Need for Development of Research Roadmap for Technological Advancements in Bridge Design and Construction

by Mark Gaines, P.E., State Bridge Engineer, WSDOT – December 2021

The transportation industry in general, and specifically the bridge and structures construction industry, is in the earlier stages of what will likely be a crisis in staffing. The type of work required to deliver transportation and infrastructure projects is often not attractive to people that are finishing high school and making career and college decisions. While trade labor (carpentry, ironwork, etc.) has attractive apprenticeship programs in place and provides excellent compensation and benefits, it is often not attractive to people just entering the workforce; the work is physically demanding, weather conditions in the field can be harsh and the hours are often long. Similarly, engineers and other technical workers are often not attracted to civil engineering related training and education. While some technical advancements have been made, Millennials frequently find this career path less interesting than true "tech" industries like application development, robotics, automation and virtual/augmented reality.

At the same time as interest in careers in transportation infrastructure design and construction is waning, the demand for a skilled workforce is on the rise. Bridges built as part of the interstate system in the 1960's and 1970's are reaching the latter part of their design lives and will require increasing amounts of engineering and trade labor to keep them operational. Other factors like resiliency, climate change, sustainability and underfunded maintenance and preservation will further increase the demand for a skilled workforce to keep our transportation infrastructure safe and well managed.

There is a need for a research roadmap to identify the technologies and research projects that will transform how bridges and highway infrastructure are constructed. While lots of great work is underway, it is often piece-meal and being done without a consistent, long-term goal in mind. While certainly incomplete, the sorts of technologies and innovations that could transform the bridge and highway construction industry include:

- **Additive Manufacturing** – processes that automate construction activities, using machines, robotics, etc. to handle much of the manual labor associated with construction. One example includes 3D printing of bridge elements. This also aligns well with Accelerated Bridge Construction initiatives.
- **Augmented/virtual reality** – Potential applications in design, construction and asset management. For example, developing a 3D model as a design deliverable that is used to construct the bridge then used throughout the life of the structure to incorporate inspection data, capture repair and rehabilitation efforts, etc. Specifically related to construction, consider ways to use augmented reality to replace plan sets (e.g. a HoloLens® replaced a plan set). The 3D model and HoloLens® are used to set geometry/dimensions of structural elements, show locations and sizes of reinforcing bars, etc.
- **Unmanned aerial vehicles (UAV's) and remote sensing for construction inspection** – With recent and anticipated future advancements in UAV's, it may soon be possible to conduct much of the construction inspection duties remotely. UAV's can observe construction materials, determine elevations and dimensions, capture construction practices and provide much of the information needed to verify contact compliance. UAV's can also produce a permanent, archivable record of bridge construction that will be useful for the life of the bridge.
- **Use of 3D models and digital twins** – This involves developing a 3D model of the bridge that is used for design, construction and long-term asset management. The model provides a living record of the bridge and

all work that is performed on it over its life. While work has been done in this area, the technology is not to a point of practical application by must State DOT's.

- **Remote sensing as a standard practice** – While remote sensing and data measurement on bridges is readily available, it is generally reserved for special or unique projects. Instrumenting bridges to measure strains, deflections, chloride iron content, temperatures, etc. as a standard practice would provide a valuable tool to monitor and manage the bridge throughout its life. It could provide an early warning of when failure is imminent, inform the need for preventative maintenance, and provide an instantaneous summary of the bridge condition after a catastrophic event.
- **Use of non-traditional materials** – Materials used for bridge construction haven't changed much in recent years; most bridges are designed and constructed using structural steel, concrete and reinforcing steel. As advances continue to be made in material science, it is likely that composites, polymers and other non-traditional materials will have new structural applications. In addition to improved structural performance, these materials may have environmental benefits compared to traditional materials, including a reduced carbon footprint, lower levels of greenhouse gas emissions during manufacturing, etc.
- **Use of non-traditional shapes and sections** – As new, innovative materials become options for bridge construction, the shapes of bridges and bridge elements will change. Geometry for today's bridges is driven by typical properties associated with steel and concrete. Composites, polymers and other non-traditional materials have material properties that are very different from traditional bridge materials. Bridges and bridge elements built with these new materials will likely be more slender and efficient then in the past.

There will be many benefits to a research roadmap and plan to my progress in these and similar areas. Benefits will include:

- Advanced technologies will be more attractive to people entering the workforce (for both trade labor and those with technical/college education). This is critical to our ability to construct and maintain the transportation infrastructure.
- Improves safety on construction projects. Using machines and technology to handle more of the construction and inspection duties reduces the personnel exposure to inherent hazards of a construction site.
- Speeds up bridge and structures construction. Many of these initiatives are consistent with constructing projects more quickly and reducing public impact. For example, around-the-clock operations are possible when additive manufacturing is used to construct bridge components.
- Reduced cost. Automating the construction process, including additive manufacturing, should in the long run reduce the number of people required to construct a bridge. Since salaries and benefits are a significant cost of construction, this should reduce the cost to deliver projects.

At the completion of this project, the deliverables will be a detailed roadmap that can be followed to accelerate the incorporation of new technologies into the construction of transportation structures. The project would start with a comprehensive review of emerging technologies that could benefit the bridge construction industry, current efforts being introduced in the United States and internationally, and active research efforts that are already underway. With this background established, the research team will develop a prioritized list of projects that should be completed to fully leverage emerging technologies in bridge and structures construction. For each project, the research team will provide a scope of work, estimates for cost and duration of the project, list of the deliverables and anticipated benefits/outcomes. Essentially, provide a draft of everything that would be needed to pursue funding and selecting a research team for the various projects.