

Project managers must ensure that the AI employed is applicable for the intended use.

Validation goes beyond traditional model and computational confirmation and must now include assessment of knowledge bases engaged in the AI-driven operation as well as the training data efficacy, including discovery of both currently known biases as well as currently unknown biases that create the potential for latent risks and insights not well supported by deeper science.

The potential for dangerous suggestions to emerge as data insights (insight without science) is a real challenge we will face, and project managers will have a key role to play here.

Should we require AI ethics for project managers?

Summary

This Executive Insight has touched upon some of the considerations and implications due to the current acceleration of deployment of AI in project industries, especially engineering and construction.

Some new considerations for project managers include:

- Veracity and quality of results
- Emerging legal and liability issues
- Thoroughness and quality of due diligence and impact assessment of AI ethical issues
- Hidden biases
- Quality and limits of training data
- Lack of verifiability
- Diagnosis of errors
- Access to sufficient data, including relevant dark data
- Access to required AI skills
- Uncertainty around compliance with existing regulations developed pre-AI
- Data integrity
- Adequacy of interoperability
- Assumption tracking and linkage to AI use cases
- Constraint awareness and tracking as it relates to the AI we deploy
- Insight into AI optimization parameters

About the Author

Bob Prieto was elected to the National Academy of Construction in 2011. He is a senior executive who is effective in shaping and executing business strategy and a recognized leader within the infrastructure, engineering, and construction industries.

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