The Engineering & Construction Industry Innovation Deficit: Is the E&C Industry Model Broken?

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Periodically it is necessary to step outside of one's day to day frame of reference and question whether a current paradigm will suffice into the future. This paper is intended as one such look at a current paradigm, in this case our own engineering and construction industry model. The purpose of this paper is to raise questions, challenge the current paradigm and leave the reader with more questions than he had at the outset of reading this paper. It will not suggest silver bullets or chart a path to improvement but essentially foster the debate as to whether the industry model is broken and whether we should attempt to improve it.

Where possible I've tried to cite relevant academic work for the curious and interested to pursue further.

My own interest in this question has grown out of early involvement as a member of the then Civil Engineering Research Foundation's (CERF) work in assessing E&C industry productivity (31, 34) and our apparent lagging in productivity growth when compared to other industries. It has been further stoked by looking at best practices and incremental innovations that I have seen in project partners over the years and recognizing what would be possible at an industry level if these innovations could be more easily systemically adopted across the entire industry. It was as a result of this consideration that my focus shifted from examining poor productivity growth (a symptom) to trying to understand the barriers to systemic innovation (a cure) which seems to be characteristic in higher productivity industries.

Is the Engineering & Construction Industry Model Broken?

The engineering & construction industry is the largest industry in the world. In the United States construction spending totals nearly 9% of Gross Domestic Product or GDP. And in many ways, today's projects are larger and more complex than any we have faced before

Yet as an industry, since about 1970, our productivity has at best been a laggard as compared to other industries. Cost overruns, unanticipated risks and schedule slippages are still too common. Why is this? And what can be done to change this situation?

Today's engineering and construction industry model was in many ways established following World War II. It's structure is "industrial" in nature and based on the "serial specialization" that existed in manufacturing at that time. But the 21st century is not like the late 20th century and experience in other industry sectors have shown that significant productivity gains coincide with industry models that facilitate systemic innovation.

What is Systemic Innovation?

Systemic innovation is that form of innovation that requires “multiple specialist firms to change their process in a coordinated fashion.” (1). It differs from incremental innovation which can be accomplished within a single firm context or within a discrete project context.

Examples of systemic innovation in the engineering and construction industry include:

- integrated supply chain management (1)
- prefabrication of building systems (1)
- 3D CAD virtual design and construction tools (1)
- BIM
- Project Finance Initiatives (PFI) and Public Private Partnerships (PPP)
- modularization

Why is Systemic Innovation Important to the Engineering & Construction Industry?

Innovation is critical to renewal of industries (5) and systemic innovations produce the largest productivity gains.

Studies have shown that more industries are migrating from functional hierarchies to project forms of organization (25) where innovation is not as well understood and where systemic innovations diffuse more slowly. As such the understanding of barriers to systemic innovation are of growing importance not only to our industry but also to many of our client’s industries.

However, the engineering and construction industry while on par with manufacturing when incremental innovation is considered (minor changes in product) is a laggard in systemic innovation where multiple firms must change their processes (25). Simply put, we have an innovation defecit, one where we continue to largely harvest from past innovation efforts but also one where we are sowing very few new seeds.

Improving our industry's systemic innovation is important to us and our clients and may be constrained by our very industry model. We need an industry model which promotes sustainable innovation and is not just focused on the short term.

Attributes of Industries with Successful Systemic Innovation

The hallmarks of industries that experience strong systemic innovation include:

- strong relational stability, that is a tendency to use a small number of firms per specialty
    - corporate interests which are more networked in nature
    - boundaries that facilitate redistribution of work, and
    - strong "network level" agents for change

These are not the hallmarks of the engineering & construction industry where project teams come together with wide variety, sometimes driven by owner preferences to preserve the "serial specialization" model of the industrial era and sometimes driven by a sole focus on first cost. Rigid trade or corporate structures together with limited flexibility in redistributing work across the various components of a project team also act to limit the opportunities for systemic innovation and real productivity improvement. While we will continue to achieve meaningful incremental improvement, does our industry model essentially preclude the opportunity for broad and meaningful systemic improvement?

Let's look at these attributes that are key to systemic innovation in turn.

Relational Stability as an Innovative Industry Attribute

Relational stability as an attribute of industries with a strong systemic innovation dimension as contrasted with industries not exhibiting such stability has been studied for over a quarter of a century. In the years since the Eccles' investigation of the quasi-firm, the construction network has evolved to shorter-term relationships with a larger set of partner firms in the United States. (1, 15). This trend is not common across various manufacturing industries or even within the engineering and construction industry in other countries.

Research has shown that weak relational stability in networks created difficulties for firms implementing object based 3D CAD innovations because knowledge and lessons learned from one project failed to carry forward to subsequent projects where the project team composition was greatly different. (1)

Weak relational stability exacerbates problems associated with implementing systemic innovation in a network of firms and leads to much slower diffusion than one might expect. In contrast, strong relational stability in a network of firms (such as what was found in studies of the Finnish engineering and construction industry and Danish wind turbine industry) mitigated the impact of shifting allocations of work associated with each systemic innovation. (1)

The deeper the "embeddedness", the more likely firms in a network are to see their interests as aligned rather than opposed. (16)

When interests accumulated at the level of the firm the effect was to exacerbate the diffusion rate of systemic innovation. By considering only their firm's interests and not attempting to share the benefits of the innovation with their partners, firms were restricting the rate of diffusion of the innovation.

In contrast, networks where the interests were defined at the network level, alleviated fears of opportunism and increased firms' willingness to share the benefits of innovation with their partners. In these networks, the network level accrual of *interests* expedited diffusion. (1)

Networked Corporate Interests

Interorganizational networks provide for a networking of the corporate interests of member firms and strong networks aid in the diffusion of systemic innovations. In interorganizational networks, groups of two or more firms work together in the interdependent production of goods or services (1, 9)

This area has been well researched and work by Stinchcombe (10) contributed to this debate by suggesting that, in construction, contracts acted as a proxy for hierarchy in this mid-range mode of economic exchange. Williamson (11) later extended the transaction cost economics framework to include the concept of hybrid organizational arrangements. Arguments for quasi-firm and hybrid organizational arrangements were rooted principally in terms of economic exchanges containing aspects of both market and within-firm hierarchical exchanges. (1)

Key to the ability of such interorganizational networks to promote systemic innovation is the degree to which knowledge and lessons learned are shared within the network. This is not easily accomplished and any assessment of the strength of an interorganizational network must look carefully at the ability or difficulty of making learning portable in the interorganizational networks. (1, 12, 13)

The question of where interests are centered (firm vs. network) affects the ability to achieve systemic innovation (1). The project model employed by the engineering and construction industry as well as other decentralized industry structures promote innovation at the project level but make broader industry adoption more difficult (14, 25, 29) Systemic innovations will diffuse more slowly than incremental innovations given this weaker (more transient) form of networked corporate interests. The continuous breaking of learning and feedback loops, as projects reach completion and new project teams are assembled, negatively impacts the ability of construction industry networks to innovate. (14)

Industry Boundaries

Boundary strength is a measure of how strongly defined and rigid the barriers between firms are and how they act to limit systemic innovation within a network. An example of the detrimental effects to systemic innovation associated with high boundary strength can be seen in the failure of Buckminster Fuller's Dymaxion house. In this example of boundary strength within the engineering and construction industry, established contractors resisted integrated prefabrication by insisting they be paid to take apart the pre-fabricated structures and then put them together again (25)

Integration of firms into a single enterprise (special purpose vehicle or SPV) promotes systemic innovation within this redefined network but only to the extent that the previous constituent parts increase their knowledge about the detailed impacts of their decisions on the balance of the network and modify those decisions to improve overall network efficiency rather than sub-optimizing for their sole tasks sake. Design build done with a fully integrated team is a first step in the engineering and construction industry. The creation of SPVs for delivery of Public Private Partnerships represents a more comprehensive vertical integration and further expands the opportunities and value proposition associated with systemic innovation.

One would expect that the permanent combination of engineer and constructor in a permanent enterprise to promote innovation. This is consistent with findings in industries that typically rely on an EPCM or EPC approach rather than those that rely of purpose assembled design and construction teams. Similarly performance benefits from tighter integration of industry participants can be seen in the performance results for design-build projects. (36, 37, 38, 39, 40)

The more extensive the integration of this delivery network and the more permanent its nature the more likely we should expect to see systemic type improvements on a sustained business.

Network Level Agents for Change

A change agent(s) is essential to the improvement of our current industry model to benefit from systemic innovation. Self organization of the engineering and construction network without a change agent will be a slow and largely unfocused process. What are the change agents available to the industry today and which new ones are likely to emerge?

Industry wide systemic innovations will be promoted by consistent types of changes across the engineering and construction industry's self organizing networks (1). These changed may flow from some of the systemic issues the industry is now facing or may flow from national imperatives. They will be further promoted by a clear understanding of the process by which networks adopt new innovations (17). The key characteristics of innovation that influence systemic adoption rates include:

- relative advantage
- compatibility
- complexity
- trialability
- observability

And one or more key factors must be present (19) for real systemic innovation to occur. These include:

- dissatisfaction with the status quo
- existence of knowledge and skills
- availability of resources
- availability of time
- rewards or incentives exist
- participation
- commitment

And most importantly, leadership.

Systemic Issues the Engineering & Construction Industry is Facing

Systemic issues the engineering and construction industry is facing (20) include:

- new business models (changed project delivery models (PPP, D/B) and long term supplier or service relationships)

    - information and knowledge (not just data) technologies

- increased “value” focus (life cycle costs, flexibility, resiliency)

- performance based standards and regulations

- human resources

- sustainability

A New Paradigm?

Systemic and sustainable innovation requires patience. It is about potentials not deliverables. It will involve failure – multiple failures – which in many ways are one of the true hallmarks of true breakthrough and systemic innovation. It will cause us to re-look at planning horizons and how we conduct both basic and applied research. We will have to rethink how products and applications are developed. Can the current Engineering & Construction industry model support this transformation or is it a principle barrier?

What might a more networked industry model look like and how might relational stability appear in such a network? Will we see more vertical integration in our industry, where owners increasingly hire permanent consortia that come with a largely developed and integrated supply chain? Is competition of supply chains a potential end state? And what degree of fluidity must be retained so that networks benefit from new industry wide approaches and ideas? Is it reasonable to expect that early integrators of the supply chain will have at least temporary first-mover advantage?

Will procurement and management practices in the industry evolve to create and capture the systemic improvements such a changed approach could hold? Will consortia members share proprietary tools or perhaps develop consortia specific ones? Will knowledge be shared openly and completely across consortia members?

These are some of the questions we should be asking ourselves. Will EPC firms with strategic supplier relationship agreements provide the basis for them to come to a project with their supply chain in tow? Will a firm's integrated framework of systems be more broadly extended to encompass their strategic partners? Will industry leading knowledge systems create a common repository of knowledge shared between engineers, constructors and their strategic suppliers?

But while some firms seek to answer these questions and create competitive advantage for themselves, it does not yet address the industry wide question of whether the engineering & construction industry model is broken or maybe more fairly, have we outgrown it in the 21st century? If the answer is yes, then it will take a "network level" agent of change.

Where will that Leadership Come From?

We are an important industry and in many ways all that we do is the foundation for many of the other industries which make up our national global economy. We must reignite the spirit of creativity which was the hallmark of our industry's "Master Builders".

Where will that leadership come from? This is question we must answer and in my view answer soon.

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