

## Summary for CIFE Seed Proposals for Academic Year 2016-17

<b>Proposal number:</b>	2016-04
<b>Proposal title:</b>	CIFE performance dashboard for Innovative and Industrialized Construction
<b>Principal investigator(s) and department(s):</b>	Martin Fischer, Civil and Environmental Engineering Department
<b>Research staff:</b>	Calvin Kam, Nirupama Kotcharlakota, Jacqueline Lo, Bochen Zhang
<b>Total funds requested:</b>	\$ 76,776
<b>Project objectives addressed by proposal</b>	Buildable
<b>Expected time horizon</b>	< 2 years
<b>Type of innovation</b>	Incremental
<b>Abstract (up to 150 words)</b>	<p><b>The problem:</b> Architecture, Engineering, and Construction (AEC) project teams have developed many valuable performance indicators to monitor the cost and schedule progress in a project's lifecycle. With the abundance of performance indicators, however, selecting an optimal subset of indicators that effectively characterizes a project's progress becomes challenging, especially in respect to the limited number of performance indicators a project could reasonably track.</p> <p><b>The proposed solution:</b></p> <ul style="list-style-type: none"> <li>• Distill a succinct set of KPIs that effectively informs a project's cost and schedule progress from a stock of proven indicators used by CIFE communities and past CIFE research</li> <li>• Builds a KPI Dashboard with project case study data to help the industry reference and track their own KPIs</li> </ul> <p><b>The proposed research approach involves:</b></p> <ul style="list-style-type: none"> <li>• Conducting rigorous case studies with CIFE members and industry partners- AGC, bimforum, AIA research and BCA (Singapore) to document performance indicators</li> <li>• Analyzing performance indicators data to yield a succinct set of KPIs that is representative of project progress</li> <li>• Reporting KPI data anonymously on a KPI Dashboard</li> <li>• Aggregating step-by-step KPI tracking guidelines on the KPI Dashboard</li> </ul>

## 1. Engineering Problem/ Business Problem

The construction industry has developed a rich pool of performance indicators. Some construction companies in the past have successfully quantified indicators such as schedule reductions (days), productivity increase (%) and direct cost reductions (\$), resulting from adopting VDC approaches, across portfolio of projects. Similar such efforts can be seen in the entire industry to formulate new metrics and indicators that measure performance. However, those indicators are measuring a lot of different construction activities that spread into broad aspects of construction. There has always been a question of which are the ‘key’ performance indicators that not only have the most impact on the project but also are easy to track over time.

The production and manufacturing industry has various key performance indicators (KPIs) such as rejection rate, overall equipment effectiveness (OEE) and takt time. Other industries, e.g. the textile industry, use KPIs efficiently by analyzing correlations and providing insights for decision-making (Zevenbergen, et al. 2006). Fields such as management accounting also felt the need to improve the planning, control, and performance measurement functions, and it utilizes performance indicators such as the balanced scorecard (BSC) (Stan Davis, Tom Albright, 2003). Evidently, the need to have KPIs for performance evaluation and benchmarking is undeniable across different industries.

Performance indicators can help Architecture, Engineering and Construction (AEC) project teams make informed decisions. Through prioritizing indicators that yield the most information about a project’s progress in terms of cost and schedule, the AEC industry can utilize minimal resources to measure a succinct set of KPIs that accurately reflect a project’s progress over its lifecycle, and make informed decisions to improve the final project performance.

### a) Limitations

The AEC industry has developed many valuable performance indicators that measures project progress on cost and schedule, e.g. planned percent complete, change order cost. A project cannot practically track all the performance indicators due to budget and labor constraints, thus a smaller subset of performance indicators will need to be selected. However, some indicators are dependent on each other and essentially different methods to measure the same performance, e.g. change order cost and number of change orders, thus generating even more combinations of performance indicators. Thus, selecting a small set of “key” performance indicators (KPIs) that effectively characterizes project performance becomes very challenging with the growing number of potential performance indicators, as the search space grows exponentially with the total number of performance indicators.

There are also well-established frameworks that have documented standardized project measurements on the national, even global, scale, such as the *SmartMarket Report: Business Value of BIM in North America* conducted by McGraw Hill Construction from 2007 to 2012. However, most of these frameworks focus on one-time measures and opinion-based feedback; while these systems deserve much merit for their adaptive and scalable approach, they fall short of providing timely and quantitative reflection of a project’s progress that are needed to make prompt and informed decisions.

## **b) Motivation**

Performance indicators that reflect a project's progress allows team members to discover anomalies and problems in the project, so that they may address and contain issues in a timely manner. However, the return of tracking additional performance indicators eventually levels off and falls as the cost of tracking and analyzing more performance indicators outweigh the added information the new performance indicators provide. Given a project's resource constraints, one would want to maximize the information obtained about the project's progress given a limited number of performance indicators the project could track, so that the project can be well-monitored and potential issues can be addressed promptly.

We propose to take stock of the metrics that are tracked across the CIFE community so that we can understand how far towards achieving a buildable structure the CIFE community has become. In short, this research aims to create a scorecard for the performance indicators commonly used in the AEC industry; this research will complement the Teicholz productivity study by reflecting the AEC industry's performance on a project level.

## **2. Theoretical and Practical Points of Departure**

### ***VDC ScoreCard<sup>1</sup>***

The VDC Scorecard was designed as a holistic, quantifiable, practical, and adaptable tool to track, access, score projects and provide recommendations regarding the effective use of VDC (Kam, McKinney, Xiao, Senaratna, 2013). Research done on VDC Scorecard provides a database of 146 projects evaluated by some of the performance indicators we are interested in and would serve as a basis for our research.

This diverse data set with 146 projects covers projects from 15 countries, 11 facility types, and all 7 stages of the construction process. It can help inform our decisions of which metrics are key and need to be developed into performance indicators in order to effectively track project performance.

### ***Parts Study***

The Parts research is inspired by the fact that our industry doesn't have a comprehensive understanding of the project's products. In contrast, in the aerospace industry both Boeing and Airbus know that their 747 and A380 jumbo jets have about 6 million parts each. Using this knowledge, they are able to develop a tight and efficient supply chain and generate clear assembly instructions. Successful strategies such as Design for Manufacturing and Assembly (DFMA) in the manufacturing industry are also based on the study of project parts. Therefore, we believe that by clearly defining a construction part, collecting and organizing part-related building information, the AEC professionals could better evaluate a project's design, delivery method, and construction strategies.

Using the working definition on construction parts, we are equipped with a usable common unit/language when talking about performance indicators. This new language will help us track project performance with part-related metrics, e.g. the number of parts installed per day, which reflects components' value addition to a project. Nonetheless, these part-related performance indicators haven't been tracked before and would need case studies to verify their importance.

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<sup>1</sup> VDC Scorecard website: <https://vdcscorecard.stanford.edu/content/vdc-scorecard>  
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### ***CII (Construction Industry Institute) Performance Management System***

Since 1996, the CII (Construction Industry Institute) has created performance indicators database from 1000 projects and has been collecting data from its partner companies. These indicators are categorized into five perspectives: Safety, Cost, Change, Schedule and Rework. These indicators are either chosen from a pool of performance indicators summarized by academia or supplied by construction companies. However, those indicators are beyond the number that a company could track. The CII database did not prioritize those performance indicators in each category to a reasonable number of trackable indicators. This database of performance indicators serves to cross-validate the important performance indicators chosen from previous VDC research with industry practices outside of CIFE.

### ***Performance Metrics Report on Previous CIFE VDC Certificate Program***

This report explored what and how performance metrics were tracked in the reported construction projects in the CIFE Certificate Program. Popular performance metrics are distilled from the reported indicators by counting their occurrence and indirectly representing the group of performance indicators that are commonly accepted and recognized by the industry.

This repository of performance indicators collected from CIFE members act as a basis for the proven set of performance indicators that are useful in the industry and can be further analyzed in the research to streamline into “key” performance indicators.

### **3. Research Methods and Work Plan**

This proposed research is based on previous studies on VDC Scorecard and Parts Study that have come up with performance indicators that can be tracked through time. These studies have examined performance indicators used by companies in the CIFE community as well as other industry collaborators, and yielded a proven list of indicators that are informative of project progress in cost and schedule, among other areas of project performance. This proposed research will leverage these valuable results to distill a succinct set of key performance indicators that effectively characterize and inform a project’s progress in cost and schedule. Tracking an optimized set of KPIs will result in more buildable AEC projects, as project team members will need less resources to monitor cost and schedule progress effectively.

Our research approach and methods consists of the following steps:

#### **a) Development of KPIs**

Defining performance indicators that are “key” and are representative of a project’s performance will be the first step of our research. We will start with proven existing indicators used by companies in the CIFE community and found by VDC Scorecard research, Parts research and other selected CIFE studies. In doing so, we will have shortlisted 20-30 candidate performance indicators. Examples of performance indicators that are proven to be informative and practical are shown in Table 1.

Table 1: Example of KPI and its associated category

<i>Performance Indicator Example</i>	Rationale for choosing the performance indicator
<b>VDC performance score</b>	Use of innovative VDC approaches can enhance performance in cost and schedule
<b>Planned percent complete</b>	Planned percent complete is a timely reflection of a project's status in schedule progress
<b># of Parts installed per day</b>	# of parts installed per day is a central measurement in industrialized construction to measure productivity needed to follow project schedule
<b>Schedule conformance to plan %</b>	Lean construction is a method that is popular in the AEC industry and is proven to have positive impact on project schedule
<b># of decisions revoked/changed after commitment</b>	Owners drive construction projects, thus they have huge influence on project performance in terms of project schedule delay and over budget
<b># of issues resolved in coordination meetings</b>	Effective collaboration among parties within the project is a key factor to reduce cost and keep up with schedule

**b) Data collection and analysis**

The research team at CIFE will collect data from industry collaborators through rigorous case studies. Performance indicator data will be collected from online forms that industry collaborators can fill out within minutes. Data will be collected from the industry collaborators in a regular basis. Members of the research team will also be in continuous correspondence with the collaborators to survey what, if any, additional information or insights they gained from measuring each indicator. The class CEE 212B is a research-based class with curriculum objectives that align closely to our research. Students in this class will help collect results from companies and populating the dashboard. We will also collect data by engaging the participants of the CIFE certification program who are involved with CIFE in enhancing their VDC knowledge. Partnering with various industry professionals from AGC, bimforum, AIA research and BCA will help us collect more data from a greater variety of projects to strengthen our results.

The importance of a performance indicator is determined by the information it provides the project team. To select the most important and effective indicators, we record the frequency and degree of information team members gain from tracking each performance indicator. By comparing the information gain from each indicator with statistical tests such as the Chi-sq test and the t-test, we can distill the performance indicators that provide significantly more information than others, and thus qualify as “key” performance indicators.

### c) Designing the dashboard

The criteria we envisage for the design of the dashboard are simple and dynamic. For the dashboard in this year, we plan to present the information pertinent to each KPI in a clear, concise format. For all KPIs within the dashboard, trends for tracking each of them will be plotted using the data collected (i.e. all data trends will be plotted on the same graph with each trend corresponding to a particular project that used this KPI. All data trends will be plotted anonymously). Within the page for each KPI, general information of the KPI will be listed, including step-by-step guidelines to track the KPI. The website for tracking the recommended KPIs will be accessible to all CIFE member companies and industry collaborators that contributed to creating the dashboard.

## 4. Expected Results: Findings, Contributions, and Impact on Practice

The expected results from creating this dashboard is to provide the industry with a point of reference for KPIs that can be easily adopted to track and improve their project performance. This study will help converge a large set of performance indicators used in different companies to a succinct set that is most effective in informing a project's progress in cost and schedule. The industry can then choose to optimize their resources to track the most impactful and informative KPIs.

By providing a set of comparable, applicable and repeatable key performance indicators, the CIFE performance dashboard will be able to drive performance and improvement of the construction industry. CIFE performance dashboard provides easily applicable performance indicators that enable comparison within the construction industry, creating healthy competition leading to higher productivity. Companies can reference their KPIs with other companies and projects to position themselves in the industry. Comparisons incentivize companies to keep learning from the best practice in the industry and drive improvements within their own company.

## 5. Research Milestones and Risks

### Milestones:

Task #	Task(s)	Tentative Deadline
1	Literature review of research on performance indicators	August 30 <sup>th</sup> 2016
2	Shortlist performance indicators	September 30 <sup>th</sup> 2016
3	Collect data from performance indicators implementations	October 30 <sup>th</sup> 2016
4	Design dashboard	November 15 <sup>th</sup> 2016
5	Publish results on the dashboard	December 30 <sup>th</sup> 2016
6	Analyze KPIs from industry partners	Start: Oct 2016 End: May 2017

There are several risks associated with this research project.

- Case studies which are chosen to be representatives might not be holistic enough owing to the vast differences in projects in the construction industry. Spanning case studies over

different project types, geographical locations, delivery methods, budget, scale and size will minimize the risk of limited sampling of data.

- Misalignment of time frames - Usually construction projects span more than 1 year and since this research will last for a year, the data points we collect might not be enough to validate the recommendations we make. By taking a large number of data points even within the limited time frame in order to collect more data, we can make appropriate recommendations.

## 6. Industry Involvement and Next Steps

Apart from being involved in data collection, CIFE members can also participate in workshops. The research team will conduct workshop to discuss and disseminate the research findings. In the workshop, we will update the CIFE members of the research progress and make recommendations for KPIs to track. We will collaborate with industry professionals from AGC, bimforum, AIA and Singapore Building Construction Authority etc. to expand our data collection process and outreach to projects worldwide.

Next steps of our research will involve carrying out benchmarking of industry projects on a continuous basis. Though, this Seed Proposal will help create this dashboard, it will be an ongoing research in order to keep it up to date with the changes in the AEC industry and analyze the data as displayed on the dashboard with inferences such as industry benchmarking.

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