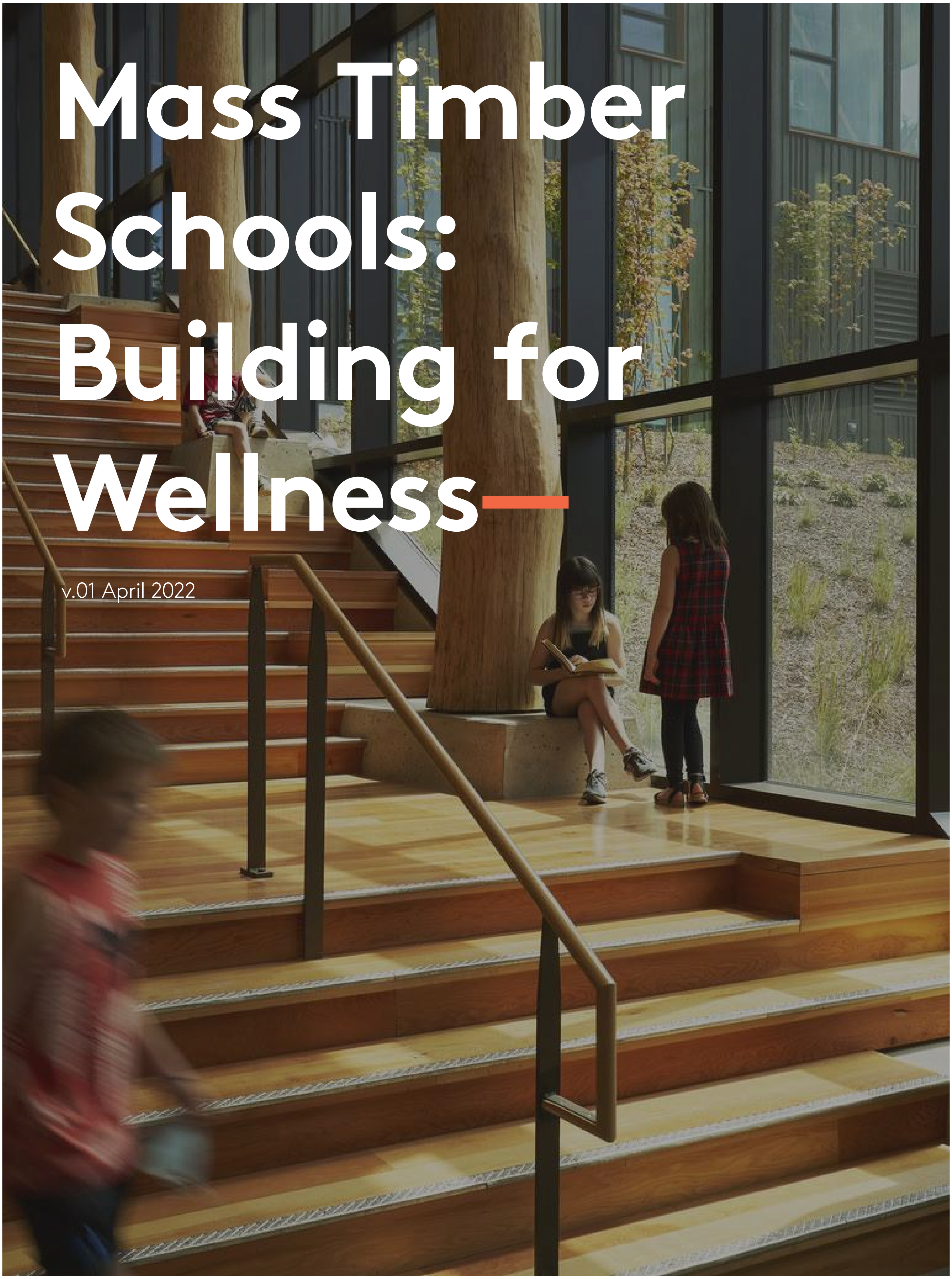

Mass Timber Schools: Building for Wellness—

v.01 April 2022

This research and report was sponsored by Mithun's Research and Development Initiative in partnership with Bayley Construction and PCS Structural Engineers. The information included in the report is based on literature reviews, existing case study review, and analysis of optimzing prefabricated mass timber products for K-12 schools.

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Executive Summary

Mass Timber Schools: Building for Wellness—

v.01 December 2021

This document highlights some of the myriad reasons why the mass timber movement in the US is growing exponentially, and why it is especially attractive for K-12 educational facilities. And, most importantly, the research demonstrates that by working fully within the design parameters of mass timber to minimize wood fiber, a 3-ply CLT solution can maximize value, minimize carbon, improve learning outcomes and be built within costs that are on par, or potentially less, than building schools with more conventional structural systems.

Why—

Mass timber as a primary construction material has many benefits. In the current market, it is cost competitive to other conventional building materials such as concrete or steel, but it begins to provide more benefits in terms of speed of construction and site logistics. In addition, when harvested responsibly from sustainably-managed forests, mass timber has a significant reduction in embodied carbon, up to about 200% compared to a steel-framed baseline.

Most importantly, there is a growing body of research that proves wood has inherent biophilic qualities that have an overall positive impact on students, teachers and staff. It has the ability to increase productivity, reduce stress, and improve overall well-being.

What—

Historically, wood's use as a construction material, while extensive, was largely limited to light-frame buildings. Typical light-frame construction features 2-by-4's and 2-by-6's as wall supports, wood joists as floor supports and wood rafters or trusses as a roof assembly.

Now, the use of wood in construction is shifting with the game-changing introduction of mass timber in North America. Public and private institutions, developers, architects and engineers, builders, the forest industry and community leaders are equally excited about mass timber's revolutionary potential in building construction. And rightly so.

How—

Schools have the opportunity to adopt a mass timber kit-of-parts for their next ground-up project, expansion or portable replacement that is both customizable and adaptable to suit a variety of learning pedagogies.

The kit-of-parts uses a framework derived from an optimized balance of efficient timber fiber volumes and classroom program. It involves an integrated systems approach between architecture, structure and mechanical systems to achieve the best learning environment for students.

Mithun Research + Development—

Mithun R+D is grounded in the firm mission — Design for Positive Change — seeking to advance design knowledge and its application. Through internal project research, external partnerships, and intellectual research pursuits, Mithun R+D transforms projects and design with meaningful inquiry and exploration. In 2016, R+D efforts were formalized within the practice to further the mission of the firm. Mithun R+D is an overarching entity that supports and guides the integration of research and development into projects, design process and culture.

MITHŪN BAYLEY PCS Structural Solutions METRIX ENGINEERS
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There is a growing body of research that associates biophilic spaces with student health and cognitive benefits.

+

Emerging mass timber technology is positively impacting the way we design and construct buildings.

=

By combining timber technology and growing biophilic research, we can Build Better Schools.

Benefits of Mass Timber in Schools—

Mass Timber has many benefits to offer school districts, students and teachers. This section distills collected research that suggests positive biophilic impacts on children, proven improvements to interior environments, and construction advantages of pre-fabrication for districts.

Mass Timber Benefits in Schools

The Human Factors

- Creativity
- Well-Being
- Physiological Benefits
- Focus and Mood
- Stress Reduction
- Student Performance
- Productivity of Teachers and Staff

Improved Physical Environment

- Healthier Buildings
- Contaminated Surfaces
- Virus Protection
- Volatile Organic Compounds

Environmental Benefits

- Operational Costs
- Biogenic Carbon Storage
- Embodied Carbon Footprint

Advantages to School Districts

- Schedule
- Site Impacts
- Safety
- Long Term Flexibility
- Curriculum Alignment & Teaching Opportunities
- Spatial Alignment with Teaching Best Practices

The Human Factor: Biophilia

The fundamental elementary school design problem asks: What environment optimizes cognitive function – learning, memory, emotion, communication, and social intelligence – in a developing child?

The modern field of neuroscience affords new opportunities to address this question through the creation of environments motivated by our understanding of human brain organization and functions, and principles of the neuronal information processing[2]. Perhaps the most pressing application for this new knowledge should be how we design learning environment since the future of human civilization surely rests upon the successful education of our children.

In the developed world, we spend about 90% of our time indoors.[3]

It's important then to get the indoor climate right. This means looking at everything from air quality, hygiene, humidity, temperatures and even the touch and feel of the materials that surround us. All of these aspects affect us in our day to day indoor lives. An increasing amount of evidence shows that wood has beneficial effects in almost all parts of the indoor climate. It helps reduce stress, blood pressure and heart-rate as well as allowing for more creativity and productivity in the workplace.[4] Wood is also an important part of what's called biophilic design; our desire to be connected with the natural environment.

Incorporating natural elements into the built environment, where people spend most of their time, contributes to human wellbeing.[5]

Most of us feel that wood creates a sense of warmth. The smell, touch and feel are regarded as pleasant and many people have generally positive associations with wood. That's the result of a 2017 study[6] of both building experts and members of the public in five different countries. In a separate Finnish study[7], natural and smooth wooden surfaces were found to be more pleasant than coated ones. The 2014 study[8] mentioned above showed that viewing or occupying a natural environment, even for a short period, has a positive effect on the mood and the human body.

Children with access to nature exhibit lower levels of stress than those without[9]; children in day-lit classrooms have test scores 7-18% higher while children without daylight saw test scores drop by 17%.[10]

Similarly, exposure to wood in indoor environments invokes positive biophilic responses. Many people feel innately better in an interior wood environment, associating wood with nature, warmth, and health[11a], and maintain a preference for wood versus other materials[12]. Preliminary research shows wood surfaces reduce activation of the sympathetic nervous system[13], helping to calm the body before the onset of stress.

2 Kandel, E. R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., and Mack, S. 2012.

3 Roberts, T. 2016

4 Ikei, H., Song, C. & Miyazaki, Y. Physiological effects of wood on humans: a review. J Wood Sci 63, 1–23 (2017).

5 Yin, J., Yuan, J., Arfaei, N., Catalano, P. J., Allen, J. G., and Spengler, J. D. (2020).

6 Strobel, K., Nyrud, A. Q., &; Bysheim, K. (2017).

7 Bhatta, S. R., Tiippana, K., Vahtikari, K., Hughes, M.,and Kyttä, M. (2017).

8 Beute, F., &; de Kort, Y. A. W. (2014).

9 Zingerle P., Beikircher W., Philippe M., 2015:

10 Strobel, K., Nyrud, A. Q., and Bysheim, K. (2017).

11 Rametsteiner, E., Oberwimmer, R., Gschwandtl, I. Poland. 2007, as cited in Nyrud, Anders Q. and Bringslimark, Tina. 2010

12 Pakarinen, T. 1999, as cited in Nyrud, Anders Q. and Bringslimark, Tina. 2010

13 Fell, D. (n.d.). Wood &Human Health Series

Trees elicit positive biophilic responses. School interiors that feature wood and bring nature indoors can provoke a similar positive psychological response.[1]

1 Alapieti, T., Mikkola, R., Pasanen, P., and Salonen, H. (2020)

The Human Factor

Creativity

In recent years, different research groups have come up with the same conclusion:

Wood grain as a texture positively influences creativity.

The most recent evidence comes from a 2019 Slovakian study [14] where people were tested in different simulated living room environments. The surroundings that had the most positive effect on creativity were the ones using both warm and cold colors as well as natural materials such as wood and textiles. These surroundings also had the most positive effect on problem solving capability, understanding and thinking ability.

Physiological

The studies on stress and wellbeing are also in line with additional studies on blood pressure and heart-rate. Several studies show that blood pressure and heart-rate go down for people living and working in wooden buildings. For example, a one-year Austrian study[16] compared fifty-two high-school students in a school fitted with two kinds of classrooms. One of the classrooms had linoleum floors and plasterboard walls while the others were wooden classrooms.

Students in the wooden classrooms have significantly lower heart rates and a lower perception of stress.

Other studies have shown lower blood pressure and higher concentration levels in wooden schools.

Productivity

An online survey of 1,000 Australian employees working in buildings studied focus.

It showed that employees were better able to focus when they were surrounded by wood.[19]

Their mood and productivity improved also. When the building included other parts of the natural environment, satisfaction went up even more. This included using plants, natural light and tables or chairs made of wood. Visible wood led to a connection with nature and triggered positive associations in the workplace. With an increasing amount of visible wood surfaces, the subjects stated that they could think more clearly and deal better with problems. Their stress levels also decreased.

Well-being

Perhaps one of the areas with the most comprehensive research is within mental wellbeing.

In short, natural environments and wood in particular help reduce stress and improve wellbeing.

Stress Reduction

A study conducted in British Columbia provides evidence that wood surfaces in an office lower the body's sympathetic nervous system (decreasing blood pressure and heart rate), thereby reducing stress.[15] Cumulative evidence from studies examining the psychophysiological effects on occupants of wood indoor environments shows that

Wood can contribute to stress reduction or recovery from stress.

Focus & Mood

A number of studies have researched the impact of wood upon the body and mind.[17] Dr. Yuki Kawamura , a researcher at Sumitomo Forestry Research, measured various kinds of health responses to wood. [18] One experiment studied the effects of wood on the brain.

It found that wood produces higher alpha wave activity, indicating higher levels of relaxation.

During mentally demanding tasks, participants exposed to wood had more beta wave activity, which pointed to higher levels of focus.

Student Performance

Studies have shown the positive benefits that air, acoustics and daylight have on learning, but recent evidence suggests the material quality of a space also impacts the creation of healthy learning environments. When wood is used in finishes, environments are enriched both visually and tactilely.

Such complex environments have been shown to increase performance on intelligence tests. [20]

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14 Vavrinsky, Kotradyova, Svobodova, Kopani, Donoval, Sedlak, Subjak, Zavodnik 2019:

15 Lowe, G. (2020, December 17).

16 Grote, V., Avian, A., Frühwirth , M., Hillebrand, C., Köhldorfe, P., Messerschmidt, D., Verena, R., Schaumberger, K., Mayrhoffer, M., and Moser, M. (n.d.). Human Research Institut.

17 Wood and wellbeing: The connection between building materials and cognitive health. TerraMai Reclaimed Woods From Around the World. (2018, October 26).

18 Grote, V., Avian, A., Frühwirth , M., Hillebrand, C., Köhldorfe, P., Messerschmidt, D., Verena, R., Schaumberger, K., Mayrhoffer, M., and Moser, M. (n.d.). Human Research Institut.

19 Knox and Parry-Husbands, 2018: Pollinate Health Report

20 Mayo, Joe. How wood in schools can nourish learning. School Construction News. (2017)

Case Study: Focus and Mood

Green Street Academy

The experiment location is Green Street Academy, a Baltimore City public charter school, located at 125 Hilton Street in West Baltimore. [21]

The school has a reputation as an innovative teaching and learning environment where teachers use project-based learning and entrepreneurship opportunities to prepare students for sustainability-oriented careers. School leaders welcomed an inquiry-based study to improve student outcomes. The design team selected middle school Math classes as the focus for the study.

Control classroom #1: Traditional classroom size, gypsum wall finish, ACT ceiling finish, carpet floor finish, mini-blinds drawn

Control classroom #2 (biophilic): Traditional classroom size, gypsum wall finish, ACT ceiling finish, carpet floor finish, Biophilic additions include wall covering organic formed ceiling panels, patterned carpet, translucent roller shades that respond to sun levels.

Demographics at Green Street Academy

6-12	grades
857	students
29%	receive special education
97%	recieve free & reduced lunch
1%	Other
2%	Caucasian
97%	African American

Case Study Conditions

3 Biophilic Design Devices for Control Classroom #2:

- Views to Nature
- Biomorphic Forms & Patterns
- Dynamic & Diffused Lighting

Students felt significantly more positive in the biophilic classroom when compared to the control classroom regarding physical space, their enjoyment of math lessons, and their level of involvement. In biophilic classrooms, students claimed to feel: more relaxed, calm, better able to concentrate, easier to focus, and have more a purpose to learn.

Interview with Teachers

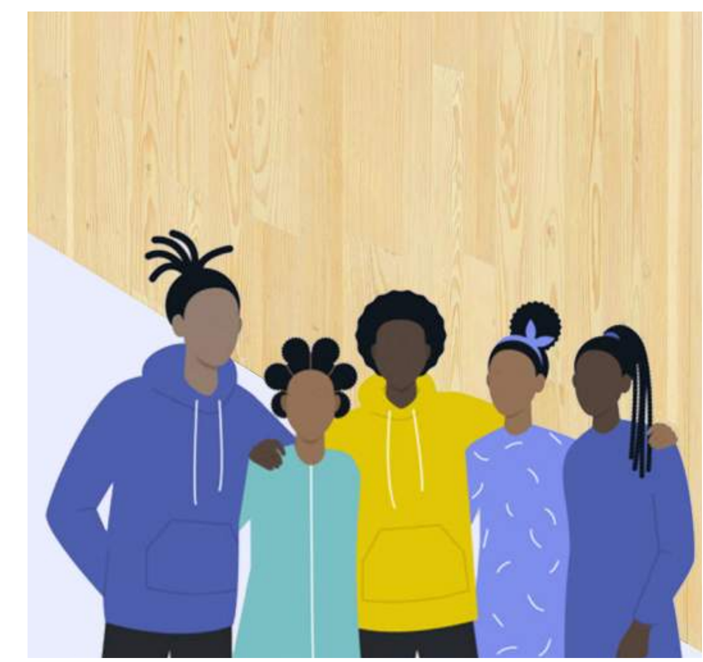
Did you notice anything different about the student behavior or mood?

"Their mood, it just seemed like they would come in a rush and frantic and chaotic. But then, after a while, they would just kind of calm themselves down. I mean, it could be attributed to the room, it could be the lighting in here, because everything is a little softer in here. Behavior - A lot of behavior shifts in the spring. I don't know if it's a hormonal thing or what it is but their behavior seems to shift in the spring. Sometimes for the better, sometimes it's just a little different but I think being in a setting where they are surrounded by a lack of chaos, a lack of clutter, just a lot extraneous stimuli. They kind of calm it down."

Do you think that this classroom makes you more effective as a teacher?

"Absolutely. Because I think the kids can sense my anxiety. Even with testing this year, I will say I've been teaching for a long time and the national test really causes me a lot of anxiety. This is probably the first year where I was not anxious at all for the testing. I don't even know what it was but I felt really comfortable watching them.

I was not anxious, I didn't have my nervousness waiting to see the results. I felt like this year, I was very effective teaching them."



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21 Determan, J.,Ackers, M., Albright, T., Browning,B., Martin-Dunlap., C, Archibald, P., Caruolo, V., (2019).

Case Study Continued: Stress Reduction

Heart Rate Variability (HRV)

HRV measures the variation between successive heartbeats. A heart rate is understood in terms of 60 and 90 beats per minute. During inhalation, heart rate speeds up and slows down during exhalation— hence, the heart rate varies between 55 and 65. HRV is the measure of this natural irregularity in the heart rate. Research has shown that HRV is a stress biomarker showing changes in the autonomic nervous system. Generally, less variability in the heartbeat (low HRV) indicates that a person is experiencing high levels of stress and when the HRV is high, this is an indication of less stress and higher resiliency.

Test Results

Green Street Academy uses the i-Ready test to understand the comprehension growth of Scholars in Math and Reading.[19] i-Ready Diagnostic is a validated test offering a complete picture of student performance and growth. By adapting to student responses and assessing a broad range of skills—including skills above and below a student's chronological grade—the i-Ready Diagnostic pinpoints student ability level, identifies the specific skills students need to learn to accelerate their growth, and charts a personalized learning path for each student. Based on Diagnostic results, i-Ready reports provide detailed information on student performance by domain and aggregates data for spotting trends across groups of students.

i-Ready tests were given throughout the 2018-2019 academic year in September, December and March. Each student was assessed with a numerical score and grade level. The Scholars' gain in math comprehension from September to December to March is the metric used in this study. A comparison of the average gain in test scores and gain in grade level between the biophilic classroom (2018-2019) and the control classroom (2017-2018) were used to determine if the biophilic enhancements made an impact on math performance.

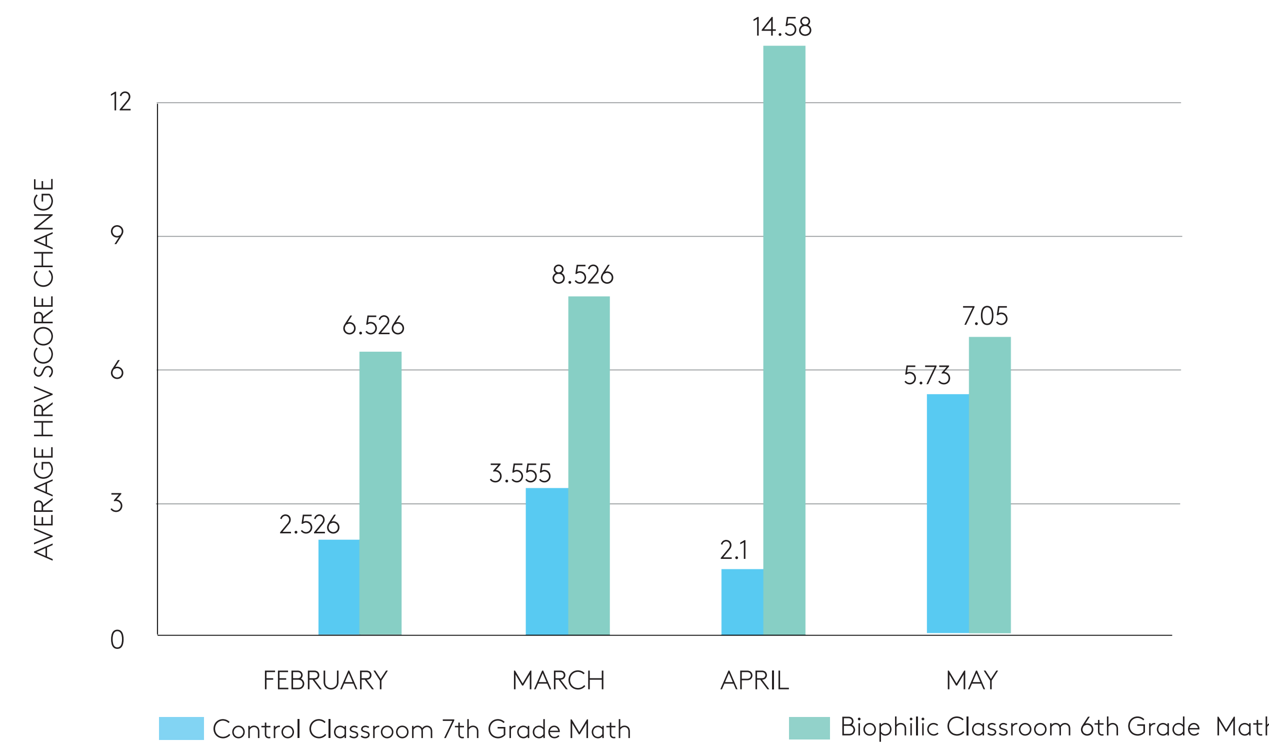
67% perceived high stress (high HRV) in the control classroom

35% perceived high stress (high HRV) in the biophilic classroom

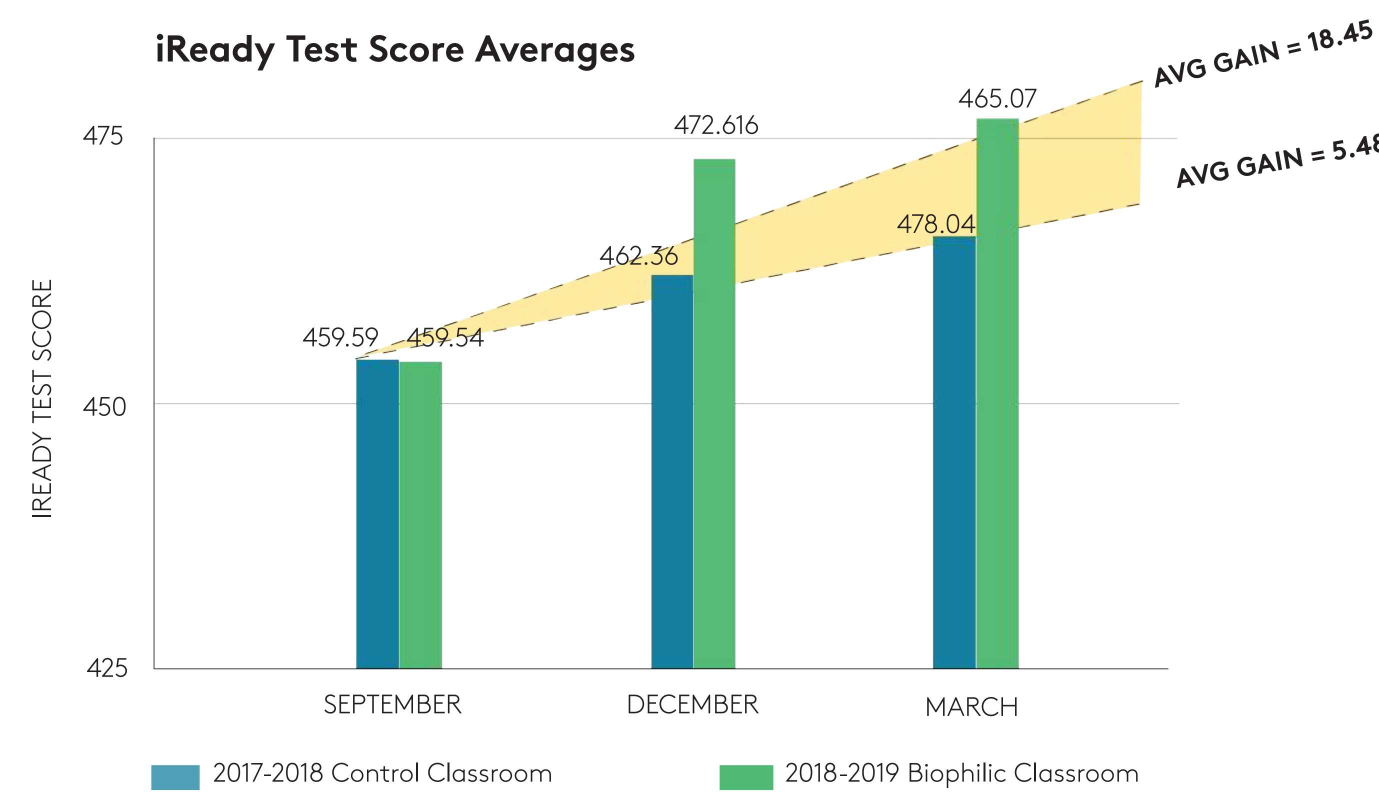
The gain in Average Test score is 3.3X higher in a Biophilic classroom.

22. *Determan, J.,Ackers, M., Albright, T., Browning,B., Martin-Dunlap., C, Archibald, P., Caruolo, V., (2019).*

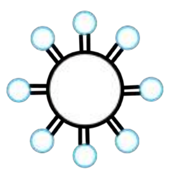
Average change in HRV scores per month



iReady Test Score Averages



On average, children spend seven hours in school per day[23]. That is 1,260 hours per year and 15,120 total hours in grades K-12, spending an average of 90% of time indoors.

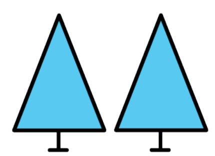


Coronavirus Protection

It turns out that if you want to avoid contracting the coronavirus, then you have a better chance in wooden environments than others.

Coronaviruses (SARS -CoV-2) applied to wooden surfaces can only be replicated for 12 hours.

On surfaces made of plastic, stainless steel, glass and masonry, the viruses remains multipliable for up to 96 hours. However, the 2020 study [24] that discovered these findings also noted that 'fresh contamination can also lead to smear infections on wooden surfaces and should therefore be disinfected and generally, applicable hygiene regulations should be considered.' In other words, just because the virus doesn't last as long on these surfaces, doesn't mean there is no risk of catching the virus on wood.



Human Natural Killer Cells

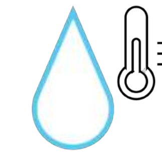
People exposed to the forest environment have enhanced human natural killer (NK) cell activity.

In Japan, the Nippon Medical School carried out a test exposing people to the essential oils from the Hinoki cypress tree. [25] Test persons were exposed to the oils with a humidifier for three nights in a hotel room. This resulted in a significant increase in NK activity. This activation of the NK cells is regarded as an indicator of a strengthened immune system. NK cells are cells of the immune system that recognise and destroy altered body cells.

Reduced Volatile Organic Compounds

Wood-based materials can reduce the amount of volatile organic compounds (VOCs) from interior spaces.

VOCs are gases that are emitted from all kinds of different materials. Some of these VOCs can be bad for your health. They can also be up to ten times higher in indoor environments compared with outdoor ones. Wood, like other materials can emit VOCs, but a 2013 study [26] showed that wood-based materials such as MDF, OSB and particle board adsorb at least 50% of these compounds. Adsorption is where a material acts as an adhesive and holds the gas molecules on its surface. The study concludes that "the gained results demonstrate their (wood-based materials) potential to reduce VOCs in indoor air." Current mass timber products utilize advanced adhesives to minimize off-gassing of VOC's. Declare labels are now provided for several CLT manufacturers, insuring their environmental responsibility.



Humidity Control

There is an ideal range for air humidity in indoor environments. Staying within these ranges (40% – 70% relative humidity) is important for health reasons. [27] Allergies, respiratory infections and even the spread of bacteria and viruses are kept to a minimum if humidity is kept within the correct range.

Wood can help in this regard, providing better moisture buffering compared with interior plaster. It means the air humidity can be kept in the ideal range for a longer period of time.

This was the result of a study [28] that compared two identical rooms, one covered with gypsum plaster and the other with various wooden surfaces. It was found that air humidity fluctuation was reduced by up to 70% in a room with untreated flat cladding boards, compared to the gypsum plaster. For cladding with round timber planks, the reduction was between 44% and 63%.

23 Craw, J. (2021, May 11).

24 Domig and Wimmer, 2020

25 Li, Q., Kobayashi, M., Wakayama, Y., Inagaki, H., Katsumata, M., Hirata, Y., Hirata, K., Shimizu, T., Kawada, T., Park, B. J., Ohira, T., Kagawa, T., &; Miyazaki, Y. (2009)

26 Niedermayer, S., Fürhapper, C., Nagl, S., Polleres, S., and Schober, K. P. (2013).

27 Bannister, M. (2021, August 1)

28 Lenz, Krus and Holm, 2005

Environmental Benefits

Carbon Footprint

Carbon emissions are recognized as the leading cause of climate change.[30] Projections suggest that we may experience an irreversible average increase in global temperature if 3 to 4 degrees Fahrenheit within 20 years, at the current rate of carbon release into the atmosphere.[31]

• Carbon emissions from the building sector are a major contributor to the climate change equation, far larger than either the transportation or industrial sectors. [32]

• The rapid development of mass timber products is creating more opportunities for the use of wood in place of steel and concrete in commercial and multifamily residential construction.

• Science is demonstrating that substituting wood for steel and concrete in construction can substantially reduce total carbon output and actually reduce existing carbon in the atmosphere through carbon sequestration.

• Time value of carbon: Embodied carbon represents greenhouse gas emissions (GHGs) at the start of the building's lifespan, which will remain in the atmosphere and affect the climate for decades before operational energy emissions reach and surpass the same levels.

Architecture 2030 has determined that "Embodied carbon will be responsible for almost half of total new construction emissions between now and 2050."[33]

30 NASA. (2021, August 30).

31 IPCC. (2021).

32 Architecture 2030. (2021).

33 Leskinen P, Cardellini G, González Garcia S, Hurmekoski E, Sathre R, Seppälä J, et al. 2018

Biogenic Carbon Storage

Forests are key to the Earth's natural carbon capture and storage system. As part of the photosynthesis process, trees take in carbon dioxide to create simple carbohydrates that can be used to nourish their existing cells or create new cells.

In the lower 48 states alone, forests store more than 14 billion metric tons of CO_2.[34]

The forest cycle can be thought of having three phases: carbon capture, carbon storage and carbon release. In the first phase of the cycle, a tree grows and uses carbon dioxide absorbed from the atmosphere as its building blocks. In the second phase, the tree is mature and no longer uses as much carbon for growth. In the third phase, the tree releases more carbon than it captures as it declines in health and parts of the tree begin to decay. As the tree dies however, a portion of the carbon remains stored in the soil. By taking advantage of this natural cycle, and harvesting young trees as part of well-managed forest production, carbon can be stored in durable, long lived mass timber products that continue storing carbon while in service.

One cubic meter of wood stores one ton of carbon dioxide.[35]

34 Mikola, M. (2021).

35 Why the building sector? Architecture 2030. (2021).

36 reThink Wood. (2015, April).

37 Himes, A., and Busby, G. (2020)

Embodied Carbon

Most processes involved in the extraction, manufacture, transport, and installation of building products rely on fossil fuels. The total amount of greenhouse gases emitted by a given product during this process is the up-front embodied carbon of that product. This can also be defined as Modules A1-A4 or "cradle to gate" in Whole Building Life Cycle Assessment.

Wood products have much lower embodied fossil energy content than concrete or steel because they require significantly less energy to produce.[36]

Additionally, biogenic carbon is represented as a negative number in embodied carbon accounting.

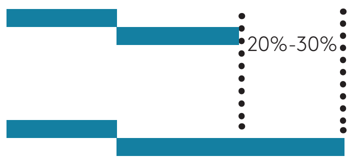
The amount of carbon sequestered in wood is typically more than the amount of carbon emitted to make the wood into a building product, resulting in a net negative embodied carbon footprint. [37]

The critical benefits of reduced embodied carbon are immediately achieved when a building is constructed.

Buildings are responsible for 39% of global energy related carbon emissions. 11% of that is embodied carbon from material extraction and construction. The industry is targeting 40% less embodied carbon by 2030.[29]

29 World Green Building Council. 2020

School District Advantages: Construction

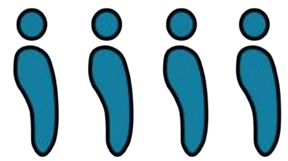


Schedule Reduction

Because the large mass timber elements are fabricated offsite in a factory environment, with extreme precision, the amount of time to construct mass timber projects is reduced significantly. This may vary from project to project.

Many studies have shown a reduction in construction schedule by approximately 25%.[39]

And due to the need for precise computer modeling of the structure, including careful machining of the mass timber connections and penetrations for mechanical, plumbing and electrical systems, the speed at which the mass timber elements are put together is astounding.



Safety

In a factory setting, there is a dramatic reduction of the hazards experienced on a construction site.[37] Worker safety is improved, and the likelihood of accidents decrease significantly. Prolonged exposure to extreme conditions, on an unshaded or freezing job site is stressful to human health and increases safety risks. Controlled temperatures, air quality and noise can be provided in a factory environment. According to research from the University of Utah,

"By moving to prefabrication, the construction industry and its workers can a experience a much safer environment by a factor of 2."[41]

European Precedent

A study of 100 mass timber buildings[40] in the UK showed **80% reduction in truck deliveries for the building structure 50 to 70 percent reduction of site staff for structural framing.**

Local Precedent

38,000 SF Carbon 12 building in Portland, OR

Only four carpenters were on site for the ten-week duration of structural erection for all eight stories.

Mass timber can increase the speed of construction and delivery by approximately 25%.[38]

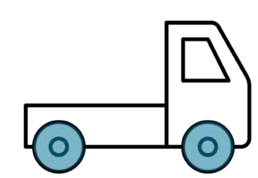
38 Think Wood. (2020, November 24).

39 reThink Wood. (n.d.). Mass timber in North America - AWC. Mass Timber in North America Expanding possibilities of Wood Building Design.

40 Waugh Thistleton Architects. (2018).

41 Blundell, S. (2019, November 15).

Photo: Bush School, Mass Ply Wood Panel (MPP) Installation; Mithun



Site Impacts

This new building approach not only leads to less time on site, but also significantly cuts down on local disruptions associated with construction such as increased traffic, lane closures and noise.

Smaller crews require fewer parking spaces, truck deliveries are minimized compared to other construction methods.

Because connections are primarily done with special screw fasteners, the construction sites are eerily quiet. Because the building's mass timber elements are premanufactured, and show up using a "just-in-time" delivery method, there is very little wood waste or on site storage required.

Precedent K-12 Mass Timber Projects

The Bush School New Upper School

Mithun; Seattle, Washington

20,000 SF; The structure utilizes mass plywood decking and panels to reduce embodied carbon and optimize efficiency. It is anticipated to be the first Passive House school on the West Coast.

Above: Bush School Rendering by Plomp

Left: Bush School Construction Photo, Fall 2021 by Mithun

Upper Right: Childcare Center Hoffeld with Binderholz CLT Mass Timber

Childcare Center Hoffeld

Aspangberg, St. Peter, Austria

Completed November 2018; +/- 7,000SF two-story childcare center using Binderholz CLT Mass Timber and BBS Solutions.

A growing number of Washington State School Districts continue to gain interest and experience building with mass timber.

- Renton School District
- Shoreline Public Schools
- The Bush School (Private, Seattle)
- Sequim School District
- Seattle Public Schools
- Mt Vernon School District
- West Valley School District
- Quillayute Valley School District
- Yakima School District

... and the list is growing!

School District Advantages: Teaching

Spatial Alignment with Teaching Best Practices

Designing physical learning environments that connect to indicators of effective educational practice reflects pedagogical commitment to student success, providing a framework for diverse audiences to think about spaces in a way that reflects shared goals, language and values.[42]

Jamieson et al. (2000) proposed a series of principles for developing learning spaces consistent with student-centered learning: spaces should be designed for multiple uses, maximizing their flexibility and considering how formerly discrete university functions and services may be integrated. Vertical height within the space is important to the user's perception and comfort. Classroom features and functionality should afford maximum control to teacher and student users. Students should also feel ownership of learning spaces, with expanded access and use.

42 Finkelstein, A., Ferris, J., Weston, C., and Winer, L. (2016).

Long Term Flexibility

New thinking around building materials and construction allows educators and students to match the features of their spaces to desired activities. The second part is that the process embeds meaning in the physical space, becoming the mechanism for constructing meaningful places.

Understanding spaces in two categories: narratives about the origin of the spaces and observations of the features and use of spaces provides insight into why spaces have meaning to teachers and students and how they become places. By observing movement and focus of teachers and students in the space, conclusions show how features of the designed space such as layout, openness, visibility, movement, and accessibility allow for more meaningful interactions and engagements.

Finally, understanding repurposing as a form of participatory design lends the perspective of infrastructuring as one mechanism that creates the capacity, connections, and sustainability for educational reform.[43]

43 Kalio, J. (2018).

Curriculum Alignment and Teaching Opportunities

Studies with adequate quality, sampling and statistical process to isolate and then evaluate the impact of different learning environment types presented evidence of a positive correlation between learning environments, and improvements in student academic achievement.

Studies on primary and secondary students in various learning environments including blended, innovative learning environment (ILE), open-plan and traditional, were completed at the University of Melbourne. The results show evidence that environments do have an impact on student learning outcomes. Outcomes were measured through computations of observed participation behaviors, a variety of standardized tests, general achievement tests, prior achievement data and participant surveys. The physical design of the environment (stimulation factors, light, air quality, and materials) showed to have the most impact to student outcomes.[44]

44. Byers, T., Mahat, M., Liu, K., Knock, A. & Imms, W. (2018).

What is
Mass Timber–

Mass Timber as a building material has gained significant traction in the United States in the last five to ten years. This section will outline the types of mass timber, local manufacturers in the Pacific Northwest and projected growth in the industry.

What is Mass Timber?

Mass timber uses state-of-the-art technology to glue or dowel small wood products together into large structural panels, posts, and beams. These strong and versatile products are known as mass timber.

Mass timber is not just one technology or product. It integrates a unique design process, offsite manufacturing technologies, and a construction process with dramatic improvements in efficiency.

Solid wood has been used for construction for millennia, but more recently the advancement of "Engineered Wood Products" has changed the building industry and offers new products and techniques with dramatic advantages over traditional design and construction methods.

Products in the mass timber family include cross-laminated timber (CLT), dowel-laminated timber (DLT), glue-laminated timber (Glulam), and mass plywood (MPP). Mass timber can be used in an array of applications and is the foundation for the mass timber building movement.

As of September 2021, 1,241 mass timber projects have been constructed or are in design in all 50 states.[45]

45 Building trends: Mass timber. WoodWorks. (n.d.).

CLT

Cross Laminated Timber

GLULAM

Glue Laminated Timber

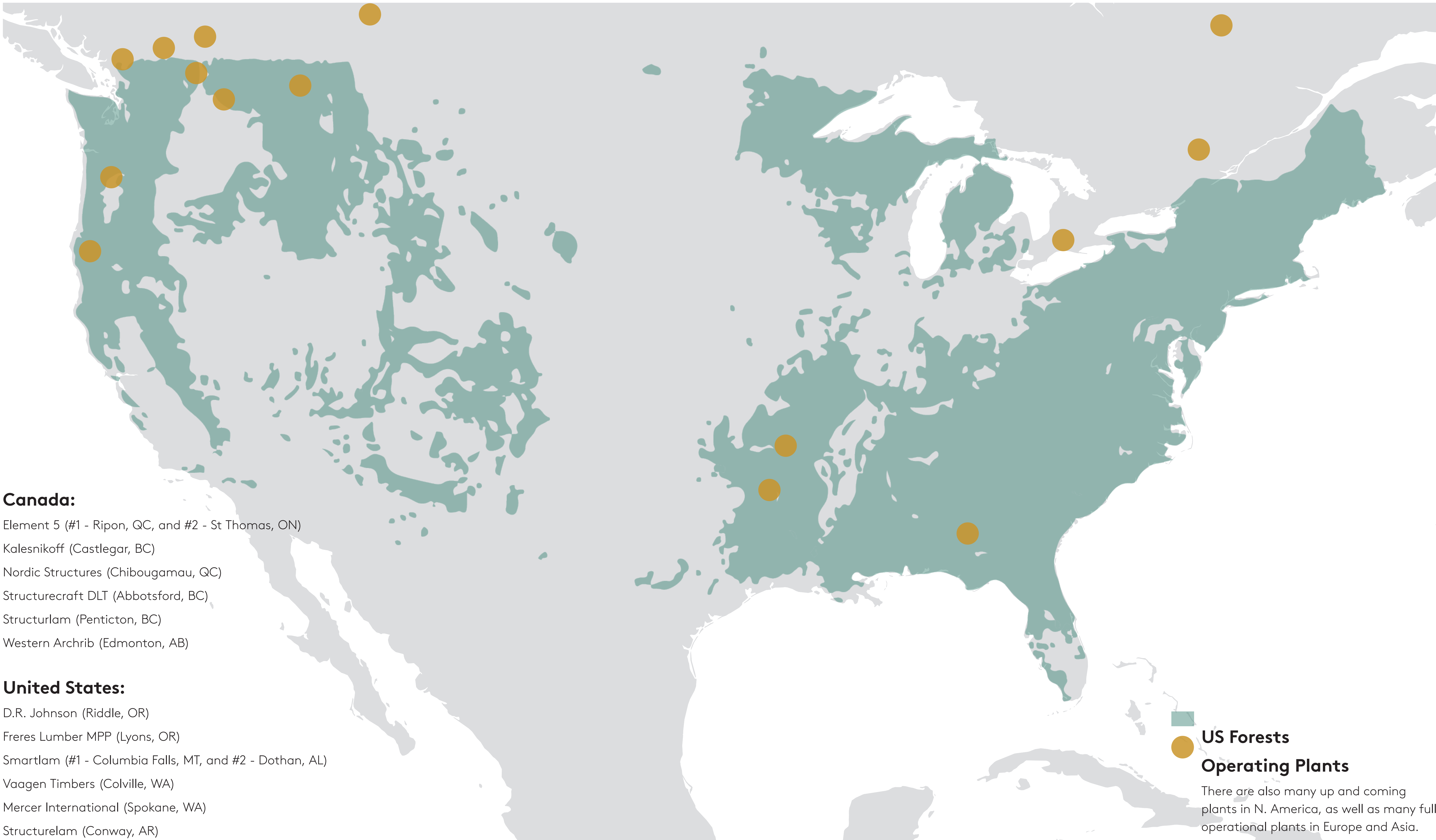
DLT

Dowel Laminated Timber

MPP

Mass Plywood Panel

North American Mass Timber Manufacturers



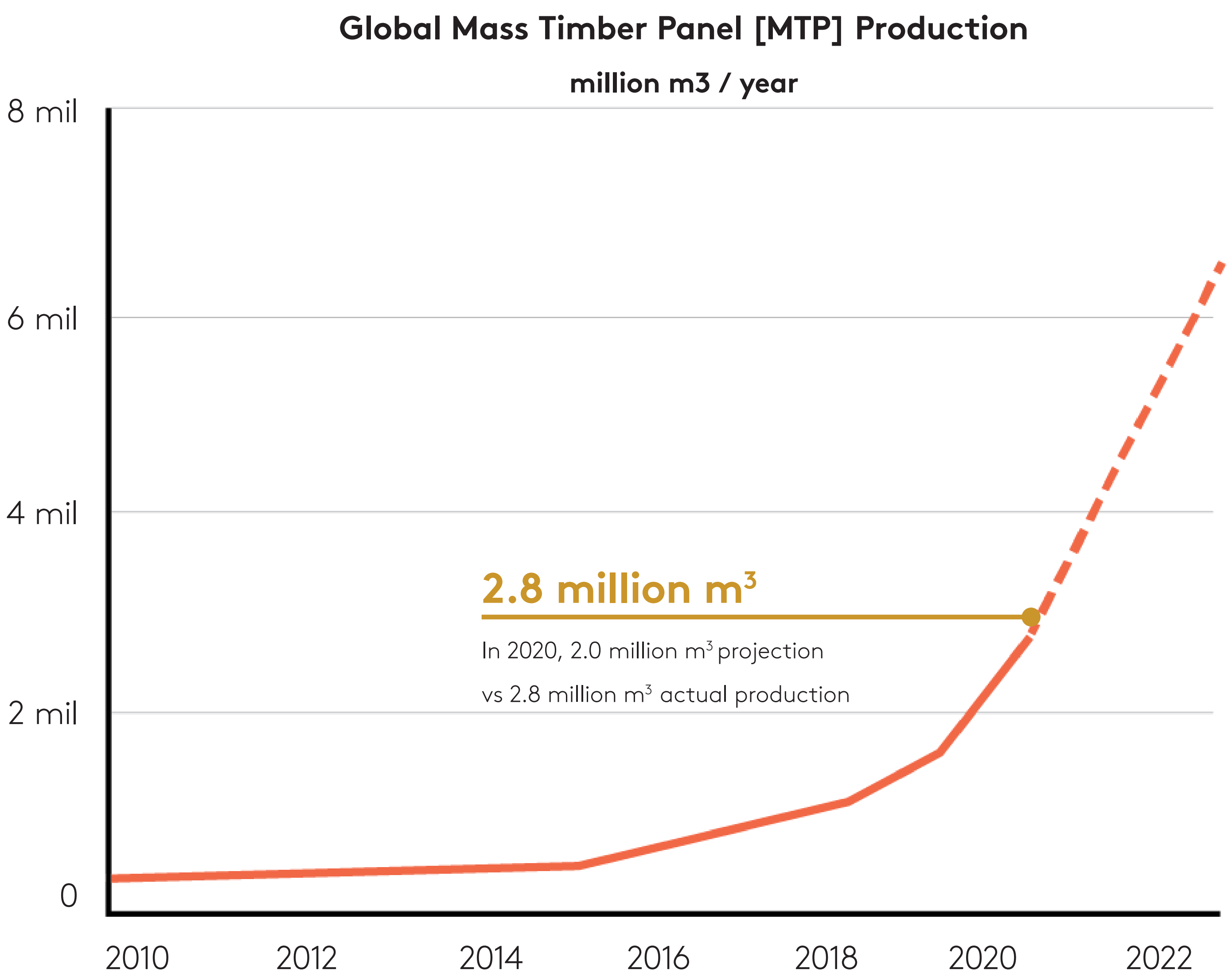
Canada:

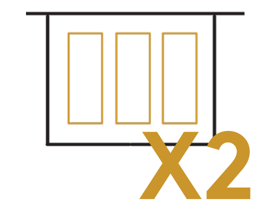
Element 5 (#1 - Ripon, QC, and #2 - St Thomas, ON)
Kalesnikoff (Castlegar, BC)
Nordic Structures (Chibougamau, QC)
Structurecraft DLT (Abbotsford, BC)
Structurlam (Penticton, BC)
Western Archrib (Edmonton, AB)

United States:

D.R. Johnson (Riddle, OR)
Freres Lumber MPP (Lyons, OR)
Smartlam (#1 - Columbia Falls, MT, and #2 - Dothan, AL)
Vaagen Timbers (Colville, WA)
Mercer International (Spokane, WA)
Structurelam (Conway, AR)

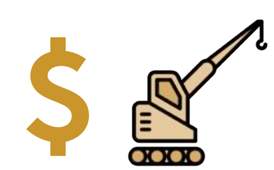
Mass Timber Growth





The number of mass timber buildings is expected to double every two years through 2034, at which point the construction industry would be storing more carbon than it emits.[46]

The mass timber panel manufacturing capacity in North America increased by more than 1,000% between 2010 and 2020.[47]



By 2025, mass timber is expected to account for $1.4 billion of the $14 trillion global construction industry.[48]

Graphical Data Source: Mantle Developments. (2020, November 5).

46 The Beck Group, Kaiser + Path, Treesource, Doug Fir Consulting LLC. (2020).

47 Mantle Developments. (2020, November 5).

48 IMARC Group, April 2019

How to Design and Build with Mass Timber–

This section defines the kit-of-parts used for core learning and performance areas. It shows the adaptability to various pedagogies and illustrates the customization of the kit-of-parts through a series of classroom model examples.

Kit-of-Parts Introduction

School districts must respond to the growing population and community expansions. The systems we use to build our schools must also be able to adapt and be customized to various school district needs. Mass Timber is a pre-fabricated product that achieves this and performs most efficiently when conceptualized as a kit-of-parts that adapts to a specific target program. In this case, the kit-of-parts is designed for suitability to a variety of school design needs.

Portable Replacement

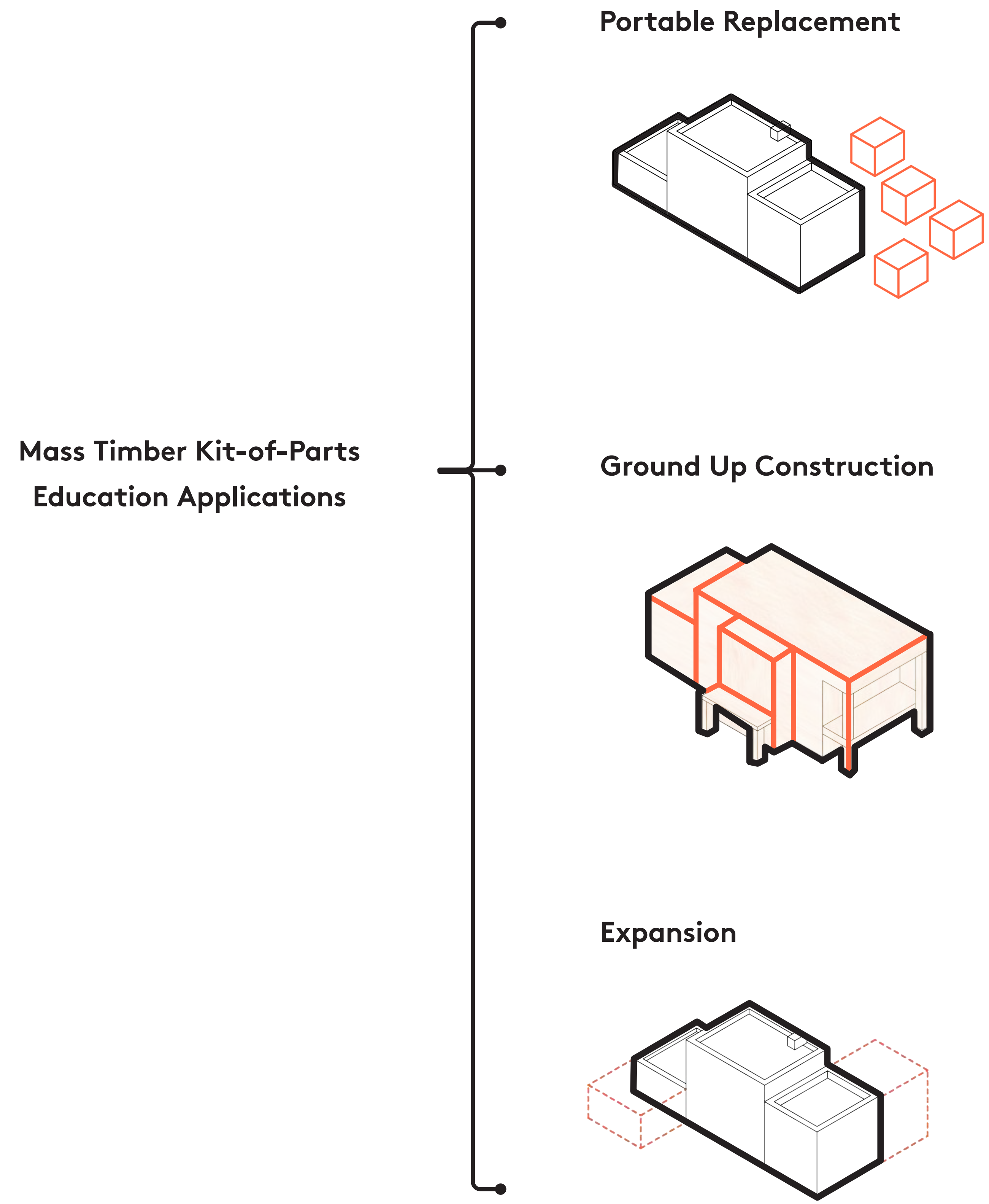
Portables are often installed at a school to temporarily provide additional classroom space where there is a shortage of capacity. They are designed so they may be removed once a permanent addition to the school is built or there is a reduction in student population. The mass timber kit-of-parts system can be installed as a pre-fabricated portable replacement to create a more equitable learning environment across classrooms.

Ground Up Construction

New construction is a large investment by the district and it's community, and thus it is important to create spaces that are durable, long-lasting, timeless, and healthy for the inhabitants. The mass timber kit-of-parts approach to a new school allows for up to three stories tall and provides long-term interior flexibility to adapt to evolving teaching strategies and pedagogies.

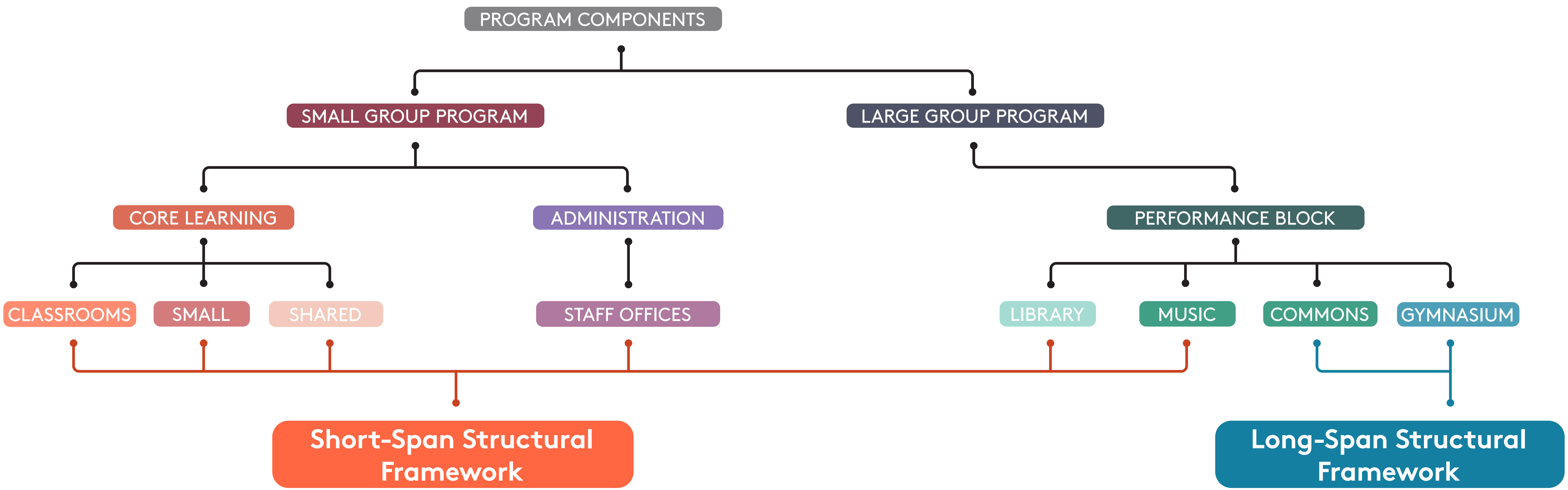
Expansion

Permanent growth in communities may ultimately result in a permanent expansion to an existing school. The mass timber kit-of-parts allows for adaptation to existing school grids. Through further structural analysis of the bridging of the new timber system and existing structural system, a seamless and sustainable approach to school additions can be achieved.



Kit-of-Parts Introduction

Mass timber's inherent structural properties inform a mass timber grid framework to achieve an optimal wood fiber volume efficiency. It responds to programmatic spatial requirements through either a short-span or long-span framework.



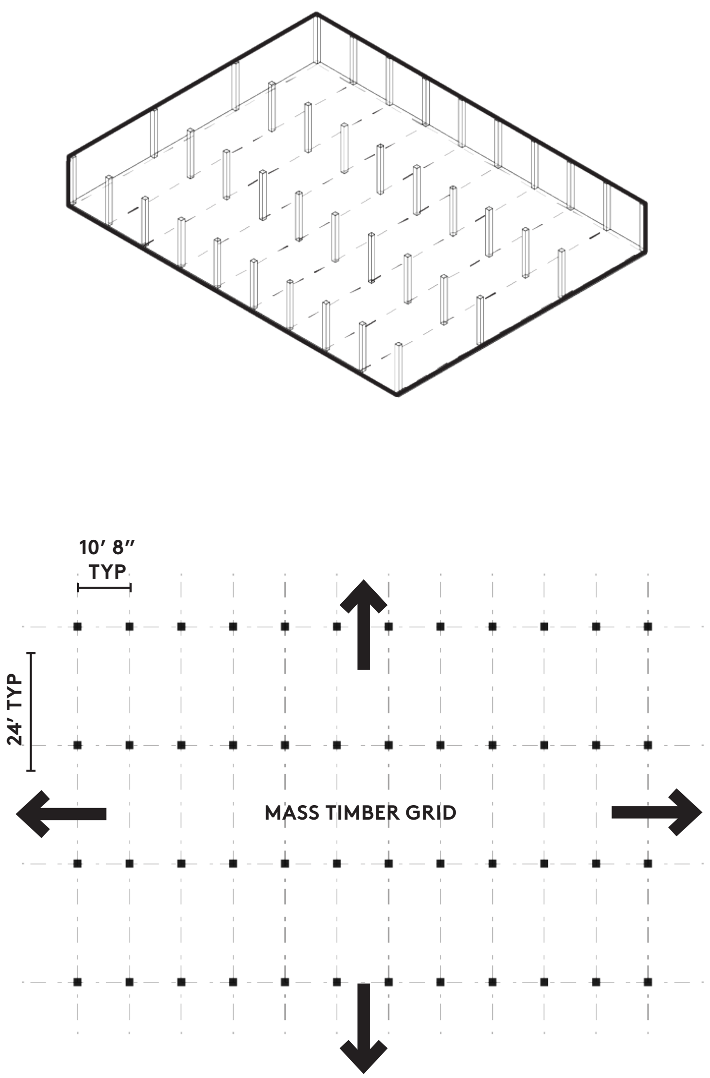
Kit-of-Parts Framework

To achieve customization and maximum adaptability to district's needs, the kit-of-parts uses a framework derived from an optimized balance between minimal ply timber spans and classroom program. Within the framework, districts can opt for collaborative environments, while still occupying the same amount of overall square footage.

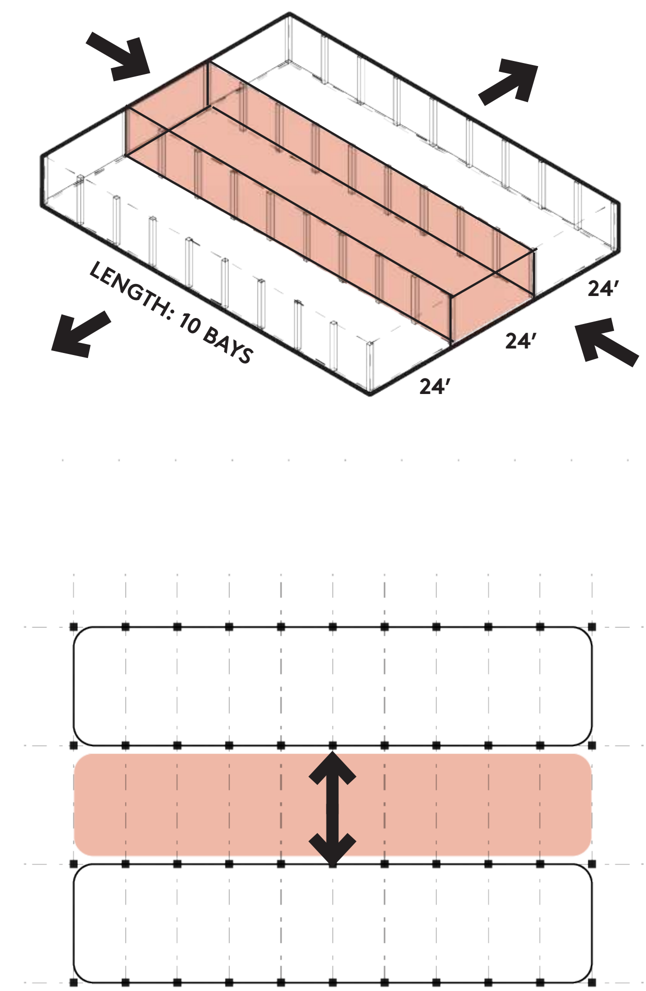
Further system flexibility can be accommodated by removing columns if the interior space planning requires. Column removal results in addition of a structural girder spanning between two columns. While possible, this approach would increase cost accordingly.

The mass timber grid offers an ability to lengthen or expand, while maintaining an equal amount of total learning area per student.

A Systems-Based Framework

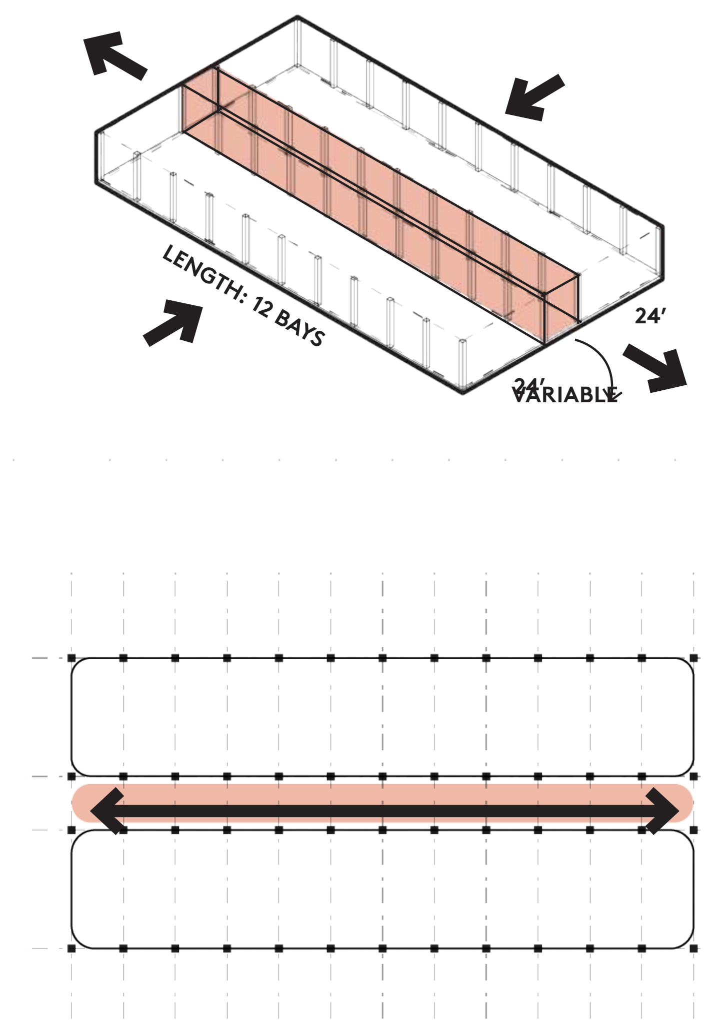


Expanded Learning Core



TOTAL AREA: +/- 7650 SF*

Lengthened Learning Core



TOTAL AREA: +/- 7650 SF*

*Includes shared learning, circulation, and support spaces. Student capacity: 144-180SF at 24-30 students per class.

Kit-of-Parts

The mass timber kit-of-parts for core learning areas is comprised of a series of elements that are adaptable to a range of educational pedagogies. The kit-of-parts is designed around the structural grid framework that optimizes the amount of wood fiber used on the project for cost and material efficiency.

The interior space planning is defined with mass timber walls located strategically at teaching walls. Metal stud and gypsum board walls support operable glazed interior partitions to allow for classroom expansion to shared learning and provide visual transparency to adjacent learning areas. 3-ply CLT ceiling panels are left exposed where possible above learning areas, with ceiling clouds only necessary for acoustics or MEP integration.

*CLT shear walls can be used depending on the building's construction type. In instances where combustible material in the exterior wall is not permitted by code, steel braced frames are used for the lateral system design.

Primary Classroom

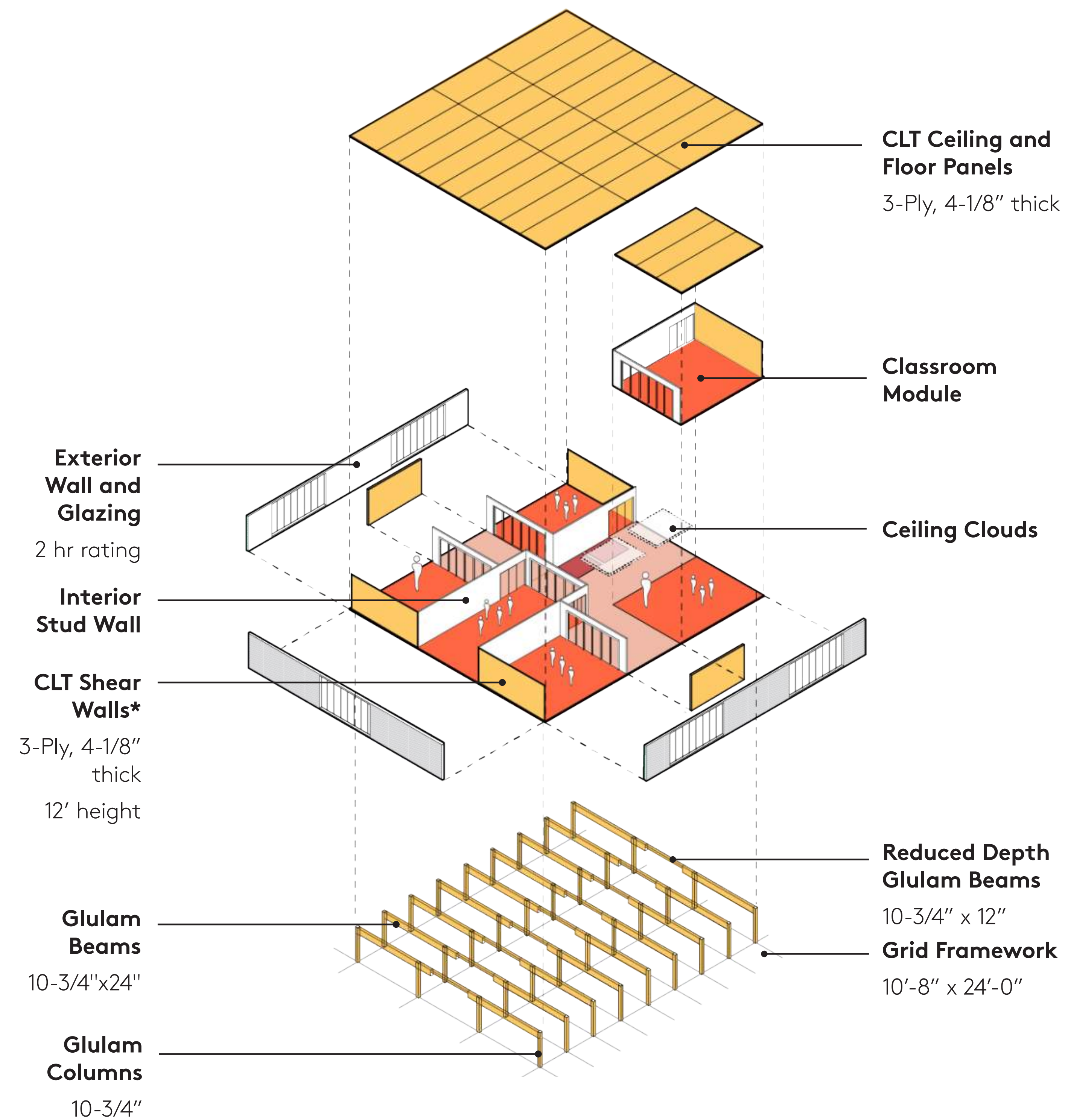
768 SF

Shared Learning

512 SF

Small Group

120 SF

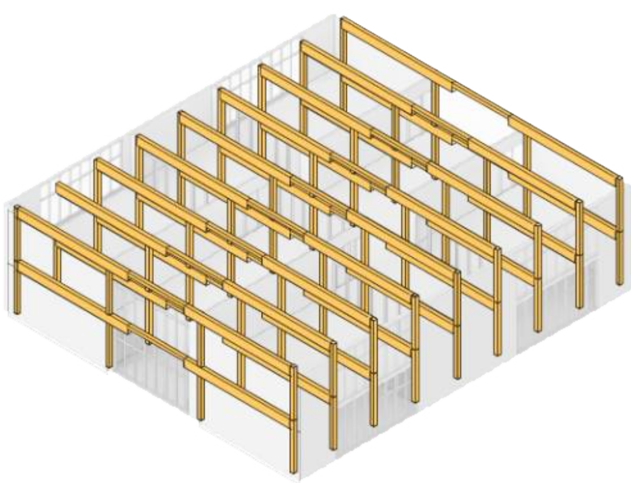


Reducing the volume of wood fiber by using 3-ply CLT panels for floors and ceilings is a key factor in the success of the kit-of-parts.

A Systems Based Approach

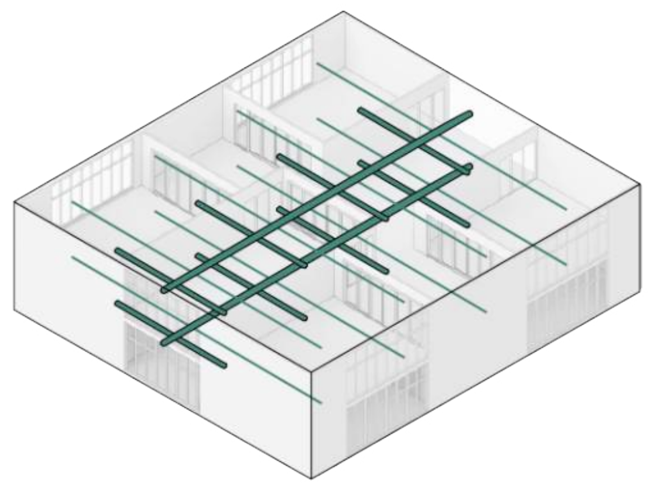
To promote flexibility, economy, and customization of the kit-of-parts, a systems-based design approach is taken, integrating the building's structural 'bones', air distribution systems, exterior enclosure and key interior components.

Structural "Bones"



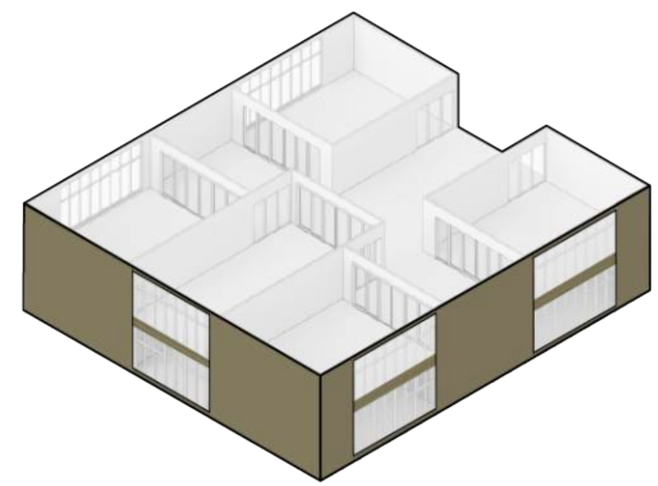
The structural grid and framework optimizes beam span, removes girders, and mass timber panel thickness, while considering mechanical routing and exterior glazing heights for daylight.

Mechanical System



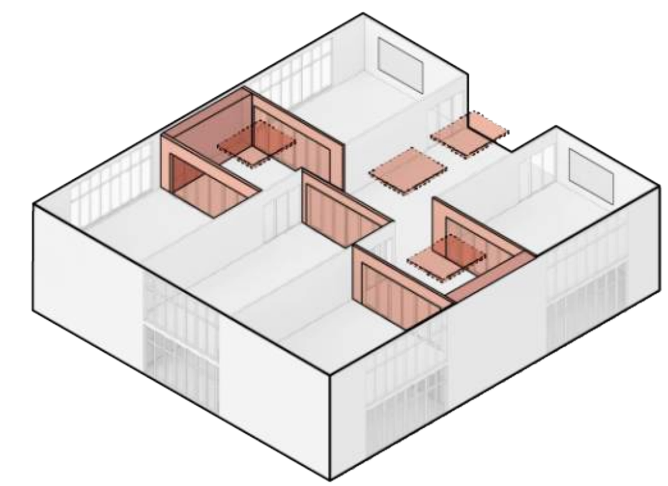
The mechanical distribution approach is centralized with strategic routing primary at shallow center beams.

Exterior Enclosure



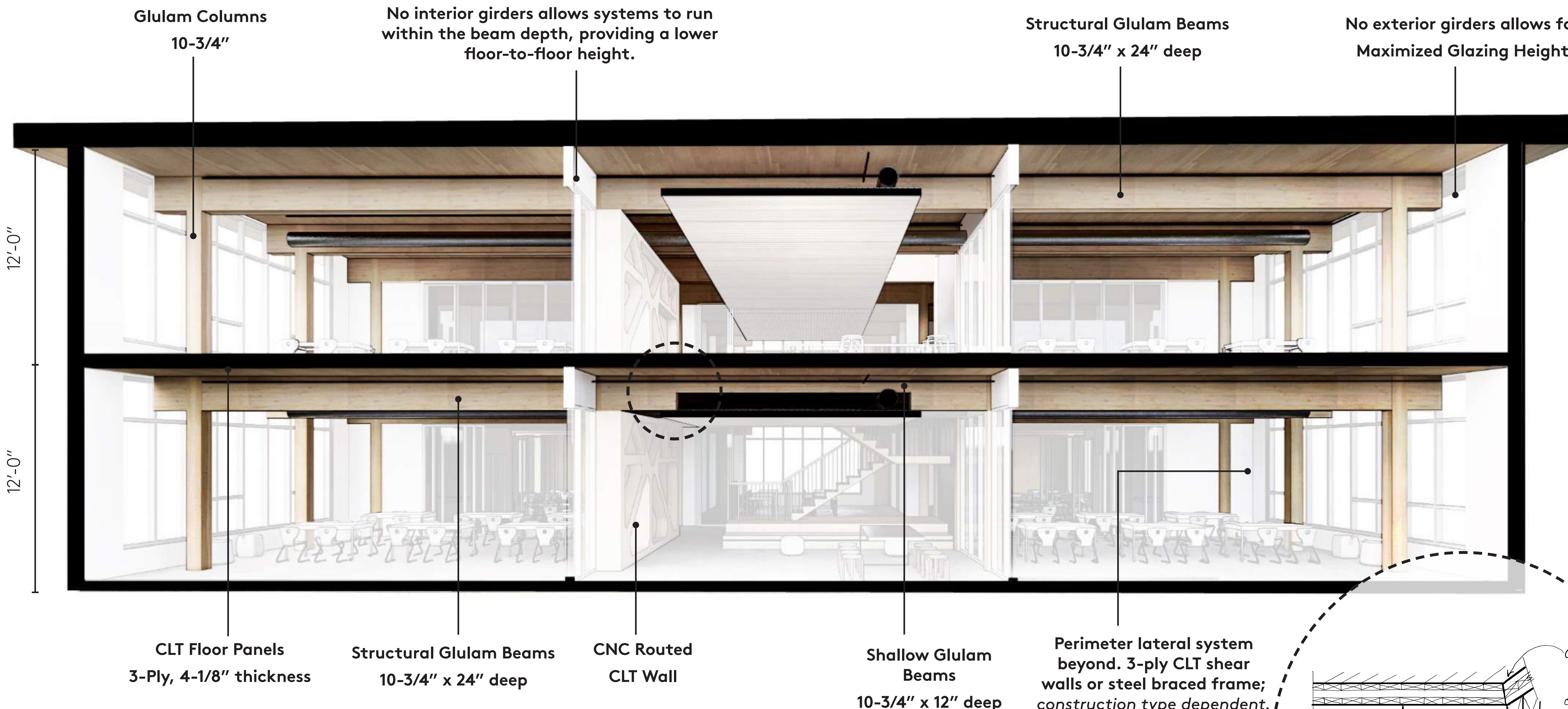
Exterior skin maximizes glazing to the underside of the CLT ceiling for improved daylighting. The repetitious grid provides opportunities for pre-fabricated exterior wall panels as an additional layer to the kit-of-parts.

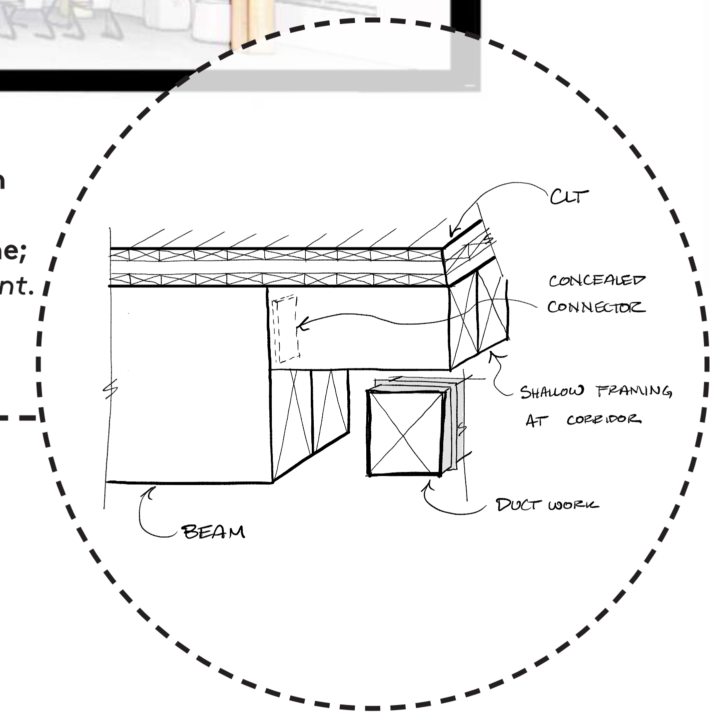
Interior Flexibility



Interior layouts are designed to maximize options and long term flexibiity. Ceiling solutions, where needed, may be incorporated as a pre-fabricated cloud solution including MEP components, acoustics and lighting.

A Systems Based Approach: Structure





To achieve a cost competitive and efficient mass timber system, three primary structural parameters include:

Reduce the Amount of Wood Fiber

To utilize the 3-Ply CLT floor and allow it to remain exposed, the building construction type should not require a floor rating. This is achieved with buildings of Type III-B and V-B Construction. 3-ply CLT floor and wall panels are the optimal number of laminated plys to limit the amount of cubic meters of wood fiber in the project. Panels are produced in maximum lengths to achieve trucking efficiencies.

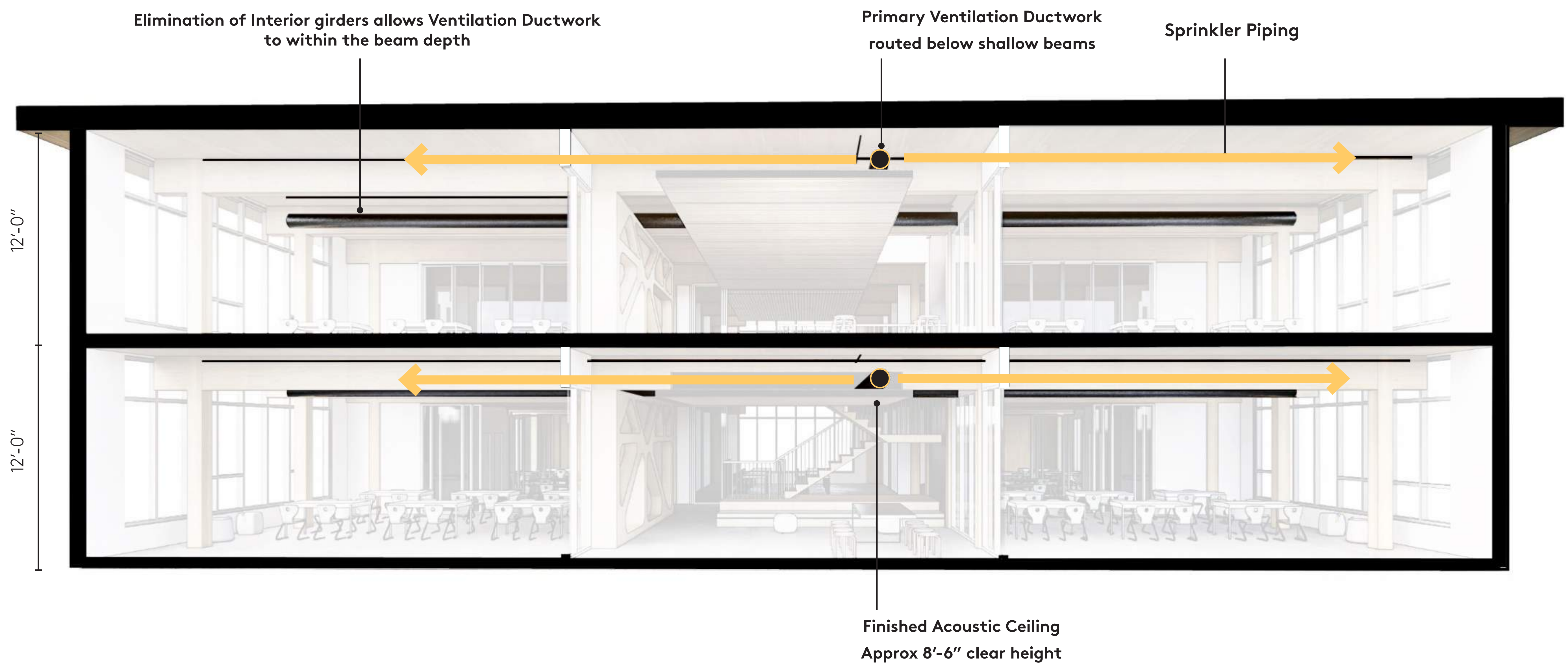
Perimeter CLT Lateral System

The building seismic design uses 3-ply Cross-Laminated Timber (CLT) shear walls at building perimeter to allow for maximum future interior flexibility. This also eliminates the steel trade on-site.

Eliminate Girders & Provide Shallow Beam Depth to Allow for MEP Distribution

The framing system is comprised of glulam beams and columns. Columns are spaced at an approximate interval of 10'-8" in order to eliminate girders to achieve efficient air distribution routing and potential floor-to-floor height savings. The central structural bay also uses a shallow beam, permitting the main mechanical ducts to distribute to classrooms without significant impact to ceiling height at the expanded learning core.

A Systems Based Approach: Mechanical



In addition to the structural framework, additional system components, including mechanical systems, are strategically designed and integrated to promote flexibility and adaptability of the kit-of-parts.

Equipment Location Strategies

The kit-of-parts is compatible with many mechanical distribution approaches. This scenario shows a centralized equipment approach with a single dedicated M/E room for each classroom wing. A decentralized equipment approach may be accommodated by allocating an equipment closet in each classroom with access from the corridor.

Heating System Design

Approaches for heating that may be compatible with mass timber include a convector system that can be integrated into the exterior wall, a radiant floor system, ductless VRF fan coils (in closet or ceiling mounted) or fan-based systems (in closet or ceiling mounted).

Ventilation & Cooling System Design

To meet local Washington State Energy code, ventilation ductwork is recommended to be distributed from the primary M/E room to the occupiable spaces. While cooling is often not a mandate in the Pacific Northwest climate, it can be accommodated by providing one of the following: a closet within each classroom, ceiling space for ductless VRF fan coil units or fan-based systems, or radiant cooling floors.

A Systems Based Approach: Enclosure

Exterior Enclosure is an important consideration for building design, longevity and daylighting. Because the kit-of-parts optimizes structural and mechanical integration, floor-to-floor heights can often be reduced, achieving exterior cladding and glazing cost savings.

Exterior Wall Ratings

While the kit-of-parts does not restrict cladding finish, the construction type and exterior wall ratings are important to note for successful implementation of the kit-of-parts. For the lateral system design, perimeter CLT shear walls can be used depending on the building's construction type. In instances where combustible material in the exterior wall is not permitted by code, such as Type IIIB Construction, steel braced frames are used for the lateral system design. If the maximum program area allows, Type VB construction permits use of CLT shear walls at the exterior wall assembly.

Window Fenestrations

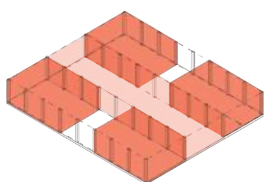
Window walls are designed to maximize daylight and views in learning areas and are strategically located to avoid glare along teaching walls. By designing with the kit-of-parts and eliminating girders along the perimeter, glazing is maximized to the underside of CLT floor panels. Window sizes, locations, and operability for natural ventilation can be tailored to district needs and budgets.

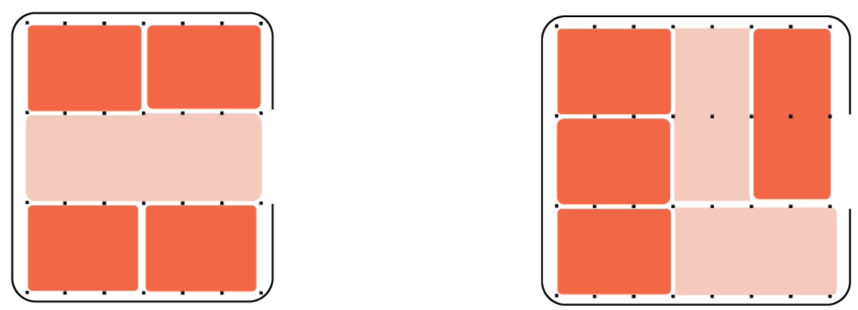
Modeling of Kit-of-Parts: Adaptability

The framework and kit-of-parts maximize adaptability to serve a wide range of teaching pedagogies and learning area requirements. It is designed to expand and contract based on the desired amount of shared learning space and number of classrooms. Possible adaptability variations are shown below.

4-UP Program

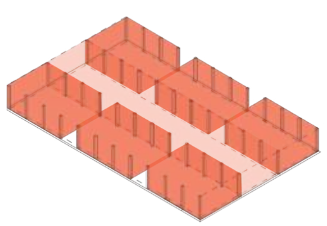
Expanded Learning Core

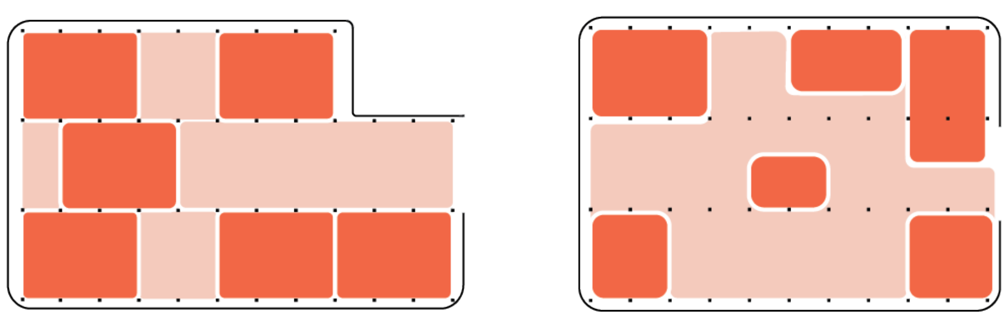




6-UP Program

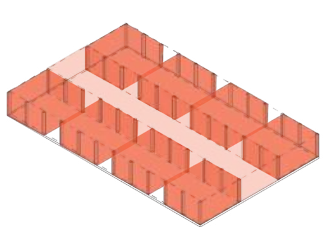
Expanded Learning Core

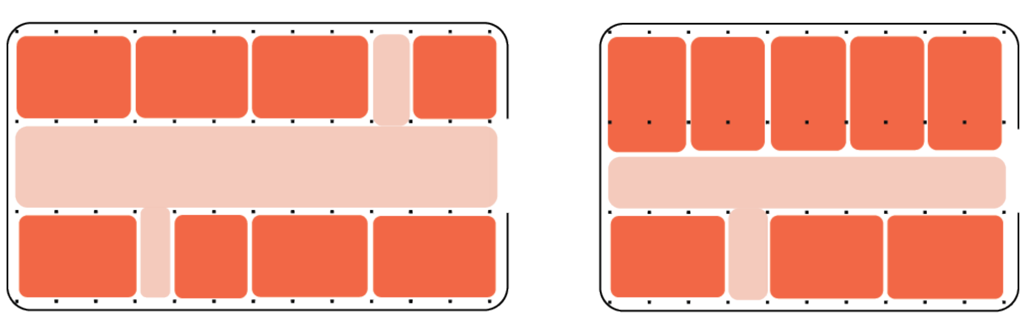




8-UP Program

Expanded Learning Core

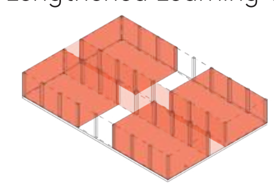


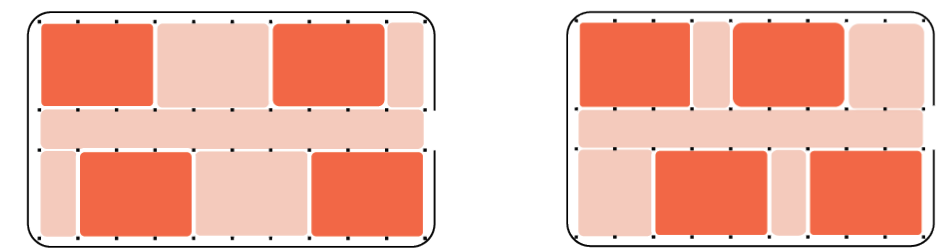


...And there are infinite more variations to promote a dynamic, engaging learning environment!

4-UP Program

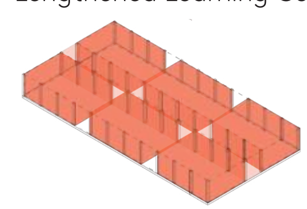
Lengthened Learning Core

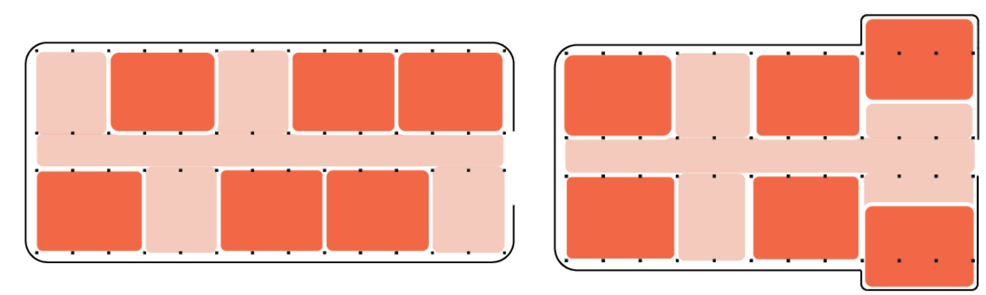




6-UP Program

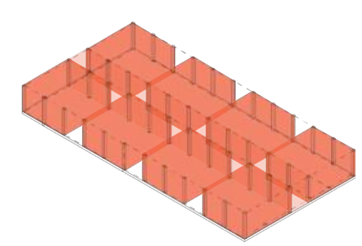
Lengthened Learning Core

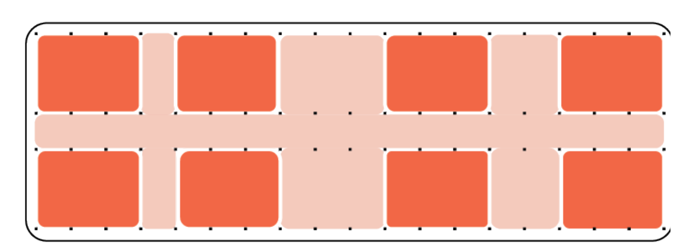




8-UP Program

Lengthened Learning Core





Core Learning

Shared Learning

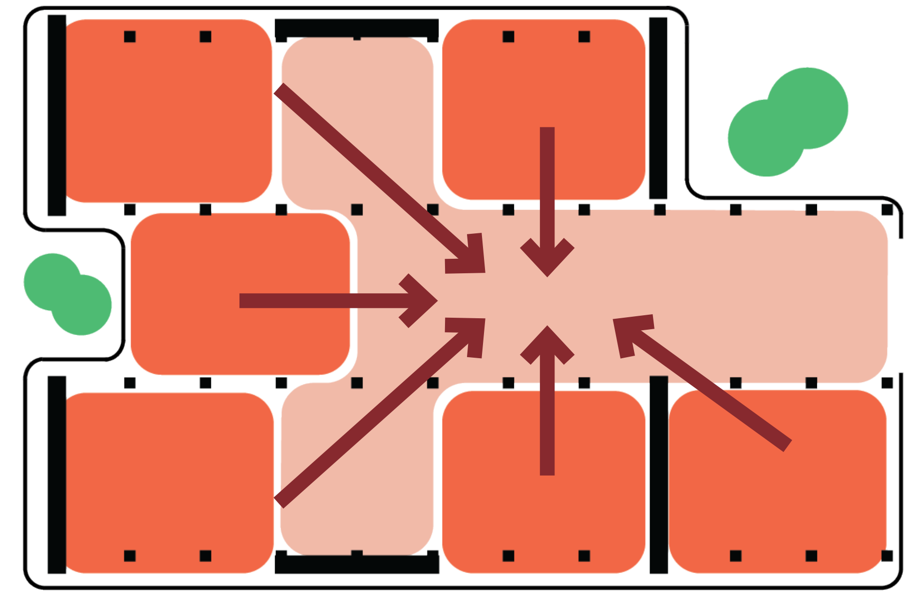
Exterior Wall Boundary

Modeling Learning Environment Agility Model Concepts

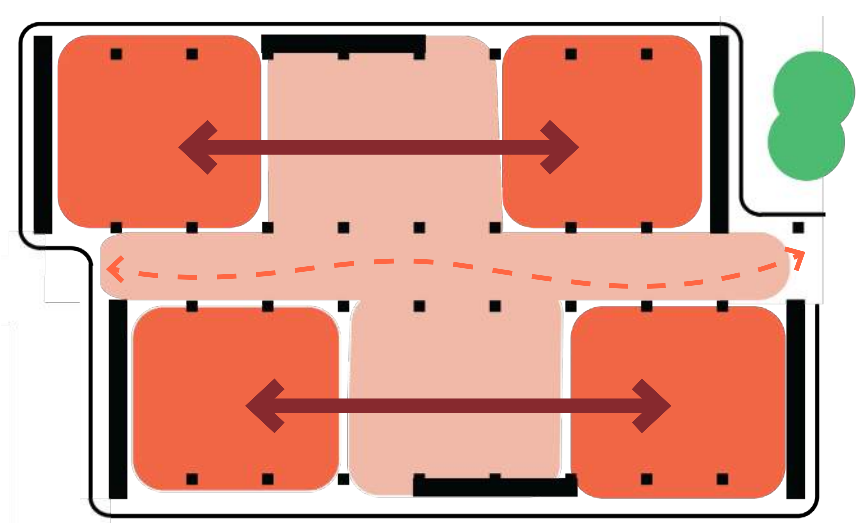
While there are an infinite number of classroom solutions, three examples are designed in more detail to illustrate the adaptability of the kit-of-parts. Each model studies different opportunities for shared learning, classroom sizing, access to the exterior and circulation through the classroom block to demonstrate design agility.

Three configurations models are explored in more detail to illustrate the kit-of-parts possibilities.

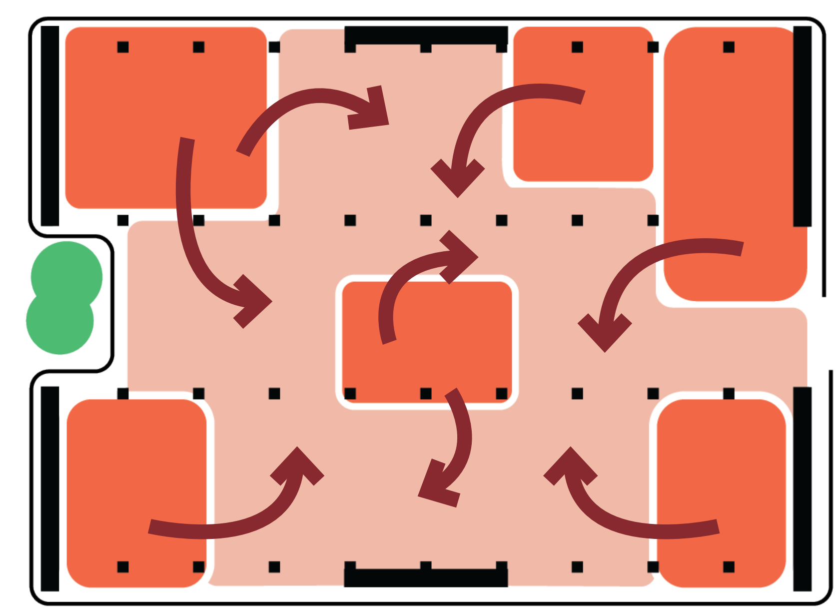
Central Learning Hub



Paired Learning Partners



Variable Learning Blocks



Core Learning

Shared Learning

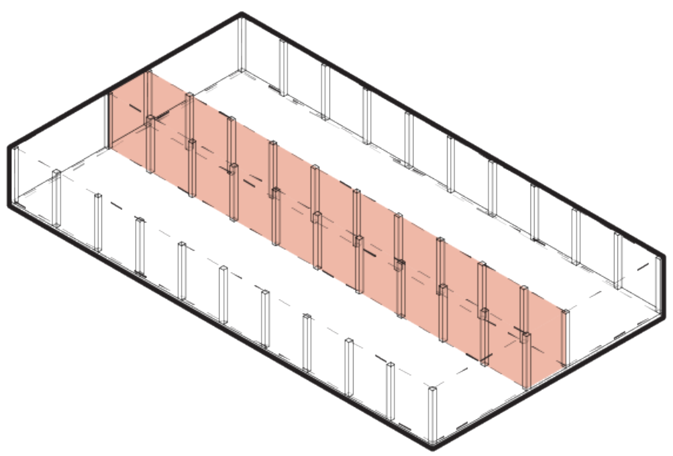
Exterior Wall Boundary

Shear Wall Location

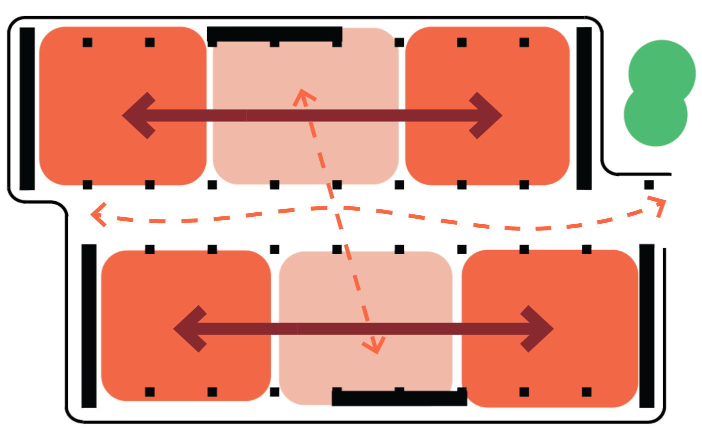
Modeling Learning Environment Agility, Plan Studies

Paired Learning Partners

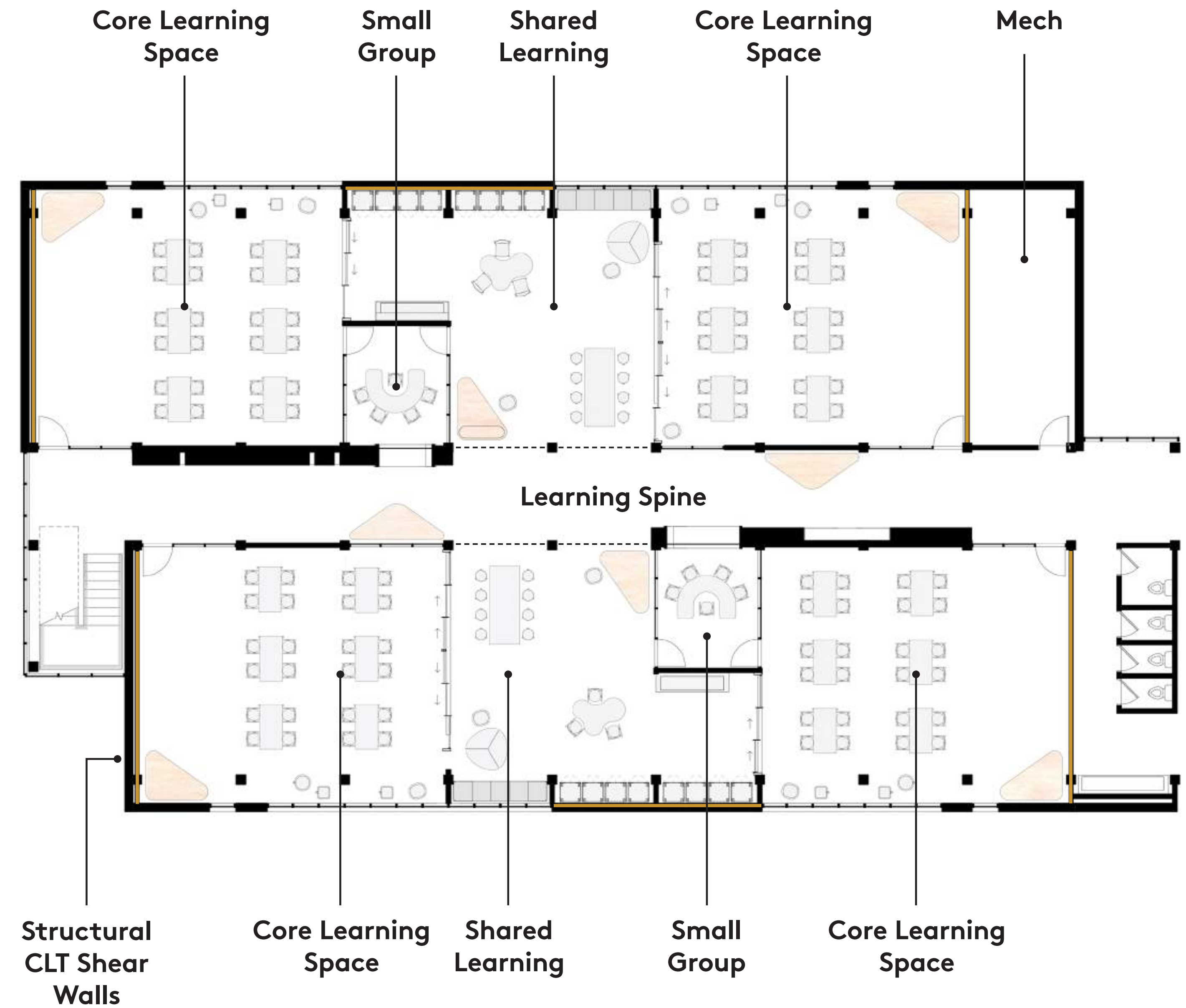
This 4-Up classroom design displays the most common or traditional double loaded corridor model approach to core learning layouts. Each pair of classrooms has the ability to expand into a shared learning space that includes shared furniture, storage, small group learning, and washing sink.



Lengthened Grid Framework



Program Diagram



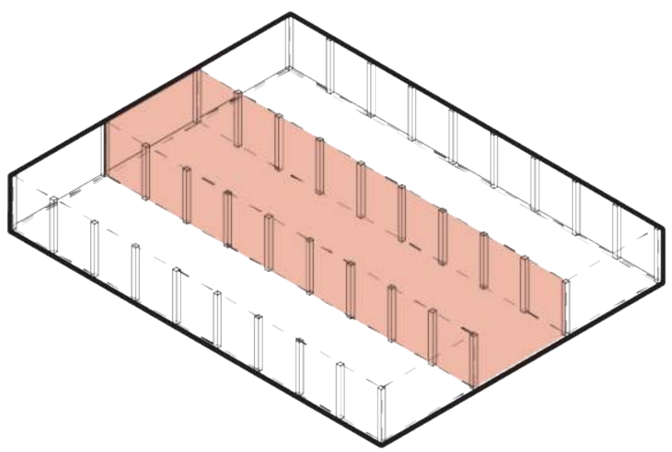
Note: Drawings Not To Scale

Paired Learning Partners—
Interior Concept Rendering

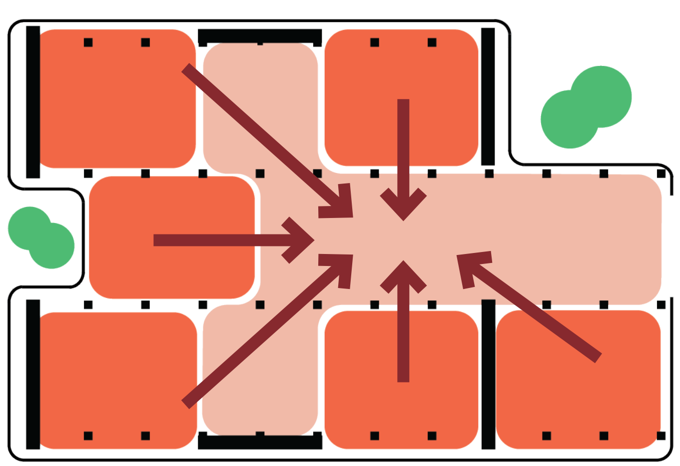
Modeling Learning Environment Agility, Plan Studies

Central Learning Hub

This 6-Up classroom design leverages the expanded learning core, by allowing all classrooms to have visual access to a central learning space that integrates small group rooms and shared furniture adjacent to an active circulation stair. Additional secluded shared learning and restrooms are designed to be shared between two classrooms.



Expanded Grid Framework



Program Diagram

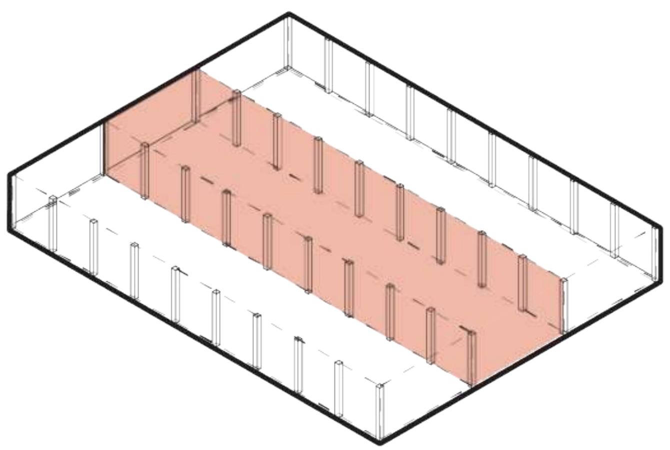
Note: Drawings Not To Scale

Central Learning Hub—
Interior Concept Rendering

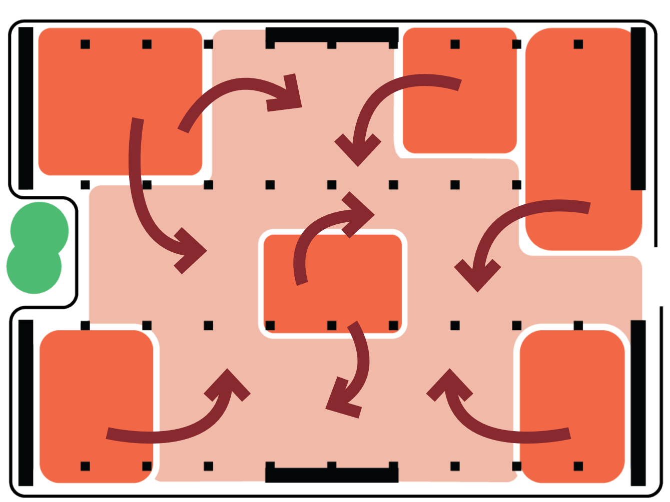
Modeling Learning Environment Agility, Plan Studies

Variable Learning Blocks

This 6-Up classroom layout offers opportunity for a different type of pedagogy. Smaller enclosed core learning spaces and greater communal shared learning area allow for increased interaction between students and teachers.



Expanded Grid Framework



Program Diagram

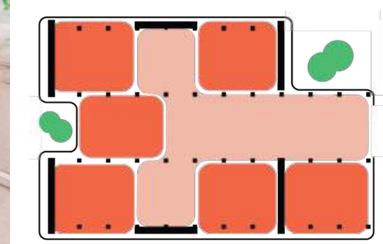
Note: Drawings Not To Scale

Variable Learning Blocks—
Interior Concept Rendering

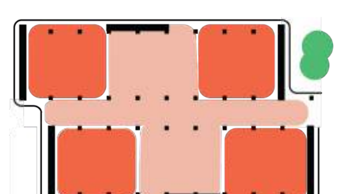
Modeling Learning Environment Agility Summary

While there are an infinite number of classroom solutions, three examples are designed in more detail to illustrate the adaptability of the kit-of-parts. Each model provides different opportunities for learning configuration access to the exterior and circulation through the classroom block to demonstrate design agility.

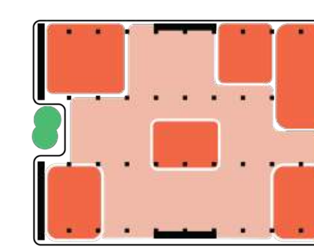
Central Learning Hub



Paired Learning Partners



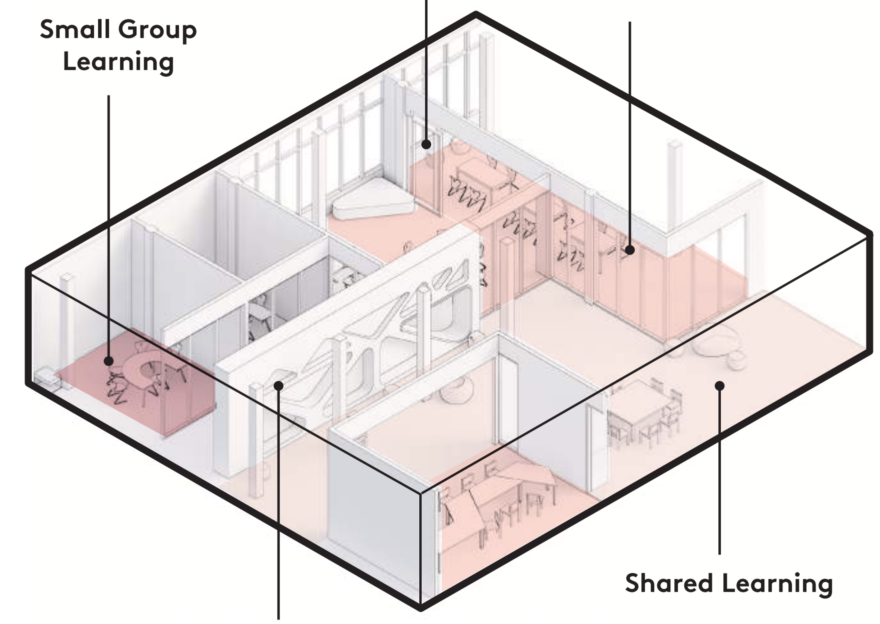
Variable Learning Blocks

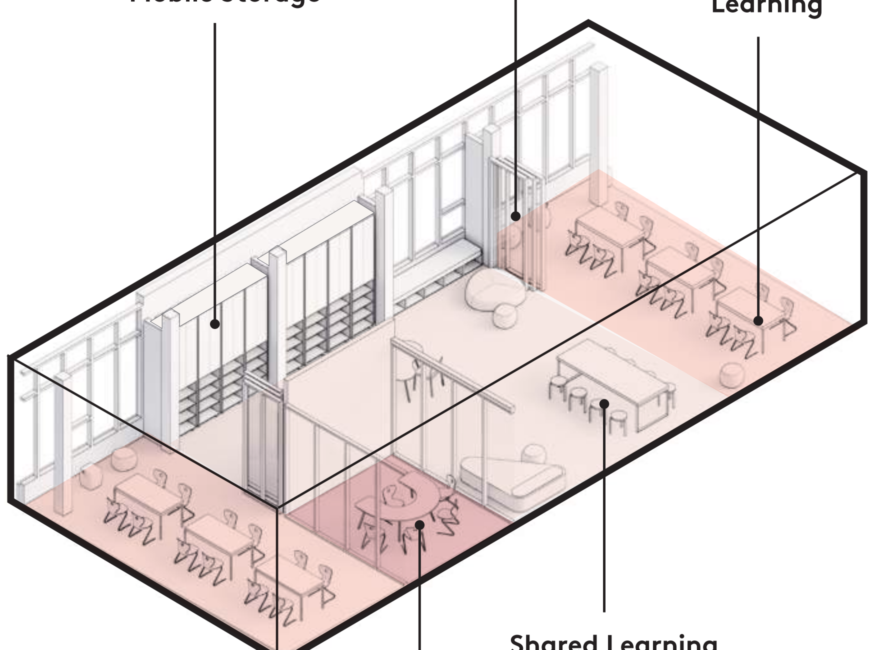


Adaptive Shared Learning Studies

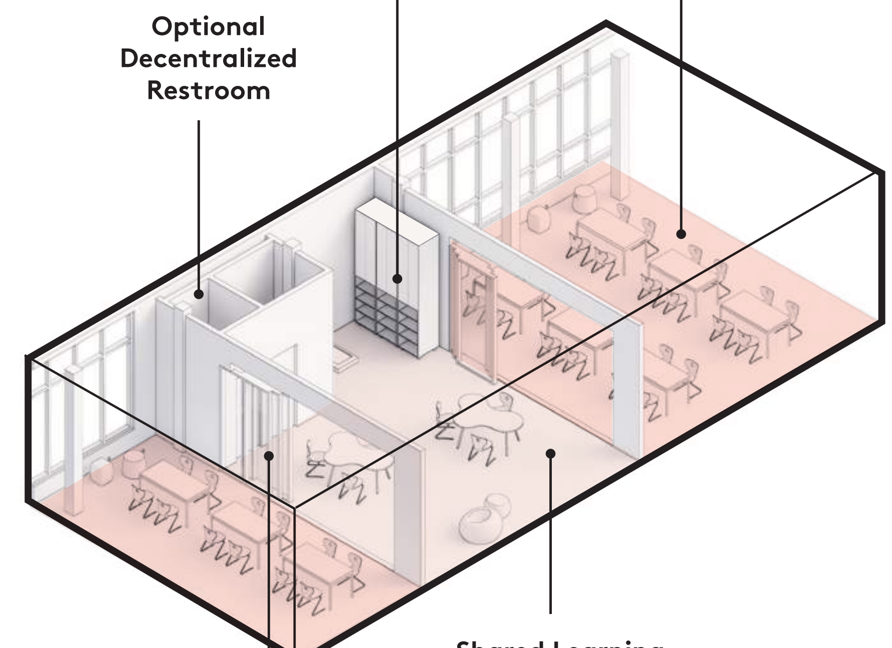
Shared learning spaces are an important part of teaching pedagogies, especially in a pandemic-ridden society where learning communities benefit from connected but partitionable and/or expandable learning space in order to safely accommodate the same amount of students. Shared learning spaces also allow for flexible interior design to accommodate different teaching 'zones' and styles.

The kit-of-parts approach allows for endlessly customizable shared learning spaces depending on district's needs or teaching style.





- Core Learning Spaces
- Shared Learning Spaces
- Small Group Learning



Pre_fabricated Building Systems That Improve Flexibility

Overcast Prefabricated Ceiling Clouds

One benefit of building with mass timber is the natural beauty of the exposed structure when paired with a thoughtful, efficient ceiling system to minimize the MEPF systems will be required for fire protection, lighting, and air distribution. Ceiling clouds may also be needed to meet acoustic requirements. A local WA State product manufacturer, Overcast Innovations, offers a pre-fabricated solution.

- Life Cycle Cost: Because the cloud and spline can be reused and updated (devices and finish choice) over time, this saves on the cost of future renovations when the owner may want to rezone/reprogram.
- Performance Certainty: The design of the cloud accelerates building technology design that typically happen much later in the design sequence and often in a fragmented way.
- Ease of operations and maintenance: Devices can be replaced or added later on. They come with AMS tags to scan and incorporate in to the facility team's CMMS making devices location and access to information like quantities, model info, etc, a lot easier to readily recall.
- Speed to Market/Schedule: Due to the offsite manufacturing of the cloud/spline, just in time delivery and quick install, the cloud and spline solution lends itself well for projects that value speed to market.
- Acoustic Mitigation: High performing acoustic finish options are available to minimize cloud area and expose the beauty of CLT.
- Aesthetic: Clouds organize ceiling systems and prevent that clustered spiderweb in the ceiling space.
- Sustainability friendly: The cloud is compatible with mechanical and electrical systems selected to achieve sustainability goals (chilled beams, LED, etc), and they can be reused, reducing future construction waste.
- Skilled Trade Shortage Solution: The cloud is a non-technical install and can be done by any trade, including the GCs self-performed trades.

Photo and text provided by Overcast Innovations

Photo: Don Rose Middle School, Squamish, BC, 2019; by studioHuB using DIRTT interior wall systems

Acoustics

Heating & Cooling

Low Voltage

Lighting

DIRTT Modular Interior Walls and Partitions

DIRTT provides the building blocks to create tailored learning spaces and environments that support critical thinking skills and creative freedom. DIRTT modular interior wall systems support diverse learning needs and ongoing change. Benefits include:

- Certainty: DIRTT's ICE technology is used to build and visualize the space in 3D before it's built. This also provides contractor benefits for a more efficient jobsite.
- Fast and on-time: DIRTT's off-site prefabricated systems decrease on-site construction time and integrate with the job site for a harmonious project
- Optimized Accessibility: DIRTT Walls look and perform like permanent walls. When an IT or facilities teams need to get inside, a special tool pops off the wall tile. It's all done quietly, cleanly and, best of all, quickly.
- Durability and Aesthetics: seamless integration into other interior design elements, that are designed to last.

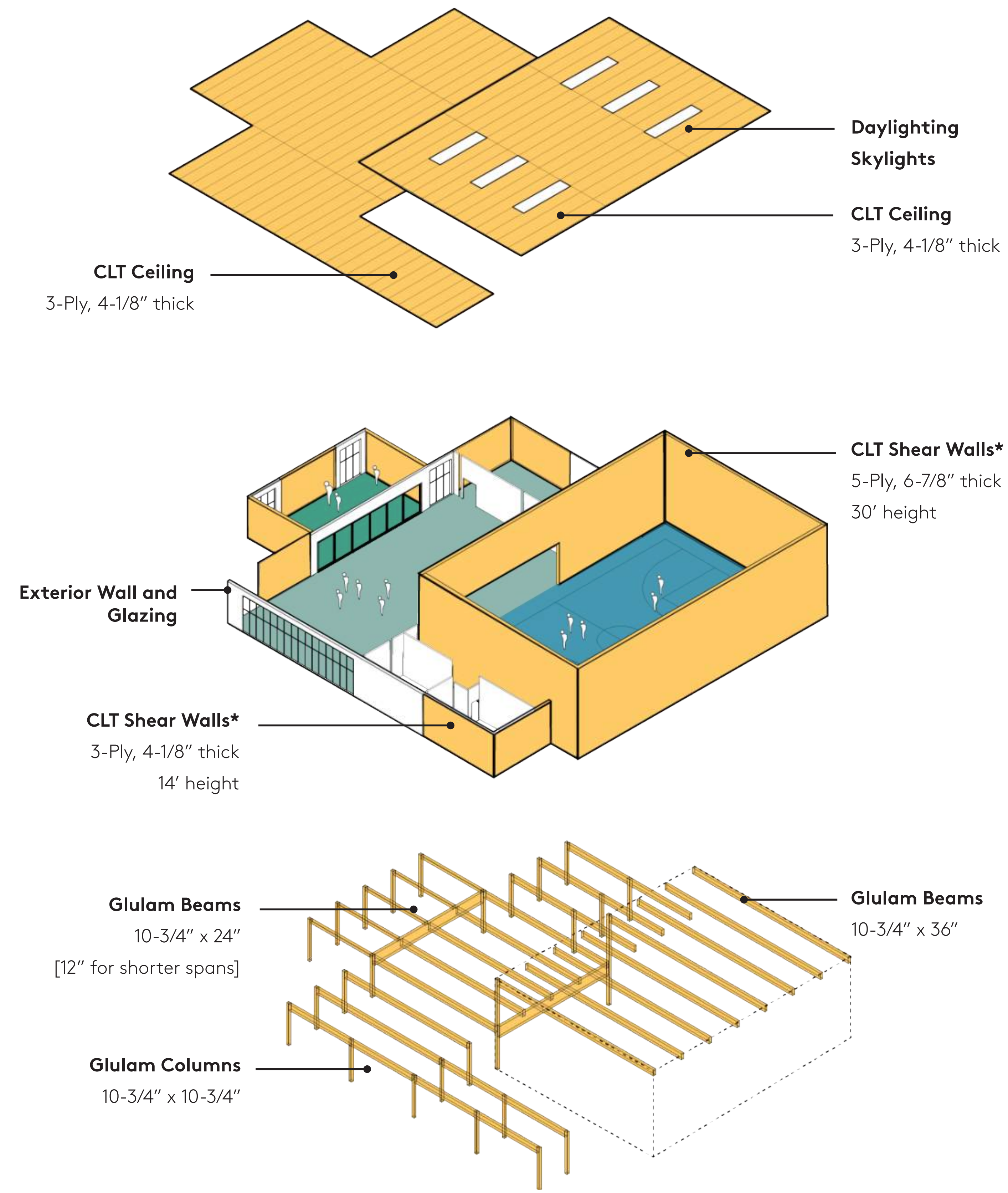
Kit-of-Parts Detail | Large Span Performance Blocks

73% of all children ages six to seventeen participate in at least one extracurricular activity, including clubs, sports, or music lessons.[41]

The performance block in schools is part of the day-to-day experience of students as much as the core learning areas. The mass timber kit-of-parts for large span areas [music, gymnasium, commons, library] is similar to the core learning kit-of-parts components, with the exception of the gymnasium which requires a long span structural framework. Together, these elements function collectively to create seamless large group gathering areas and embrace the structure and wood material. The commons, library, and music program spaces are designed on the same short span framework as the core learning, however, where free span spaces are desirable, girders can be added to effectively eliminate columns and allow for column-free zones.

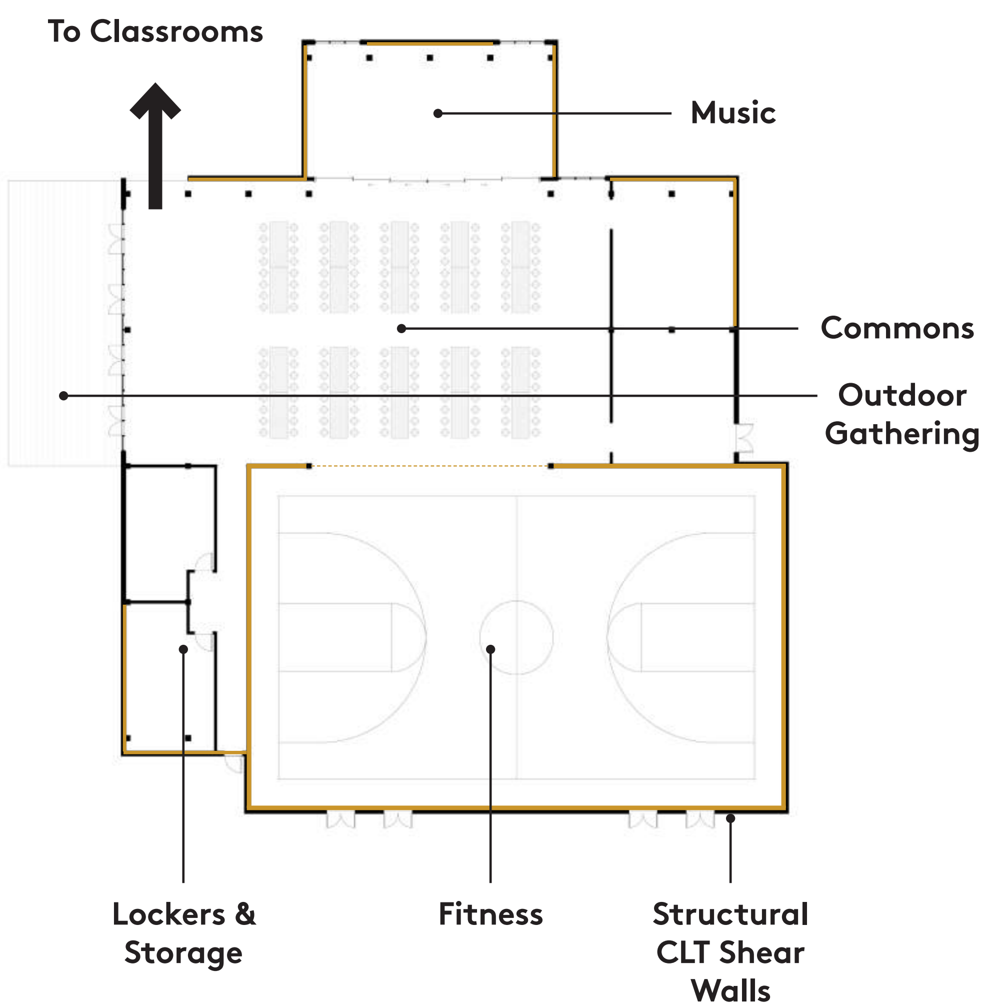
*As shown in the diagram at right, CLT shear walls can be used depending on the building's construction type. In instances where combustible material in the exterior wall is not permitted by code, steel braced frames are used for the lateral system design.

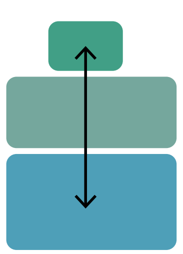
41 Pew Research Center. (2020, May 30)



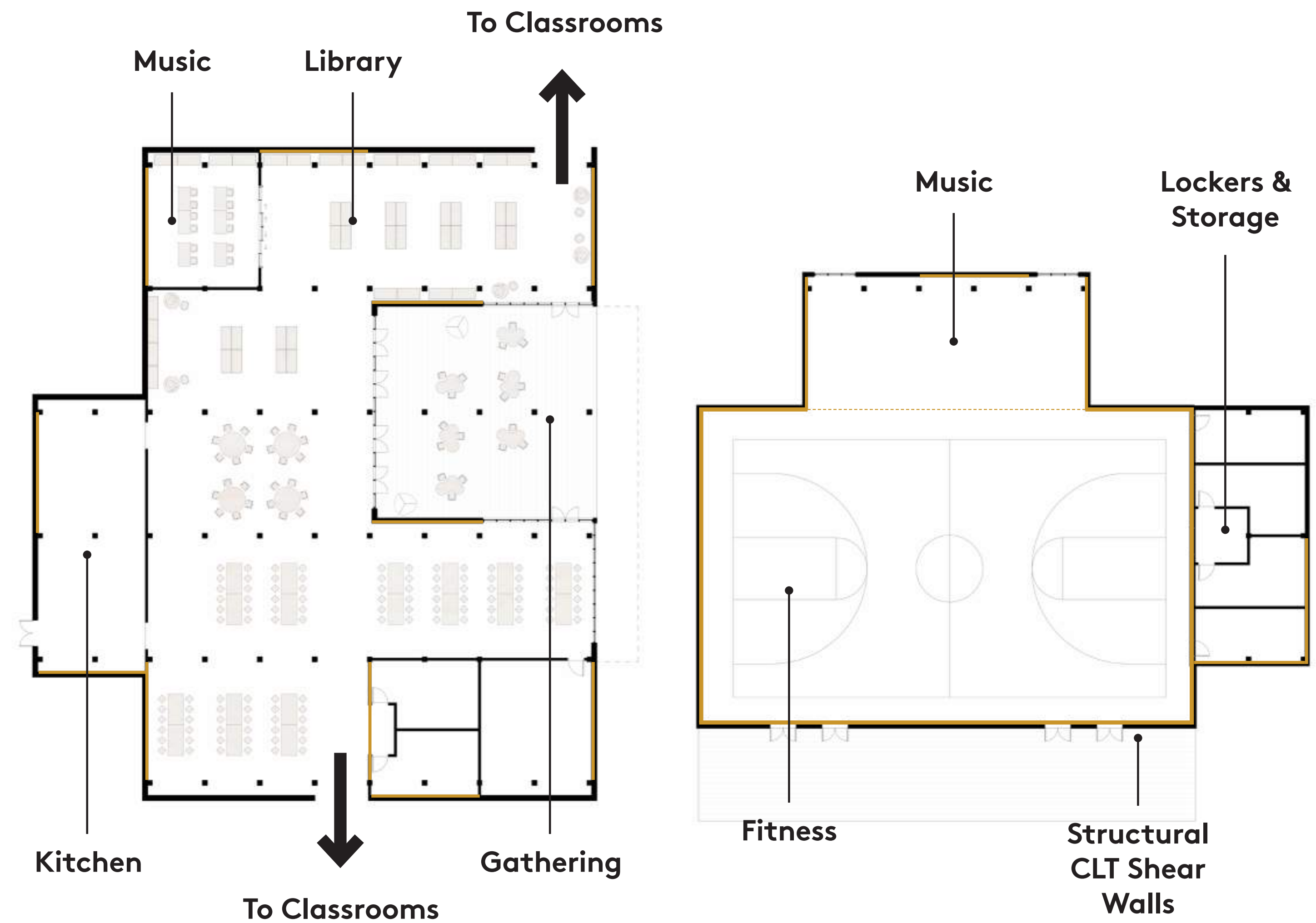
Modeling Performance Block Agility

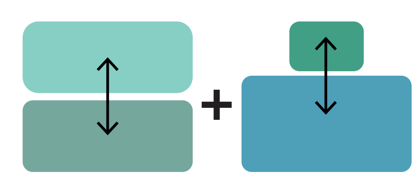
There are many possible configurations for the performance block layouts. Two examples are provided to illustrate likely adjacencies overlaid onto the structural grid framework.





Traditional Performance Block Model





Learning Commons + Performance Block Model

Note: Drawings Not To Scale

Costs & Conclusions—

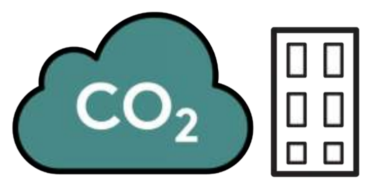
This section provides cost analysis data to support the thesis of mass timber benefits in K-12 schools. It illustrates the various structural analyses that were completed in order to efficiently design a school with mass timber. Finally, the team partners and their associated K-12 experience are credited as part of this effort.

Mass Timber Advantages

As proven, there are many advantages to districts, students, and teachers by using mass timber as a primary building material in K-12 schools. Some of the primary benefits include construction schedule reduction, reduced embodied carbon, increased productivity in students and staff, and improved overall well-being. Depending on market fluctuations, cost has potential to be seen as an additional benefit of building with mass timber. In some markets, mass timber may show higher first costs compared to a steel and concrete structure. However, it is proving to be cost competitive and often, the other benefits outweigh any premium seen in up-front costs of building with mass timber.

1. Schedule Reduction

Many studies have shown a reduction in construction schedule by approximately 25%

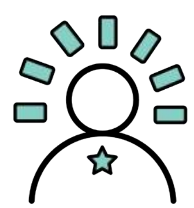


2. Embodied Carbon Reduction

The Building Better schools prototype represents a 102% reduction in embodied carbon compared to the steel-frame baseline.

3. Increased Productivity & Test Scores

One study proved a gain in Average Test score that was 3.3X higher in a Biophilic classroom.



4. Improved Well-Being

Natural environments and wood in particular help reduce stress and improve wellbeing.

Bonus Advantage: Cost Competitive

Whole building costs for mass timber designs can be equal or very competitive with concrete and steel building designs.

Total Cost Analysis

In addition to schedule, site, and environmental benefits, mass timber is also a cost competitive building material. As wood accounts for over 75% of the cost of CLT, the mass timber system is designed with 3-ply panels to reduce minimize the amount of wood fiber.

A building cost analysis compares a conventional concrete and steel structure with a mass timber CLT structure. The results illustrate that mass timber is cost competitive. Building component cost impacts can often be seen in these major categories:

- Exterior Enclosure

  Savings are achieved through reduction of floor-to-floor height by approximately two feet of vertical area. This is possible when structural framing members run one-directional and allow for mechanical ductwork distribution at the same elevation as structural members. Structural members in central corridor are reduced depth in order to allow for main ducts distribution to classrooms.

  Refer to Structural Framing cost analysis for more detail.

- General Conditions

  Case studies have proven that pre-fabrication minimizes on-site labor and results in faster on-site installation, reducing overall project duration and GC overhead costs.

- Concrete Foundations

  When considering mass timber lateral system design, foundations for mass timber shear walls may incur an average cost increase of +/-10% when compared to steel braced frame foundations.

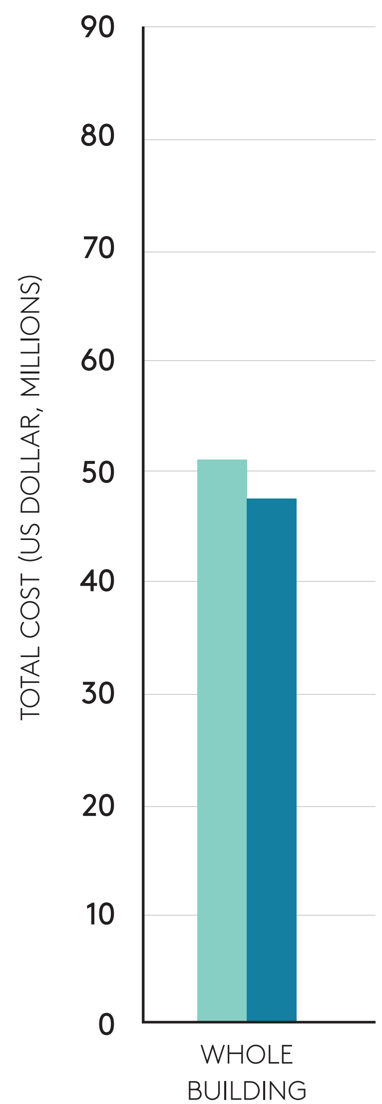
- Wall Framing and Fire Rating

  Mass timber building for non-rated construction types allows for less framed walls and gypsum board finishes.

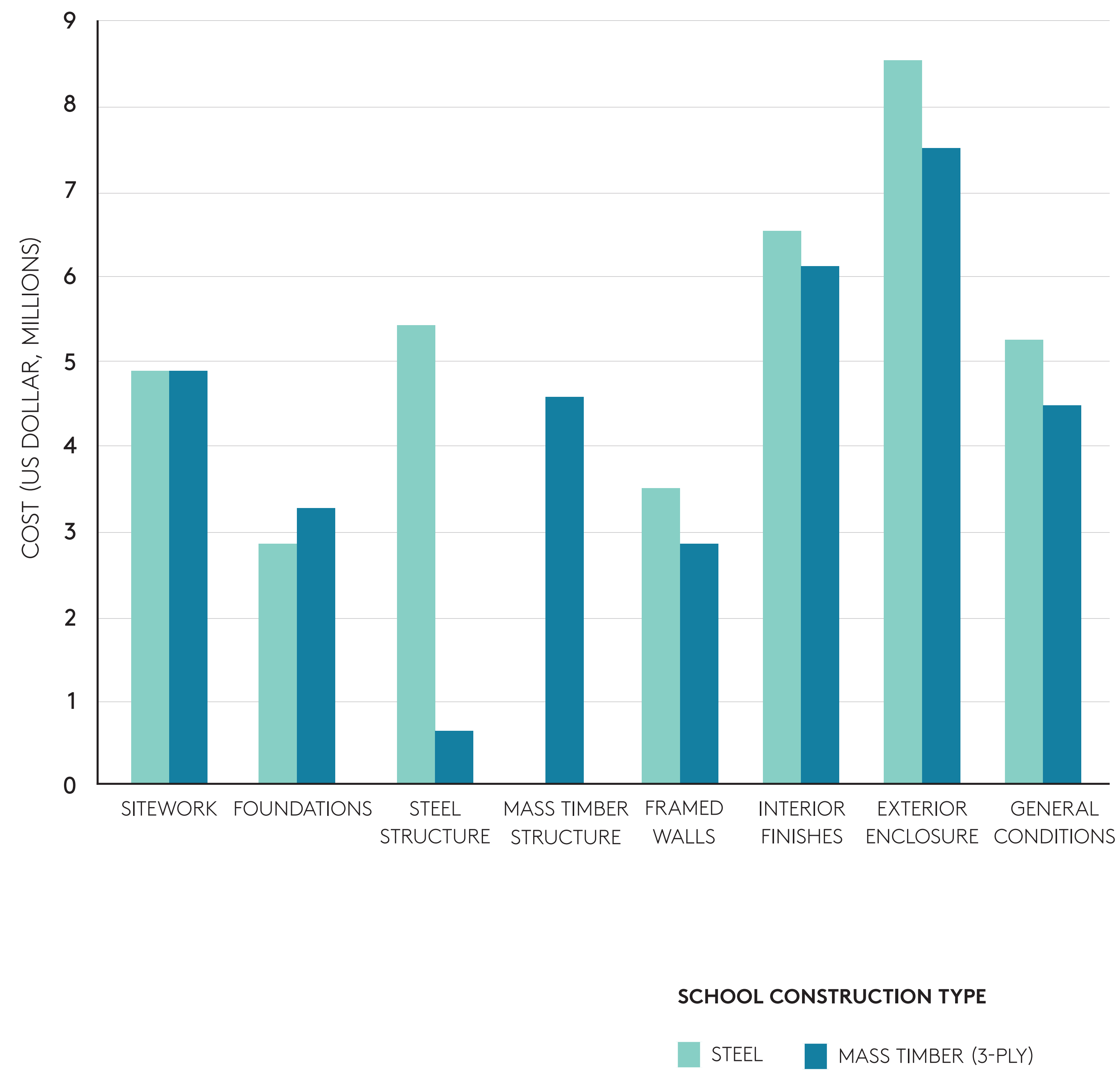
- MEP

All cost data represents up-front costs only and was sourced in August 2021 in collaboration with Mass Timber Services. Costs are based on 108,000 Gross Square Feet.

Total Building Cost



Building Material Costs
Steel School vs 3-ply Mass Timber School



Mass Timber Structural Framing: Supporting Cost Data

Designing with mass timber is different. To illustrate how early design decisions can affect overall cost, we have provided this example. Architectural, structural, and MEP systems are inherently integrated into building design, early consideration of structural and mechanical distribution relationships need to be understood. In order to optimize material, costs, and achieve an efficient distribution of mechanical ductwork to classrooms, while not sacrificing user experience. An analysis of mass timber structural framing is shown.

Findings suggest that more columns with reduced grid spacing eliminates the need for glulam girders to support CLT floor panels and is more cost effective than fewer columns with greater grid spacing and glulam girders.

All cost data was sourced in August 2021 in collaboration with Mass Timber Services**.** Costs are an analysis of +/- 15,000 Gross Square Foot, two-story classroom wing and include supply and install costs

GLULAM BEAMS AND GIRDERS

Structural framing design includes glulam columns spaced at 21'-6" O.C. with glulam girders spanning between columns. This design forces mechanical distribution below girders, resulting in average floor-to-floor height of 14'-0".

	Quantity	Cost
Footings	n/a	$ 0
Columns	n/a	$ 0
Exterior Skin	43 SF	$ 2,150
Glulam Girders at Corridor	126 LF	$ 9,576
Glulam Girders at Perimeter	84 LF	$ 5,754

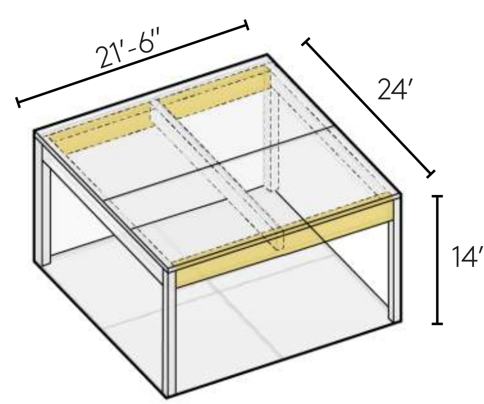


Diagram illustrates one structural bay.

GLULAM BEAMS ONLY

Structural framing design includes glulam columns spaced at 10'-8" O.C. without glulam girders spanning between columns. This allows for ease of mechanical routing and reduced floor-to-floor height by 2'.

	Quantity	Cost
Footings	8	$ 2,587
Columns	4	$ 1,536
Exterior Skin	n/a	$ 0
Glulam Girders at Corridor	n/a	$ 0
Glulam Girders at Perimeter	n/a	$ 0

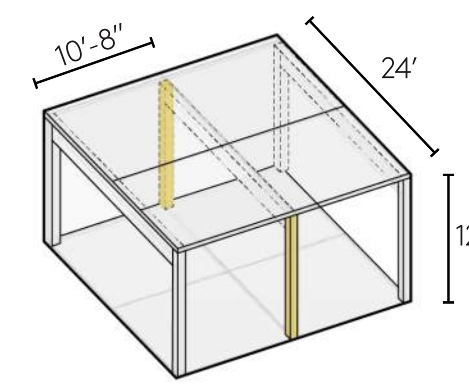


Diagram illustrates two structural bays.

Lateral System Analysis: Supporting Cost Data

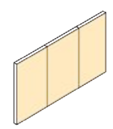
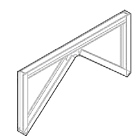
Designing with mass timber is different. To illustrate how early design decisions can affect overall cost, we have provided this example. The structural lateral design of a building can be dependent upon many factors— seismic zone, construction type, number of stories, structural materials, etc. This analysis compares an all CLT lateral system against a steel braced frame design for the two-story prototype.

Findings suggest that an entirely CLT building is more cost effective than introducing the steel trade for the lateral system. By using CLT shear walls throughout, it also eliminates the need for a seismic joint to separate spaces designed with CLT shear from steel braced frames.

Cost data was sourced in August 2021 in collaboration with Mass Timber Services. Costs assume +/- 15,000 Gross Square Foot, two-story classroom structure and +/- 19,000 Gross Square Foot Performance Block (gym, commons, library, music). Costs include supply and install.

CORE LEARNING AREAS

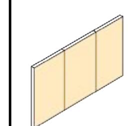
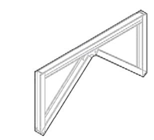
Structural lateral system analysis compares CLT shear walls* and steel braced frames at 12' height per level with concrete footings.

	CLT SHEAR WALLS	STEEL BRACED FRAMES
Steel Braced Frames	n/a	$ 328,125
105mm CLT Shear Walls*	$ 149,760	n/a
175mm CLT Shear Walls**	n/a	n/a
Braced Frame Footings	n/a	$ 85,050
CLT Shear Wall Footings	$ 142,200	n/a
Seismic Joint	n/a	n/a
Total	**$ 291,960**	**$ 413,175** **+ 34.38%**

PERFORMANCE BLOCK AREAS

Structural lateral system analysis compares CLT shear walls and steel braced frames typical with concrete footings. 30' tall CLT shear walls** are designed at gymnasium exterior walls. A seismic joint is designed between gymnasium CLT structure and adjacent steel braced system.

	CLT SHEAR WALLS	STEEL BRACED FRAMES
Steel Braced Frames	n/a	$ 234,375
105mm CLT Shear Walls*	$ 59,904	n/a
175mm CLT Shear Walls**	$ 230,256	$ 230,256
Braced Frame Footings	n/a	$ 49,995
CLT Shear Wall Footings	$ 59,415	n/a
Seismic Joint	n/a	$ 17,375
Total	**$ 349,575**	**$ 532,001** **+ 41.38%**

Embodied Carbon Impact

The structural system of a building comprises up to 80% of the embodied carbon footprint of a building, due to the carbon intensity of structural materials like steel and concrete. These high-impact materials are often referred to as carbon "hot spots" in Life Cycle Assessment (LCA) analysis.

Using mass timber as a primary building material can reduce embodied carbon in the following categories:

Building Structure

- The most significant carbon benefit is swapping hot spot structural materials for wood materials
- The reduced weight of a mass timber structure compared to a concrete baseline can also reduce foundation sizing

Floor-to-Floor Height

- The ability to reduce floor to floor heights minimizes overall material use. Beyond the building structure, this can have a significant impact at the exterior envelope and interior walls, reducing architectural hot spot materials including exterior cladding, framing, insulation and gypsum wall board.

Interior Finishes

- Building with wood can also reduce surface area required for finishes including nylon carpet, acoustic ceiling tiles and gypsum wall board, which can all be hot spot materials. In addition to reducing embodied carbon, this can boost biophilia and minimize the use of materials that can negatively impact human health.

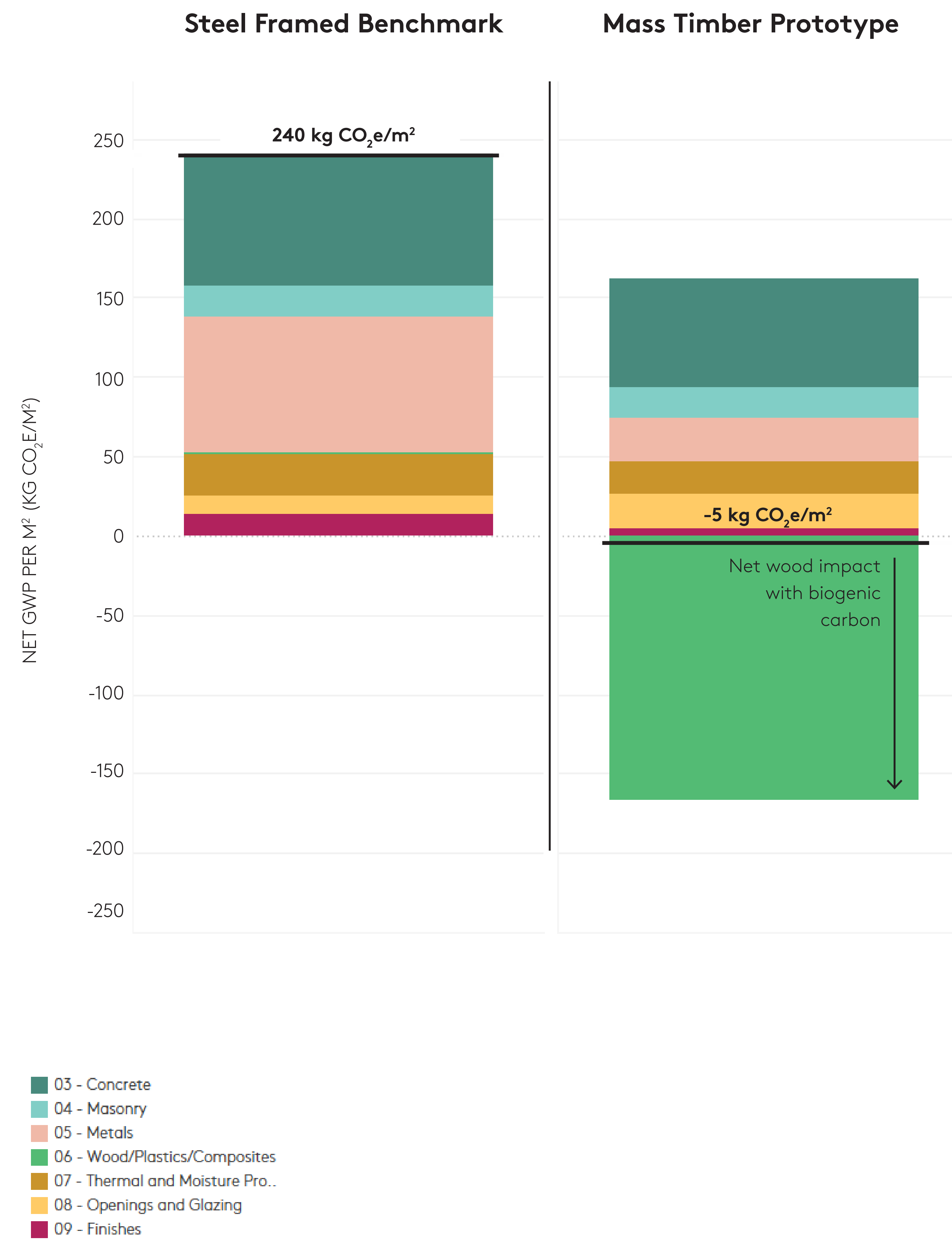
To illustrate the potential carbon impacts, LCA is used to compare the global warming potential (GWP) in classroom wings of the Building Better Schools prototype and a steel-frame elementary school of similar scale. Tally for Revit is used to quantify up-front embodied carbon emissions (from raw material extraction through construction), and includes estimates of the biogenic carbon stored in wood products.

The carbon sequestered in the wood materials results in a net negative embodied carbon footprint, meaning the building stores more carbon than is emitted incurred during material production. This represents a 102% reduction in embodied carbon compared to the steel-frame baseline.

Key Findings

- Using mass timber can have secondary benefits such as reducing finishes or foundation sizing. In this case, mass timber reduced finishes by approx. 65% by area compared to a steel school. (Benchmark included GWB, ACT and Carpet Flooring).
- Using mass timber can offset the carbon emissions of other building materials. Results show that mass timber can offset all emissions incurred in material manufacturing and production, reducing GWP by up to 200% compared to a steel-framed benchmark.

The Building Better Schools mass timber prototype reduces emissions from material manufacturing and production by about 30% compared to a steel-framed benchmark.



Carbon Sequestering & Wood Sourcing

There is an important caveat to the measured carbon benefits of using wood products: material sourcing and forest management practices can significantly shift the net embodied carbon footprint.

Most Life Cycle Assessment (LCA) studies do not include the upstream carbon impact for how the source forest of wood products was managed. Considering "upstream" embodied carbon is an emerging practice in LCA, but it is generally understood that forest management practices have significant impacts on forest ecosystems and therefore embodied carbon.

In the case of sustainably-managed forests, more carbon is sequestered than is represented in our totals. Conversely, in the case of poorly managed forests or forests replaced by development after harvesting, the adverse carbon impacts can rival the embodied carbon of concrete, resulting in higher emissions than are accounted for in our totals.

Sourcing from sustainably-managed forests can reduce a building's net carbon by approx. 140% over sourcing from a poorly managed forest.

Team

This Research + Development project could not have been possible without the dedication and interdisciplinary collaboration of our teams— Mithun, PCS Structural Solutions, and Bayley Construction.

Additional contributors include Metrix Engineers, Overcast Innovations, and Mass Timber Services.

MASS TIMBER SERVICES

Mass Timber Services (MTS) is a provider of premium mass timber products + personalized service for designers and builders to create innovative and beautiful engineered wood structures. The mass timber cost data provided in this report was provided by MTS.

METRIX ENGINEERS

Metrix Engineers is a mechanical and electrical design and consulting firm specializing in K-12 construction. Metrix corporate mission, vision and values guide their design and production approach and the relationships they establish with their colleagues and clients. Their mission is to (1) ensure client satisfaction, (2) add value for our clients, and (3) provide employees with a rewarding work environment.

OVERCAST INNOVATIONS

Overcast Innovations is a product manufacturer based in Seattle, WA. We use an industrialized construction approach to manufacture smart, integrated MEPF ceiling appliances that are union-assembled in WA state and serve spaces without sacrifice. Overcast has provided clouds for projects in higher education, to commercial office, to life sciences across the United States and has extensive experience in mass timber and CLT projects within the education market.

MITHŪN

Mithun is an integrated architecture, interiors, and landscape design firm headquartered in the Seattle area, with additional offices in Los Angeles and San Francisco. Mithun is an industry expert in mass timber with experience in a range of mass timber applications including primary and secondary education, multi-family housing, civic centers, museums, and more.

In 2021, Mithun's recently completed Blakely Elementary School received the Polished Apple Award through the Association for Learning Environments (A4LE), who's mission is improving the places where children learn. Their Polished Apple Award Program recognizes outstanding educational facilities in the state of Washington.

Image: Blakely Elementary School, Bainbridge Island, WA

Photography by: Kevin Scott

BAYLEY

Bayley Construction is a leading full-service general contractor with offices in Washington, Arizona and California. Founded in 1963, our company brings a high level of experience and expertise in the education, retail, entertainment, office, sports and government sectors. Our team of over 170 people are all passionate about what they do and are willing to take on complex challenges with a "can-do" attitude.

Bayley has experience in all delivery methods, specializing in accurate negotiated Guaranteed Maximum Price contracts, as well as GC/CM, Design-Bid-Build and Design-Build. Our team has extensive experience with historic renovation, seismic retrofitting, adaptive re-use and new construction. Our services include pre-construction, construction management and construction.

Image: Rivers Building at The Little School in Bellevue, WA

Photography by: LightCatcher Imagery

PCS Structural Solutions

PCS Structural Solutions is a single-discipline structural engineering firm with 50+ years of experience focused on structural design for learning environments. Founded in 1965 with offices in Seattle, Tacoma, and Portland, the firm has partnered with school districts throughout Washington State on state-of-the-art new schools, additions, renovations, modernizations, evaluations, and seismic and life safety upgrades. PCS offers active solutions for flexibility and customization while balancing the school district's specific priorities and desires, coordinating seamlessly with the full project team in traditional and advanced project delivery such as design build. PCS engineers have led structural design and research into CLT and mass timber usage for schools and other buildings, finding ways to highlight this sustainable structural material within budget constraints.

Image: Birney Elementary School, Tacoma, WA

Photography by: Doug Walker

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Appendix

Total Cost Analysis Support Data

In addition to schedule, site, and environmental benefits, mass timber is also a cost competitive building material. As wood accounts for over 75% of the cost of CLT, the mass timber system is designed with 3-ply panels to reduce minimize the amount of wood fiber.

A building cost analysis compares a conventional concrete and steel structure with a mass timber CLT structure. The results illustrate that mass timber is cost competitive. Building component cost impacts can often be seen in these major categories:

- **Exterior Enclosure**

  Savings are achieved through reduction of floor-to-floor height by approximately two feet of vertical area. This is possible when structural framing members run one-directional and allow for mechanical ductwork distribution at the same elevation as structural members. Structural members in central corridor are reduced depth in order to allow for main ducts distribution to classrooms.

  Refer to Structural Framing cost analysis for more detail.
- **General Conditions**

  Case studies have proven that pre-fabrication minimizes on-site labor and results in faster on-site installation, reducing overall project duration and GC overhead costs.
- **Concrete Foundations**

  When considering mass timber lateral system design, foundations for mass timber shear walls may incur an average cost increase of +/-10% when compared to steel braced frame foundations.
- **Wall Framing and Fire Rating**

  Mass timber building for non-rated construction types allows for less framed walls and gypsum board finishes.
- **MEP**

The industry needs to adopt new ways of designing to allow mass timber to be cost competitive- start the project with mass timber and let the inherent properties of the system influence the design. You won't be disappointed with the results!

All cost data represents up-front costs only and was sourced in August 2021 in the Pacific Northwest Region of the United States. Costs are based on 108,000 Gross Square Foot. All cost data represents up-front costs only and was sourced in August 2021 in the Pacific Northwest Region of the United States. Costs are based on 108,000 Gross Square Foot..

	STEEL & CONCRETE SCHOOL		MASS TIMBER SCHOOL	
	Building type is inclusive of concrete foundation and floor slabs with structural steel floor framing, columns and superstructure.		Building type is inclusive of concrete foundation with cross-laminated timber floor assembly, 3-ply CLT shear walls for the lateral system and glulam structural framing.	
	Cost	% of Total Building Cost	Cost	% of Total Building Cost
Sitework	$ 4,941,889	9.7 %	$ 4,941,889	10.4 %
Foundations	$ 2,909,288	5.7 %	$ 3,200,621	6.7 %
Structural Steel	$ 5,378,585	10.6 %	$ 571,000	1.2 %
Mass Timber Structure	n/a	0 %	$ 4,502,660	9.5 %
Wall Framing and Fire Rating	$ 3,520,572	6.9 %	$ 2,954,181	6.7 %
Floor Build Up	n/a	0 %	$ 135,000	0.3 %
Interior Finishes	$ 6,530,300	12.9 %	$ 6,236,221	13.1 %
Exterior Enclosure	$ 8,445,511	16.6 %	$ 7,447,335	15.7 %
MEP	$ 13,487,665	26.5 %	$ 12,678,405	26.7 %
Vertical Transportation	$ 421,467	0.8 %	$ 421,467	0.9 %
General Conditions	$ 5,173,984	10.2 %	$ 4,139,187	8.7 %
Total	**$ 50,809,261** **$ 467/SF**	**100 %**	**$ 47,465,711** **$ 436/SF**	**100 %**