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Connected construction: Reviving the United States' central nervous system

US infrastructure could again act as the country's central nervous system—if the industry joins together to pursue connected construction.

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Eisenhower-era infrastructure has been the backbone of the United States since the 1950s. Today, the convergence of physical and digital assets is creating next-era infrastructure that has the potential to serve as the nation's central nervous system—and dramatically redefine the ways infrastructure serves society. In this vision, the central nervous system will not only enable the movement of people and goods but it will enable digital activity such as commerce and online content to be consumed, visualized, edited, and made actionable throughout the transportation network.

Building the new central nervous system requires industry-level change. The construction industry has demonstrated an institutional resistance to technologies that can lead to meaningful productivity improvements. As decades-old workflows and siloed teams continue to characterize the industry, scale remains the primary lever to even the score. Yet, despite the hopeful optics of bigger machines and teams, these strategies have not resulted in meaningful improvements in the quality or cost of our infrastructure.

Some players are already there. Around the world we see projects and project owners proving that technology-based transformation can, in fact, improve project delivery. Improvements in task-level productivity are enabling predictable, on-time delivery of discrete tasks. At the same time, integration and sharing of information between stakeholder groups throughout the production continuum result in on-time, on-budget delivery of the final project. Digital transformation of construction is underway today and at an accelerated pace; however, the only organizations positioned to benefit are those owners, agencies, and municipalities demanding and adopting new thinking. These are the change agents that will drive the nation's progress toward the new central nervous system and gain real value today.

Connected construction is the foundation

Creating the new central nervous system begins with connected construction. The word "connected" has become ubiquitous in the marketing jargon of a broad range of industries. Wireless connectivity is one aspect of being connected—but other impactful forms, such as sensor-based asset management and offsite construction, deserve attention. The prevailing benefits of connectivity are improved task productivity, process integration, and the ability to connect the digital and physical worlds simultaneously and transform project delivery.

Through connectivity, stakeholders can speed up delivery, achieve cost efficiencies, and reduce environmental impact. Connected construction provides all participants with confidence through improvements along five key dimensions: productivity, quality, safety, transparency, and sustainability (see sidebar, "The connected construction site").

Productivity

Hardware and software technology alone or in combination increase the chance of on-time delivery and improve quality. Productivity is subdivided as task and process integration, and implementing these technologies can result in a significant improvement in the development of infrastructure.

Task. Productivity tools such as global navigation satellite systems (GNSS), laser scanning, 3-D modeling software, imaging, machine control, and inertial navigation can drastically improve productivity. In our experience, engineers, machine operators, and surveyors using these technologies have doubled productivity when compared with conventional techniques.

Process. Process improvements along the life cycle of the project enable the infrastructure owner to deliver the project 30 percent faster than when conventional design, build, and maintain processes are used. The constructible

The connected construction site

The connected construction site combines task productivity with process integration along the construction continuum. The transformation of infrastructure projects is akin to 3-D printing: design, validation, and iteration are exclusively digital processes, but the "printers" are technology-equipped machines such as pavers and trenchers.

The process consists of creating a geometrical representation of the infrastructure digitally and then coupling attributes, such as soil types, utilities, or right of way, to determine potential overlaps, gaps, and design flaws that might exist prior to the physical build. The output results in a constructible model that can be used by all stakeholders on the project and becomes the single source of truth that all engineers, surveyors, estimators, and machine operators utilize throughout each phase in the continuum.

The constructible model is continually updated as the work progresses, and heavy equipment automatically reports on work performed (when, where, and how much). The updated model is then used to track schedule and cost to provide the owner and all stakeholders with a real-time view as the asset is being built, maintained, or operated.

model becomes the single source of truth throughout the design, build, operate, and maintain phases. Users can view cost in real time and address potential issues that cause delays and cost overruns. Because all stakeholders contribute and collaborate in the same ecosystem, all teams share reliable information.

Quality

Studies have shown that the costs of rework in construction can be up to 25 percent of the contract value and 10 percent of the total cost of the project,[1] often due to management, planning, and communication issues. Coupling task productivity and process integration makes it possible to better understand design intent while on-site and collaborate more easily, which in turn can reduce errors. This is accomplished by using accurate sensors on machines and instrumentation during the build phase. Rework is also reduced by using the constructible model across the continuum. The single source of truth is seamlessly transported between phases and stakeholders to reduce transcribing errors, undetected overlaps, or gaps in the design.

Safety

Task productivity tools enable workers to perform out of harm's way. For instance, they can take measurements virtually instead of in the middle of roadways or runways. In addition, by creating the constructible model in advance of physical work, stakeholders are able to run safety scenarios to determine potential hazards related to the project plan, weather challenges, and completed design features antagonistic to everyday use. These scenarios enable organizations to reduce injuries and lessen the likelihood of needing to modify the design after construction.

Transparency

Task productivity and process integration enable all stakeholders to determine the schedule, cost, and critical path of their piece of the project. This integrated approach to project management makes it possible to recognize and prioritize problems and visualize them on-screen—and solve them at any stage of the project (including after completion) before they affect schedule, cost, or quality. Since all project data is recorded in a protected cloud environment, this data can be

[1] Mahsa Khaksefidi and Mohammad Miri, "Cost management in construction projects: Rework and its effects," *Mediterranean Journal of Social Sciences*, December 2015, Volume 6, Number 6 S6, p. 212, mcser.org.

used to audit, track progress, and reduce the likelihood of fraud or malicious behavior.

Sustainability
Task productivity tools, such as machine control, reduce rework, which in turn reduces wasted resources. In grading and excavating, failing to reach the specified grade the first time wastes fuel, time, and money due to trips back to the work site. Overcuts require the same, as well as requiring replacing materials and potential new compaction cycles. Reducing rework also results in using fewer materials and generating less waste; when we know exactly what we are building, we can maximize the potential of all raw materials.

The path forward

Connecting the digital and physical worlds can also apply to the funding process. Today, the United States still has one of the premier highway systems in the world. If we do nothing, it is likely to degrade significantly within 20 years. As a society, we must think ahead to a multimodal infrastructure that enables and facilitates electric vehicles, autonomy, platooning (of both commercial and consumer vehicles), high-speed rail, and autonomous bus services.

The ideal transportation network of the future will also be multiuse. It will become a framework to socialize, network, and work. Roadways may become Wi-Fi hotspots, facilitating commerce and improving business efficiencies. Road networks could even be active electrical charging systems for the vehicles using them and the surrounding communities. Multimodal, multiuse infrastructure will draw new users and new industries to create a sustainable funding base for the next 70 years. Conventional funding methods and use-based taxes will not adequately fund the central nervous system network, but innovative partnerships and approaches built from the joint benefits of connectivity can help the United States achieve this vision successfully and sustainably.

The construction industry and its workflows have been largely unchanged for decades. But to build a smart, connected, sustainable central nervous system, all stakeholders must work more efficiently and collaboratively and rethink the role of technology in improving productivity, quality, transparency, safety, and sustainability. Connected construction is an attainable goal that will form the foundation for a vision that aims to better connect and serve communities across the country.

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