MULTI-STOREY MODULAR MANOEUVRES – Innovative architectural stacking methodology based on three Swedish timber building systems

Magnus Larsson¹, Alex Kaiser², Ulf Arne Girhammar³

ABSTRACT: The authors present a logical outline for an innovative architectural stacking methodology based on three Swedish timber construction systems. They discuss the increased architectural–engineering quality, sustainable advantages, and cost effectiveness of those systems and their application in an exploration and a challenging of the limits of cross-laminated, panel-and-stud, and post-and-beam timber construction, as compared to traditional buildings. A comparison with the tallest timber residential building in the world, the Stadthaus precedent in east London, provides an appropriate quantitative background for evaluating the decisions made throughout the project, while references to Edward Glaeser’s recent study, Triumph of the City, form the theoretical backdrop for a discourse on what potential benefits an adoption of the scheme on an urban scale could have. Particular emphasis is placed on finding methods for obtaining new, avant-garde architectural expressions to simultaneously widen and deepen the current narrow-and-shallow canon of multi-storey timber buildings. The final outcome is presented both as diagrams of stacking methods and a full drawing set of the final building examples, with notations describing the structural and constructional applications of the building systems chosen. Furthermore, the paper covers a comprehensive account of how these new modular buildings sit within their architectural context, and how the formal logic underpinning them can be assimilated further and used as the point of departure for future studies.


1 INTRODUCTION

The cradle of construction as we know it was clearly cut from wood, the oldest of all building materials. From prehistoric times until today, the evolution of timber architecture has reflected the cultural and technical advances in different societies throughout the world. Progress in woodworking has led to a large variety of technical possibilities for creating highly functional and radically innovative wood structures.

While seemingly contemporary applications such as laminated wood have been around since the early Egyptians, it is only in recent years that the vocabulary of contemporary timber engineering has been vastly extended through the addition of a wide range of new solid wood timber components at larger cross-sections and longer lengths than were previously available. These larger dimensions are accomplished through the strategic bonding together of several pieces into one. From simple sawn solid timber via structural veneer lumber through to cement fibreboards, there is no lack of engineered timber products on the market today.¹ However, the combination of the relative novelty of these elements and the conservative characteristics of the building market has led to a comparative shortage of interesting architectural applications using solid wood products. As the wide variety of technical and architectural possibilities remains largely unexplored, interesting possibilities for challenging the limits of engineered timber construction prevails. We seek to provide a logical outline for one such attempt, based on an innovative architectural stacking methodology based on existing systems and construction methods for multi-storey timber buildings using prefabricated units.

2 COMPANIES AND SYSTEMS

The study is founded on cross-laminated, panel-and-stud, and post-and-beam timber construction systems from three Swedish companies. The Martinsons Group presents itself as “Sweden's largest producer of glulam, and ... the Nordic leader in wooden bridges and building systems using solid wooden frames,” Moelven claims to be “the leading producer of glulam in Norway and Sweden,” while Byggma ASA states it is “a leading distributor of building components to the Nordic countries”. Masonite Beams AB, within the Byggma Group, produces wood-based I-beam systems and provides technical solutions to the building industry.

2.1 MARTINSONS: CLT BUILDING SYSTEM

Martinsons's building system includes a comprehensive range of prefabricated building components that are divided into two mutually supportive tiers. The first of these features glulam frames made from finger-jointed boards that are glued together to form long structural
members, and which are used for the post-and-beam construction of large open spaces. The second tier features pre-fabricated solid or cross-laminated timber (CLT) components that go together into multi-storey blocks of flats, and multi-layered wooden boards forming elements that can be prepared with electrical/water pipe fittings and sound proofing (built-in sound insulators provide sufficient acoustic levels internally, while the finished elements satisfy sound transmission class B). This study focuses on Martinsons's Building System with CLT panels, with which the company has completed buildings up to eight storeys to date.²

2.2 MOELVEN: GLULAM MODULAR SYSTEM

Moelven supplies both standardised solutions and constructions tailored to specific requirements. Their flexible system solutions are roughly divided into three tiers: laminated load-bearing timber constructions, interior systems, and different building modules. The latter are used for both temporary and permanent buildings, and are produced under ideal conditions indoors, reducing the workforce on the building site. Moelven are also able to fit their modules with electrical installations. Their interior systems are tailor-made and delivered ready to assemble. Moelven's Trä8 Modular System is a post-and-beam system with specially manufactured stabilising elements: box-type components made of glulam core members and laminated veneer lumber (LVL) sheathing. The stabilising elements act as a cantilever anchored to the foundation up to a height of four storeys.³

2.3 BYGGMA: MFB SYSTEM

The Masonite Flexible Building (MFB) system is based on prefabricated units, and meets prevailing requirements regarding fire safety, moisture conditions, strength, stabilisation, thermal comfort, and acoustic insulation. The MFB system consists of prefabricated wall, floor and roof elements that come flat-packed and are assembled on site. Lightweight timber I-beams are integrated with a composite laminated panel (plyboard) to form a rigid frame for wall and floor elements. Intended at present for buildings up to eight storeys and floor spans up to eight meters, the elements meet fire requirements of REI 60 and noise requirement class A. It is believed that the plyboard wall panels combined with I-studs and the suspended floor elements make the MFB system adaptable for up to 20-storey buildings.⁴

3 PRECEDENT STUDY: STADTHAUS

The nine-storey Stadthaus high-rise in Murray Grove, Hoxton, east London, is the tallest residential timber building in the world. Comprising a combination of private and affordable housing, it provides a total of 29 living units across nine storeys. The ground floor holds commercial space, there are three floors of social housing and five floors of private residential units.⁵ The building was assembled using a unique, cross-laminated structural system provided by KLH of Austria.

Figure 1: T Scraper A, night-time perspective render showing basic T stacking structure together with lit-up living units and aerial circulation bridges.

Techniker were the structural engineers who integrated the technology without sacrificing any of the design principles laid down by the architects, Waugh Thistleton. The cross-laminated solid timber panels form a cellular structure of load-bearing timber walls, including all stair and lift cores, with timber floor slabs. The resulting high-rise is marketed as the tallest pure timber building in the world.⁶

Why timber? The first reason is to do with sustainability: timber absorbs carbon throughout its natural life and continues to store that carbon when cut. This tower stores more than 181 tonnes of carbon. Getting rid of the concrete frame saved a further 125 tonnes of carbon from entering the atmosphere. That’s equivalent to 21 years of carbon emissions at this scale – or 210 years at the current requirement of 10 percent renewable. Recording the changing light and shadows formed on the empty site by the surrounding buildings and trees gave rise to the pattern (created using a sun path animation) on the façade. The resulting image was pixelated, picked up, stretched and wrapped around the building. The exterior cladding forming this pixelated image is made up of over 5,000 individual panels across the building in three shades: white, grey and black. The 1200x230mm panels are manufactured by Eternit and made up of 70% waste timber.⁷

The panels are prefabricated and include cut-outs for doors and windows. Maximum production dimensions are 2.95x1.65x0.5m. The production process is zero-waste: all off-cuts, wood shavings, sawdust, and so on are re-used, with KLH even manufacturing their own biomass pellets. The panels are cut using state-of-the-art CNC technology. The thermal emissivity of an exposed wooden surface is excellent at a value of 0.87.⁸

The design is a honeycomb structure with rotated plans. Walls, floors, and core carry loads. Floor panels were designed to double span or cantilever under accidental loading. Simple “off-the-shelf” brackets and screws were used to create effective ties between floors and walls. The cross lamination within the engineered material together with high in-plane stiffness provides “built-in” redundancy. Walls and floors that are dimensioned to provide adequate acoustic separation and thermal
performance have plenty of substance to also resist the levels of applied loading encountered. Over and above structural considerations, two other areas were of principal interest to the architects, engineers, and developers: fire and acoustics. The fire issue was split into two distinct phases: developing phase and fully-developed phase. During the developing phase, combustibility can be modified using retarding chemicals (though timber is, of course, still combustible). Solid timber is also not readily ignited: temperatures in excess of 400°C are required. In buildings of solid timber charring is relied on for structural fire resistance. During the fully-developed phase, while exposed surfaces initially burn fairly vigorously, they soon build up a layer of insulating charcoal. Timber is also a poor conductor of heat, with minimal transfer of heat into unburnt material (the char layer has 1/6 the thermal conductivity of solid timber). Timber is also highly predictive when exposed to fire.9

Errors can be relatively easily corrected on site with a skill-saw and holes added.11 Considerations include the simplicity and familiarity of trades. The site remained completely tidy at all times, as assembled within nine weeks, one week per storey. Cross laminated panels arrived by lorry in erection centres, based on capitalist doctrines of hyper-density, are perhaps too often, in the words of Rem Koolhaas, well on their way to “a grotesque saturation point of total extrusion”.

The world population has experienced continuous growth since the end of the Bubonic Plague, the Great Famine and the Hundred Years Wars in 1350, when it was about 300 million.13 While annual births have reduced to 140 million since their peak at 173 million in the late 1990s, and deaths are expected to increase from 57 to 80 million by 2040, current projections still show a continued increase of population to upwards of 10.5 billion by the year 2050.14 This is a good thing. Not only does it mean there will be more intelligence in the world, more beautiful innovation, more valuable human capital, more education, more culture, more heartbreaking works of staggering genius.15 We can also look forward to a future in which more of us will be living in larger and larger cities – indeed, according to a 2011 United Nations report, more than half of the world’s roughly seven billion people now live in urban areas. There seems to be a great need for urban densification, for people coming together to experience that most beautifully intriguing of human inventions: the city. More and more people will find their way to our cities, taking up more and more space, turning these machines for living (in the true sense of the word) into close-packed human clusters. Emotional and intellectual playgrounds built on complexity and diversity, our great cities are humanity’s most successful invention for delivering prosperity and progress.

The young and the poor don’t go to the countryside to make their fortunes. They go to cities. This migration towards metropolitan cores intensifies the urban experience but not, crucially, the heedless burning of fossil fuels. As David Owen points out, in comparison with the rest of the USA, New York City is “a model of environmental responsibility”.

Since the 96m tall Latting Observatory went up in 1853, New York has given birth to 12 buildings that were the tallest in the world at the time of their completion. Most of them sought to maximise livable space through an “exploitation of congestion”.

The resulting conurbations should be pinnacle achievements in the history of the world. And yet the resulting urban centres, based on capitalist doctrines of hyper-density, are perhaps too often, in the words of Rem Koolhaas, well on their way to “a grotesque saturation point of total extrusion”.

Glaeser is interested in the role cities play in the progress of human achievement, and his book essentially argues that “cities magnify humanity’s strengths.” With great enthusiasm for the possibilities inherent in the planet’s urban nodes, he writes about how the city is a facilitator for innovation through face-to-face interaction, an incubator for the relationships and communications systems necessary for everything from excellent restaurants to artistic innovation, a talent-sharpening catalyst through competition, and an engine for economic growth. While he enjoy’s Jane Jacobs’s writings on the benefits of mixing residential and retail programs, he wastes no love on her small-scale neighbourhoods; indeed, he’d rather see neighbourhoods of skyscrapers than the explosion of suburban sprawl now associated with the outskirts of many great American cities. Glaeser clearly has issues with cities that don’t allow for vertically stacked densities,
denouncing planners in cities like Paris and Mumbai and London, while promoting an ever-rising urban silhouette that goes up and up and up.

5 LOW-DENSITY TIMBERSCRAPER

If we are to believe professor Glaeser, more people means more density means more possibilities. While this argument is largely true, it fails to take into consideration other metrics than people/area. In fact, it offers a rather two-dimensional idea of density – one seemingly inspired by the stacking diagrams of yesteryear’s architects and engineers rather than the three-dimensional digital models of today. Could it be that not only how many people you can squeeze into a specified footprint matters, but also how those people live, interact, and perform?

With the present proposal for a tall timber building, we offer an alternative to the “grotesque extrusions” that Koolhaas writes about. A radical redefinition of the closely-stacked logic of contemporary urban typologies, our skyscraper is based on the notion of low-density mass housing.

In architecture, “low density” is usually a term used to describe a suburban context or property: the expression conjures up thoughts of sprawl, of the suburban condition of programmatic thinning out until not much is left apart from oversized bingo halls and lowbrow malls. Seth Harry has defined the “suburban comundrum” as a ratio of size to distance: “road and box sizes typically increase in an inverse relationship to the decrease in connectivity and gross density”. Another way of describing this theory is to say that the further away from the city (the lesser the urban density), the bigger the retail units, and the larger the distances in between them.

With this background in mind, it is hardly surprising that most architects still hail high-density living as the only conceivable way forward. Surely, if we want to achieve a sustainable alternative to the sprawl, we need for people to live as close to each other as possible?

This proposal argues that most architects could be wrong, that there are alternative ways of achieving architectural intensifications and favourable urban conditions than by relying on the monotonous repetition of identical floor plates evenly stacked on top of each other, with living units routinely separated by unvaried party walls. While high density is clearly a better alternative to suburban horizontal diffusion, we believe low-density volumes can be “plugged in” vertically into the urban fabric as volumetric and programmatic antidotes to higher-density buildings. This argument is based on the simple observation that while it is rarely possible to alter the distance between buildings in the city in the horizontal, and through that the footprint of the individual structure, it is often easier (planning laws permitting) to influence the height of the building envelope. If we can find economically feasible ways of exploiting less dense typologies, we can begin to experiment with spatial configurations that offer new and uncharted possibilities.

So what if we could alter the idea of low density into being a serious architectural consideration rather than a planning feature? What if we could abandon the age-old paradigm of maximising the ratio of sellable-floor-area-to-footprint by refusing to simply extrude the plot boundary vertically into the air and instead investigate the effects of breaking up the solid massing of today’s high-rises in order to promote new ways of living, working, and building? Could such a focus on lower density lead to the invention of a new paradigm that promotes more sustainable communities, supporting healthier, pedestrian-oriented lifestyles? Could it help us reduce energy use, foster social interaction, and promote active living? And perhaps most importantly: could it actually be achieved in a way that is financially sustainable?

We think so. Within the dense pockets of today’s Gotham, we would introduce shafts of light: a gradient of spatial use that begins with the existing, hyper-dense areas and moves up through the air towards something much more penetrable, light, even airy.

And perhaps it will be possible to read this gradient within our capitalist everyday: real estate is already one of the world’s most sought-after products, and uniquely configured space that has not been ruined by the tyranny of repetitive floor plates might be one of tomorrow’s most cherished commodities. Chances are, those with the means will opt for low-density rather than high-density living. In the city, the important thing is not so much floor space as the interior of the living unit and its connection to the rest of the building and the city outside. Urban dwellers seek a refuge from the pressures of the density outside. They need not so much a living room as some breathing space, and this is what the low-density skyscraper offers.

This reasoning acknowledges the need for vertical extrusions while arguing that many downfalls of the contemporary metropolitan condition, in particular in a non-western context – overcrowding, environmental stress, social inequalities, lack of light and air, food security, diseases – could be overcome through the controlled use of spatial redundancy. This term, which we borrow from the world of data compression, is used here in two ways. By using a stacking paradigm and prefabricated timber units, we achieve compression in the time and effort it takes to construct the building. And by shifting those units across the length of the skyscraper, we create de facto redundant spaces; bodies without organs; volumes without walls and floors; strategic perforations in the city fabric. This internal logic is based on a programmatic reconsideration of what it means (or should mean) to live in a skyscraper – smaller contained interior spaces are matched by exterior spaces that offer framed views of the streetscape below, with vertical volumes acting as supporting storage capacities; bridges in the sky allow for chance meetings on the 14th or 21st floor; at pavement level, the street is given back to the city’s inhabitants; at the top, a restaurant offers the public astonishing views of the inner circuits of the great computer for human interactions that is the metropolis.
To live in a low-density “timberscraper” is to embrace a new mode of living. The units are smaller than they would be in a high-density building that seeks to maximise the walkable floor area. As opposed to this paradigm, a low-density building seeks to maximise the perceived living volume. In a city such as London or Paris or Stockholm, where very few buildings rise to a considerable height, even this kind of “light skyscraper” would introduce a higher level of density to the urban fabric. Interweaving this new typology with existing high-density floor plates might be one way of experimenting with different ways of inserting density without endlessly repeating the same inflexible search for maximising the value of developments in accordance with outdated standards.

6 ARCHITECTURAL STRATEGIES

6.1 SPECTACLE FROM REDUNDANCY

The stacking methodology presented here can be seen as the latest point along the trajectory of modularity in timber construction. But it is also perhaps the latest point in another trajectory, that of stacking itself. As an architectural strategy, the idea of collocating volumes one on top of another perhaps began with the invention of the skyscraper in the late 19th century (perhaps with Arthur Gilman and Edward H. Kendall’s 1870 seven-floor Equitable Life Assurance Building in New York, engineer William Le Baron Jenney’s 1885 ten-storey Home Insurance Building in Chicago, or the same city’s Burnham & Root/Holabird & Roche-designed 16-storey Monadnock Building in 1891), but arguably came to a climax with Moshe Safdie’s Habitat ‘67 building in Montreal.23 This model community of interlocking forms was in turn a building borrowing some of its basic ideas from the Japanese Metabolist movement, introduced at the World Design Conference in Tokyo in 1960, which saw avant-garde architects such as Kenzo Tange, Arata Isozaki, and Kisho Kurokawa design buildings such as the Kagawa Prefectural Government Hall (Tange, 1958), the Shinjuku Project: City in the Air (Isozaki, 1961), and the Nagakin Capsule Tower (Kurokawa, 1971).24

Ever since, modular stacking of spaces has been a recurring theme throughout a wide array of architectural projects, ranging from housing schemes (MVRDV’s Sky Village, 2008) via iconic exhibition spaces (SANAA’s New Museum, 2007) through to the series of stacked pitched-roof boxes that make up Herzog & de Meuron’s VitraHaus (2011) and the “stacked houses in the sky” system that produced their 56 Leonard St project (underway), as well as the essay in mixed programs that is the Bryghusprojektet (OMA, projected for 2015). The mastermind behind the latter building, Dutch architect Rem Koolhaas, once talked about skyscrapers as “a stack of individual privacies”,25 inferred that the stack-loving Metabolist architects “define(d) the contours of a post-Western aesthetic,”26 and wrote about one of his buildings that its stacking “maintains the independence of each block, optimizes views from the site and creates a dynamic relationship between the building and its surroundings: Spectacle from Convention.”27

If this vision of spectacle being derived from convention – played out in a cityscape thriving on density and seeking to maximise vertical extrusions of limited footprints – is not just Koolhaas’s but all of contemporary urbanism’s norm of today, then the present proposal seeks to investigate a different kind of stacking: one that explores the potential for sectional variety inherent within our proposed formal system. The result is a seemingly infinite variety of spatial experiences, programmed sequences, and unexpected instances being created as extensions of a simple strategy: that of a more porous (selective, subtractive) series of stacking patterns, in which “implied” space (areas without habitable floors that are still experientially connected to individual living units) becomes as important as the more commonly calculated rentable floor space. By connecting the floor plans of the units sectionally, variety is added to move the building beyond a mere act of generic repetition without difference to a more tectonically adventurous structure enhanced through overlaps, superimpositions, and interpenetrations of the volumes themselves. Variations on a theme lead to a spatial difference, interest, connectivity, and variety rarely associated with this typology. Cumulative effects of variation play out on the different floors, highlighting the possibility of divergent dynamics, nonstandard configurations, alternative habitation patterns.

This insistence on sectional variety opens up new possibilities for unconventional configurations, leading to the obvious insight that the most historically common methods of densification (the simple vertical repetition and extrusion of identical floor plates) is not the only way of intensifying the city. Intensification might also arise from a strategy that abandons traditional floor plate stacking in favour of vertical arrangements that allow for meticulously controlled perforations through its core: Spectacle from Redundancy. In his book, Content, Koolhaas writes that “the skyscraper has become less interesting in inverse proportion to its success. It has not been refined, but corrupted. (...) The intensification of density it initially delivered has been replaced by carefully spaced isolation.”28 We hold that precisely a carefully spaced isolation (albeit of building volumes rather than entire buildings) might recover some of the interest supposedly lost in that presumed corruption of the skyscraper’s status. Furthermore, this unfolding of the densely stacked skyscraper into a low-density building promotes the creation of a transformative series of perspectives and outward vistas, offering visual integration with the changing site conditions, as well as inward connectivity to other units and inhabitants, composing a narrative of constant movement and transformation. Opening up the core of the building redefines the relationship between explicit and implicit space, while allowing connecting bridges to traverse the void introduces a connective tissue between private and shared volumes. The bridges,
again, further detaches the project from the modernist tradition of simply stacking functions and programmatic features on top of each other, by catering to the need for direct (rather than technical) communication and allowing for new possibilities of having effects lead to affects: potential chance meetings and interesting moments, as public spaces, green spaces, and spaces for cultural events are introduced. The timberscraper is a truly mixed-use building because of the fact that it’s stacked, rather than despite its being stacked.

While remaining rigidly repetitive in its exterior volumetric expression, the sectional approach turns the building into much more than a plain exercise in stacking on the interior, pushing this tall timber building towards a logic suggestive not so much of simply piled platonic solids as of Chinese puzzles (or rather Greek puzzles, as the first known ones appeared there in the 3rd century BC.), whose interlinked and interlocking pieces are mutually self-sustaining, or the elements – tricubes and tetracubes – that make up Danish architect Piet Hein’s Soma Cube puzzle (famously invented during a Werner Heisenberg lecture on quantum mechanics).29 The sections of the resulting buildings exhibit potentials for programmatic interest and functional curiosities, engaging stratagems of continuity and discontinuity.

### 6.2 Low-Density Typologies

Having established our position with regards to stacking, we define strategies that allow for the production of 81 formal typologies, all based on different iterations of convex wooden polyhedra (cuboids) in couplings, heaps, stacks, mounds, and pyramids. On occasion we allow the cuboids to be transformed (cut, angled, truncated, skewed, incised, rotated) before being stacked with other volumes, creating alternative configurations. The formal manoeuvres are logged and saved for future development: the beginning of a catalogue of stacking tactics. Using this 9x9 typological matrix of formal experiments as our starting point, we proceed to craft the novel strategy at the heart of this proposal. We rearrange our 81 models and further subdivide them into categories based on stacking method, scale, and programmatic context, then funnel down the alternatives into a series of promising typologies from which to pick our final candidate. Pros and cons are weighed against a list of parameters derived from the precedent study of the Stadthaus (above), seeking to maximise architectural interest and sustainable credentials, as well as structural and constructional potential. This yields a shortlist of nine typological models, which are further investigated using the three building systems outlined above.

The nine typology models all have their advantages and disadvantages. The first (Big Books) is a strictly gridded, bookshelf-like configuration reminiscent of natural systems such as honeycombs, which some inhabitants might find ideal, others intrusive. The second (Deep Façade) is based on the notion that the outermost interface between the building and its immediate environment is programmable through formal and geometrical manipulations that create interesting effects easily achieved through modular stacking. The third (Double Model) begins with a parallelepiped that is parametrically cut at an angle into a new volume that is then mirrored/rotated/scaled into a new composition. The fourth (Park Rise) uses a programmatic concern as its catalyst, as it redefines parking lots as urban plots ready for development. The fifth (T Scraper) uses T-shaped modules to break up the rigidity of the building body, while the sixth (Plug-in Scraper) minimises the footprint by lifting its volumes off the ground on spindly legs. The seventh (River Crossing) is a hybrid between a horizontal skyscraper and a bridge, its roofing a public walkway, while the eight (Rotational Parasite) sees volumes shaped as the letter C stack up against each other. The ninth and final typology (Stacked Cuts) is based on a perfectly regular and symmetrical stacking of blocks, but in layers that are cut through at diagonal angles, giving rise to interesting effects in both the horizontal and the vertical direction, or in both directions at the same time. Following this logic, vistas are created, circulatory passages cut out, and individual units given new programmatic possibilities. A wide range of different formal arrangements is made possible, and surprising local moments are created that could easily be harnessed for architectural functions.

While tempted by this latter typology, we decide upon the T Scraper (Fig. 01) as our chosen candidate for further (final) development. This novel configuration breaks with the modernist tradition that calls for “rational” and equally spaced stacks of footprint-sized floor plates, to instead use a combination of horizontally and vertically stacked cuboids on top of each other in an arrangement that somehow seems both rigid and flexible at the same time. The resulting building challenges predominant notions of the optimisation of space – it is the embodiment of the low-density principle delineated above. The T Scraper lifts its first few storeys off the ground, giving up the ground (street) datum to the public, and encapsulates a void of implied living space in its centre.

The reasoning for choosing the T Scraper is based on several different factors, including orthogonality (a quality that is probably easier to achieve using the existing building systems than more sinuous alternatives would be), scalability, modularity, construction feasibility, ease of calculation, static properties, formal aspects, and programmatic rationale. We decide to test these conditions by designing three different versions of the T Scraper, each with its own underlying principles. These three final building types are then further explored through extensive sets of drawings and diagrams, including experiments based on scalar shifts, alternative façade modulations, fenestration strategies, and material manipulations.

Timber is easily workable and offers potentials that are comparatively hard to achieve with other materials: wood can be drilled through (even at an angle), and is easily modified on the surface level – in particular using CNC technologies. Timber elements can be fixed using a wide assortment of fasteners including screws, nails, glue, and bolts. This material logic was used as a starting
point for the material experimentation at heart of our architectural investigation. Once the volumes were stacked, the typologies evaluated, and the T Scraper had emerged as our most promising formal alternative, the volumetric and typological studies gave way to a material one.

6.3 MATERIAL LOGIC

As Mario Carpo recounts, the power of identical copies arose at the beginning of the Modern Age from two parallel developments: as an extension of the intellectual ambitions of the Renaissance humanists and as the inevitable by-product of mechanical technologies. Leon Battista Alberti’s (1404-1472) definition of architecture as an authorial, allographic, notational art persisted until quite recently, and still defines many if not all of the architectural principles that our present digital culture is currently unmaking. Alberti separated notation from construction, insisting that the final notation of an object (its blueprint) was to be materially executed without any change. This approach to design – the elaboration of form over its subsequent materialisation – has largely dominated architecture as a material practice. With the advent of digital fabrication methods, however, a curiously high-tech analog of preindustrial artisanal practices is being formed, through which today’s digital architects are increasingly designing and making at the same time. This becomes highly interesting in the context of tall timber buildings manufactured from prefabricated parts. Since engineered wood panels are easy to work with using ordinary tools and basic skills, as designers we are given a generous palette of possible surface manipulations and joining methods: wooden panels can be cut, carved, drilled, routed, fastened, jointed, sanded, planed, filed, scratched, grooved, pierced, marqueted, parqueted, scraped, scorched, weathered, steam bent, rased, gouged, engraved, moulded, kerfed, braced, charred, lacquered, laminated, veneered, burned, chiselled, glued, painted, stained, varnished, oiled, waxed, and so on. Different panels, even from different species of wood, can be sandwiched together. Wood has figure, grain, and colour. We can bend panels in a radius. We can work parallel to the structural axis of the panel, or across the grain. We can manipulate the wooden panel’s performative capacity in different ways, modulate its properties, and integrate different computationally driven processes in the design of the final elements. The possibilities are formidable.

The performative capacity of wood is amplified further by the large panel sizes, which speeds up construction by reducing the number of pieces to be handled and installed, and while they should all have a low tolerancy and be a precise fit when they arrive, a new panel can fairly easily be cut on site, or an existing one adapted, if for any reason the design were to change. Timber, as any building material, has a material logic that is uniquely its own. This natural composite of cellulose fibres, strong in tension, embedded in a matrix of compression-resisting lignin, is of course anisotropic: stronger with than against the grain (this dictates the directionality of the panels). The beauty and complexity of the fibre, grain and figure shows through even when the wood is painted. Being an organic material, seasoned wood never completely stabilises, but continues to swell and shrink with seasonal variations in humidity and temperature. The material properties of wood – such as its relative hardness and fragility – vary with the species of the wood, as well as its age, and are dependent on temperature and moisture content.

We explored the depth, plasticity, and surface effect of this underlying material logic in three ways, one for each of our final prototype buildings, allowing a certain degree of formal articulation to be derived from direct manipulations of the wood. In the first timber scraper, we were interested in the additive/subtractive transition from lattice to scaffold to sheet to element; in the second, we focused on how a computerised drilling machine could be utilised to perforate the building skin with a pattern of strategically placed and angled apertures; and in the third, on how prefabricated units can be stacked (Fig. 2).

7 SYSTEMIC APPLICATION

In order to make the prototypes buildable using the three different wood building systems, a series of iterative adaptations were carried out in accordance with their respective properties and rules. The internal logic of the three timber systems were thus translated into the chosen T Scraper configurations. This called for an initial analysis of the prefabricated cross-laminated timber of Martinson’s CLT system as compared to Moelven’s Trä8 modular glulam solution and Byggma’s MFB method, all of which share some standards (for instance the maximum transportable sheet size), but differ in others (for instance the maximum sheet size that can be cut).

The systems also have slightly diverging tectonic advantages. The multi-ply cross-laminated timber boards from Martinsons provide a construction component with a stable form and a high load-bearing capacity relative to
its own weight. The post-and-beam Trä8 system from Moelven provides an innovative stabilising system that frees up a building’s corners, and features elements that are fixed to the foundation by using special anchoring devices. The lightweight prefabricated MFB system from Byggma allows large free spans (up to 10 metres) and employs a unique steel hanging connection detail that intelligently eliminates compressive stresses between panels.

We opted to test these systems by allowing them to have an impact on the actual design decisions, as opposed to simply forcing them to perform according to a predefined set of tasks. The end result of this strategy was that each or our three timberscrapers adopt one of the three systems: T Scraper A is constructed using the CLT system from Martinsons, T Scraper B (punctured by irregularly placed apertures in accordance with the sun’s path) uses the Trä8 system, while T Scraper C exploits the hanging concept offered by Byggma’s MFB system.

8 ARCHITECTURAL ANALYSIS

8.1 MAKING LESS SPACE MORE VALUABLE

Historically, the essence of the skyscraper has been based on the discrepancy between the area of the footprint it occupies and the reproduction of this area in its vertically stacked floor plates. While the ensuing simple extrusion of the site to a more or less arbitrary height and its traditional internal copy+paste arrangement of floor datums – skyscrapers comparable to enclosed and scaled-up versions of Sol Lewitt’s anonymously modular lattice sculptures – has undeniably been an effective tool for the creation of great urban density, T Scrapers A, B, and C are examples of an alternative framework that introduces sectional variety through a combination of implicitly and explicitly enclosed space. By breaking up the tyranny of the repeated plan configuration and instead allowing a more varied and sparsely stacked scattering of volumes, we achieve a perhaps oxymoronic (and in some respect almost alchemical) architectural sleight of hand through which less space becomes more valuable. Quality replaces quantity, a line is drawn between mere volume and architectural space. These timberscrapers open up the city fabric, offering a new kind of intensity by adding voids to the figure through a 90° tilting of the focal plane from plan to section, producing a density of vertical rather than horizontal configurations.

This conceptual and formal shift leads to an immense contrast between the layout of the timberscrapers’ living units as compared to the traditional arrangement of enveloping curtain walls and internal party walls. Instead we now have individual volumes stacked on top of and intersecting each other to form a varied Chinese puzzle of cuboids that cater to alternative habitation models: vertical volumes for storage support horizontal living spaces. In terms of circulation, the resulting interlocking structure with its communal bridges connecting cantilevered solaria to the stacked volumes brings to mind Aldo van Eyck’s idea of “labyrinthian clarity,” which softens the boundaries of space and time and facilitates casual encounters, relationships and conventions (Fig. 3). It favours the appearance of thresholds, indefinite spaces where relationships are formed, which are gradually given shape with use. This is how we understand the intersections of movement patterns as habitants traverse the building: as junctions for transitory assemblies. That is also how we view the programmatic functions as well as the phenomenological and haptic aspects of experiencing the timberscraper’s spatial configuration and material palette, the complex reciprocity between basic materiality, overall form, stacking logic, and structural qualities: as a series of ephemeral points of systemic convergence. The boundaries soften in the same way that the thresholds between individual living units are to an extent blurred: the implied spaces between them are suspended between private and communal. The different strategies for fenestration and surface treatments help filter light into the building and modulate it to perform in accordance with environmental influences and forces. The resulting piece of architecture is a built diagram of its own production and assembly sequence, a force chart swept with a timber profile. It is radical in its raw materiality, urban concept, structural stacking methodology, labyrinthine program, and sectional configuration principles.

8.2 ADVANTAGES

It is also radically sustainable, in fact even post sustainable. The earth contains about one trillion tonnes of wood, which grows at a rate of 10 billion tonnes per year. As an abundant, carbon-neutral renewable resource, woody materials have been of intense interest during the past decades as a source of renewable energy. In 1991, approximately 3.5 billion cubic meters of wood were harvested. Dominant uses were for furniture and building construction – though rarely for skyscrapers. Skyscrapers are built using steel supported by what is arguably the most important building material in the
world: cement. Of all existing materials, humans use water (by volume) the most. But in second place, at more than 17 billion tons consumed each year, comes concrete, usually made with Portland cement. As of 2006, about 7.5 billion cubic meters of concrete are made each year—more than one cubic meter for every person on Earth. Today, the cement industry is one of two primary producers of carbon dioxide. There are two reasons why the manufacturers of cement have grown so big as to threaten the planet: habit and cost. Concrete is not only immensely strong but also omnipresent and easily obtained in large quantities for comparatively small amounts of money. To keep feeding humanity’s concrete habit, however, is obviously detrimental to the environment.

Viewed in that light, the timberscraper becomes an attractive option indeed. As Stadthaus architects Waugh Thistleton point out, the energy produced during construction can account for a third of the overall carbon cost of a building over its lifetime. Replacing concrete and steel with wood reduces the environmental impact of the building during the construction process as the building programme is shorter, the foundations considerably reduced, and the need for tools and equipment such as cement mixers and tower cranes minimised. Timber is one of the only truly sustainable structural building materials in existence. Since trees absorb approximately one tonne of CO2 for every cubic metre they grow, wood is carbon neutral and can even—this is what we mean by “post sustainable”—achieve a negative carbon footprint. According to the UK’s wood promotion campaign, Wood For Good, the amount of energy required to produce a tonne of brick is four times the amount for sawn softwood, concrete is five times, glass six times, steel 24 times, and aluminium 126 times. Using wood instead of other building materials saves an amount for sawn softwood, concrete is five times, glass six times, steel 24 times, and aluminium 126 times. When compared to the energy required to produce these Agricultural advantages (which the right developer could capitalise on) and sustainability-related virtues, these timberscrapers might also be cost effective compared to their traditional counterparts. Potential savings might be made throughout the project, including during construction (as time is likely to be saved on site) — the Stadthaus development was completed for a total net cost of £3.8 million, or less than £1,400 per square metre. It should be noted that this was for a scheme branded as being based on “groundbreaking material innovation,” quite contrary to the well-established and comprehensive Swedish systems used here, which have already been used for the construction of thousands of buildings. It seems likely that implementing these proven existing systems to build timberscrapers three times as tall as today’s buildings would only bring costs down further.

9 CONCLUSIONS

As has been shown, this first part of an ongoing research study has yielded a large variety of architectural forms applicable to multi-storey timber construction using the systems studied. Our results indicate a wide range of potential benefits of using these timber construction systems for buildings at the timberscraper scale, including augmented architectural–engineering qualities, sustainable advantages, and increased cost effectiveness. More strength capacity can be exploited in tall timber buildings. This typology has so far essentially been devoid of typological and architectural precedents and methodologies. While the Stadthaus development is a structurally, constructionally, and sustainably laudable initiative, it only rises to nine storeys and is far from architecturally groundbreaking. The stage is set for more interesting tall timber structures to be added to the urban fabric. Fairly basic improvements in detailing (for ties and bearings, for instance) could see 25-storey timber buildings being constructed that would still retain economic wall thickness.

But that’s for a traditional, standard high-density skyscraper. Adopting a low-density approach such as that outlined in this proposal, we might be able to go higher than that, while avoiding issues with sight lines, illumination levels, and other planning/zoning restrictions. Prefabricated storey-height units, the timber elements making up the proposed lightweight construction system could soar into the sky, not only as beacons of nonconformist ways of living, but points of departure for a future, post-sustainable urbanism.

ACKNOWLEDGEMENTS

The authors express sincere appreciation to the Regional Council of Västerbotten, the County Administrative Board of Västerbotten and The European Union’s Structural Funds – The Regional Fund, for their financial support.

REFERENCES

[6] Ibid.
[7] Ibid.
[8] Ibid.
[10] Ibid.
[12] Ibid.
[22] Spatial redundancy is duplication of elements within a structure (e.g. repeated pixel values in a still image). Compression of data is the exploitation of spatial redundancy.
[31] Thompson, H. Ibid., pp. 15-16

[34] Labyrinthian clarity is a term coined by Aldo van Eyck to refer to what must characterise a house, or a city. Cf. Smithson, A. M. Team 10 primer. Cambridge: M.I.T. Press, 1968.