CONSTRUCTION SUPPLY CHAIN MATURITY MODEL – CONCEPTUAL FRAMEWORK

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ABSTRACT

Construction supply chain management has been researched and discussed in various academic and industry segments for a few years now. Members of FIATECH are discussing and defining the processes, standards, and schemas around construction supply chain management. There is a growing realization among the members of the AEC community of the need to remove inefficiencies in the construction supply chain and improve operational excellence, but the steps to achieve them is not clear. In this paper, the authors will present a conceptual framework of construction supply chain maturity model (CSCMM) to address the above issues, drawing on similar research done in manufacturing supply chains and software processes. The objective of the framework will be to provide a roadmap for members to realizing operational excellence so that collectively the construction project can realize the benefits of improved performance. This paper will explore the maturity model and its benefits to performance of both firm level and construction project level performance.

KEY WORDS

Maturity model, Construction supply chain management.

INTRODUCTION

Construction supply chain management (CSCM) refers to the management of information, flow, and money in the development of a construction project (Simchi-Levi et al. 2000). The idea of managing the construction supply chain as a way to improve business process has been widely discussed. Figure 1 shows a typical construction supply chain. Any company is typically involved in multiple projects and hence supply chains. CSCM is starting to become a strategy among firms looking to realize operational efficiencies. Operational efficiency can be realized by streamlining operations vertically within functional business units or horizontally across the entire construction project including through effective collaboration between upstream customers and downstream suppliers. It can be achieved through improved business processes, use of software tools (that imply a change in business process) or a combination of both. The goal of effective CSCM is to reduce the information lag and operational inefficiency due to data duplication leading to human error from the customer to the tier n supplier like the building products manufacturer across the multiple supply chains a firm is working on.

Multiple techniques have been developed in the recent past to address the needs and provide solutions for the same. There are process experts from lean construction recognizing the needs and defining cooperative cross-firm business processes for better planning and collaboration (Ballard 2000). There are software tool vendors that are

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extending their product offerings by automating its ability to exchange data with complementary products. The Industry Foundation Classes (IFC) data exchange standards (IAI 1996) and Building Information Model (BIM) (Autodesk 2002) parametric modelling are two approaches to exchanging data between software tools. For instance, CAD vendors have recently started bundling complementary functionality with rendering including analysis and collaboration to name a few. To realize true value from such technology enabled tools and their standards, there is an inherent need for process change that permits exchange of data between firms working on the complementary functions (architect or engineer vs electrical or mechanical sub-contractor). In other words, contractual and other organizational changes need to happen prior to extracting value from these tools. Finally, there are academic/industry consortia like FIATECH coming up with data and process interoperability standards to do the same. (FIATECH 2003).

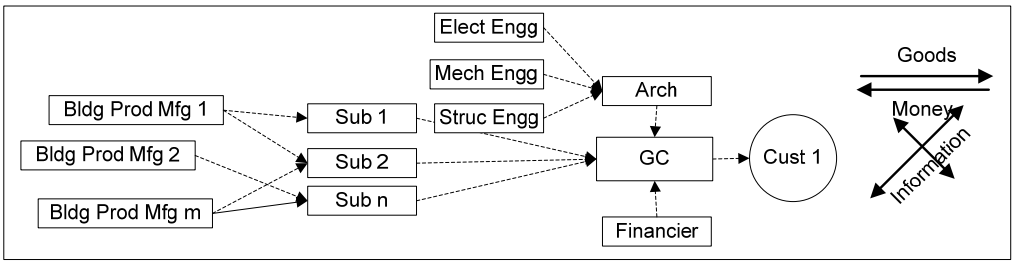

Figure 1: Construction Supply Chain

As a player in the industry, all these choices are a confusing albeit pleasant set of choices to consider from. The value propositions of the individual efforts are well understood but the collective impact of the processes and tools are ill understood and their impact speculative, at best. As a company in the AEC market, looking to layout a corporate long term strategy to improve operational efficiency, two questions need to be answered: (1) What is the current benchmark of the firm?; (2) What steps need to be taken to improve on the status quo.

This paper attempts to address some of these questions through a supply chain maturity model. The rest of the paper is organized as follows. First we review related work on maturity models for other related industries to discuss on how to compare, extend, and draw analogies to the needs of the construction industry. Second, we present a motivation to develop one for the construction industry. Third, we build on the previous models and draw upon the needs of the construction industry to layout the framework for the construction supply chain maturity model (CSCMM). Finally, we discuss the benefits of the maturity model and identify areas of development that need to be done. We wrap up with some conclusions along with ideas for future research and development.

BACKGROUND

The origin of maturity models lies in the field of quality management which describes quality improvement through a five level maturity grid (Crosby 1979). This and subsequent work led to orienting companies to think of their organization as a set of interrelated processes rather than functional silos. Research and surveys proved that processes have a maturity life cycle and that there is a correlation between improving process maturity and business performance (McCormack and Lockamy 2004). As processes mature, institutionalization takes place through policies, standards, and organizational structures (McCormack and Johnson 2000) and consistency in capability

can be expected. Business process maturation also reduced conflict and encouraged greater cooperative behaviour while improving performance.

Table 1: Stages of Maturity in a Process

Level	Description
Level 1	Some awareness of this practice; sporadic improvement activities may be underway in a few areas.
Level 2	General awareness; informal approach deployed in a few areas with varying degrees of effectiveness and sustainment.
Level 3	A systematic approach / methodology deployed in varying stages across most areas; facilitated with metrics; good sustainment.
Level 4	On-going refinement and continuous improvement across the enterprise; improvement gains are sustained.
Level 5	Exceptional, well-defined, innovative approach is fully deployed across the extended enterprise (across internal and external value streams); recognized as best practice.

The process maturity model assumes a five level maturity model as illustrated in Table 1 above. As illustrated, it is generic and can be applied across any industry; but in order to operationalise it for a particular industry, two additional developments need to happen – (1) Provide benchmarking criteria for each maturity level; and (2) Provide roadmap strategy to go to the next maturity level. The generic maturity model describes the 'what' to achieve process maturity, but in order to provide details on the 'how', the industry specific characteristics are needed.

One of the most well known is the Capability Maturity Model (CMM) developed for the software engineering process (Paulk 1995). It has been developed by the Software Engineering Institute (SEI) of Carnegie Mellon University (CMU). The CMM model has specific benchmarking tests to determine the current maturity level of a company. And the actions/roadmap to improving the maturity a.k.a performance in software development is specified as well. The CMM certification is compared to an ISO9000 certification (Nightingale and Mize 2002) and has become a way to have expectations of a software development organization. The SPICE project was one of the first significant research efforts to adopt the CMM model for the construction industry (Sarshar et. al. 1999). Through a questionnaire, case study, and expert panel survey, the researchers concluded that industry participants were in general in agreement for the need to develop process maturity models for the construction industry. They expected similar benefits to that derived in the software industry. The researchers concluded that even though there was a lot of similarity between the software and construction industries, the CMM model could not be directly applied to the construction industry primarily because CMM is applicable only for a single enterprise and did not capture the multi-enterprise supply chain aspects of the industry.

Recently, the project management industry adopted the maturity model to develop a *Project Management Process Maturity Model (PM)*^{2} (Kwak and Ibbs 2002) wherein the authors adopted the process and functional model developed by Project Management Institute in its Project Management Book of Knowledge (PMBOK) (PMBOK 2005)

techniques to the maturity model as a way to benchmark various players who do project based businesses. The model notes that as companies mature in their project management techniques, they migrated from thinking about functions to processes and managing a single project to multiple projects as an integrated program.

PRTM (http://www.prtm.com) developed a four level *Manufacturing Supply Chain Maturity Model* for manufacturing companies to strive for as they realize process efficiencies (Figure 2) in the manufacturing sector. Starting with functional automation, the maturity model describes how a company can move to an enterprise level automation, and finally to effective cross- company collaboration across the entire manufacturing supply chain. The model provides a strategic direction for each manufacturing company. Recent research has correlated supply chain maturity with improving performance (McCormack and Lockamy 2004). But a recent survey conducted by PRTM showed that only 16% of companies have gone from Step 1 and 2 (PRTM 2005). Very few have been able to get to Step 4, mostly because of internal organizational conflict and lack of contractual resolution to the cross-company collaboration.

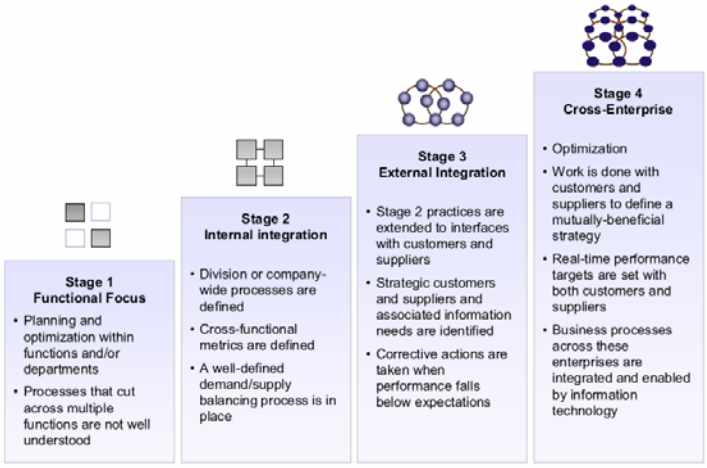

Figure 2: Stages of Manufacturing Supply Chain Maturity

The Lean Aerospace Initiative (LAI) at MIT under the aegis of the developed a *Lean Enterprise Transformation Maturity Model* to assess the players in the aerospace industry in their 'degree' of leanness (Nightingale and Mize 2002). The researchers of the LAI realized that there was a strong correlation between process maturity and degree of leanness achieved within an enterprise. As processes matured, there was reliability achieved which in turn was the objective of the lean enterprise as well.

In summary, the literature survey reveals that while conceptually all the maturity models are the same, their adoption to a particular industry helps encapsulate the industry characteristics better. And that encapsulation provides a better platform and provides actions oriented roadmap for the participants to gain process maturity.

MOTIVATION

The construction industry is in its infancy of supply chain management and process based thinking. One of the unique characteristic of the construction industry is that unlike any other industry there is a strong inter-firm collaboration across the entire CSC needed to complete a project. Although there are similarities to the software and project based industries to the construction industry, the CMM and $(PM)^2$ maturity models cannot be directly applied because they have been developed for a single enterprise. As seen from

the SPICE study, for construction there is a need for one that takes the multi-enterprise supply chain aspects into account. The LAI maturity model is tempting but again it has been developed for the aerospace industry and hence is probably not directly applicable as well. The manufacturing supply chain maturity models do address the multi-enterprise collaboration but process maturity in the manufacturing industry has a linear logical progression path as illustrated in figure 2 that takes organizational and contractual alignment into account. To elaborate, since the manufacturing of each item is exactly the same in typical manufacturing, it makes sense for companies to first automate tasks in individual functional areas and then provide processes and tools for automating a business across functional areas within a company. Since all of this is within a corporate entity, the financial incentives are aligned to achieve this target. Finally, they can extend the automation and streamlining of processes to downstream suppliers and upstream customers. This linear progression has been exemplified by the computer manufacturer Dell. Dell has been able to gain dominant market share in the computer manufacturing industry and achieve the advanced process maturity in the industry through a combination of business process and tools (BusinessWeek 2001 and Vaidyanathan and O'Brien 2003). But within the overall manufacturing industry, the incentives and contractual details for cooperative business practices do not yet have standards and wide adoption (see PRTM survey results above (PRTM 2005)).

In comparison, for the AEC industry, the logical progression path to process maturity is unclear. Each player in the AEC industry depending on their organization and business focus has one or more functional units, and typically works on multiple projects. In addition, a construction supply chain typically involves collaboration between multiple firms. Hence, for complete operational efficiency of the construction supply chain, process maturity has to be gained along three dimensions - functional, project, and firm and not necessarily in that order. Various players in the industry might adopt a different order to achieve complete integration that need not be all consistent. A robust CSC maturity model is a uniform and consistent way for companies to self-evaluate themselves and others and organize themselves for process maturity. The framework should take these industry dynamics and unique characteristics into consideration for widespread adoption. The proposed framework below has this motivation. It takes the multi-enterprise project supply chain and applies a maturity framework to its based on the CMM framework.

CONSTRUCTION SUPPLY CHAIN MATURITY MODEL

The construction supply chain maturity model builds on the idea that process maturity is achieved in stages by incrementally controlling and managing the CSC business process along the three dimensions described above. We propose a four stage maturity model for construction supply chain management. Figure 3 illustrates the conceptual behaviour of the maturity model. The various stages of the model are described below:

- **Ad-Hoc:** At this level, there are little to no processes. Each project runs independent of each other as indicated by the lack of arrows connecting similar business functions across supply chains. Within a project, collaboration across firms is ad-hoc, needs based and done more on a reactive than a proactive basis as illustrated by the dotted arrows. There is little to no planning and there is information flow in all directions. There is no visibility within the various tiers of communication. There are some processes and/or automation for functions within

a company but no standards. There is no cross-functional cooperation and hence automation. Targets, if defined are missed. Heroics by people are required to get projects done. All of this leads to high SCM costs and low customer satisfaction.

- **Defined:** At this level, there is some recognition to look at cross project information functionally within the context of a single firm (dotted lines across projects indicate this). For instance, a sub-contractor might decide to plan across the needs of multiple projects within their firm while respecting the information needs of a GC within the context of a single construction supply chain (across firms). Collaboration needs are more defined (like the lean project delivery process). Targets are defined, tracked, and met at times. Performance is not consistently predictable. SCM costs are still high, but customer satisfaction is improving.
- **Managed:** This level is the breakthrough level. SCM is part of the corporate strategy. Organizational structures are aligned with CSC. Tools and processes for cross-project, cross-firm, and cross-functional collaboration are available and starting to be adopted. There a more steady flow of information and visibility across the various tiers. GCs for instance might streamline communication with their tier 1 suppliers and collaborators while a sub-contractor might focus on better resource management across projects (indicated by solid arrows). Targets achieved more often and consistently. SCM costs are dropping. No need for heroics to meet targets and complete projects. Marked improvement in customer satisfaction.
- **Controlled:** At this level, CSC is completed controlled, predictable, and managed. Traditional functions are replaced with SCM process oriented functions. Advanced SCM practices, SCM measures are deeply embedded in the organization. At this level, a company SCM has been completely imbibed into the corporate culture. Competition is through network of companies that form a supply chain. Firms are aligned through trust and mutual dependency beyond contractual and organizational boundaries. Supply chain competency is core to success. Targets are met as defined and customer satisfaction is high while keeping SCM costs low.

MATURITY LEVEL ASSESSMENT

The above framework provides for a strategy to progress towards long term process maturity once a company can establish their current status. The maturity level at which a company is at can be assessed through the following categories of assessment:

- **Process Assessment:** This assessment will be to identify the current as-is business process methodology. Assessment should be done along each of the three dimensions discussed above.
- **Technology Assessment:** This assessment is done by evaluating the various tools currently being employed for business process efficiency. Availability of tools within the company is studied as well as their usage pattern. The usage pattern of the tools and type of features used will indicate the maturity of usage of tools and their associated business processes.

- **Strategy Assessment:** This assessment is to determine the current business strategy of the company. Strategy is assessed in terms of the company expectations on doing repeat business with customers and suppliers and willingness to setup long term contracts and relationships.
- **Value Assessment:** This assessment is to assess the current pain points with the as-is business process and CSC maturity. Mitigating some or all of that pain with newer process, tools, and strategy will provide the value and motivation for the company to migrate to the next maturity level of CSCMM.

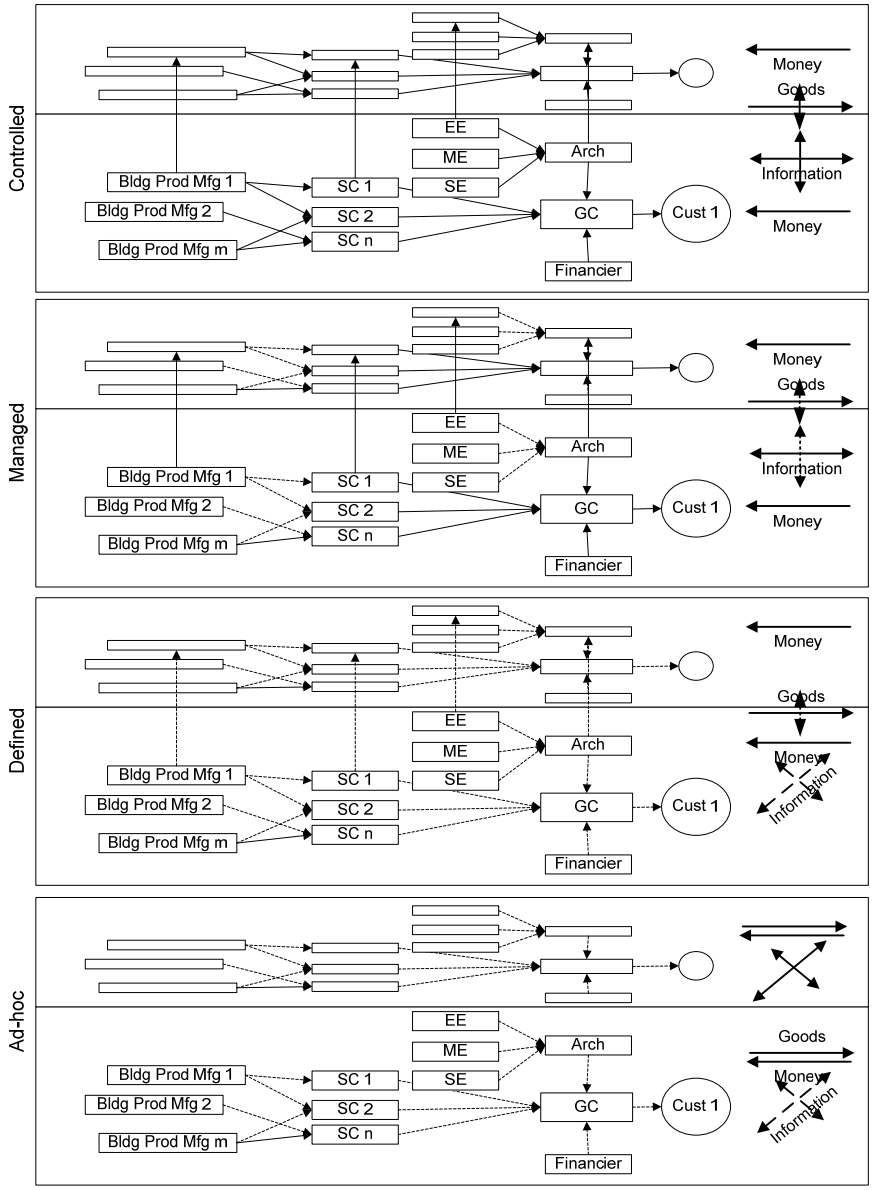

Figure 3: Construction Supply Chain Maturity Model (CSCMM)

A combined result of the above four assessments will determine a company's current SC maturity level. It is important to realize that maturity should be realized in steps since the changes in going from one maturity stage to another are involved. There could be process changes, possible installation and the use of new technology enabled tools, and even

organizational changes redefining roles of people. Achieving process maturity is a long term process and not a short term quick fix. It is a continuous process achieved by doing things consistently, repeatedly over the years. Hence, while forming networks of companies for an SC, companies can and should ideally partner with companies at the same maturity level and with similar strategic alignment. The CSCMM maturity ranking can be a criterion to drive the decision on whom to partner with in a project. As is evident, all the participants in the CSC should be at the same maturity level since the weakest link of the CSC dictates the boundaries of process maturity that can be achieved. To that end, when a company decides to outlay a plan to go from one maturity level to another, it should ensure that its future customers and suppliers will also have a similar roadmap to be at its targeted future CSCMM maturity level.

CSC PROCESS MATURITY ADOPTION MODEL

Process maturity has to happen along three dimensions as discussed above. But the requirements to mature along each of those criteria are different as shown in Figure 4 and highlighted in its legend.

Functional integration requires very little business process change. Technology enabled tools should help adequately. For instance, there is data duplication when estimation and scheduling is done from CAD drawings for a construction project. Performance will be dramatically increased and propensity for human error reduced if tool vendors could enable information sharing across CAD, estimation, and scheduling to achieve the desired results.

On the other hand, *multi-project integration* within a single business unit requires not only software tools, but also process and organizational alignment to work across projects. For instance, there is procurement efficiency to be gained by aggregating procurement needs across projects. Similarly, scheduling of resources that are shared across projects within the same firm can be done through the use of better tools and processes. But either or both of these imply that the company is willing to create an organization and incentive structure that works across projects. Roles need to be redefined to achieve this result.

Finally, *multi-firm integration* implies seamless communication across firms. For instance, there is value to be realized from streamlining communication from GC to sub-contractors and/or material suppliers. Tools can here provide value only if contractual hurdles can be overcome to enable this information sharing. Once that is done, business process can be modified to take advantage of the possibility and process level interoperability standards can be defined. Technology tools are only then required to reduce data duplication and improve communication requirements.

For a sub-contractor that typically employs direct labour and procures materials, a process maturity adoption path along the functional and multi-project levels make for easier justification within the firm and provides for more value to the bottom-line of the company. Finally, to expand the capability beyond the firm boundary will make sense. On the other hand, for a GC, collaboration is of a bigger need and hence a process maturity path along the functional and multi-firm dimensions initially and then finally extending it to multiple projects makes logical sense. At a supply chain level the maturity level alignment has to ensure that these competing adoption paths do not conflict. The CSCMM is to provide uniformity across these competing criteria to help companies evaluate partners on their path to gaining process maturity.

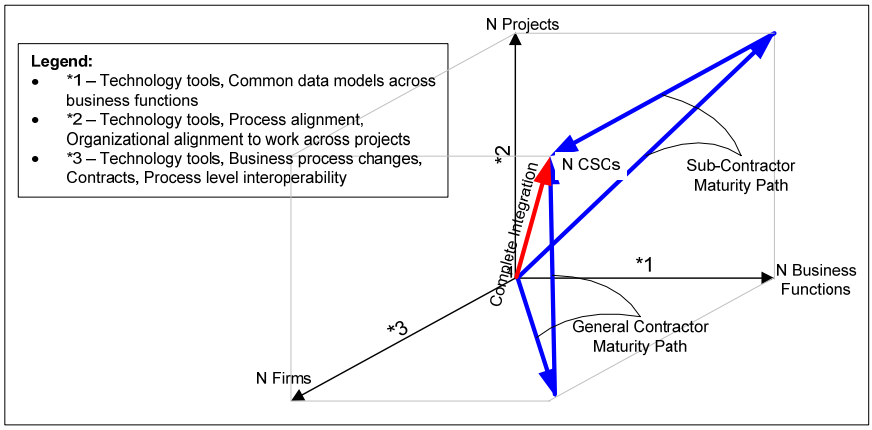

Figure 4: CSC Process Maturity Adoption Model

DISCUSSION

CSC, being in its infancy implies typically there are little to no processes and tools that are widely used for CSC at most AEC companies. There are no organizational structures that are aligned for CSC and there is little conscious effort to coordinate requirements across supply chains. All this leads to the general conclusion that the construction industry is currently at the ad-hoc level 1 of the maturity curve.

With the recognition of the need for CSC and the concepts of collaboration coming of age either through tools and/or through business processes like the Last Planner System™, (Ballard 2000) there are signs of some movement towards a more defined approach to CSC heading towards the defined level 2 of the maturity level. There are technology enabled tools being used today, but they are piecemeal and used without an explicit strategy towards conscious business process management towards the entire CSC. The tools could be a combination of collaboration tools, eCommerce type procurement tools, project management tools, estimation tools, and CAD tools to name a few. Data and process interoperability standards help exchange information across these tools, but it needs to be put in the context of achieving supply chain maturity. The maturity model framework proposed above is a new way of thinking and organizing the disparate CSC efforts around processes, tools, and standards by recognizing the need for a conscious strategy around CSC. As discussed above and illustrated in Figure 4, the path of maturity for various players need not be the same as motivations are different and needs (of GCs and sub-contractors) are different even though the overall objective (to complete a construction project) is the same.

As the proposed framework is described, the objective more efficient CSC is to improve upon the maturity of the overall CSC through a combination of tools, processes, and interoperability. There is no one size fit all solution. Depending on the CSC, the need for one or more or all of them will be different. Also, when a firm is moving from level n to level n+1 on the maturity curve, it does not mean that there are using advanced tools and processes compared to before; it only implies that they have the capability to achieve the objectives of being in a more mature CSC level.

The maturity model proposed will by definition be dynamic and evolving. As the industry further matures the CSC theories, we need to further develop the benchmarking tools to assess a company's maturity level based on the various assessment criteria listed above. The assessment can lead to a CSC maturity level certification that companies can use while partnering for a CSC or for coming up with a combined corporate strategy to go

from level n to n+1 within the maturity model. Performance outcome criteria need to also be developed that match the expectations from a certain maturity level. Companies can look to consistent processes, performance, and expectations as a result of achieving certain maturity. The benefits of achieving this will be of tremendous value to improving the processes in the industry as a whole.

CONCLUSION

A conceptual maturity model for the construction supply chain management has been proposed. The model provides a framework to both assess where a company is today along the maturity curve, and how they can go to more advanced maturity levels. It integrates the efforts of the various efforts of the tool vendors, process experts, and interoperability research and allows for companies to adopt some or all of them as part of their CSC strategy. Corporate strategy and organizational incentives can now be aligned along CSC to provide better value for the customer while proving better operational efficiencies for a company.

Future research work will involve a study project to validate the conceptual model. Once validated, as discussed above, the model needs enhancements to its benchmarking criteria. The maturity model is expected to be dynamic and changing as we further recognize the CSC as being critical to corporate success. There is a need for further research to develop the model. Further research is needed to correlate this model to business performance. Applicability to different types of construction – building, non-building, commercial, residential etc. needs to be done. Real-world case studies on how a company used the maturity model to set up a CSC partnership and the benefits it reaped from maturing its CSC will be beneficial as well.

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