Summary for CIFE Seed Proposals for Academic Year 2020-21

Proposal number:	2020-12
Proposal title:	Critical Success Factors and Guideline for openBIM and VDC on Infrastructure Projects
Principal investigator(s)[1] and department(s):	Prof. Martin Fischer, Civil and Environmental Engineering Department
Research staff:	Dr. Calvin Kam, Jacqueline Lo
Total funds requested:	$ 79,558
Project URL for continuation proposals	**http://**
Broad Category Addressed in this Research[2]	**resilience / quality of life for society, community, and people / experience improved for all stakeholders**
Project focus area addressed by proposal[3]	**Vision for the Future of Urban Districts / Team Collaboration / Project Collaboration**
Stakeholders' benefitted by the research[4]	Research is *primarily* expected to benefit each of the following stakeholder groups: **Owners, Designers, Builders, and Operators/Facility Managers**
Expected time horizon to impact the industry	**< 2 years**
Type of research[5]	**Exploitation**
Industry Involvement	**buildingSMART USA, AASHTO**

1 The PI(s) must be academic council member(s) at Stanford.

2 Remove the categories that do not apply to this research proposal.

3 Remove the focus areas that do not apply to this research proposal.

4 Remove stakeholders that you do not anticipate to primarily benefit from this research.

5 **Exploitation -** "refinement, choice, production, efficiency, selection, implementation, and execution;" **Exploration -** "search, variation, risk taking, experimentation, play, flexibility, discovery, innovation." For more information please take a look at the following article.

Abstract **(up to 150 words)**	Increasing global infrastructure demand will require investment of ~$94 trillion between 2016 and 2040. Public agencies are starting to recommend or mandate the use of openBIM globally, recognizing its ability to enhance collaboration and hence eliminate waste on projects. In 2019 the American Association of State Highway and Transportation Officials passed a resolution on IFC openBIM schema, and recommended its adoption as the national standard for their projects. Infrastructure project leaders must quantify and report costs and benefits that VDC and openBIM bring to their projects, but are challenged by the lack of a standardized framework for benchmarking and reporting these values. We will fill that need by studying 10 global infrastructure projects, identifying critical success factors of openBIM, and compiling a set of assessment metrics covering associated operational cost, project performance, and operation & maintenance metrics. We will document and share these insights into a guide for public use.

Business Problem

Infrastructure is central to modern economic development and necessary for upholding the quality of life of citizens. From the transportation of goods and people, communication networks, to supporting basic human needs like electricity and clean water, infrastructure is critical to publics' health and welfare. Therefore, infrastructures' condition has a crucial impact on economy and the investment to maintain the well-functioning of infrastructures become an important part of infrastructure investment. Oxford Economics (2017) estimated that global infrastructure investment demand to be $94 trillion between 2016 and 2040. To meet this investment need, the world will need to increase the proportion of GDP dedicated to this from 3% to 3.5%. As shown in Figure 1, many countries are facing an investment gap in infrastructure.

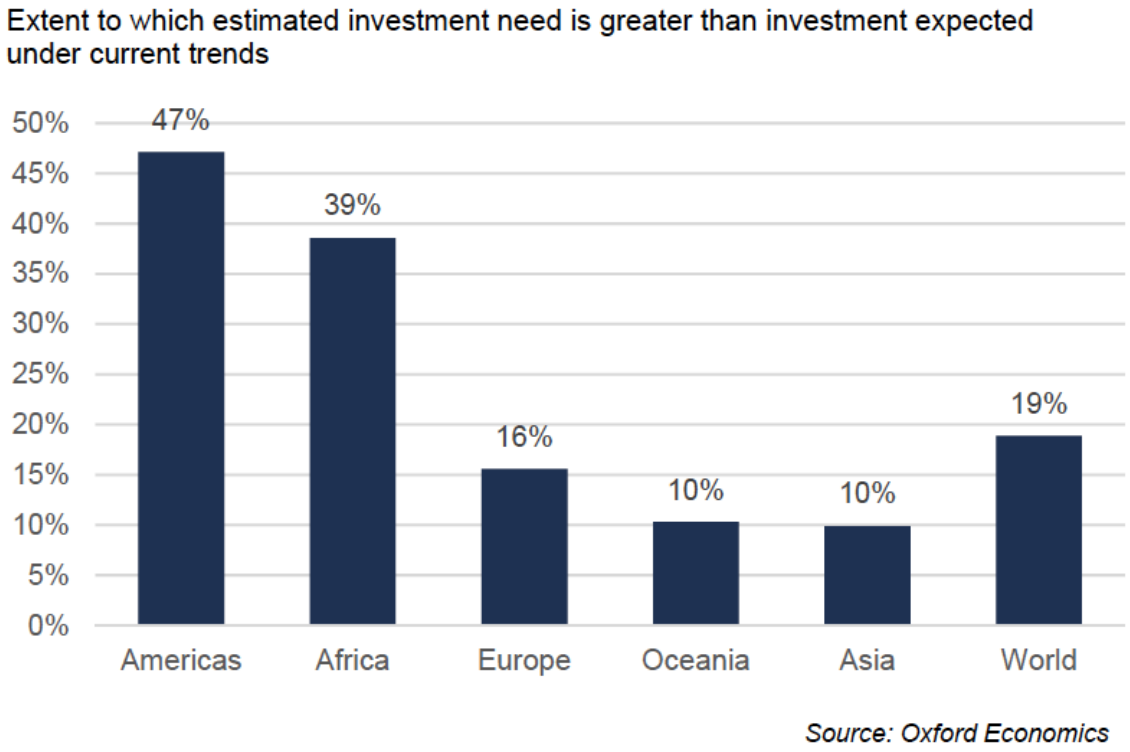

Figure 1: Infrastructure Investment Gap by Region, 2016 – 2040

In addition, the current COVID-19 pandemic has caused serious global economic depression. To stimulate economic recovery, the US Government has planned to spend $2 trillion and investing in infrastructure projects is one of the ways to inject the money to the market.

In its 2016 economic study, ASCE state that failing to close this infrastructure investment gap brings serious economic consequences:

- $3.9 trillion in losses to the U.S. GDP by 2025;
- $7 trillion in lost business sales by 2025; and
- 2.5 million lost American jobs in 2025.

Responding to this circumstances, global public sectors start to recommend the use of openBIM in infrastructure projects as a part of their cost-saving efforts and measurement to improve the performance of these projects. As defined by the buildingSMART International,

openBIM is a comprehensive approach to collaboration, design, construction and operation of built assets based on open standards and workflow. It supports seamless collaboration for all project participants, enhancing the interoperability and transparency of data flow, and improving the reliability of data exchange. Leveraging standard data schema such as openBIM becomes important for infrastructure project leaders when they harness innovation available.

Infrastructure project leaders, who must quantify, and report costs and benefits that VDC and openBIM bring to their projects, will be challenged by the lack of a standardized framework for benchmarking and reporting these values. How can we quantify potential benefits from openBIM such as enhanced interoperability, improved productivity and the associated operational cost like additional training cost, extra effort to input the required data for the standard data schema? How can we balance these factors and take advantage of openBIM instead of seeing it as a possible burden?

Our research team proposes to fill the need of a standardized framework by studying 10 global infrastructure projects, identifying the critical success factors for the use of openBIM, and compiling a set of assessment metrics to quantify the impact of openBIM. These metrics consists of 3 main categories, covering associated operational cost, project performance, and operation & maintenance metrics. In addition, our group will document the findings and recommendations including essential factors for successful implementation of openBIM in infrastructure projects, lessons learned in previous projects, metrics used, and more into a guide. The goal of this proposal is to support infrastructure project leaders to better manage implementation of IFC or other openBIM schema under the VDC framework.

Theoretical and Practical Points of Departure

The VDC Scorecard Research

The effort in understanding, measuring and even scoring the implementation of VDC in project-level has been around for years. Here in CIFE, our research group has also developed a VDC assessment tool: VDC Scorecard to access the maturity of VDC implementation in a project. The scorecard uses weighted metrics to score the given project through interviews or surveys. Performance indicators and key aspects of a successful implementation of VDC in project-level are recognized in the process of developing the scorecard and data analysis on the diverse data set with 146 projects from 15 countries, 11 facility types, and all 7 stages of the construction process.

Throughout the years, students from Stanford class CEE 112/212 have used VDC Scorecard (Kam, Song, and Senaratna 2017) to assess some infrastructure projects, for instance, the Filstal Bridge project in Germany, as shown in Figure 2. As one of the four pilot projects for the introduction of BIM in national infrastructure construction activities, there are a lot of room for improvement; in particular, the integration of discipline models and involvement of end users in the design and construction projects. VDC scorecard is not designed for evaluating infrastructure projects, resulting in a lack of metrics that are tailored for infrastructure projects only. In addition, the portion within the scorecard on data exchange is very limited, making it unable to represent accurately the performance of implementation of openBIM schema in projects. Although VDC Scorecard and our class did not focus on the assessment of infrastructure and openBIM schema, these example of VDC Scorecard assessment can act as a basis for developing the assessment metrics for evaluating the performance of the IFC implementation in infrastructure projects, as

openBIM can be seen as an important founding block of the VDC framework. Experience on developing the scorecard can help identify critical areas for our case studies, and help extract useful performance indicators.

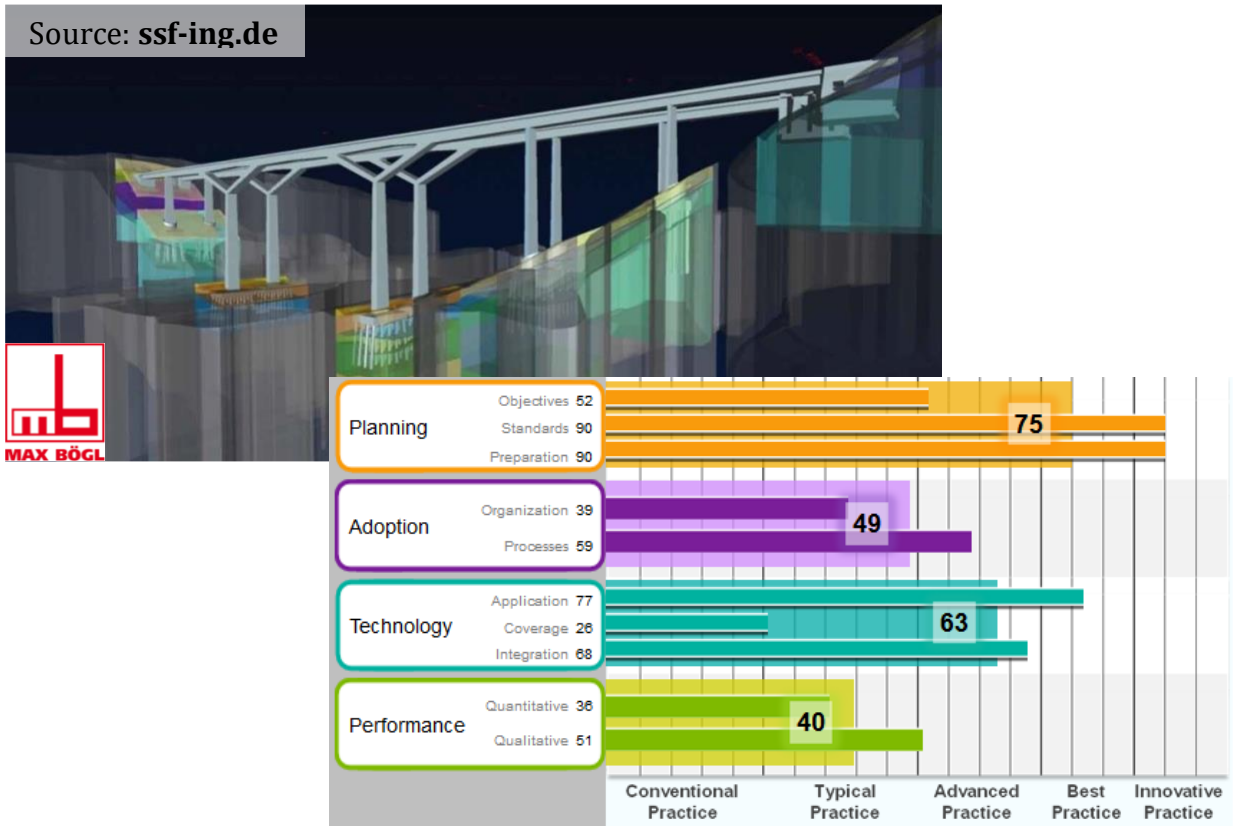

Figure 2: VDC Scorecard Assessment of Filstal Bridge

buildingSMART's Infrastructure Room[6]

Recognizing the importance of infrastructure and the need to develop open data standards for these structures, buildingSMART International formed a "room" that sole purpose is to enable process and data integration for infrastructures through open data schema. The scope of their work includes information exchange and process standards, linking and integrating across BIM and GIS. The objective of this infrastructure room is to:

- Enable data exchange based on open standards for the planning, realization and maintenance of infrastructure works and ultimately all aspects of the built environment
- Enable the exchange of information and open data access between asset management databases
- Enable enduring archives of asset information based on open standards
- Enable life cycle information management for infrastructure based on open standards
- Enable the merging of project related information e.g. requirements and risks, with asset information

Figure 3 below illustrates their current project and activities, including bridges, alignments, roads, tunnels, etc. This current emphasis and development of open data schema provides a perfect

6 https://www.buildingsmart.org/standards/rooms/infrastructure/

opportunity for the design of a standardized evaluation framework that fits the "new" approaches, and assist the management of projects that utilizes it; helps quantify the impact of IFC and better leverage its potential.

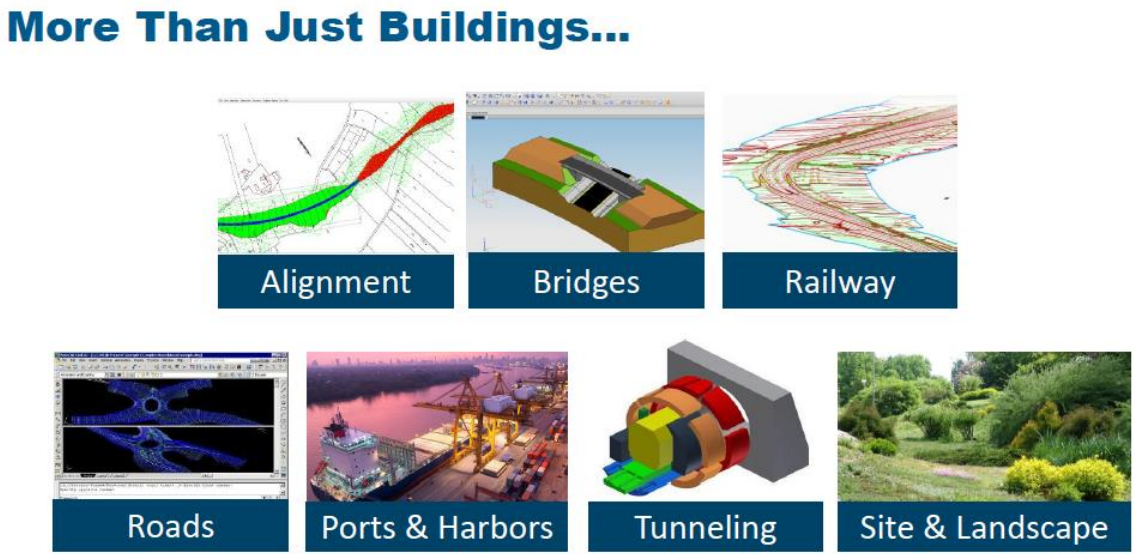

Figure 3: IFC Development on Infrastructure (BIMForum19 BIM for Bridges and Structures)

Research Methods and Work Plan

To learn from previous projects, the 10 or more case studies, identify patterns and lessons learned, the proposed research will be divided into 2 major tasks.

Task 1: Identify and conduct case studies

Based on previous experience in the assessment of VDC on building projects, we will first identify and select case studies for the proposed research. The selection of the infrastructure projects should help facilitate the extraction of essential factors for successful implementation of openBIM. For each case studies, we will focus on major areas to assist organized documentation and extraction of the experience learned from projects. For instance, the BIM execution plan, the information flow between project participants, quantitative objectives set up, etc.

Task 2: Document insights into a guide for infrastructure project leaders

Extract essential factors of openBIM implementation and lessons learned to avoid pitfalls

The research team will document the case studies, including project type, contract type, openBIM strategy, key performance indicators used, and more. From these cases, we will summarize the lessons learned, like common challenges, solutions to tackle the challenges, legal or security issues to avoid, etc. These lessons learned/ pitfalls will be further documented into essential factors for successful implementation of openBIM in infrastructure projects under the lens of VDC.

Design assessment metrics for openBIM implementation under VDC framework in infrastructure projects

We will also design and recommend metrics during this task to measure the performance of openBIM implementation. This set of assessment metrics includes the associated operation

cost and benefits, and will be validated through the case studies.

Expected Results: Findings, Contributions, and Impact on Practice

This research will **deliver a guide** for infrastructure project leaders which consistently documents the case studies and share our insights that includes:

- **Essential factors identified:** Critical factors that support or hinder the successful implementation of openBIM in infrastructure projects. E.g. which contract type may be best based on the case studies for the implementation of openBIM.
- **Lessons learned:** Identify patterns of applications, challenges and solutions of the projects. For example, what may be some challenges that the project team faces when assigning responsibilities and roles to team members for the insertion of data? What are some legal or security issues that future project leaders should avoid?
- **Assessment Metrics:** Design and recommend metrics that helps infrastructure project leaders quantify the impact of IFC implementation and supports their management of VDC. These metrics are designed based on the metrics collected from the case studies and the experience learned. These metrics composes of 3 main categories:
    - **Associated Operational Cost Metrics**: implementation cost, training cost, operation cost, etc.
    - **Project Performance Metrics**: increase reliability of construction time and cost, enhanced productivity, etc.
    - **Operation and Maintenance Metrics**: more precise project delivery, reduced asset management cost, etc.

Aside from the guide to share our insights and recommendations, the research team are also open to offer workshops or webinars for CIFE members to share our research work, in particular the metrics and methodology extracted from the case studies.

It is expected that there will have huge investment in infrastructure projects in coming years for economy revitalization after the pandemic. The proposed research helps support decision-making for infrastructure project leaders on how to better adopt IFC or other openBIM data schema under the VDC framework. Based on the case studies, this research can also help facilitate the explanation of the value, through quantification, behind IFC implementation in projects for different stakeholders and parties involved through better understanding of the value behind the "extra" efforts. For theoretical contributions, this research help identifies the essential factors for a successful openBIM-project, and establish a pool of case studies and their lessons learned regarding data ownership, data exchange, legal and security issues, and etc.

Industry Involvement

Currently, we have aligned around 10 infrastructure projects for case studies from AASHTO and buildingSMART International (bSI). bSI can also offer award cases for our research, such that we can learn from the high performed projects. We will continue collaborating with these organizations for data collection and to understand their requests and concerns in order to tailor the focus of the research for industrial needs. As our research depends on the quality of case studies, sufficient amount of data collected is crucial for a confident result. All CIFE members are welcome to provide, nominate or recommend infrastructure projects to extend our coverage of infrastructure

types, supporting the research to become a more valuable one. We plan to focus on a minimum of 10 cases and may screen or select the cases based on their depth of VDC implementation or metrics used.

Research Milestones and Risks

Table 1 shows the four research milestones that the research team will use to track the progress of the proposed research.

Table 1: Research Milestones for the Proposed Research

Tasks		Tentative Deadlines
Conduct 10+ case studies:		
-	Identify essential factors for successful implementation of IFC	December 30th 2020
-	Extract lessons learned, e.g. challenges faced, pitfalls, etc.	February 30th 2021
-	Design and recommend metrics for infrastructure project leaders	May 30th 2021
-	Finish the guideline for infrastructure project leaders	July 20th 2021

The major risk of this proposal is on the variability of the case studies. The differences between various types of infrastructure projects are much more significant than in building projects. The critical factors of a bridge project may be very different than that of a tunnel project. Therefore, the variability of case studies hinders the generality of the metrics designed for quantifying the impact of IFC or other openBIM data schema on infrastructure projects. To minimize the adverse effect of insufficient variation, we will do our best to collect as many case studies as possible to cover varying infrastructure types. If there were not enough projects for some specific type, we will categorize the metrics based on infrastructure type to maintain the applicability of our findings.

Conclusion and Next Steps

Infrastructure is critical to publics' health and welfare. Infrastructure project leaders, who must quantify and report costs and benefits that VDC and openBIM bring to their projects, are challenged by the lack of a standardized framework for benchmarking and reporting these values. We propose to fill that need by studying at least 10 global infrastructure projects, identifying critical factors supporting/hindering use of openBIM, and compiling a set of assessment metrics for quantifying the impact. This proposed project help identify essential factors for a successful IFC-project and establish a pool of case studies that documents the experience from previous projects, supporting the decision-making of infrastructure project leaders.

Given the development of openBIM, further research should be done on the integration of GIS and BIM, measuring the effectiveness of the integration on infrastructure projects. In this research, we aim to provide a general guide for infrastructure projects. Nevertheless, if more and more cases are available, we can extend the research to cover all project types, including integration with previous researches on IFC for buildings.

References

Kam, Calvin, Min Ho Song, and Devini Senaratna. "VDC scorecard: formulation, application, and validation." Journal of construction engineering and management 143.3 (2017): 04016100.
Economic Development Research Group. "Failure to Act: Closing the Infrastructure Investment Gap for America's Economic Future." ASCE, 2016.
Oxford Economics, "Global Infrastructure Outlook", 2017

Sponsor:	CIFE
Submission Type:	New
Budget Preparation Date:	4/7/2020
Budget Start Date:	10/1/2020
Project Name:	-
Department:	Civil Engineering
Principal Investigator:	Martin Fischer
Administrator:	Blanca Rebuelta

				Period 1	All Periods
			From	10/1/2020	10/1/2020
			To	9/30/2021	9/30/2021
Personnel Salaries					
Graduate Students					
Research Assistant - TGR	Academic		50.0%	36,134	36,134
	Summer		0.0%	-	-
Research Assistant	Academic		0.0%	-	-
	Summer		50.0%	11,693	11,693
Total Graduate Student Salaries				47,827	47,827
Contingent Staff					
Hourly RA				7,500	7,500
Total Contingent Staff Salaries				7,500	7,500
Total Salaries				55,327	55,327
Benefits					
Graduate				2,439	2,439
Contingent				593	593
Total Benefits				3,032	3,032
Total Salaries and Benefits				58,359	58,359
Other Direct Costs					
Tuition					
Research Assistant - TGR	Academic		50.0%	10,642	10,642
	Summer		0.0%	-	-
Research Assistant	Academic		0.0%	-	-
	Summer		50.0%	7,557	7,557
Total Tuition				18,199	18,199
Other Direct Costs					
Conferences and Meetings				3,000	3,000
Total Other Direct Costs				21,199	21,199
Total Direct Costs				79,558	79,558
Total Amount Requested				79,558	79,558

Rates Used in Budget Calculations

Benefit Rates

Graduate:	FY 1 05.10%;	FY 2 05.10%;	FY 3+ 05.10%;
Contingent:	FY 1 07.90%;	FY 2 07.90%;	FY 3+ 07.90%;

Indirect Cost Rates