# Master of Engineering
# Smart Infrastructure Finance (SIF)

**Core Faculty**

Program Director: Peter Adriaens (CEE)

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## A. Summary

The Master of Engineering (MEng) degree in Smart Infrastructure Finance is a one-year (26 credit + 1 credit internship) program that offers students a professional degree oriented towards data-driven finance and business models for smart and resilient infrastructure designs. The Program supports a student pipeline for the new Center for Digital Asset Finance. More detail on this center can be found at https://www.difin.io.

This one-year degree program is targeted at students who hold a B.S. degree and/or equivalent experience in civil and environmental engineering, business, policy and law. The anticipated off-take market for this degree program includes construction engineering, consulting or financial services (e.g. banking, insurance, private equity) after completion of their degree.

The MEng in Smart Infrastructure Finance will enable students to:

- *Explore the Innovation Opportunity of Smart Infrastructure as an Asset Class*
- *Develop Performance Benchmarks Based on Infrastructure Characteristics*
- *Understand How Data Facilitate Risk Management in Infrastructure Investment*
- *Categorize Data Types, Their Value and Pricing in the Marketplace*
- *Develop and Test Financial Models to Capture the Value from Data*
- *Inform Infrastructure Designs that Target Financial and Resiliency Objectives*
- *Participate in a Required Internship with our Infrastructure Finance Partners*

Students in the SIF Program will be required to take 5 core courses in infrastructure, finance and data analytics, as well as an elective concentration drawn from three areas: business models, financial theory and models, and data science tools. It is not the intent of this document and the course offering to be too prescriptive, but rather to allow the student to tailor the program to their expertise and interest, in consultation with the program advisor. An internship in financial services or the broadly defined smart infrastructure industry is part and parcel to the program.

## B. Motivation: Smart Infrastructure and Data

Built and natural infrastructure systems underlie the largest sectors and GDP enablers of the economy being disrupted by ‘smart designs’. In large part this is due to the integration of ubiquitous sensing devices and enterprise software, as well as new materials, to improve operations, increase efficiencies, and reduce risk for construction companies and investors. Smart infrastructure is up-ending industry supply chains as well as information data streams, resulting in the emergence of valuable digital supply chains.

This requires companies (see Section C.) to retool, seek out new partnerships, and develop data-driven business models (DDBMs). From transportation, commercial and residential buildings, water conveyance and treatment systems, energy facilities, and the agro-economy, hard assets are increasingly integrated with enterprise software and data processing capabilities. This not only impacts design methods and life cycle analysis, or building information modeling (BIM), but is redefining infrastructure as a service product.

The industry refers to smart infrastructure as: "*The business of interdependence, with cross-industry 'handoffs' of data in virtually-connected sustainable infrastructure systems to develop new customer value propositions and new business models*".

The investment management industry has capitalized on the data trend. Infrastructure is data, business models are increasingly based on data, and investment models are structured around data trends. For example, digital platforms such as block chain are being explored to disrupt financing of sustainable cities, water and energy provision in developed and developing economies. In addition, ESG (environmental, social and governance) risk criteria are becoming integrated in investment decision making around project finance, green bonds, and other asset classes. This so-called financial technology (FinTech) megatrend is at the cusp of unplugging new capital flows towards investment in infrastructure systems.

The opportunity addressed here is that data can help bridge the infrastructure finance gap, unlock efficient capital, and democratize investment for more equitable distribution of quality of life across communities.

Civil and environmental engineers have traditionally focused on financial decision tools and models such as net present value (NPV) and discounted cash flow (DCF). More recently, life cycle cost analysis (LCCA) and the integration of environmental externalities has become part of the decision toolbox. The time is right to connect the design of smart infrastructure systems with the financial opportunities they offer.

### C. CEE Opportunity: Building New STEM Skillsets for Emerging Profession

*With CEE at the center of intelligent infrastructure innovations, the integration of infrastructure finance skillsets in the discipline leverages the transition from product- to data-centric values.*

The American Society for Civil Engineers (ASCE) and the International Water Association (IWA) are calling for new infrastructure finance models such as public/private partnerships (P3), securitization, insurance and impact bonds that capitalize on data streams. In addition, blockchain uses for evidence-based decision making in catchments, water utilities, as well as transportation and building infrastructure are being explored in mainstream venues. New applications are emerging with companies including Ferrovial, Cintra, Bentley Systems, WSP, Blockchain Triangle and Integrated Roadways.

Pilot and full-scale applications are being implemented as well. For example, DC Water has financed green infrastructure deployment using an impact bond with interest rates tied into performance measurements. The Michigan DOT is demonstrating a 65-mile connected roadway pilot with Sidewalk Infrastructure Partners by integrating digital infrastructure in public assets (e.g. I-94) between Corktown and Ann Arbor. Cisco announced a $1 bn. smart cities debt and equity program to implement smart sustainable infrastructure with less pollution, safer streets, and better quality of life for citizens. IBM Water, EcoLab and Microsoft have been working on a data-driven investment strategy for aquifer restoration, water body and quality monitoring, and pricing models for water infrastructure services. Executive education workshops in Singapore, the UK and the EU are focused on building digital twins to improve services and construction for smart roads, bridges and buildings, adaptive to the needs of next-generation construction and operations.

Multi-lateral organizations such as the UN Department of Economic and Social Affairs (DESA), which is responsible for implementation of the sustainable development goals (SDGs), is discussing smart infrastructure as part of the solution. The UN indicated the need for retraining its staff in new financing models in Doha, Qatar. Civil engineers, economic developers, and financiers are actively exploring the 'beyond public finance' paradigm of infrastructure. The European Investment Bank (EIB), Asia Development Bank, Asia Infrastructure Investment Bank and Canadian Infrastructure Bank are exploring pilots to capture data assets from connected infrastructures (roads, buildings, energy) into new data contract mechanisms for financing. More recently, the Bank for International Settlements has been prototyping digital platforms for green bond tokenization and infrastructure finance.

### D. What related programs exist?

Educational programs in infrastructure project finance are new to the engineering discipline and have evolved from the integration of business and policy disciplines with engineering skillsets. No integrated educational programs targeted to infrastructure finance currently exist at UM or in Michigan, except for the CEE MEng that has been offered twice (2020-21; 2021-22). The UM campus offers several discipline-specific research programs focused on the integration of data science, industry value chains, and finance,

through the Center for Digital Asset Finance (CEE), the Ross School of Business (Center for Value Chain Innovation; FinTech Initiative), and the Law School (Center for Finance, Law and Policy).

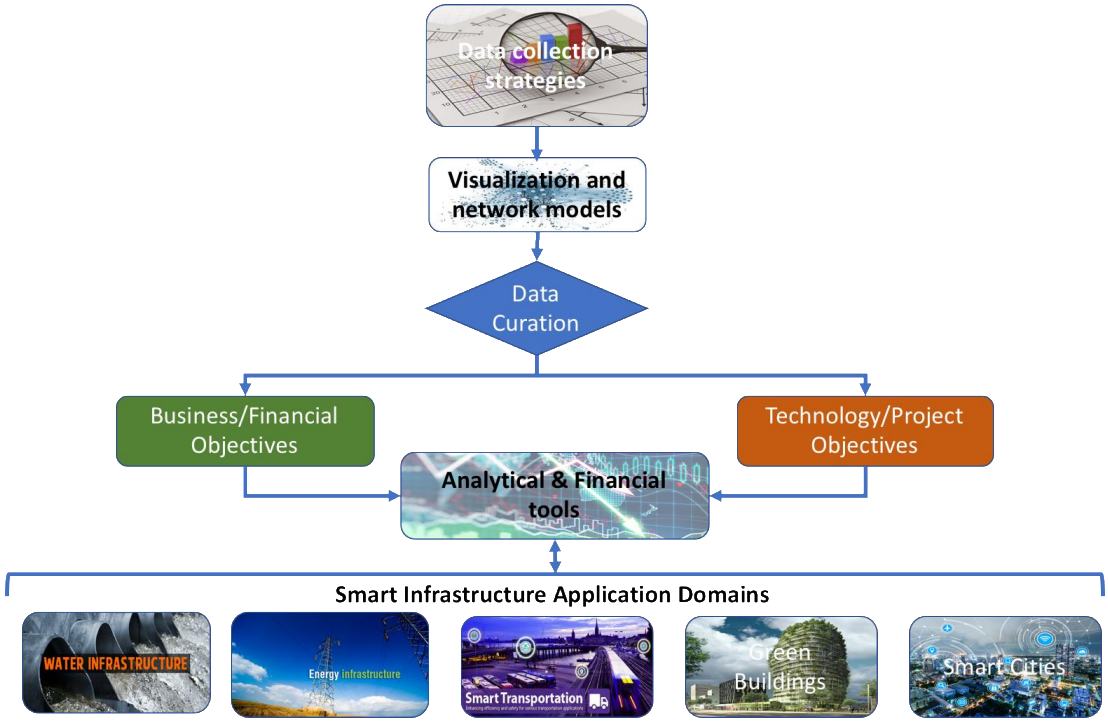
Student interest in financial technology programs is expanding. The student FinTech and Cryptocurrency Clubs, comprised of engineers and business school students, each have memberships of 150+ students, easily the largest on campus. The objective is to advance block chain-based transaction models and other digital finance opportunities across industry applications, including infrastructure.

Nationally and internationally, there are a few related programs. Stanford University's Global Projects Center, affiliated with its Civil and Environmental Engineering Program, seeks to facilitate understanding of the financing, development, and governance of critical infrastructure worldwide through interdisciplinary research, engagement with industry leaders, and education of future leaders within the infrastructure finance and development space. The University of Maryland - Department of Civil and Environmental Engineering has a Build America Center focused on "innovative financing and delivery for transportation infrastructure." Its mission is to help the Federal Highway Administration (FHWA) and the Build America Bureau to perform cutting-edge research related to innovative financing, project delivery, and policies. The Illinois Institute of Technology hired several civil engineering faculty with backgrounds in finance and derivatives in its Business School. Colombia University's Water Center has faculty focused on risk finance associated with water infrastructure and water-dependent businesses. Oxford University has a Center for Stranded Assets, which takes a finance approach to risk associated with natural and built infrastructure systems. Aside from Stanford and Oxford, no systemic programs are available that build on CEE skills and integrate data science and finance in the core disciplines.

### E. Curriculum Design

Audience: The proposed MEng program is intended to attract a multi-disciplinary audience into the discipline, in addition to CEE graduates. All students admitted in the program will have to adhere to the CEE undergraduate requirements detailed in Section F. The two pilot years have engaged students from engineering, business, policy and economics, as well as professional students. Upon graduation, these students have found employment at accounting firms, private equity funds and real estate investment trusts (REITs), as well as technology firms.

Program overview. A generic flowchart overview of the smart infrastructure program is provided in Figure 1. Students will be trained in data collection, visualization, and analytical/financial tools to develop decision models that integrate business/financial and technology/project objectives in a number of infrastructure application domains. The application domain will be developed in cooperation with the internship program. A final report after the internship program will be designed to demonstrate that the student has mastered the integration of data science/finance/smart infrastructure elements.




At least 50% of the course work needs to be completed in CEE. The students need to fulfill a core requirement of 5 courses and an elective concentration of 3 courses, in addition to attendance at seminar series and completion of a for-credit internship course (CEE 505).

***Figure 1. Organizational curricular structure of SIF MEng***

Credit Hours Distribution. A minimum total of 26 credit hours (excluding a for-credit internship course) is required to complete the MEng (Smart Infrastructure Finance) degree. Students will be exposed to intelligent infrastructure systems, data science and finance faculty members so they have an opportunity to gain maximum benefit from the program and the resources that support it.

### F. New Courses:

Four new courses have been developed to support the MEng program

1) *CEE 504. Engineering Economics and Finance.* Engineering Economics and Finance focuses on evolving financial decision making in engineering practice. Topics like accounting, public and private investment decision making, project management and risk and uncertainty are covered and linked to practical problems that are meaningful to (smart) infrastructure systems and the student's professional future.
2) *CEE 505. Smart Infrastructure Finance Internship.* The course consists of a 6-week internship at financial service, data analytics or construction/project development firms. The internship work is supplemented by a required workplan/approach and final report deliverable to the SIF MEng committee.

3) *CEE 503. Infrastructure Project Finance.* Course discusses project financing approaches, including municipal bonds, debt and equity finance, public private partnerships, securitization of revenue, and other mechanisms used to finance public and private infrastructure. The latter part of class emphasizes digital financing mechanisms such as Infratech bonds and tokenized green bonds, and asset-backed securities public private partnerships (ABS-PPP). Multiple use cases are used to illustrate the mechanisms, including toll roads, desalination plants, ballparks, ports, and mass transit.
4) *CEE 501.001. Introduction to Smart Infrastructure Systems.* This course introduces students to systems analysis of infrastructure. What is an infrastructure system in the context of analysis, data acquisition and performance evaluation? Connected infrastructures are a new concept in systems analysis, exhibiting cascading risks and effects that influence design and financing options.

### G. Curriculum

*Core Courses (15 credit hours):* All students must complete courses in a recommended set of 5 topical areas covering infrastructure systems and financial concepts in capital budgeting, financing instruments, and financial technology integration, as well as analytical tools with exposure to data visualization, optimization, stochastic processes, and statistics. If courses are not available each year or semester, similar elective courses can be taken as alternatives with the approval of the advisor.

1. **Engineering Economics & Finance: CEE 504** - Engineering Economics and Finance or **CEE 531** - Construction Cost Engineering
2. **Infrastructure as a System: CEE 555** - Sustainable Civil Infrastructure Systems **or CEE 501.001** – Introduction to Smart Infrastructure Systems
3. **Infrastructure Internet of Things (IoT): CEE 575** - Sensing for Civil and Environmental Engineering **or CEE 533** - Engineering Process Modeling and Risk Analysis
4. **Optimization/Scenario Modeling: CEE 553** - Infrastructure Systems Optimization or **IOE 561** - Risk Analysis I
5. **Infrastructure Finance: CEE 503** - Infrastructure Project Finance (to be cross-listed with Public Policy School – course number to be assigned)

*Electives/Concentration Areas (9 credit hours):* In addition to the core courses, each student must take 3 elective courses from 2 areas chosen in consultation with the Program Advisor in the following concentration areas (example courses are shown below). Students must have completed prerequisite courses or receive consent from instructor.

**Data Science Options**

1. **EECS 545** - Machine Learning (Prereq EECS 592 – Intro Art Intell)
2. **CEE 572** - Dynamic Infrastructure Systems (Prereq Math 417)
3. **CEE 554** - Data Mining in Transportation
4. **IOE 541** - Optimization Methods in Supply Chain
5. **CEE 435** – Building Information Modeling (Prereq CEE 331/Graduate Standing)

**Finance Options**

1. **PubPol 744** – Economics of the Public Sector
2. **PubPol 715.001**: Budgeting and Financial Planning
3. **CEE 588 -** Sustainability Finance: Investment Models for Green Growth
4. **IOE 453** - Derivative Instruments
5. **IOE 452 (MFG 455)**- Corporate Finance
6. **Fin 583** - Energy Project Finance

*Seminar Participation (2 credit hours):* Students are required to attend a seminar course aligned with the core and electives of the program to become exposed to experiential knowledge from professionals in the construction, finance, management, or data science industries. When seminar courses are not available for credit, the student needs to enroll in a comparable independent study assignment focused on a topic of

choice related to infrastructure financing. The seminar selection or independent study must be approved by the MEng student advisor. An independent study can be spread over two semesters.

### H. Requirements

Students holding B.S. degrees in an engineering discipline, or a physical or social science, may be admitted if they have achieved the technical background necessary to pursue advanced work in the SIF program. This background includes one year of college-level calculus, one year of college-level physical science, one semester engineering-level probability and statistics and one semester computer programming. More specifically, it is expected that applicants will have successfully completed the following courses in their undergraduate preparation prior to applying:

- Physics 140 (mechanics) and 240 (electricity and magnetism) or equivalents
- Mathematics 215 (multivariable calculus) and 216 (differential equations) or equivalent
- CEE 373 (probability and statistical methods) or equivalent
- CEE 303 (computational methods) or equivalent

If an admitted applicant has not completed these courses, some additional undergraduate coursework may be required to be completed (without credit) to complete the MEng. degree in Smart Infrastructure Finance. In such situations, the specific additional courses to be completed will be determined by the MEng Advisor for the SIF specialization.

### K. General Program Requirements and Policies

Students must have completed three semesters of calculus and one semester of physics or equivalent. They should also have completed a semester of statistics (e.g. CEE 373. Statistical Methods for Data Analysis and Uncertainty Modeling or equivalent). Students lacking this background will need to complete prerequisite courses before formal admission into the program.

Credit hours and normal progress: A minimum of 26 credit hours of acceptable graduate work must be completed for the MEng degree. Twelve regular course credits plus a one credit seminar is the usual full-time course load per semester. It is recommended that students plan to complete all of the courses required for the MEng degree in two regular semesters. Grades: The grade point average for the 26 hours of courses used to fulfill the requirements for the MEng degree program must be equivalent to at least a straight B (3.00). Grades below C (2.00) are not acceptable for graduate credit but are considered for the student's grade point average.

Time limit: A student must complete all work within a period of three consecutive years after first enrollment in the MEng degree program.

Graduate transfer credit: A maximum of two graduate courses equivalent to those offered in the core or elective component of the SIF Program may be transferred from another institution. These must be from graduate level courses taken either in residence or on-line with a grade of B or better from an accredited institution approved by the Rackham School of Graduate Studies. Students may request the transfer of such credits through the CEE Department after completion of one semester in the MEng program.

Undergraduate transfer credit: No undergraduate transfer credits are allowed for the MEng program, and prerequisites required for the core or elective coursework will not be counted towards final degree credits. An exception can be made by the program director for 400-level courses that are equivalent in content to core of elective coursework. These decisions will be made by the program director, in coordination with the cognizant faculty member of the SIF course that the student seeks to replace. However, 400-level courses that are required in the current undergraduate degree programs of the Department of Civil and Environmental Engineering or other undergraduate programs where the student graduated cannot be used for MEng graduate credit.

Internship course (CEE 505; 1 credit hour; 6 weeks or as structured by hosting company). All students will be required to participate in an internship program during the Spring or Summer term at companies within

the financial services, data management, or smart infrastructure industries. The internship will be for credit and will provide for professional exposure across non-traditional CEE industries.

Priority will be given to financial services companies such as MSCI, Nephila Advisors, Credit Spectrum, Dana Investment Advisors, Silicon Valley Bank, BlackRock, and NGOs such as WWF-Finance, Ceres, and WRI-Finance. These companies have paid internships, which will help to offset the cost of the credit hour. International students who have no work permit need to be aware of this requirement and cost. The MEng program committee will work towards a sponsored program in the future to offset the cost of the internship credit. An example of an internship engagement with MSCI is enclosed in Appendix C.

> The internship course objectives are to merge program knowledge with internship goals, which may include analysis of industry dynamics, business models, market trends, and investment analytics in a single or multiple industry sector, as related to infrastructure finance. A final report will be prepared for the client who will ultimately approve the quality of the work. Inasmuch as intellectual property and client confidentiality requirements are not violated, the report will be bookmarked and catalogued. At a minimum, the student will be required to submit a report to the Program Committee with an assessment of the client on the quality of the work.

It is anticipated that after a year of corporate engagement in the MEng program, the Program Administrative committee will have a chance to define the constraints and requirements for the internship and to streamline requirements.

### L. Program Administration

Administration. The Program Administration will be directed by faculty members Peter Adriaens and Glen Daigger, Carol Menassa, SangHyun Lee, Branko Kerkez, Yafeng Yin, who will work closely with the Graduate Commitee. Professor Adriaens will lead the programmatic implementation in collaboration with the MEng Admin team. Since all but the Internship and the Engineering Economics and Finance courses are existing offerings in the Department, the College or across campus, no extra burden for the directing faculty is expected beyond student advising. Letters of support have been requested from the affected Schools and Departments, following informal agreements from the faculty (please see Appendix D)

Program Stewardship. The program will be evaluated annually during the ADGE graduate program discussion with the Department Chair in the Fall. The Program Director will first prepare a report that reviews admissions, enrollments, student completion progress, course offerings, faculty participation, and student outcomes. This report will be discussed and revised if necessary by the Program Committee and the External Advisory Team at a dedicated review meeting. The Program Director will then discuss the revised report with the Associate Dean for Graduate Education at an annual meeting. After three years and every year thereafter, an anonymous survey of students (current and graduated) and faculty involved in the program will be conducted to solicit feedback and assess program format and participant satisfaction.

Recruitment and Graduation Audits. Student recruitment will be conducted through the regular CEE Master's application and other on-campus degree transfer programs (e.g. Business, Law, or Policy). To facilitate attracting non-CEE students, we will adhere to Rackham's transfer of credit program policy, as warranted. Within CEE, the Graduate Committee will handle all applications, from the perspective of whether the students meet the undergraduate requirements. The MEng Program Administration faculty will be responsible for admission in the MEng Program once students are admitted for graduate study in CEE, for graduation audits, and to address curricular issues once the students are admitted.

As indicated in Section F, prospective students are counseled to review program admission requirements and prerequisite course requirements prior to considering applying to the Program. Since this is a new program, which reaches out across campus to and to the professional community, recruitment guidelines and audits will be updated as needed.

Marketing. Promotional materials will be distributed as other CEE MEng programs via e-media and social networks. We intend to target a broad audience of students across engineering, business, policy and law disciplines with an interest in the deployment of smart and sustainable infrastructure systems in developing and developed economies.

Costs. It is expected that initially the Program will be able to leverage existing recruitment and marketing infrastructure. However, once the Program is fully implemented, a recruitment and marketing/communications coordinator will be appointed, with associated HR, office and IT infrastructure costs.

### M. Faculty

Professor Peter Adriaens. Dr. Adriaens is Professor of Environmental Engineering, Finance and Entrepreneurship. His research in the Center for Digital Asset Finance focuses on digital finance, fintech, and business models for infrastructure and associated supply chains. From 2014-2016, he was Finnish Distinguished Professor at the Research Institute of the Finnish Economy, He serves as advisor to the Great Lakes Impact Investment Platform, an institutional impact investment fund, and is on the advisory board of two infrastructure firms (Integrated Roadways and Blockchain Triangle). He teaches Environmental Finance, Entrepreneurship, and Infrastructure Finance courses and is a member of the Royal Belgian Academy of Applied Science and the Arts.

Professor Glen Daigger. Dr. Daigger is Professor of Engineering Practice at the University of Michigan and President and Founder of One Water Solutions, LLC, a water engineering and innovation firm. He previously served as Senior Vice President and Chief Technology Officer for CH2M HILL where he was employed for 35 years, as well as Professor and Chair of Environmental Systems Engineering at Clemson University. Actively engaged in the water profession, and as author or co-author of more than 100 technical papers, four books, and several technical manuals, he contributes to significantly advance practice within the water profession. He is a member of the US National Academy of Engineers (NAE).

Professor Carol Menassa. Dr. Menassa is Professor & John L. Tishman Construction Management Faculty Scholar. Her research focuses on understanding and modeling the impact of occupants on energy use in buildings, and on developing cost-based decision frameworks to sustainably retrofit existing buildings. She uses energy simulation, complex adaptive systems modeling, high-level architecture and informatics, and options-based decision tools, and manages research in international construction, integrated project delivery and quantitative assessment of project manager competencies.

Professor SangHyun Lee. Dr. Lee is Associate Professor & John L. Tishman Construction Management Faculty Scholar. His work focuses on understanding and managing construction dynamics and human-infrastructure interface through sensing, data analytics and computer simulation. Particularly, he is interested in achieving the maximum benefit from technologies like wearables, automation, and robotics for humans in construction and infrastructure. He also applies these technologies to direct smart and connected communities and cities toward social equality.

Professor Branko Kerkez. Dr. Kerkez is an Assistant Professor in the Civil and Environmental Engineering department. His research interests include water, data, and sensors. He heads the Real-time Water Systems Lab, where his group is conducting fundamental research on “smart” water systems. Dr. Kerkez is the founder of Open-Storm.org, an open source consortium dedicated to freely sharing technologies and lessons for the sensing and control of water systems. He received his M.S. and Ph.D. in Civil and Environmental Engineering, and an M.S. in Electrical Engineering and Computer Science, all from UC Berkeley.

Professor Yafeng Yin. Dr. Yin is current CEE Department Chair. His interests include analysis, modeling, design and optimization of transportation systems towards achieving sustainability and economic efficiency. His ongoing research involves examining the interdependency of urban infrastructure systems and investigating the implications of emerging vehicular and information technologies on urban mobility. He is Editor-in-Chief of Transportation Research Part C: Emerging Technologies, and edits for key journals in transportation systems.

Professor Seth Guikema is appointed in the departments of Industrial & Operations Engineering and Civil and Environmental Engineering at the University of Michigan. He is also a Professor II (adjunct) in the Department of Safety, Economics, and Planning at the University of Stavanger as well as a Data Science Research Fellow at One Concern, Inc. President of the Society for Risk Analysis (SRA). He was chairperson of both the Foundations of Risk Analysis and Engineering and Infrastructure specialty groups

and is a Fellow of the Society for Risk Analysis. He currently serves as the Area Editor for the Natural Hazards area for Risk Analysis and as the Area Editor for the Mathematical Modeling area for Risk Analysis.

The core team will work closely with finance and data science experts in business, policy and law to complement expertise represented among the CEE management team. Specifically, faculty at the Michigan Institute for Data Science (MIDAS), the Center for Finance, Law and Policy (CFLP; Law/Policy), the Center for Venture Capital and Private Equity Finance (CVPE; Ross), and the Center for Value Chain Innovation (VCI; Ross) will be engaged under ad hoc agreements.

### N. Enrollment, Scheduling Plans, and Implementation

Students have registered in the program for enrollment in Fall 2020 and Fall 2021. It was anticipated that up to 10 students will enroll in the first year, but we hope to cap enrollments at 25 students when the program matures.

### O. Specialized Facilities, including External Sites as Required

External sites to be offered by the sponsoring company. Selected courses may be live-streamed or videotaped for off-site students and professional participants from industry, NGOs or multi-lateral organizations as indicated earlier.