UNC Charlotte – Lee College of Engineering Senior Design Program
Company Information

Company Name	*Systems Engineering*	**Date Submitted**	*07/15/2019*
Project Title	*Risk-Aware Decision-Support System for Construction Project of Large-Scale Engineering Structures* **UNCC_RADS**	**Planned Starting Semester**	*Fall 2019*

Funding:

What is the source of funds that will be used to cover all of the direct costs of this project?
Department of Systems Engineering & Engineering Management

Is this source of funds already secured? Yes ___x____ No _______

Technical Contact(s)*

	Technical Contact 1	Technical Contact 2	Technical Contact 3
Name	Simon Hsiang		
Phone Number	704-687-1958		
Email Address	shsiang1@uncc.edu		

*We would like to have more than one technical contact, so there is a back-up in case of travel, sickness, job re-assignment, etc.

Personnel

Typical teams will have 4-6 students, with engineering disciplines assigned based on the anticipated Scope of the Project.

Please provide your estimate of staffing in the below table. The Senior Design Committee will adjust as appropriate based on scope and discipline skills:

Discipline	Number	Discipline	Number
Mechanical		Electrical	
Computer		Systems	5
Other ( )			

Project Overview and Requirements:

1. Constructability to Digital Twin

A construction project for an large-scale engineering structure (e.g., small nuclear reactor, wind energy farm, etc.) requires an extensive capital investment with a prolonged planning horizon. Due to increased uncertainty in regards to both finances and time, such large-scale projects can easily stall. The general objective is to develop a risk-aware decision-support framework to improve *constructability*, *transportation*, and *manufacturability*, which must be integrated into a single tool that assimilates various modules. This risk-aware decision-support framework must not only provide a series of project schedules and plans, but also elaborate upon risk information involved in those alternatives. To this end, the specific aim is to develop a thorough communication channel and feedback loop between construction project management and the Digital Twin.

The Digital Twin is a tool that ideally accounts for whole systems of commercial products or services. It keeps track of all necessary information about a system and from that assists in the decision-making process, from conceptualization of operations, requirements, and architecture, to detailed design, implementation, integration, and testing, to system verification and validation, operations and maintenance. In each step, the focus is usually on developing robust information modularity and standardization to be insensitive to the uncertainties of a product life cycle.

To emphasize the differences to a commercial product (e.g. jetliner or submarine), a construction project needs to adapt and mitigate many causes of variability, from weather changes, to labor forces (e.g., absenteeism, morale, strikes), local traffics, prerequisite work quality, design or construction method changes, tool or equipment breakdown, and material and component inconsistences (e.g., strand pattern, concrete-temperature-humidity).

Furthermore, while decision-making occurs in a chronological manner, the decision-support framework must consider decisions in a reverse-chronological manner. That is, the completed plant will be the result of the executed decisions in the construction schedule; the feasibility of construction schedule depends on the decisions made for transportation of modules to the site, and the feasibility of transportation plan relies on the manufacturing schedules.

Consequently, it is important and difficult to thoroughly investigate and digitize local/historical construction site data including texts and anecdotes into tangible and relevant inputs to the Digital Twin, such as visualization of potential access and storage spaces for material and equipment at the design stage. Further examples of these inputs include estimations of minimum time for below ground operations and time to ensure early enclosure, candidates for suitable materials, equipment and skills required, sites for in-situ simple assembly, allowable tolerances and responses due to hazardous weather changes, options of practical sequences of operations, avoidance of return visits by trades, schedule conflicts, and construction site safety.

2. Digital Twin to Constructability

In return, the Digital Twin provides management/supervision/information flow to develop the work plan/schedule, provide guidance/instruction, and answer questions when they arise:

1. Senior management coordination – early warnings that the job site is being overcrowded, over-commitment (i.e., having more work scheduled during the week than is feasible to accomplish), weather forecasting, coordinating work spaces and sequencing of different trades, communication between owners and project managers, and impacts of changes in the scope of work.
2. Material management shortages and reactions – when materials do not arrive from a supplier, subsequent operations will likely have to wait, but the work sequence can be mitigated.
3. Prerequisites and constructability assessments and plans – variation pertaining to prerequisites, such as reworks, waiting for inspections, the quality of previous work, and the completion of previous work.
4. Crew management assessments and plans – The crew size, personnel turnover, and learning curves are all associated with crew management.
5. Tools and PPE assessments and plans – availability and serviceability of hand tools, PPE, and power tools.
6. Standards and complexity assessments and plans – Strict specifications, quality assurance, and work complexity. When either specifications are strict or complexity is high, there will likely be a greater quality control requirement that may be observed using the Digital Twin.
7. Labor force assessment and management – Worker experiences, socializing, attendance records, lacking instruction on the work methods.
8. Equipment coordination – the availability of cranes, forklifts, etc.

By integrating various sources of information, the emphasis of outputs from the Digital Twin into construction site management is to provide effective communication, situation awareness (i.e., situation-dependent data regarding what is happening? so what? now what?), and opportunities to quicken and visualize many what-if scenarios for the entire construction site/processes. Utilizing the Digital Twin in this manner also ensures that digitized workflows are (re)organized quickly and effectively, and reaction plans are based on better insights to leverage time and cost saving.

In addition, by using Virtual Reality to see through cluttered information under one database, the construction site manager can have a clear overview of the entire construction progress, diagnostic problems at hand, and prognosticate potential problems. They can focus on value-added activities, make better and faster decisions and achieve continuous improvement.

3. Computational Intelligence

The inputs (i.e., from construction site management to the Digital Twin) and outputs (i.e., from the Digital Twin to construction site management) will be used to establish the causal relationships through following steps. These steps are commonly used in data mining and machine learning procedures.

1. Canonical Correlations (for measures in interval and ratio scales) and Canonical Correspondence (for contingency tables, text mining tallies, counting data) will be used to identify the eigen-structures between the inputs and outputs.
2. Multi-Dimensional Scaling (based on Singular value decomposition) and Hierarchical Clustering analysis will be used to determine potential similarity and organization within the input variables and output variables.
3. Data Envelopment Analysis will be used to determine potential directions of improvement based on three different performance criteria: (1) maximizing the productivity of outputs given a set of inputs;

(2) minimizing the resources of inputs give a set of targeted productivity; (3) maximizing the efficiency based on the ratio between the outputs over the inputs.

4. Develop potential Bayesian Network models to enhance the diagnostic and prognostic capacity for potential system verifications and validations required by the Digital Twin.
5. Choquet Integrals will be used to visualize the priority based on various classifications of design and manufacturing processes and local construction requirements.

Expected Deliverables/Results:

Deliverables include:

- Review of a selected construction project (TBD): report that describes the construction procedure for the construction project. (SD 1)
- Risk analysis: report that thoroughly analyzes risk factors of the construction configurations and procedures, along with spreadsheet and codes. (SD 1)
- Decision-making tool: report that describes the optimization model in detail, and executable tool that provides solutions (i.e., configurations and procedures). (SD 2)
- Demonstration in a scaled-down construction project using 3D printing technology to compare trade-off among various optimal configurations and procedures. (SD 2)

List here any specific skills, requirements, specific courses, knowledge needed or suggested (If none please state none):

- Must have taken SEGR 4141 (Dr. Hsiang)

[1] R. J. Schonberger, (1981) Why Projects Are "Always" Late: A Rationale Based on Manual Simulation of a PERT/CPM Network. *Interfaces* 11(5):66-70.