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Decision analysis using virtual first-run study of a viscous damping wall system

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Preface to the A3

An A3 is a problem-solving tool, however, it can be used in other ways and the corresponding A3 formats vary depending on the purpose of use. For example, Toyota uses three basic types of A3 reports (Shook 2008, Sobek & Smalley 2008):

- problem solving
- proposal
- status.

This A3 is a summary of our research on Virtual First-Run Studies (VRFSs), therefore its story line represents the flow and structure of a scientific paper.

In creating this A3, the authors attempted to structure it so as to add the most value to *Lean Construction Journal* readers. Only the information and data judged to be the most essential are presented in a logical flow to help readers quickly capture the key contents and results of the research. For a detailed description of the research method used, the case study itself, and evidence to support the conclusions, readers may want to read the full paper by Nguyen et al. (2009) published in the Proceedings of the 17th IGLC Annual Conference.

This A3 is submitted by way of experiment to the *Lean Construction Journal* and we look forward to receiving further comments and suggestions from researchers and practitioners on the value of reviewing research results in this format.

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A3: Decision Analysis Using Virtual First-Run Study of a Viscous Damping Wall System

1 Objectives

The objective of this study is to investigate the possibility of performing a first-run study (FRS) in a virtual environment during a project's design phase.

a. Researchers have analyzed the effectiveness of 4D simulation in different areas of design and construction but no framework exists to guide the cross-functional project team to structure coordination meetings that take full advantage of 4D simulations in a Lean Project Delivery System™.
b. The challenge is to incorporate innovative ideas generated from the design coordination meeting to both product design and process design in order to streamline fabrication, logistics, and construction/installation processes.
c. VFRS is a first-run study carried out in a virtual environment, where objects of study are created in a computer model in three dimensions, and those objects are linked to process- and resource data to represent the process of construction.
d. While first-run studies (Ballard and Howell 1997) help with process design during the construction phase, the use of VFRSs is proposed to help integrate product- and process design during the design phase.

2 Method

Action research: Researchers became part of the project team, collecting data through observations, interviews, and document analysis while participating in the implementation of the experiment and helping make adjustments to the experimental process.

a. Researcher worked with the project team to establish a VFRS framework.
b. The VFRS framework was tested in a Viscous Damping Wall (VDW) case study.
c. Researcher adjusted the VFRS framework and recommended the new framework for future application.

3 Proposal

Virtual First Run Study PDCA work flow (Nguyen et al., 2009)**:**

PLAN

- Identify supply chain participants involved in the design, fabrication, transportation, handling, and installation of the component or system under study and inform them on scope, schedule, and objective of the VFRS.
- Acquire preliminary data on product, process alternatives, and cost from related trade partners.
- Acquire 3D objects from trade partners and combine them into one 3D model.
- Link 3D objects to time/sequencing information to create a 4D simulation of the construction process.

DO

- Present the 4D simulation to cross-functional team and collect reflections, ideas, and suggestions for improvement.
- Map out construction/installation alternatives using cross-functional process mapping technique (Damelio 1996).

ACT

- Select the preferable alternative;
- Revise design, map process, and conduct 4D simulation according to the agreed decision and publish results in project database for reference and use later during the construction phase.

CHECK

- Compare advantages and cost of alternatives using Choosing By Advantages (Suhr 1999).

4 Case study

A cross-functional team at Cathedral Hill Hospital Project applied the VFRS framework to visualize and evaluate installation options for a Viscous Damping Wall (VDW) system.

a) A VDW consists of an inner steel plate connected to an upper floor, a steel tank connected to a lower floor, and viscous fluid in the gap between them as shown in Figure 1.
b) CHH project will comprise 155 units of VDWs in the current structural design, standardized to three different sizes of 7'x 9', 7'x 10', and 7'x 12'
c) The VDW presented a coordination challenge for logistics and field operations thus the Integrated Project Delivery (IPD) team at the CHH project wanted to further explore different methods for their installation.
d) 4D simulations of installation alternatives were presented to the team. Discussion contents fell in five categories: constructability, fabrication, transportation, site logistics, and installation.
e) As the result of the discussion, the team came up with another alternative (alternative 4) which was similar to alternative 1 but instead of shipping VDW directly from the fabrication shop (DIS) to the site, VDW will be transported to structural steel fabrication shop (Herrick) and then loaded on the same truck with adjacent columns and girders to be transported to the site.
f) By the time of submitting this paper, the final decision has not been made since it is not the last responsible moment for this decision.
g) Although alternative 4 costs about $52,000 (12%) more than alternative 3, it ranked highest, in terms of total importance of advantages, at 415. The team may decide to select alternative 4 to install the VDW system if they agree that the increment in the importance of the advantages outweigh the increment in cost.

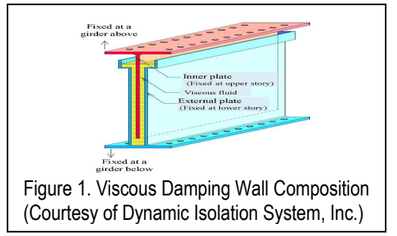
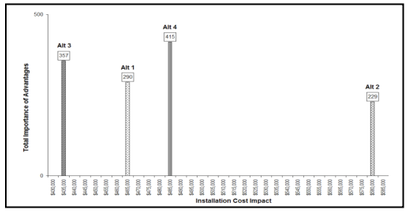


Figure 1. Viscous Damping Wall Composition (Courtesy of Dynamic Isolation System, Inc.)



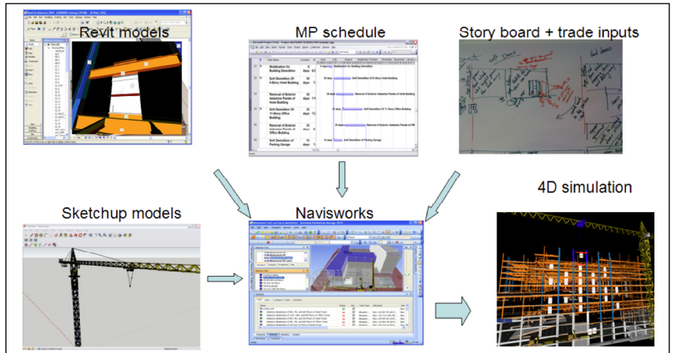


Figure 2: Inputs to a 4D Model

← Figure 3: Total importance of advantages relative to total cost

	Alternative 1 Pre-bolting		Alternative 2 Inserting		Alternative 3 Sequencial		Alternative 4 Pre-bolting - Alt. 1 modified	
Total Cost (excluding material cost)	$ 465,000		$ 581,950		$ 434,350		$ 486,700	
Factor: **Interference** *Criteria:* Cause work stoppage/ interference/ productivity losses to related activities. Less is better.	Steel workers and tower crane need to shift between structural steel and VDW		Could install a large batch of VDWs after finishing structural steel of one floor or more		Could install a batch of VDWs after finishing structural steel of one floor level		Steel workers and tower crane need to shift between structural steel and VDW	
Attribute: / *Advantage:*	!	0	Much less interference	50	Less interference	41	!	0
Factor: **Reliability** *Criteria:* Assure reliability of the method. More is better.	This method is used widely in Japan. Very good for handling tolerance issues		Rarely used. Tolerance may be a problem.		This method is used in Japan. Tolerance may be a problem		This method is used widely in Japan. Very good for handling tolerance issues	
Attribute: / *Advantage:*	Much more reliability	90	!	0	More reliability	72	Much more reliability	90
Factor: **Coordination effort between trades.** *Criteria:* Reduce the coordination effort required between trades. Less is better.	Tight coordination needed between DIS, shipping companies, and Herrick for just-in-time delivery of columns, girders, and VDWs		VDWs could arrive after finishing installation of structural steel on one or several level		VDWs could arrive after finishing installation of structural steel on a portion of one level		VDWs shipped to Herrick fabrication shop and then shipped to site with columns and girders	
Attribute: / *Advantage:*	!	0	Much less coordination	65	Less coordination	55	Less coordination	55
Factor: **Street congestion** *Criteria:* Less is better.	Two trucks on street during installation		One truck at a time, unload quickly		One truck at a time, unload quickly		One truck on street during installation	
Attribute: / *Advantage:*	!	0	Much less congestion	70	Much less congestion	70	Much less congestion	70
Factor: **Tower crane usage** *Criteria:* Reduce occupancy of tower crane. Less is better	May need one lift for every combined VDW+upper girder		Could lift a rack containg three to four VDWs and place it on structural steel		Could lift a rack containg three to four VDWs and place it on structural steel		May need one lift for every combined VDW+upper girder	
Attribute: / *Advantage:*	!	0	Less crane usage	44	Less crane usage	44	!	0
Factor: **Temporary space** *Criteria:* Minimize temporary space usage for VDW handling. Less is better	No temporary space needed		Need to temporary place VDWs on structural steel		Need to temporary place VDWs on structural steel		No temporary space needed	
Attribute: / *Advantage:*	Much less temporary space	40	!	0	!	0	Much less temporary space	40
Factor: **Labor safety** *Criteria:* More is better.	VDW and upper girder bolted on ground.		All connection performed on structural steel		All connection performed on structural steel		VDW and upper girder bolted on ground.	
Attribute: / *Advantage:*	Much more safe	60	!	0	!	0	Much more safe	60
Factor: **Ease of installation** *Criteria:* Ease for worker's operations and equipment operations during installation. More is better	The resistance of viscous fluid allow external plate of the VDW lowering down slowly, which enable a precise installation.		.The team has not figured out exactly how the VDW could be inserted into the gap between girders		Need to tight up upper bolts in a certain sequence for the inner plate to raise up		The resistance of viscous fluid allow external plate of the VDW lowering down slowly, which enable a precise installation.	
Attribute: / *Advantage:*	Much more ease of installation	100	!	0	More ease of installation	75	Much more ease of installation	100
Total importance		**290**		**229**		**357**		**415**

conclusions

By helping a project "*see*" what will happen, VFRS facilitates the coordination between specialists, assists look-ahead planning, and yields reliable estimates of manpower and process-related cost.

In the design development phase, an integrated team of designers, engineers and specialty contractors could perform a VFRS of construction processes to understand the impact of design decisions on coordination, logistics, and construction/installation processes.