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Rethinking Construction - Consider Timber

An introduction to Guides 26, 27, 28 and 29

Technical Design Guide issued by Forest and Wood Products Australia

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Authors

Timber Development Association NSW Ltd

Professor Perry Forsythe
Faculty of Design Architecture and Building
University of Technology Sydney

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1 Introduction

Timber's sustainability credentials are attracting world-wide interest and advancements in timber engineering have made it an increasingly cost-competitive proposition for commercial projects.

Encouraging the construction industry to adopt innovative approaches needs information and evidence. Attention to technical design, construction costs and site processes is critical to show the value proposition of timber construction to industry participants and optimise its use.

This Guide provides an introduction and overview of a research project that developed designs for four building types with timber solutions, as well as alternative designs with conventional steel portal or concrete construction.

The project aimed to provide a source of timber costing information to building professionals by comparing the cost of timber commercial buildings to the cost of those constructed using traditional materials.

The timber solutions were designed to optimise functional performance, constructability and cost effectiveness and provide guidance for compliance under the National Construction Code (NCC).

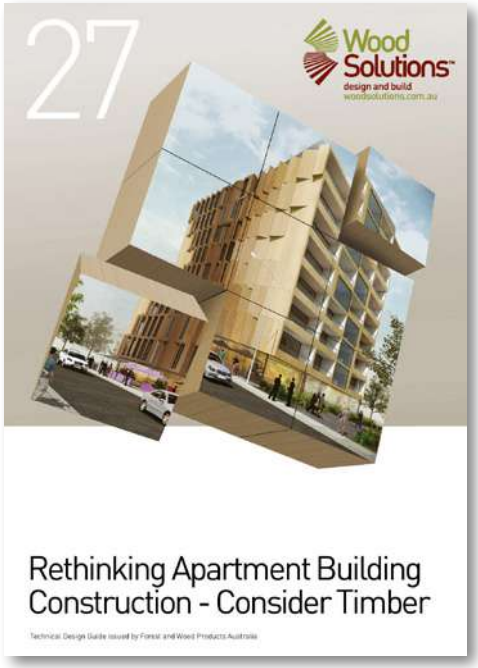
The project investigated four building types:

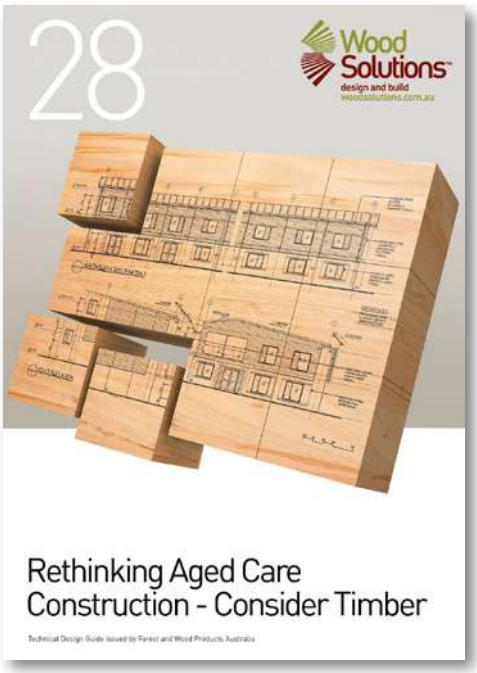
- A medium rise (7-storey) office building
- A medium rise (8-storey) apartment building
- A low rise (2-storey) aged care facility
- A single-storey industrial shed.

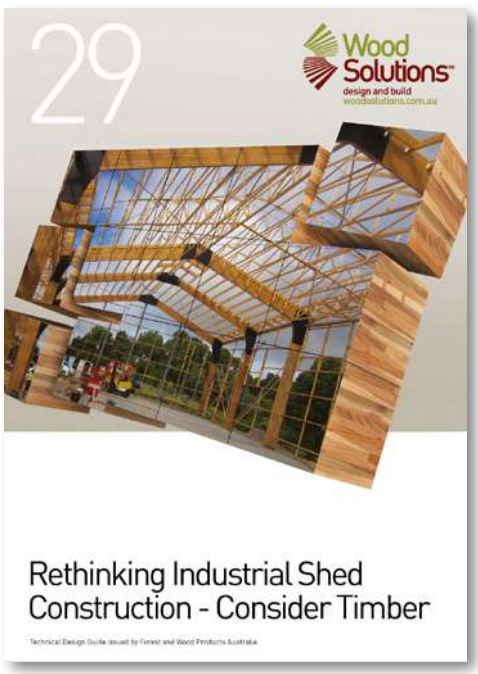
Each solution was designed and then independently costed for a timber option as well as a more conventional concrete-framed or steel-framed solution. The cost plans were based on a reference location in suburban Sydney. The site was assumed to have no significant cost implications concerning site access, ground conditions or neighbouring properties.

In 2018, a timber-framed design was added to the apartment building comparison to complement the cross-laminated timber design. Furthermore, the CLT design was also amended to comply with the current NCC requirements as well as to change the CLT supply from Europe to Australia. The apartment building with its three options and along with the office building where repriced to current market prices.

For details and cost comparisons for each the four building types, please refer to the Design Guide dedicated to each type:







Each of these Design Guides details a cost comparison and a commentary for the specific building type. The commentary discusses the makeup of each building, any issues encountered and how they were dealt with, as well as the outcomes and areas of possible improvement.

In all cases, the costs of the timber structural solutions were found to be significantly lower or lower than the competing non-timber solutions. Some of the main components were found to be significantly cheaper in timber for each building type investigated.

The gross savings were even greater; however, fire protection of some of these structural elements, the extra engineering cost (fire engineering) and the cost of termite protection reduced the overall cost savings. For the office building and apartment building, the major savings were generally found in the preliminary costs, an area not fully recognised when comparing costs (see Section 4).

Section 3 of this introductory Design Guide gives a summary of the cost plan results. Refer to the individual Design Guides for each building type for full descriptions of each timber solution and corresponding non-timber designs.

2 Project Development

The research project was carried out in four steps:

1. Develop a model design for the four building types.
2. Design each building using timber and also a non-timber material.
3. Develop an independent cost plan for each building type.
4. Develop a commentary on each building type to inform design professionals of the reasoning behind decisions and what was considered in the cost plan.

2.1 Model Building Designs

The first step of the project was to develop the designs for each of the model buildings being considered. It was decided to advance new designs instead of using those of existing buildings, as privacy and intellectual property issues prevented the publication of information on specific buildings. To develop the model designs, a number of industry experts and stakeholders were involved.

The project was led by the Timber Development Association (TDA) with the University of Technology Sydney (UTS) and the Royal Institute of Cost Surveyors' Building Cost Information Service (BCIS). UTS co-developed the research method and mediated the strategic direction of timber solutions pertaining to detailed design, construction, cost and site productivity issues. BCIS provided the quantity surveying, cost estimating and cost planning input for both the timber solutions and the corresponding non-timber traditional solutions. The cost plan for the apartment and office building was updated in 2018, and this was carried out by MBM.

The design teams varied for each building type. Team members collaborated in providing feedback for their particular building and driving the development process, which included meetings, interviews, concept development sessions, design charrettes, cost planning studies and detailed design studies to develop the model building under consideration and find a cost-effective timber solution for it.

Each building was designed to the extent that the key differences in costs for each one could be ascertained. For the office and apartment buildings, the design had to incorporate much more than just structural consideration; it also included heating, ventilation and air conditioning (HVAC), façade, acoustics, and so on. These aspects drove the structural design decisions and are discussed in detail in the Design Guides for the office and apartment buildings. As is the case for complex buildings, specific designs for each building varied for each building type.

Various companies within the timber industry provided input to all the building designs. Timber companies were able to explore options that could not be done under real project conditions. The companies involved were engineered timber manufacturers, suppliers and associated connections including: Tilling Timber, Meyer Timber, Nelson Pine, Carter Holt Harvey Wood Products, MiTek, Hyne and XLAM. These companies provided input on timber supply costs, the viability of designs, design properties, manufacturing processes and the availability of appropriate timber componentry.

2.1.1 Office Building Design

The designs for the office buildings were developed by design teams involving staff from the following organisations:

- Fitzpatrick and Partners – An architectural firm specialising in office design with significant experience in all the major cities in Australia. They provided feedback on client needs and helped design the model office building and the related timber solution.
- Arup Ltd – A global engineering firm with expertise spanning structural, acoustic, fire and services engineering. They provided design and engineering input into the timber solution and the corresponding concrete solution as well as assisting in HVAC and acoustic decisions.
- RBE Contracting – A construction project management company with expertise in large-scale timber construction. They provided input into the timber solution and the competing concrete solution, especially in terms of design management and site process-driven variables.

The revised cost model carried out in 2018 did not change any of the original design.

2.1.2 Apartment Building Design

The design for the apartment buildings was carried out twice. The first time as a CLT only solution, and the second time as a lightweight timber-frame and Australian CLT solution. The initial design was developed by design teams involving staff from the following organisations:

- Studio 505 – An architectural firm with a strong understanding of the design and the effects of material and system selection. They prepared and led the design of the model apartment building with case specific input into the related timber solution.
- Taylor Thompson Whitting (TTW) Consulting Engineers – An engineering firm with specialised services in structural, civil and facade engineering. They provided the structural design for the concrete solution.
- AECOM – A global multi-disciplinary engineering firm with expertise in structural, acoustic, fire and service engineering. They provided specialist advice on the design of the timber solution. TDA designed the cross-laminated timber (CLT) components in collaboration with the CLT supplier SmartStrut, and AECOM provided specialist CLT assistance.

The later revision involved additional companies;

- Zimmermann Design Studio: An Architectural firm that led the design of the timber-framed apartment building and provided input into the related timber solution. The original concept design of the building is based on a design undertaken by studio505 the firm from which Zimmermann Design Studio emerged from.
- Timber Imagineering and Tim Gibney and Associates: Heavy timber Fabrication Company and structural timber engineering services. They provided the specialised design of lateral resisting frames as well as analysis of the CLT core.

2.1.3 Aged Care Facility Design

The aged care building was much smaller and, since the chosen structural system is well established in timber and alternative materials within the marketplace, it was not necessary to establish a multi-discipline design team. The architectural model design was developed by Plan Source, a building design company experienced in residential and small commercial buildings. Structural design for both design options was provided by TDA with assistance from Tilling Timber and Meyer Timber. The design was then supplemented with input from timber and steel frame and truss suppliers.

2.1.4 Industrial Shed Design

An existing design developed for the Structural Timber Innovation Company was used for the industrial shed, so there was no need for a design team. The exercise was to reprice the existing design and an alternative timber design was considered to further explore attributes of a timber portal frame. This design explored another bay spacing arrangement and an alternative connector system.

2.2 Cost Plan Development

The Royal Institute of Cost Surveyors (RICS) provided quantity surveying, cost estimating and cost planning input for both the timber solution and the corresponding alternative solutions for the initial study. In most circumstances, RICS used the pre-existing knowledge within its own information system to develop the comparison costs. However, as the timber designs for the office and apartment building were unique, a price for each one was obtained from the marketplace that included all costs up to delivery to the reference building site. RICS sourced these prices directly from the market, independent to the research team.

SmartStruct provided the CLT price for the apartment building and the cores in the office building, while Meyer Timber provided the price for the office building's beams, columns and floor and roof cassettes.

For the aged care building, the costing information was sourced from the BCIS database, with independent prices sourced from the market place as a parallel exercise. The market place prices confirmed the accuracy of the BCIS cost information.

One key element in developing a cost plan was the consideration of the construction program time. Time savings affect preliminary costs, and this was a key difference in the costing of the office building and apartment building. An independent contractor experienced in both timber and concrete construction was used to program the office building. The apartment building was estimated by BCIS, as they have information on CLT design from their parent company in the UK, where CLT design has been used for more than 11 years.

The revised cost plan carried out in 2018 for the office building, and lightweight timber-framed and CLT apartment utilised a different company, MBM. MBM is a national independent construction consultancy specialising in quantity surveying. They provided quantity surveying, cost estimating and cost planning input for the 2018 version of the timber-framed solution and the corresponding concrete solution. They have, in recent times, developed real experience in timber construction and costings. XLAM provided the cost for the CLT.

3

Cost Plan Results

The cost comparison for each building type was only undertaken for the parts of the building that were considered to have significant different costs, both positive and negative, under the two competing design scenarios. Therefore, items such as mechanical, electrical, plumbing, floor coverings, car parking levels and fit out were excluded. In order to create stable costing, it was assumed that the building would be constructed in suburban Sydney, with no significant cost implications concerning site access, ground conditions or neighbouring properties.

In all cases, it was found that the timber solution was more cost effective than the alternative material considered (see Table 1.) The price differences shown in the tables are for elements of construction considered and do not represent the overall costs of the buildings.

Each of the main components was found to be significantly cheaper in timber for each building. The gross savings were found to be even greater; however, the fire protection to some of the structural elements, the extra engineering cost (fire engineering) and the cost of termite protection reduced the cost savings. For the office and apartment building the major cost savings were generally found in the preliminary costs – an area not fully recognised when comparing costs (see Section 4).

Building type	Cost of structural solution		Cost savings of timber compared to conventional
	Timber	Conventional	
7-storey office building	$7,237,259	$8,379,104	-$1,141,485
8-storey lightweight timber frame apartment building	$4,073,727	$4,698,581	-$624,854
8-storey CLT apartment building	$4,406,714	$4,698,581	-$291,867
2-storey aged care facility	$697,020	$809,620	-$112,600
Single-storey industrial shed	$216,342	$238,861	-$22,519

Table 1: Summary of all cost comparisons.

3.1 Office Building Cost Comparisons

For details of the 7-storey office building cost comparisons, see the *Design Guide #26 Rethinking Office Construction – Consider Timber*.

The timber building provides a saving of $1,141,845, being a 13.6% saving compared to the reinforced concrete solution (see Table 2).

Element	Timber	Concrete	Variance
Columns	$450,218	$307,224	+$142,994
Staircase	$319,700	$305,865	-$13,835
Uppper floors	$4,491,903,	$4,736,195	-$244,292
Roof	$593,105	$792,480	-$199,375
Shafts External Walls	$345,825	$522,000	-$176,175
Shaft Internal Walls	$521,268	$717,600	-$196,332
Ceiling Finishes	$997,740	$997,740	$0
Preliminary Adjustments	-$482,500	-	-$1,141,845
Total	**$7,237,259**	**$8,379,104**	**-$1,141,845**

Table 2: Office Building – Cost comparison of major items for each building solution.

In analysing the differences between the two plans, the timber building provides a saving of $1,141,845 is 13.6% cheaper than the concrete solution. Specific savings under the timber solution are as follows:

- Floor: $244,292 (4.7% less)
- Lift, Stair and Air shafts: $356,342 (23% less)
- Roof: $199,375 (25.1% less)
- Preliminary costs: $482,500 less.

Additional costs under the timber solution (relative to the concrete solution) include:

- Stairs: $13,835 (3% more)
- Columns: $142,994 (31.8% more)
- Connections: $59,769 more
- Termite & Fire Engineering: $35,000 more.

Additional savings could be possible by deleting the suspended ceiling and exposing the timber beams and floor. This would result in a further potential savings of $997,740, but this would incur additional costs for neater fixing of the mechanical air supply and lights, estimated to cost $266,064. The overall saving for the timber solution, in this case, would be $1,873,521 (22.3% less than the concrete solution), a very substantial cost saving.

3.2 Apartment Building Cost Comparisons

For details of the 8-storey apartment building cost comparisons, see the *Design Guide #27 Rethinking Apartment Construction – Consider Timber*.

Two timber solution were considered, and both provided saving. The lightweight timber-framed solution provides a saving of $624,854, being 13% lower than the reinforced concrete solution (see Table 3), while the Cross Laminated Timber solution provided a saving of $291,867 or 6% lower (see Table 3).

Element	Timber Framed	Cross Laminated Timber	Concrete
Columns	34,935.00	34,935.00	365,644.00
Upper Floors	1,567,887.00	2,539,961.00	1,810,398.00
Staircase	81,200.00	81,200.00	66,150.00
Roof	256,260.00	233,100.00	356,617.00
External Walls (excludes rain screen)	335,511.00	518,082.00	416,165.00
Internal Walls	1,417,544.00	1,286,436.00	1,224,522.00
Wall Finishes	Included	Included	Included
Ceiling Finishes	667,390.00	Included	459,085.00
Preliminaries	-287,000.00	-287,000.00	-
Total	**4,073,727.00**	**4,406,714.00**	**4,698,581.00**

Table 3: Apartment building – Cost comparison of major items for each building solution.

Specific savings under the timber solution (relative to concrete) were:

- •Concrete transfer slab at Level 1 ($173,091). As both the timber solution is lighter in weight (20% of the mass of concrete) than the concrete solution, a thinner and cheaper concrete transfer slab was possible.
- •The loadbearing structure, including walls, floors, columns, roof and their coverings was cheaper for the lightweight timber framed solution ($352,527) and marginal difference for the CLT solution ($9,917). Savings were possible due to the reduction of material required for the roof and core walls and also the removal of columns throughout the building by the use of loadbearing walls.
- •Preliminary costs for the project. The timber solution included an estimated saving in preliminaries of $287,000, based on a construction program saving six weeks compared to the concrete solution.

Each week was estimated to save $52,000 based on labour cost savings for site management, site sheds and plant such as crane, hoist and scaffolding hire when compared to the concrete option. An allowance of $25,000 was deducted from this saving to cover the extra cost of termite protection to the timber elements.

Additional costs under the timber solution relative to concrete were:

- Increased fire protection to the lightweight timber-framed and CLT elements. The extra cost for the timber solution related to the additional linings required for fire protection of timber load-bearing walls and floors for both timber solutions.
- Termite protection of the timber elements. The timber solution sits on top of a concrete basement (car park) and concrete retail level. As an additional precaution, the timber structure has termite protection by way of a stainless steel mesh to all hidden entry points from the ground to the concrete structure. This protection was estimated at an additional cost to the timber solution of $25,000.

3.3 Aged Care Facility Cost Comparisons

For details of the aged care facility cost comparisons, see the Design Guide #28 *Rethinking Aged Care Construction – Consider Timber.*

The timber-framed solution cost plan for the 2-storey aged care facility shows a saving of $112,600, being a 16% reduction when compared to the steel-framed solution (see Table 4). These costings include wall and floor coverings.

Item	Timber	Steel	Variance
Columns	$2,646	$3,330	-$684
Upper Floors	$63,138	$226,357	-$163,219
Roof	$259,611	$300,635	-$41,024
Walls	$371,625	$279,298	+$92,327
Total	**$697,020**	**$809,620**	**-$112,600**

Table 4: Aged care facility – Cost comparison of major items for each building solution.

Main savings for the timber solution:

- Upper floor framing $163,219 or 72% lower than the steel solution
- Roof framing $41,024 or 15% lower than the steel solution

Additional costs were found to be in the wall framing $92,327, a 33% additional cost.

An exercise was carried out to independently verify the cost plan findings via real quotations from the market place. Quotes were obtained from leading timber and steel frame suppliers as a package delivered to site. The quotes are for framing materials only; note, the cost plan included wall and ceiling coverings.

- Steel $231,000
- Timber $193,133
- Difference $37,867 (20% saving).

As with the cost-planning exercise, these figures indicate that the timber solution is cheaper, but at a lesser amount of $37,867 (20%). The savings were identified mainly in the upper floor framing, which parallels the main findings from the cost planning exercise.

3.4 Industrial Shed Cost Comparisons

An existing design was used for the industrial shed, and an alternative timber design was considered to further explore attributes of a timber portal frame. This design explored another bay spacing arrangement (see Table 5 for a summary of the cost comparisons).

For details of the industrial shed cost comparisons, see the Design Guide *#29 Rethinking Industrial Shed Construction – Consider Timber.*

Item	Timber portal solution 1 6.67 m Bay Spacing	Timber portal solution 2 10 m Bay Spacing	Steel portal solution 8.0 m Bay Spacing
Purlin	$39,483	$74,595	$46,190
Girts and columns	$20,761	$28,247	$60,496
Portal Frame	$147,310	$91,500	$98,635
Footings	$19,480	$22,000	$33,540
Total	**$227,034**	**$216,342**	**$238,861**

Table 5: Industrial shed – Cost comparison of major items for each building solution.

The timber solution with the 10.0 m portal spacing is the cheapest option, followed by the timber solution with the 6.67 m portal spacing, being 9.4% and 5.0% cheaper than the steel option, respectively.

4 Conclusion

This project developed cost plans for the structure of four building types: a 7-storey office building, an 8-storey apartment building (lightweight timber-framed and CLT version), a 2-storey aged care facility and a single-storey industrial shed. Each solution was designed and then independently costed for a timber option as well as a more conventional concrete-framed or steel-framed solution for a reference location in suburban Sydney. The site was assumed to have no significant cost implications concerning site access, ground conditions or neighbouring properties.

The investigation considered only the elements of the building for which there were significant differences and ignored the cost of elements that were the same.

This project has shown that timber building designs can be as cost-effective as traditional non-timber building designs. The overall costs of the timber solutions for these four building type scenarios were found in all cases to be less or significantly less than the competing non-timber solutions.

The cost of each of the main components was found to be cheaper in timber for each building. The gross savings were found to be even greater; however, the fire protection to some of these structural elements, and the cost of termite protection reduced the overall cost savings for some building types.

4.1 Cost Savings from Preliminaries

For the office building and apartment buildings, the major savings were generally found in the preliminary costs, an area not fully recognised when comparing costs.

A significant proportion of the savings in a timber solution were found from using pre-fabricated methods of construction for the office and apartment buildings. Pre-fabrication reduced onsite construction time due to compression of the construction program and reduced the need for expensive on-site labour. A compressed construction program saves site infrastructure costs such as scaffolding, site accommodation, hoists, craneage and construction site administration costs.

These cost savings can potentially be significant but are hard to quantify under a cost plan scenario, as they are included under a cost centre called preliminaries. Cost planners tend to use set percentage rates for preliminaries, which means these costs are often calculated as the same for each material considered. Until more timber buildings are actually built and real data is incorporated into cost planners' databases, these fixed preliminaries will hide some real advantages for timber solutions.

The two cost planners utilised for this project took a conservative view of what preliminaries savings could be used, as there is a lack of evidence to justify doing otherwise. Acceptance of the shorter program time for timber buildings is presently hard to accept, as there is little documented evidence for construction programs of real buildings available.

The cost plans developed for this project's buildings only included hire cost savings for major items such as site accommodation and plant (crane and hoists) and the reduced site administration labour cost. Further cost savings were identified but were excluded because, as stated above, there is little publically available evidence in the marketplace of actual time or material savings. The commentary that accompanies the cost plan for each building type discusses these other possible savings, and they are particularly significant in the apartment building and office building designs.

Refer to the specific Design Guides for the details of potential cost savings relating to:

- removal of scaffolding
- reduced first fix time, being the time to carry out rough-in for mechanical, electrical and plumbing within timber structures
- reduce footing/foundation costs
- reduced crane size or type.

A greater understanding of the productivity gains and their effect on preliminaries around timber product installation is required for a true cost comparison to be possible. This information will become more readily available as the use of timber solutions for commercial buildings becomes more widespread in Australia.

4.2 Other Findings

Many lessons learnt from this project are already assisting in the design of actual commercial timber buildings by the project partners. Of the four building types investigated, the designs of the timber solution buildings for the aged care and industrial buildings were well understood, easy to detail and had cost information readily available. This was not the case for the office and apartment buildings where the timber options were relatively unknown. The office building was particularly difficult to design, as the solutions available from the timber industry were numerous but there was little experience in what system worked best or suited the building constraints.

Some findings in relation to cost reduction were:

1. Maximise the use of stock timber products and sizes.

Using timber items and sizes that are readily available in the supply chain provides cheaper building solutions. Where items are especially manufactured or fabricated, costs quickly inflate. Non-standard sizes also may generate significant wastage, which also adds to the cost.

2. Increase fire resistance through timber's char capacity.

Designing for the required fire resistance was found to be cheaper when the char capacity of timber itself was used and dependence of plasterboard was reduced.

There are two general approaches in providing fire resistance; the first, which is considered the traditional approach, is to install plasterboard fire protection. The second approach is to use the char capacity of timber and oversize elements so that there is capacity in the timber element to provide fire resistance and structural resistance under fire load conditions.

The cost to install plasterboard makes systems designed around this relatively expensive. By increasing the size of key timber elements, there are substantial labour cost savings as there is less plasterboard to be installed.

3. Reduce crane movements.

It is important to consider the number of elements that need to be moved by crane as this directly affects the construction program and, consequently, costs. Having large elements or combining elements together on the ground and lifting in place saves time and costs.

However, this needs to be balanced with waste generation, best seen in CLT wall use. If a wall has a large opening in it – such as for a door or windows – this potentially creates a lot of offcuts, which become waste if they can't be used elsewhere. Dividing the panel into a number of separate components to reduce the generation of offcuts will increase the number of crane lifts required for the same amount of installed wall. Consequently, there is a balance between waste generation and construction program time increase, with costs dependent on a number of variables.

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