CIV E 709 Smart Digital Construction Systems

Fall Semester 2025

Class time: 11 am - 1.15 pm Fridays — Location: NRE 2-080
Tutorials time weeks 1 to 4: 1.15 - 2 pm Fridays — Location: NRE 2-080
Tutorials time weeks 5 to 12: 9-11 am Fridays — Location: CIC Lab NRE- 4-120

Instructor

Prof. Vicente A. Gonzalez, PhD, CRC.
Office hours: 9.45 - 10.45 am Fridays (in-person)*
Room: DICE 6-289
E-Mail: vagonzal@ualberta.ca

* To avoid delays, please email in advance to book a time slot. You may also email to arrange appointments for alternative times or in-person office visits. Zoom meetings can be accommodated if scheduled via email beforehand.

Course Description

The "Smart Digital Construction Systems" course is fundamentally rooted in Lean Construction 4.0, which has emerged in response to advancements in the architecture-engineering-construction-operation (AECO) industry. This approach addresses the adoption of new production management theories for the AECO industry, the digitalization of the sector, and the broader challenges faced by individuals and organizations—not only within the industry but also across society as a whole.

Since its inception in 1994, Lean Construction has fundamentally addressed theoretical and practical aspects associated with the new production management theory in the AECO industry. Initially, the general perception was that Lean Construction was merely an extension of Lean Manufacturing principles applied to the AECO industry. However, this view has shifted as Lean Construction has established itself as a production management theory in its own right. This evolution has been driven by transformative changes in Lean Construction research and implementation worldwide over the past 30 years, highlighting the triad of people, processes, and technology as the most critical components in modern business.

In the 1970s, automation revolutionized manufacturing operations, from order processing and billing to computer-aided design (CAD) and manufacturing, leading to dramatic productivity gains. In the 1980s, the advent of the Internet enabled unprecedented levels of integration across the supply chain, both locally and globally. Today, the onset of the "Fourth Industrial Revolution" and its associated technologies—such as cyber-physical systems, mixed reality, the Internet of Things (IoT), cloud computing, and artificial intelligence (AI)—and their impact on the AEC industry demand a rethinking of Lean Construction's role as a driver of continuous improvement. Its foundational principles of reducing waste and

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increasing value must now adapt to this new era of digital transformation. Indeed, Lean Construction's ability to effectively integrate into this digitally driven age calls for a redefinition of the people-process-technology triad within its theoretical and practical framework. This necessitates a shift toward what this course terms Lean Construction 4.0.
As such, Lean Construction 4.0 represents the synergy between a Lean-drive production theory for construction (Lean Construction) and smart digital technologies grounded in Industry 4.0, with a focus on culture and people through human-centred design. It transcends the mere integration with Building Information Modelling (BIM) or the implementation of Construction 4.0. Instead, it seeks to redefine how we design, manage, and operate capital projects in this modern era, marked by social, economic, political, and environmental challenges. Researchers and practitioners worldwide have cautiously explored various aspects of Lean Construction and digital and intelligent technologies. While Lean Construction 4.0 remains an aspirational concept, as the construction industry is still largely in the equivalent phase of Industry 3.0, elements of Industry 4.0 are visible, albeit fragmented and lacking consolidation.

Ultimately, this course aims to channel these efforts and propose a holistic vision where Lean Construction's principles are appropriately integrated with existing smart digital technologies. It focuses on strategically designing practical implementation pathways for the AECO industry, integrating digital and Lean methodologies while prioritizing human-centered design to transform AECO organizations.

This course will include weekly online lectures and tutorials, readings, team and/or individual assignments and a final project, and mid-term and final exams.

Prerequisites

None

TA Information

TA in charge of tutorials, assignments and final project:
Zhong Wang <zhong15@ualberta.ca>

TA Help Desk (Tutorials, Assignments and Project) Time TBA @ Zoom; to avoid waiting, email TA

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Office hours: Time TBA. Office hours will be provided through live sessions on Canvas.

Lecture Information

1. The lectures will be presented online via Canvas in an asynchronous manner.
2. All questions related to the lecture or any other questions can be submitted/asked on the General Discussion Forum on Canvas, to the instructor/TA via email, or during office hours.

Course Goals and Learning Outcomes

The main goal of this course is to *"describe and use the Lean Construction 4.0 concept as the integration of lean production-based theory for construction, people and culture, and industry 4.0-inspired smart digital technologies, everything under the umbrella of human-centred design".*

The Course Learning Outcomes (CLO) are as follows:

CLO01: Distinguish the different Lean Construction 4.0 components, namely Lean Production theory in Construction, Industry 4.0-driven Smart Digital Technologies, and Human-Centred Design, which in unison, can improve the production performance of AECO projects.

CLO02: Evaluate the potential of Lean Construction 4.0 and its components to be implemented in AECO projects.

CLO03: Create human-centric strategies to optimize the implementation of Lean Production and Industry 4.0-driven Smart Digital Technologies in AECO projects.

CLO04: Evaluate management approaches to effectively integrate Lean Production principles with Industry 4.0-driven Smart and Digital Technologies in AECO projects.

CLO05: Evaluate the impacts of using Lean Construction 4.0 principles and tools on AECO project's performance.

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Marking Scheme and Alignment with Learning Outcomes

Activity	Due/Scheduled	Weight
Assignments	As defined on the assignment **cover page** and on Canvas 4 Assignments (group work). Tutorial provided to develop assignments.	40% (10% each assignment)
Project	As defined on the project **cover page** and on Canvas (group work). Tutorial provided to develop the project. **Due: December 5th, 2025**	25%
Midterm	**Due: October 24th, 2025 (1 hr)**	10%
Final Exam	**Due: TBA (2 hr)**	25%

The faculty recommended a grade point average of 3.3 for 600-level courses. “Instructors have the leeway to deviate from this average and can assign grades based on their own scheme. All grades are approved by the department chair (or delegate). The office of the Dean has the final oversight on all grades”.

Assignment, Project and Weekly Tutorials

In order to evaluate and design implementation pathways of smart digital technologies, Lean Construction, and people and culture in tandem, supported by human-centred design as stated by Lean Construction 4.0, a number of assignments and a final project will be undertaken and will be required of weekly tutorials in addition to the lectures. Four assignments and one project have been designed for the entire semester, and they are intended to be carried out in teams. The assignments and project have been designed in a way that the completion of each assignment will represent one step further in the completion of the project itself, i.e., the progressive and step-by-step completion of each assignment will allow the completion of the project itself. Thus, assignments and the final project will be aligned and integrated in terms of objectives and scope. As such, the assignments and project are described as follows:

Assignment 1: Storyline Development

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- Objective: To develop a compelling storyline around a problem and related solution in a construction project, incorporating design thinking, user-centric design, and lean construction principles.

Assignment 2: BIM Communication & Collaboration

- Objective: To simulate real-world BIM/Lean-based design and collaboration processes by assigning roles, establishing a communication plan, and managing design revisions within your group.

Assignment 3: VR Scene Development

- Objective: To translate the BIM/Lean model into a VR Scene, enhancing communication and understanding of the project.

Assignment 4: Computer Vision Integration

- Objective: To explore the potential of computer vision to identify lean waste (e.g., waiting time, rework, unnecessary transportation) in construction by extracting information from a video and integrating it into the VR Scene.

Final Project: Project Summary and Future Improvement Plan

- Objective: To synthesize the work throughout the course and propose innovative improvements using robotics and other advanced technologies.

Tutorials will be run on a weekly basis and will provide the necessary technology-driven skills for students to complete the assignments and final project. In any case, the pedagogical strategy in this course is to make the technology development as smooth as possible and not necessarily central to students. Instead, it is envisaged to provide tools and aids to design and plan the implementation of smart digital technologies in unison with Lean Construction and people and culture in order to understand the key points of implementation that then can be outsourced by specialists (e.g., software engineers, electrical engineers, mechanical engineers, graphic designers).

Term Work

All term work solutions will be posted no later than the last day of classes. All term work will be returned to students by the final day of classes, with the exception of major term work due in the last week of classes. The latter will be returned by the day of the final examination or the last day of the examination period if there is no final examination in the course as per university policy; instructors will make accommodations to return these term work.

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Accommodation Requirements:

Accommodation support is available to remove barriers for eligible students who encounter limitations or restrictions to their ability to perform the necessary coursework as defined by the University of Alberta regulations. For assistance, visit the Student Success Center and Course Accommodations web pages.

Grading guide:

The University of Alberta employs a letter-based grading system on a four-point scale to evaluate student performance. This system has been in place since 2003, replacing the previous nine-point scale, though records from before 2003 still reflect the older system.

In this framework, each letter grade corresponds to a specific grade point value, reflecting the instructor's assessment of a student's achievement in a course. For instance, an 'A+' is equivalent to a 4.0, indicating excellent performance, while a 'D' corresponds to a 1.0, representing minimal pass. An 'F' signifies failure, with a grade point value of 0.0.

Instructors assign these grades by evaluating raw scores, ranking assignments or exams by merit, and then determining the appropriate letter grade based on performance. This method ensures a standardized assessment across different courses and faculties.

Students and interested parties are encouraged to consult the official Assessment and Grading webpage for a comprehensive understanding of the grading system, including detailed grade descriptors and their implications.

Additional Notes:

Late submission is generally not allowed by the Canvas system; contact the TA in charge if you have special reasons for being late, and up to 50% penalty may apply to late submission within 24 hrs of the due time; Zero credit and self-mark after 24 hrs. Academic Integrity and AI Tool Usage Policy. In this course, our primary focus is cultivating an equitable, inclusive, and accessible learning community that emphasizes individual critical thinking and problem-solving skills. To ensure a fair and consistent learning experience for all students, the use of advanced AI tools such as ChatGPT or Dall-E 2 is strictly prohibited for all academic (written/coding/creative/etc.) work, assignments, and assessments in this course. Each student

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is expected to complete all tasks without substantive assistance from others, including AI tools. Any use of AI tools in your academic work may result in academic penalties and be considered an act of cheating and a violation as outlined in the relevant sections of the University of Alberta (November 2022) Code of Student Behaviour.

Textbooks and References (recommended)

They are available at the University of Alberta Library in the online format (e-books) and on the Internet with the provided link.

González, V. A., Hamzeh, F., and Alarcón, L. F. (2022). Lean Construction 4.0: Driving a Digital Revolution of Production Management in the AEC Industry, Taylor and Francis.

Ballard, G. (2000a). *The Last Planner System of Production Control*. PhD Dissertation, School of Civil Engineering, Faculty of Engineering, The University of Birmingham, Birmingham, U.K. https://lean-construction-gcs.storage.googleapis.com/wp-content/uploads/2022/09/08152942/the-last-planner-system-of-production-control-ballard2000-dissertation.pdf

Sawhney, A., Riley, M. and Irizarry, J. (2020), Construction 4.0: An Innovation Platform for the Built Environment, Routledge, London, eBook ISBN: 9780429398100, doi: 10.1201/9780429398100.

Interaction Design Foundation (2018). The Basics of User Experience Design. https://bpb-eu-w2.wpmucdn.com/sites.aub.edu.lb/dist/c/13/files/2019/06/the-basics-of-ux-design.pdf

Koskela, L. (2000). An Exploration Towards a Production Theory and its Application to Construction. PhD Dissertation, VTT Building Technology, Helsinki University of Technology, Espoo, Finland. https://publications.vtt.fi/pdf/publications/2000/P408.pdf

LaValle, S.M. (2017). Virtual Reality: Cambridge University Press.

Spitler, L. & Talbot, L. 2017, 'Design Thinking as a Method of Improving Communication Efficacy.' In:, 25th Annual Conference of the International Group for Lean Construction. Heraklion, Greece, 9-12 Jul 2017. pp 437-444. http://www.iglc.net/Papers/Details/1370

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Note: Any material and links to guidelines associated with digital tools and methodologies used in this course will be delivered via Canvas and in the tutorial sessions.

Course Website: Canvas.

Modules

Date	Lecture Topic	Assignment/Project
Week 1/Sep 5	1.0 Introduction to the course 1.1 Nature of Production of AECO Projects 1.2 AECO Supply Chain 1.3 Brief Introduction to Lean Construction Principles, Theory and Tools	
Week 2/ Sept 12	2.1 AECO Industry Productivity and Digitalization Gap 2.2 Construction 4.0 Basics 2.3 Lean Construction 4.0 Basics	
Week 3/ Sept 19	3.1 Design Thinking 3.2 UX-Design 3.3 Synergies between Design Thinking, UX-design, and Lean Construction	Assignment 1
Week 4/ Sept 26	4.1 Introduction of the BIM Basics 4.2 Integration of BIM and Machine Learning in the AECO Industry 4.3 Integration of BIM and Lean Construction	
Week 5/ Oct 3	5.1 Extended Reality (XR) in Construction Engineering and Management 5.2 Scan to XR Workflow in AECO Projects 5.3 Integrating Serious Games into VR Simulation for AECO Projects	Assignment 2
Week 6/ Oct 10	5.4 Integrating SG, VR, and Lean Construction for AECO Projects 5.5 Integrating AR and Lean Construction for AECO Projects 5.6 Understanding the Socio-technical Nature of Projects Using VR Technology and Lean Construction for AECO Projects	
Week 7/ Oct 17	6.1 Internet of Things (IoT) Principles and Applications in the AECO Industry	Assignment 3

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	6.2 Computer Vision (CV) Principles and Applications in the AECO Industry 6.3 Digital Twinning (DT) Principles and Applications in the AECO Industry	
Week 8/ Oct 24	**Mid-term (1 hr)** 6.4 IoT and Lean Construction in AECO Projects 6.5 CV and Lean Construction in AECO Projects 6.6 DT and Lean Construction in AECO Projects	
Week 9/ Oct 31	7.1 Reliable Commitment Model 7.2 System Identification and Control Theory in AECO Project Production 7.3 Basics of Computer Simulation Modelling	Assignment 4
Week 10/ Nov 7	7.4 Linking CSM and Lean Construction Using Conceptual Modelling 7.5 Buffer Design and Management Modelling	
Reading Week/ Nov 10-14		
Week 11/ Nov 21	8.1 Basics of Robotics in Construction 8.2 Synergies between Robotics and Lean Construction	
Week 12/Nov 28	9.1 Example and guidelines to implement Lean Construction 4.0 in AECO Projects 9.2 The Future of Lean Construction 4.0	
Week 13/ Dec 5	**Course wrap up/Final Project**	

Did you know that the University of Alberta has various low-to-no-cost services to help students succeed? Visit http://www.deanofstudents.ualberta.ca/ for information about the academic, wellness, and various other support services available to U of A students. It's never too early or too late to seek help!