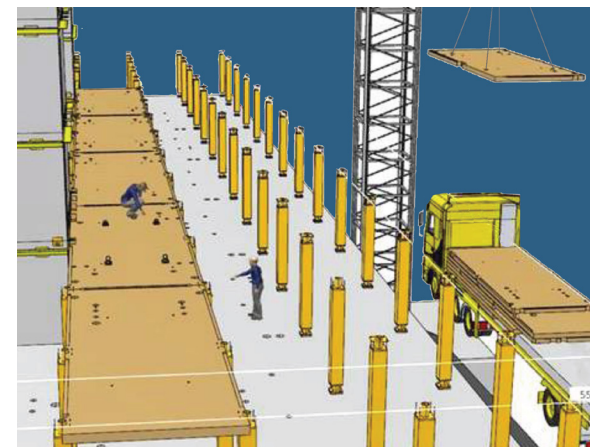
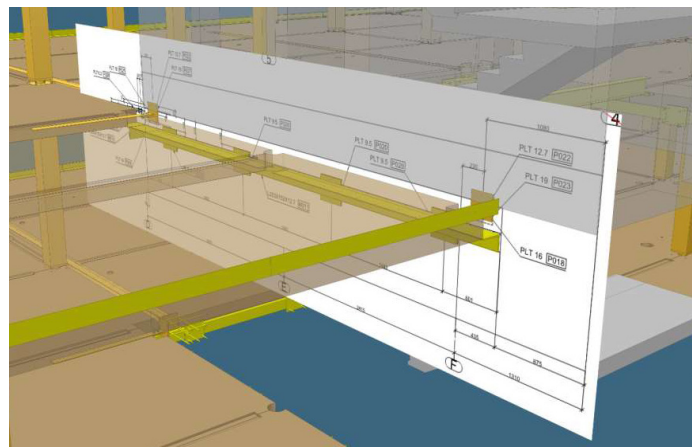
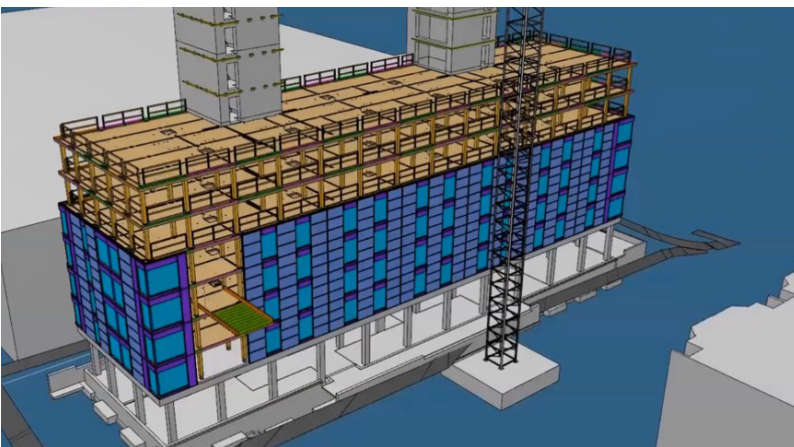


innovation in hybrid mass-timber construction

CONSTRUCTION OF A TALL WOOD BUILDING

# BROCK COMMONS TALLWOOD HOUSE: CONSTRUCTION MODELLING











## DIGITAL MODELLING

### VIRTUAL DESIGN AND CONSTRUCTION MODEL

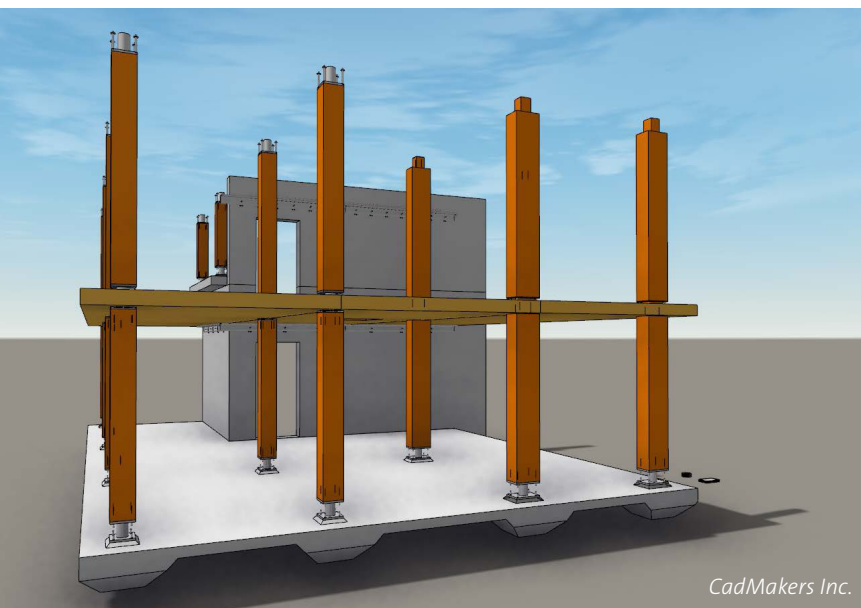
As part of Brock Commons' design and preconstruction phase, a virtual design and construction (VDC) model of the building was created. This VDC model was a comprehensive 3D model composed of all the building elements, from the structure to interior finishes to the mechanical and electrical systems.

CadMakers Inc., the dedicated VDC consultant, worked from the consultants' 2D drawings and 3D models concurrently with the development of the stamped construction documents. Every detail, including excavation, was included, along with precise geometries, so that any construction process could be animated and any element or set of components could be exported in various formats.

During the design phase, the VDC model's primary function was to assist in design development and decision making. The modellers worked in close collaboration with the design team, promptly incorporating design iterations and updates and notifying the team of any issues and conflicts that needed to be addressed, in order to ensure the model was

always accurate and detailed in its representation of the project. The VDC model also functioned as a tool for communicating with the construction trades prior to tender. It helped in describing the scope of work relative to the project as a whole and in demonstrating that the design, while innovative, was not complex or highly risky.

During preconstruction, the VDC model was used to create a full-size, proof-of-concept mock-up of part of two floors of the building. The mock-up helped to validate the VDC model, as well as the design decisions, with the help of feedback from the trades. It also provided an opportunity to study constructability and installation feasibility, test communication procedures for prefabrication, select installation equipment, and identify options for efficiencies. These experiences and knowledge informed the construction planning, including sequencing and prefabrication assembly packages. The VDC model was also the basis for the fabrication model that was used directly by the CNC machines for the CLT panel stress tests.

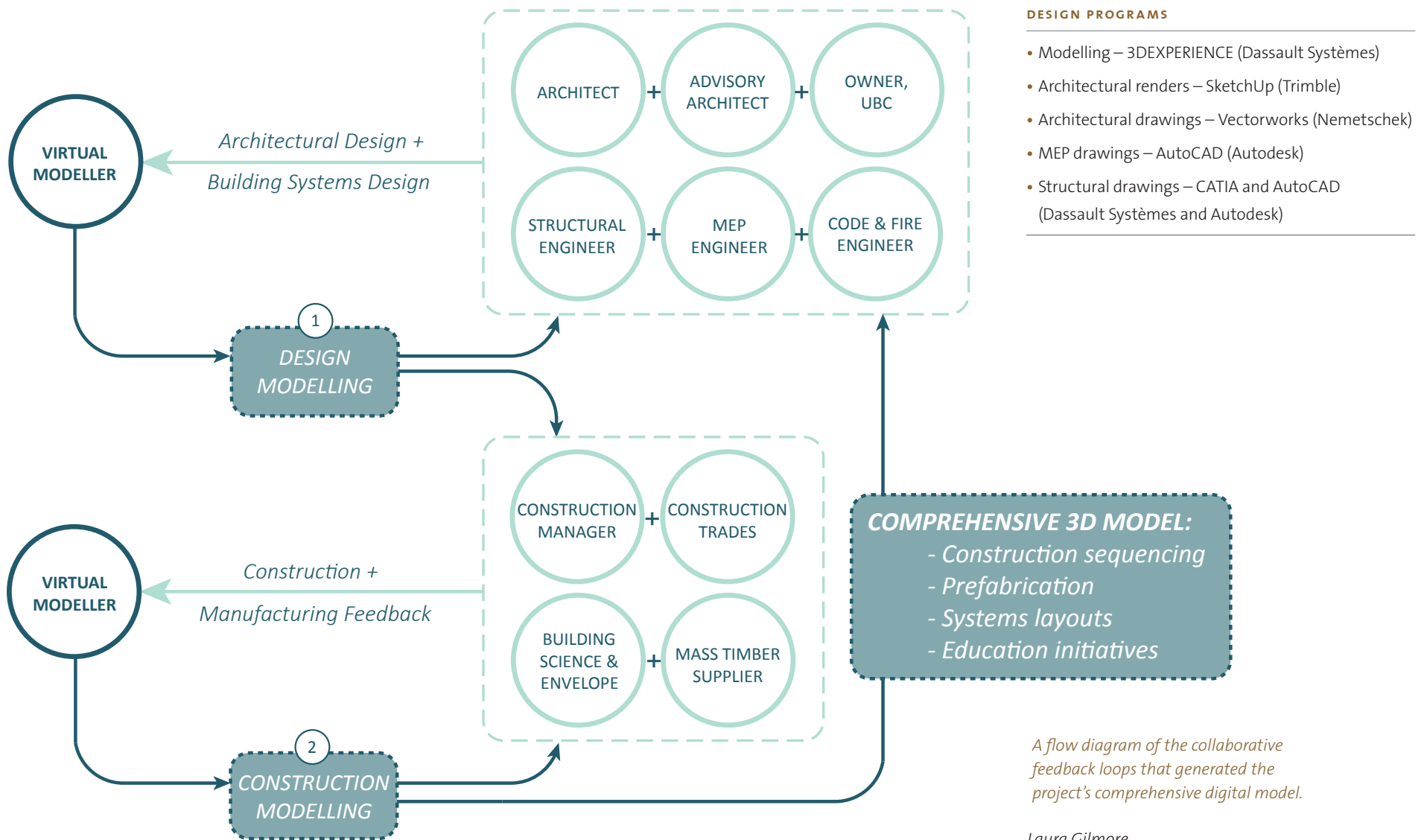


CadMakers Inc.



Urban One Builders





*A flow diagram of the collaborative feedback loops that generated the project's comprehensive digital model.*

*Laura Gilmore*

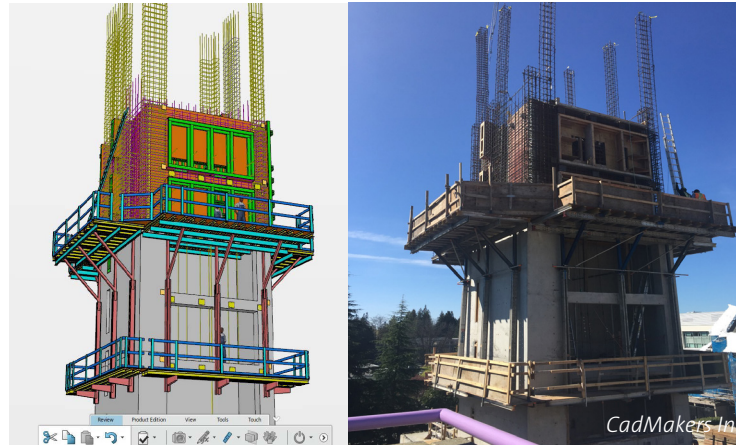


#### USE OF VDC MODEL IN CONSTRUCTION PLANNING

As the project owner, the University at the outset directly hired the VDC modelling firm to be a part of the project team, and the firm's modellers functioned as facilitators throughout design development and construction. The VDC modellers represented the owner's interest, rather than a specific discipline, and were empowered to contact the consultants and trades directly to request and coordinate details of the building elements and assembly. The communication between team members and the VDC modellers was constant and included formal reports which tracked design changes, as well as phone calls, emails, and coordination meetings. This approach enabled them to keep the model updated and address challenges and improvements throughout construction.

The VDC modellers worked closely with the construction manager, Urban One Builders, and the rest of the team, on the construction planning for Brock Commons. The schedule for the project was very aggressive, which, along with the small size of the site, placed importance on the coordination of the production, storage, delivery, and installation of all the building components. The planning was a highly collaborative process; it included input and feedback from all the specialized trades and personnel regarding the constructability and safety of building assemblies and the sequencing of specific activities.

As a key tool within the planning process, the VDC model was used to develop animated simulations that illustrated the sequences of installation and assembly outlined in the construction schedule. Also known as time-based construction modelling, these animations were highly detailed and based on 1-hour increments. Animation was essentially a virtual construction process for the building, which allowed the construction manager and the trades to work through the installation procedures in 3D and confirm their feasibility prior to actual construction.

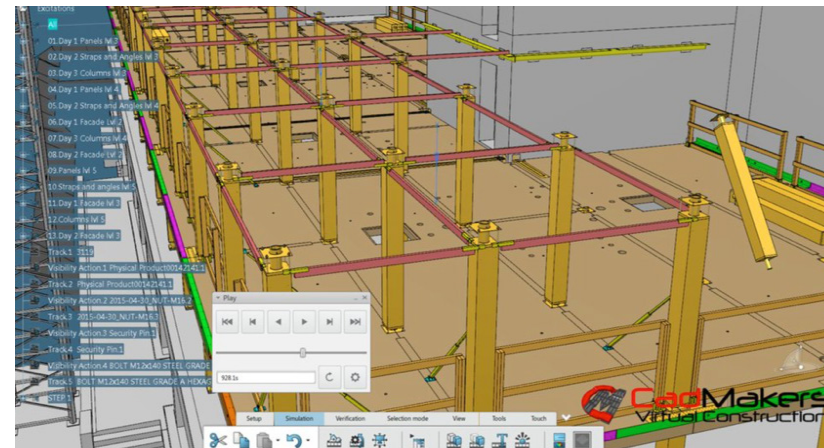
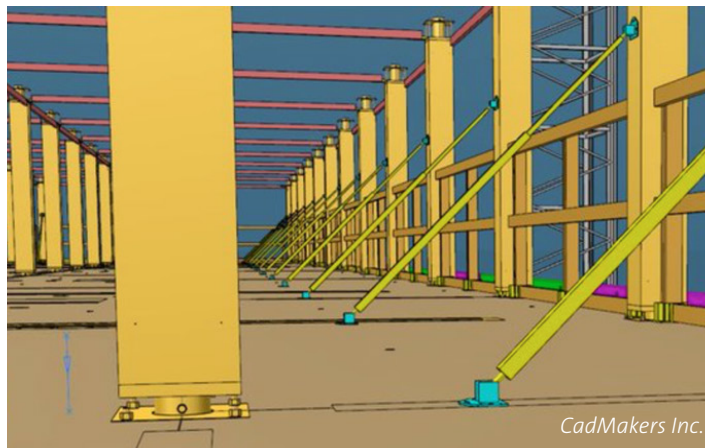
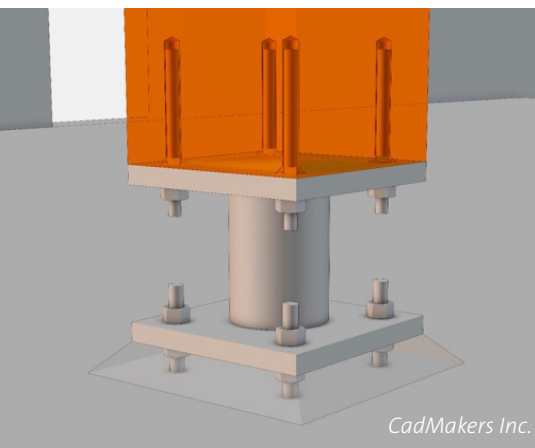


*Modelled and actual construction.*

Some assumptions about the time required to complete tasks, for example regarding crane speeds, had to be made prior to the beginning of construction, and these were included in the original schedule. However, over the course of construction, the modellers recalibrated the simulations to reflect the actual durations of activities as they became known, thus improving the planning and scheduling of the remainder of the work.

The model was also employed in financial planning through the development of rapid budget prototyping. Individual budgets were developed by the construction manager and the VDC modellers, with input from the design-assist trades, for each design decision point, using materials quantities from the model, and estimates of labour productivity and work-step durations. Due to the extensive detail available in the model it was possible to create accurate materials quantity estimates in real time. These budgets allowed different options to be analyzed and helped control the project's finances.







## PREFABRICATION

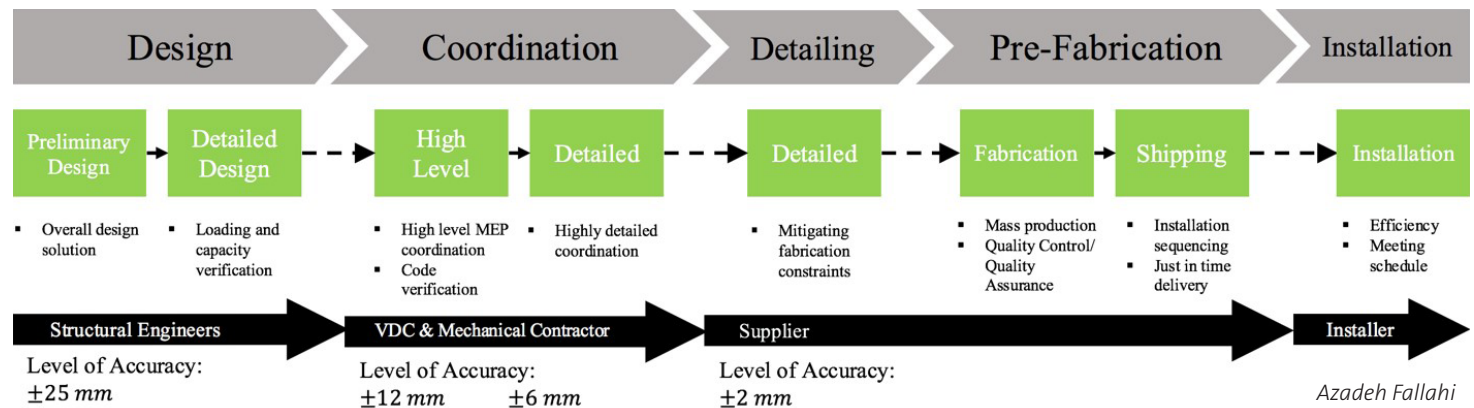
### USE OF VDC IN PREFABRICATION AND SYSTEM DESIGN

Prefabrication of structural and envelope components was a key strategy in meeting the project's timelines and budgets. The Brock Commons project used this type of construction approach—i.e., “kit-of-parts” prefabrication—to an extent not usually seen in high-rise residential building construction.

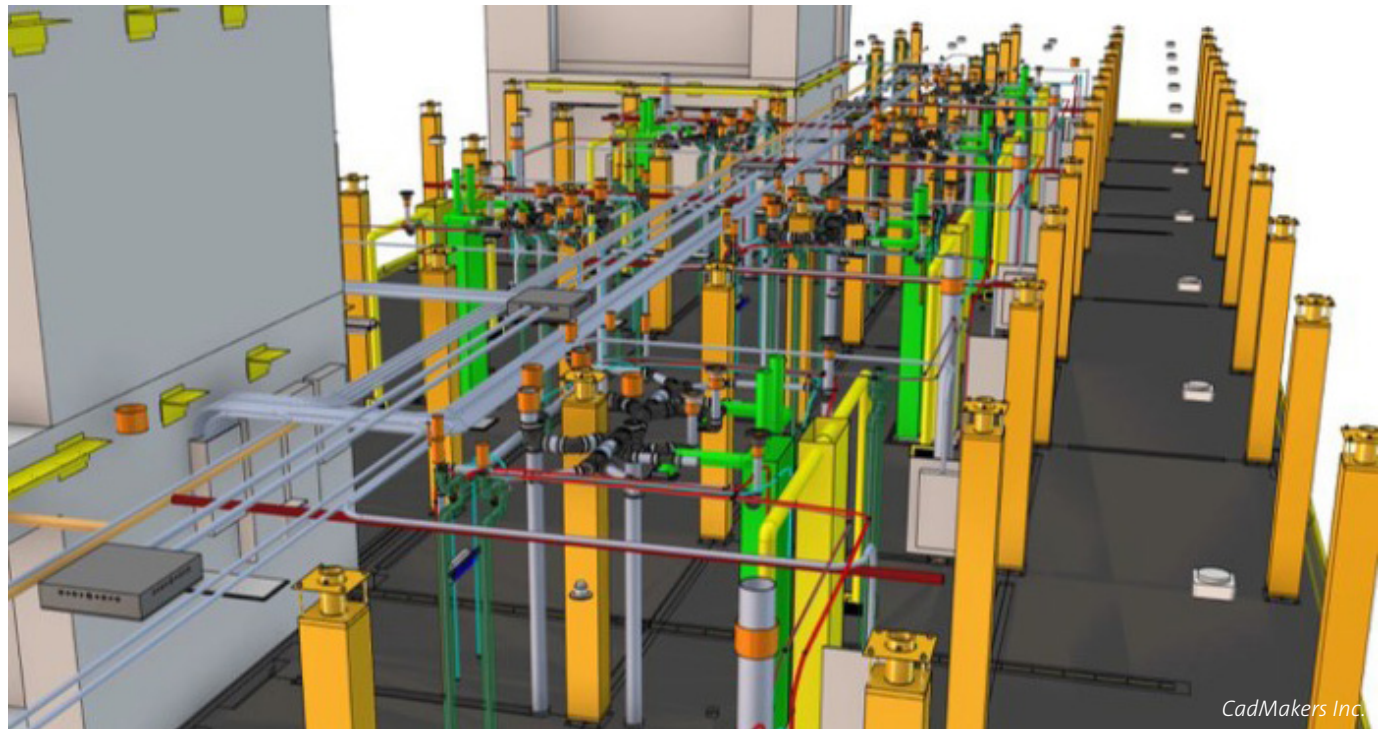
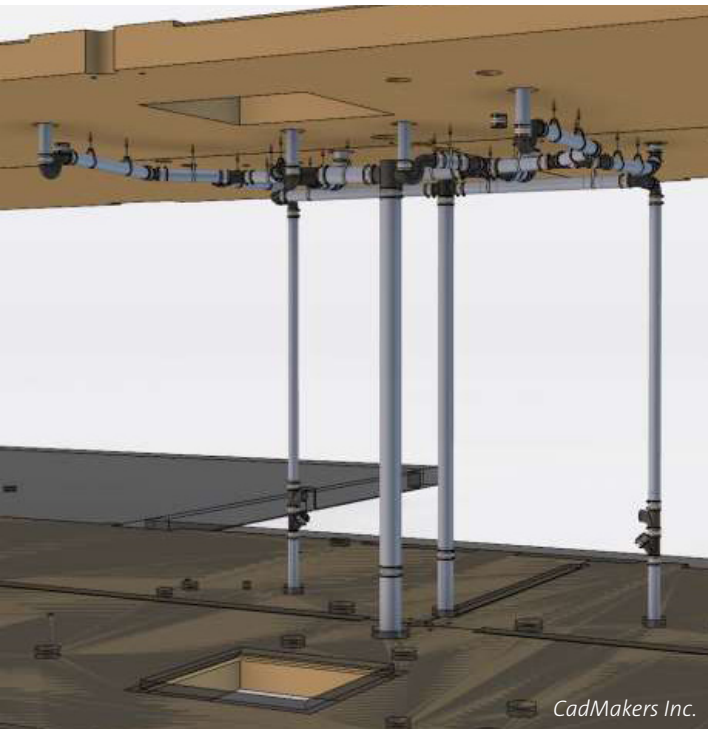
For the mass-timber structure, models of the specific components were generated from the VDC model and validated by the structural engineer and transferred directly to the mass-timber supplier, Structurlam Products LP. This included the wood elements—CLT panels, and PSL and GLT columns—as well as the steel connections and drag straps. The steel fabricator was subcontracted to the wood fabricator in order to streamline the process and achieve the tight tolerances. The supplier then modified the model to ensure the tight tolerances were achieved—while accommodating the mechanics of fabrication, such as saw thickness and drill-bit diameter—and then used the resulting fabrication model to operate the CNC machine to cut the pieces to size and drill the penetration holes. The tolerances for the mass-timber components were  $\pm 2$  mm, a requirement that would have been challenging to meet without the use of the VDC model.

The mechanical, electrical, and plumbing (MEP) systems on this project were included in the VDC model. Typically, engineers design these systems and their specifications but leave the spatial layouts to the construction trades to decide at the site in conjunction with the construction manager or general contractor. For Brock Commons, the VDC modellers worked with the engineers and the trades to fully design and model the layout of the MEP systems within the building.

This level of detail was required for the prefabrication of the CLT panels so the cutouts for each system penetration could be made during fabrication rather than on site. It also enabled the construction manager and trades to develop an accurate bill of materials and detail the sizes and dimensions of the system components to facilitate procurement, off-site preparation, and on-site assembly and installation. For example, the detailed modelling of the mechanical room enabled the cutting and welding of pieces to be done off site, thus reducing the on-site construction time from the typical 3 to 4 months to less than 1 month.







*Detailed modelling of the building systems, in coordination with the mass-timber structural elements.*







## CONSTRUCTION

### EFFECTS OF THE MODEL ON THE CONSTRUCTION PROCESS

The detailed planning and sequencing, along with the prefabrication of major elements, enabled the project team to meet an aggressive schedule: the concrete foundation, ground floor, and second-floor transfer slabs were completed in 3.5 months; the concrete stair and elevator cores were completed in 3.5 months; and the mass-timber structure, the steel roof, and the majority of the envelope were completed in about 3 months. Also, detailed planning, made possible by the VDC model, allowed construction processes to be standardized and streamlined.

Interdisciplinary cooperation among the project team during construction was critical. The VDC model was an important tool in facilitating communication between team members by giving everyone a common frame of reference. Construction planning, using the modelling of construction sequences, was a collaborative effort that helped to secure buy-in from the construction trades. The on-time performance required by the aggressive schedule was a challenge for some of the trades that were accustomed to more flexible timelines for on-site work. The trades' input not only helped ensure a realistic work plan and schedule, but also helped give them a sense of ownership in the project.

*The total construction duration of the 17 floors of mass-timber structure was less than 10 weeks, and the total duration of installation of 16 floors of envelope panels (excluding the ground-floor curtain wall) was less than 9 weeks.*

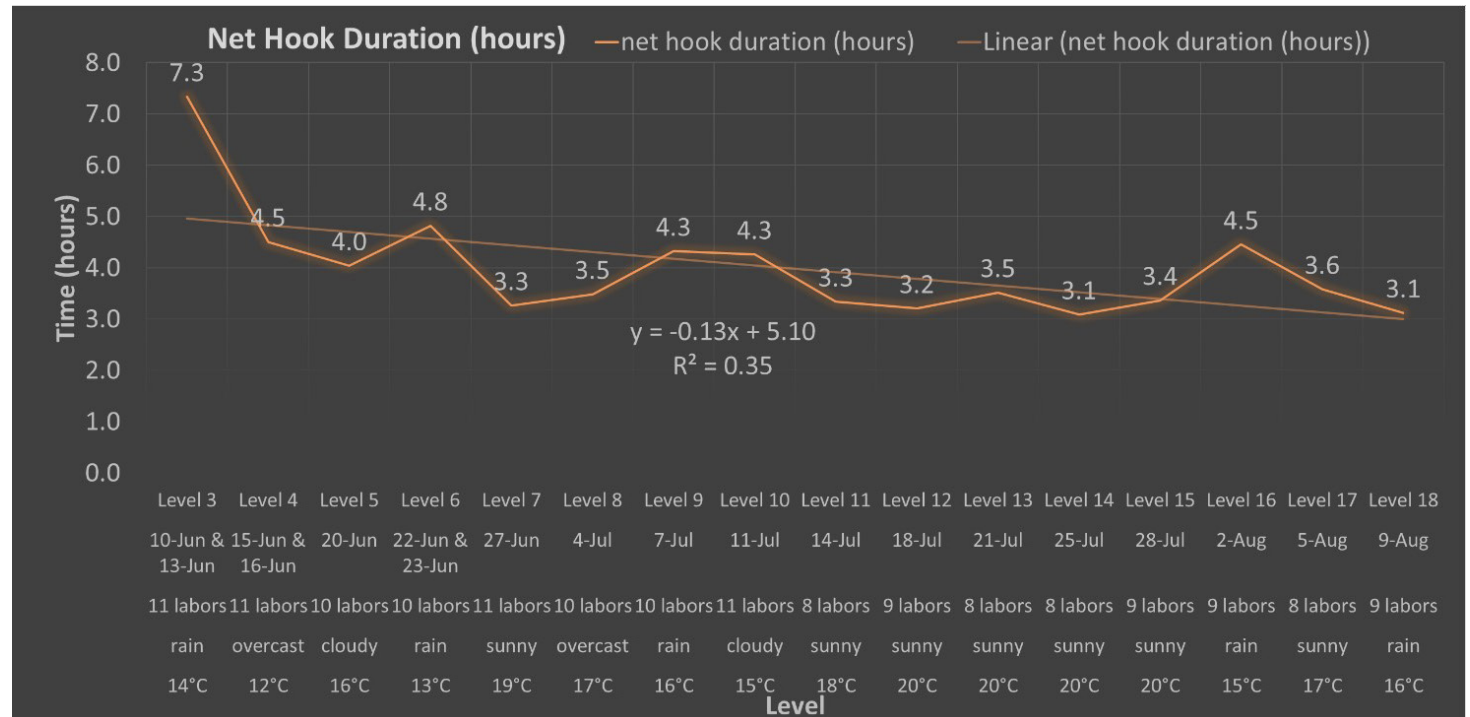


Azadeh Fallahi

As part of the sequencing, the prefabricated components were sorted and loaded onto trucks to minimize on-site handling. Thus when a truck reached the construction site, the components could be craned out in the required order and directly installed on the building or positioned in staging areas on each floor. The model helped the construction team visualize the work, establish the loading and installation order for the components, and facilitate the coordination between the different crews on site.

The repetition of the structural and envelope design on each floor and the use of a standardized installation sequence also contributed to the trades' learning efficiencies as the project progressed. For example, based on a productivity analysis of hook time, the first floor of CLT panels (floor 3) took 7.3 crane hours to install, while the last floor (floor 18) took 3.1 crane hours. And, the first floor of residential envelope cladding (floor 2) took 12.7 crane hours to install, while floor 15 took only 4.4 crane hours.

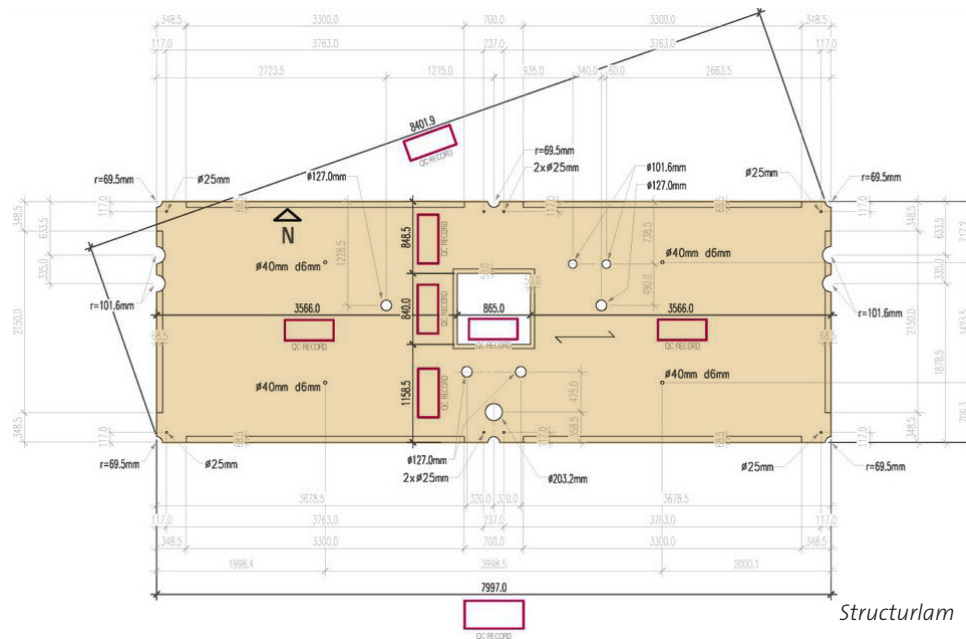
*Analysis of on-site productivity by measuring hook time—the duration of one cycle of the crane used to deliver materials to the floors. During the mass-timber construction there was a total of 464 crane cycles, or 29 cycles per floor. Variation typically corresponded to changes in weather conditions, the number of workers and their level of familiarity with the process, and, in two cases, instances of rework. By Mohamded Kasbar.*





Prefabrication and just-in-time delivery decreased the extent of on-site assembly time, which was somewhat complex because of the limited size of the construction site. These processes also improved the quality and precision of the components, productivity of fabrication, and overall safety for the trades because the detailed work and critical tasks could be completed in the controlled environment of the factory rather than on site by workers at significant heights in variable conditions. Prefabrication also reduced waste, both on and off site, because the specific sizes and dimensions of components were determined in advance by means of the VDC model and the components were made or cut to the tight specific specifications, with limited trial and error being necessary.

*The model was sent to the fabricator in an STP file format. STP is a simple geometric file that can be utilized by different software programs. The VDC modeller used CATIA, and the fabrication process used Cadwork Wood.*



## LESSONS LEARNED

The VDC model facilitated planning and communication throughout multiple aspects of the design and preconstruction phase and the construction phase because it provided a comprehensive, accurate, and highly detailed representation of the building.

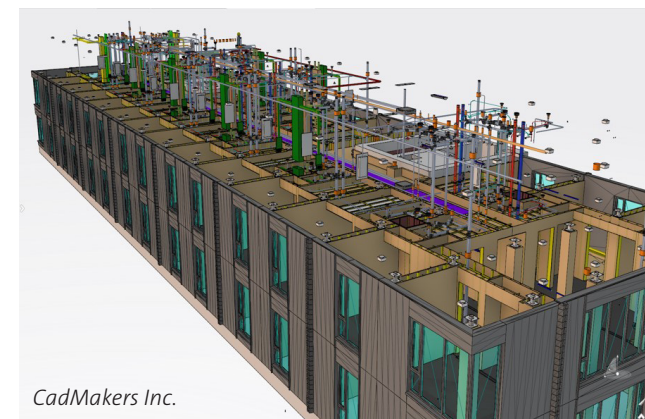
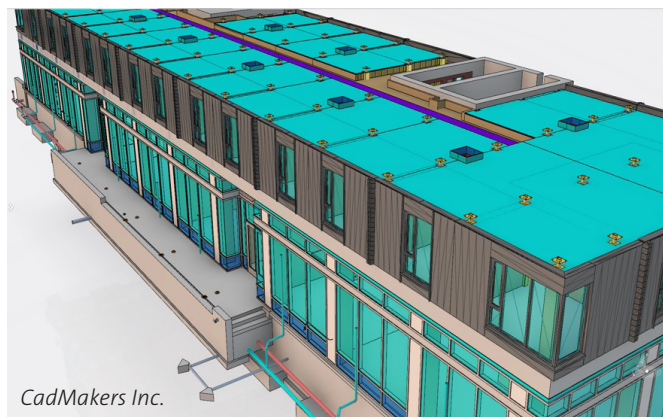
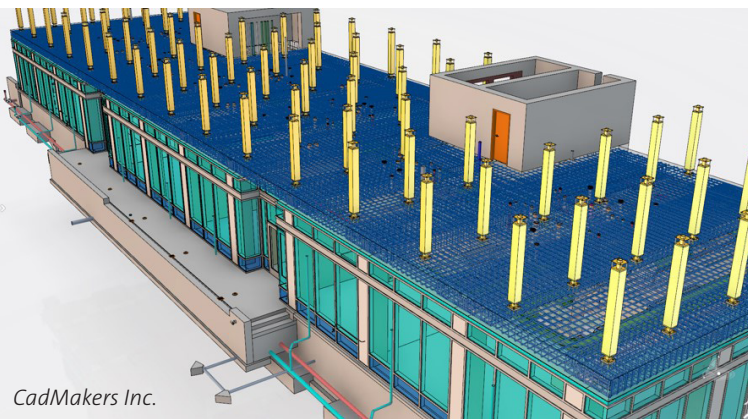
The owner empowered the VDC modellers to collect information from the entire project team, and act as facilitators through the entire project.

- The VDC modellers worked directly with the consultants and trades to understand the building design, the constructability and safety issues, and the installation processes, and to identify areas of potential clashes or improvements.
- The model was kept up to date throughout the construction phase by incorporating design changes in the drawings, site instructions, requests for information responses, approved shop drawings, and as-built deviations.

The use of the VDC model helped minimize issues related to communications among the construction crews—e.g., crew positioning and activities, types of required equipment, and understanding the various roles within the larger process—which allowed the construction manager to focus on other matters, such as identifying opportunities to improve construction efficiency.

Use of the single primary model as the basis for prefabrication design and coordination was key to making the rapid assembly process possible.

- The MEP contractors created a detailed design layout for the building systems with the VDC modellers prior to the fabrication. This design helped inform the locations and sizes of the cuts in the CLT panels during prefabrication, thus ensuring all the components would fit together correctly.
- The VDC model was transferred directly to the mass-timber fabricator to use in the prefabrication of the CLT panels and GLT/PSL columns—with all the specific dimensions, cuts, and penetrations included in the file—thereby minimizing on-site work and rework.
- The construction manager utilized the VDC model to create the installation sequencing and procedures, including the grouping and shipping of elements to the construction site, in order to optimize the use of the crane and the crews.





## CASE STUDY

This case study was prepared by the University of British Columbia's Centre for Interactive Research on Sustainability. The contributors are:

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## OWNER'S REPRESENTATIVE

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## PROJECT MANAGER

UBC Properties Trust

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## TALL WOOD ADVISOR

Architekten Hermann Kaufmann ZT GmbH

## STRUCTURAL ENGINEER

Fast + Epp

MECHANICAL, ELECTRICAL, FIRE PROTECTION  
ENGINEER / LEED CONSULTANT  
Stantec

## BUILDING CODE &amp; FIRE ENGINEERING

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## BUILDING ENVELOPE &amp; BUILDING SCIENCES

RDH Building Science Inc.

## ACOUSTICAL ENGINEER

RWDI AIR Inc.

## CIVIL ENGINEER

Kamps Engineering Ltd.

## LANDSCAPE ARCHITECT

Hapa Collaborative

BUILDING ENERGY MODELLING  
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VIRTUAL DESIGN & CONSTRUCTION  
MODELLERS  
CadMakers Inc.

## CONSTRUCTION MANAGER

Urban One Builders

## DESIGN-ASSIST TRADES

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Seagate Structures  
Whitewater Concrete Ltd.  
Trotter & Morton Building Technologies

## COMMISSIONING CONSULTANT

Zenith Commissioning Consulting

## TIMBER ERECTOR

Seagate Structures

## TIMBER SUPPLIER

Structurlam Products LP

## CONCRETE TRADE

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## CONCRETE SUPPLIER

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## STEEL REINFORCING

LMS Reinforcing Steel Group

## STEEL SUPPLIER

Bar None Metalworks Inc.

## BUILDING ENVELOPE FABRICATOR

Centura Building Systems Ltd.

## ROOFING TRADE

Raven Metapro Systems Ltd.

## MECHANICAL TRADE

Trotter & Morton Building Technologies

## ELECTRICAL

Protec Installations Group

## DRYWALL

Power Drywall Ltd.

## IMAGE CREDITS

## PHOTOS

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Acton Ostry Architects Inc.  
Urban One Builders  
Structurlam Products LP  
UBC Research Team

## RENDERS

CadMakers Inc.

## DIAGRAMS

UBC Research Team  
UBC Centre for Interactive Research on Sustainability

## OTHER RESOURCES (DESIGN, PRECONSTRUCTION, AND CONSTRUCTION PHASES)

Brock Commons Phase 1: Overview Case Study  
Brock Commons Phase 1: Code Compliance Case Study  
Brock Commons Phase 1: Design Modelling Case Study

Brock Commons Tallwood House: Construction Overview  
Case Study  
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