

# Rethinking the making of our buildings:



## A timber construction research and skills development facility in the Pretoria CBD

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Submitted in fulfilment of part of the requirements for the degree Master of Architecture (Professional) in the Faculty of Engineering, Built Environment and Information Technology, University of Pretoria. December 2020.

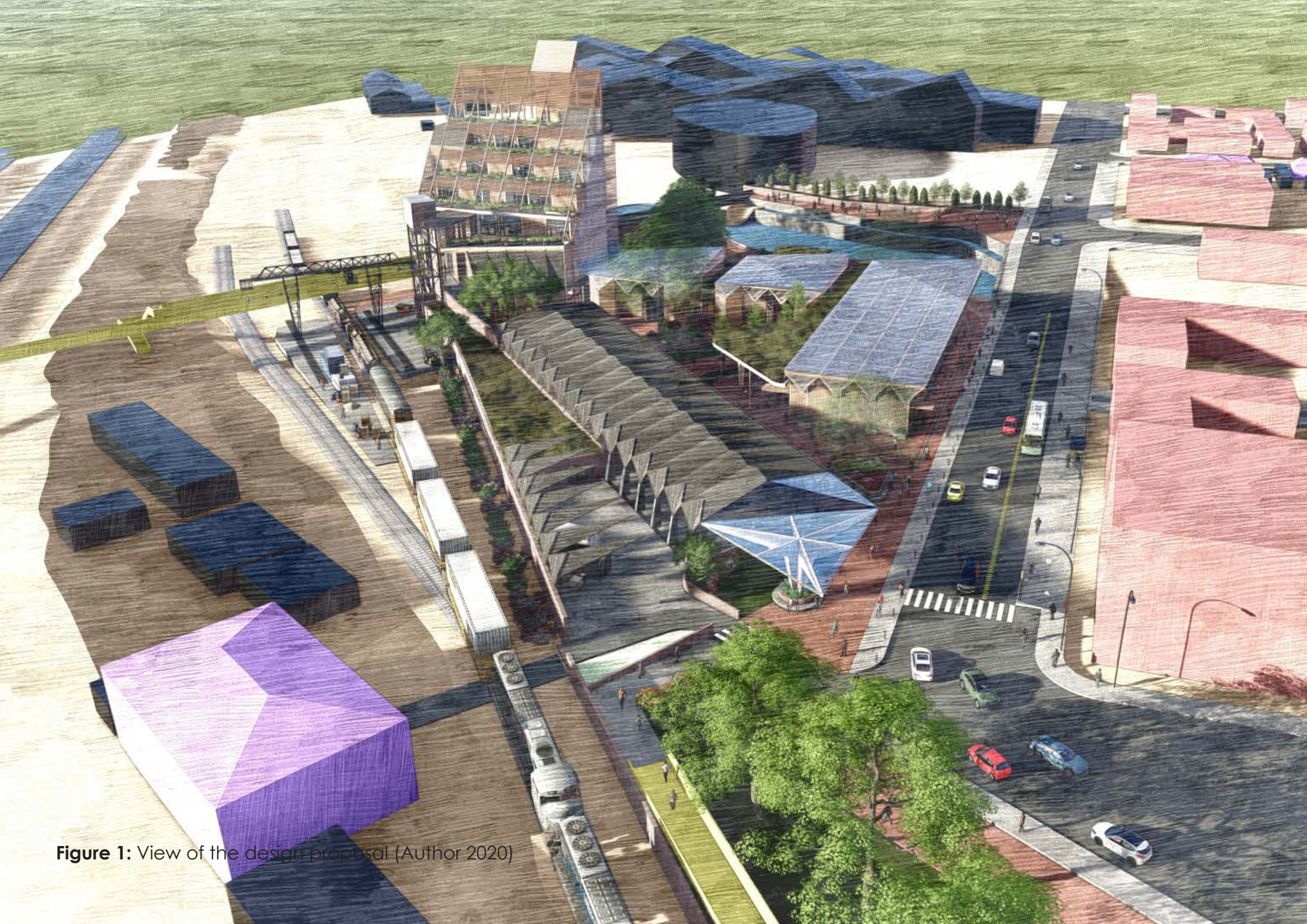


**Figure 1:** View of the design proposal (Author 2020)



# Chapter 1- Project summary

# Ekserp

Verskillende materiale verskaf aan argitekte 'n kreatiewe medium om uitdrukking te gee aan idees, die vermoë om vernuwende ontwerpe die lig te laat sien, en die voorreg om te kan skep. Hoofsaaklik maak die hedendaagse argitek gebruik van die volgende materiale in sy bou-arsenaal om gestalte aan sy planne op papier te gee: staal, beton, steen, glas en hout. Persoonlike voorkeur, opinies, wetlike vereistes, omgewingsfaktore en beskikbaarheid is verder bepalende faktore wat bydra om die tipe materiale wat gebruik word, te identifiseer om sodoende die gewenste eindproduk te bewerkstellig.

Die gebruik van hout in die Suid-Afrikaanse boubedryf moes nog altyd so effe terugstaan vir die gebruik van meer bekende materiale soos beton en staal. Desnieteenstaande, bied die massagebruik van hout as boumateriaal nie net ekologiese en omgewingsvriendelike voordele nie, maar ook vaardigheidsgebaseerde voordele omdat hout voorsiening maak vir komponent vervaardiging asook die saamflans van die eindproduk (Green, 2019).

Onlangse goedkeuring deur die Suid-Afrikaanse Buro vir Standaarde (SABS, 2020) ten opsigte van ingenieurs vervaardigde hout soos bv. kruis gelamineerde hout (CLT – cross laminated timber), was die dryfveer agter die ontwikkeling van 'n hout navorsingsfasiliteit wat volledig uit hout gebou is, in die middestad van Pretoria. 'n Hoë-tegnologie konstruksie soos bovermelde, maak gebruik van vervaardigingsprosedures soos die integrasie van bou-informasie bestuur (BIM – building information management) programme met rekenaargetalbeheer (CNC – computer numeral control) masjiene om ongeskoolde werkers in staat te stel om die gebou aanmekaar te sit in plaas daarvan om die gebou te bou op 'n tradisionele manier, soos in die verlede.

Die hoofdoel van hierdie verhandeling is om die lokale wetlike vereistes rondom houtkonstruksie uit te daag, om ongeskoolde werkers te bemagtig om komplekse/grootskaalse bouprojekte aan te pak en om die publiek se opinie te verander rondom houtkonstruksie, om sodoende 'n sterker houtkultuur te vestig in Suid Afrika.

## Erkennings

My Hemelse Vader wat vir my die talent, 'n sterk wil, gesonheid en krag gegee het deur my studie jare asook 2020 om die verhandeling aan te pak.

My ouers, Jan en Louise Greyling se harde werk, wat vir my die geleentheid gegee het om te kon swot asook vir die finansieële en morele ondersteuning deur my studie jare.

My vrou, Stefnie Greyling, vir jou liefde, omgee, bystand en ondersteuning met my wildste drome.

My mentor, Cobus Bothma, vir al die weeklikse kontak sessies en goeie raad.

André Eksteen, vir jou passie vir argitektuur, asook die toekoms daarvan.

# Abstract

Architects use materials to express an idea, give form and create shelter for whatever the reason might be. The architect's arsenal comprises five main materials: steel, concrete, masonry, glass and timber. When and how these materials are used is dictated by personal preference, public opinion, legislation, environmental aspects and availability.

The use of timber in the South African built environment has not taken centre stage, yielding to superior materials such as concrete and steel. Nevertheless, a mass timber building not only offers ecological and environmental advantages, but also immense skill-based advantages mainly because timber allows for component manufacturing and assembly (Green, 2019).

Recent approval by the South African Bureau of Standards (SABS, 2020) of engineered wood such as cross laminated timber (CLT) has sparked interest in developing a timber research facility completely built with wood in the Pretoria central business district (CBD). The high-tech construction of such a facility would utilise manufacturing methods like the integration of building information management (BIM) programs with computer numeral control (CNC) machines to enable unskilled workers to make a building instead of constructing the building.

This dissertation aims to challenge local legislation around timber construction, empower unskilled workers to make complex/ large-scale buildings and change public opinion about timber construction, as well as to create a stronger timber culture in South Africa.

## Declaration

In accordance with Regulation 4(c) of the General Regulations (G.57) for dissertations and theses, I declare that this dissertation which I hereby submit for the degree Master of Architecture (Professional) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

I further state that no part of my dissertation has already been, or is currently being, submitted for any such degree, diploma or other qualification.

I further declare that this dissertation is substantially my own work. Where reference is made to the works of others, the extent to which the work has been used is indicated and fully acknowledged in the text and list of references.



Christian Greyling
November 2020, Pretoria



"I've never seen anybody walk into one of my buildings and hug a steel or concrete column. But I've actually seen that happen in a wood building."

-Michael Green, Michael Green Architecture

**Figure 2:** Opposite - View to the timber tower's entrance (Author 2020)

# Project summary

**Study leader**
Cobus Bothma

**Course coordinator**
Prof. Arthur Barker

**Editor**
Alexa Barnby

**Hypothesis**
Mass timber construction can bridge the gap between high-tech design tools of the Fourth Industrial Revolution and limited local skill. To enable the unskilled worker to participate in the act of making a building.

**Keywords**
Engineered wood, mass timber construction, premanufacturing, assembly, skill, timber culture, material awareness, component manufacturing, digital manufacturing, craft

**Program**
Timber construction research and development (R&D) facility; visitor information centre; public viewing deck; community workshop centre; public park; lecture rooms; cafeteria.

**Research field**
Environmental potential

**Site location**
1 Koch street, Salvokop, Pretoria Central, 0002
GPS: 25$^0$45'32.83" S 28$^0$11'14.74" E

**Site description**
The site is located south of the Pretoria Train Station, directly west of the footbridge that crosses the railway and connects the station to the north with Salvokop, which is situated to the south of the railway.

**Stakeholders**
The City of Tshwane
The Department of Public Works
The South African Bureau of Standards (SABS)
University of Pretoria Faculty of Engineering, Built Environment and IT

**Theoretical approach**
Led by theories of skill, industry potential, digital manufacturing and craft.

**Architectural approach**
The use of a pre-manufacturing design approach together with component manufacturing as a means of making instead of building, as a model for the architectural investigation.

**Terminology**
Mass timber construction (MTC) refers to "[c]onstruction where the predominant structure of the building is timber". This includes post and beam construction as well as panel construction from the various engineered timber products available (Evison, Kremer & Guiver 2018:128).

**Figure 3:** Opposite - Interior courtyard (Author 2020)



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**Figure 4:** Southern view of the design proposal (Author 2020)



**Figure 5:** Public cafeteria on Koch street (Author 2020)



Figure 6: Timber tower as a landmark (Author 2020)





Figure 7: Timber source (Sappi - Mpumalanga) vs steel source (Shisen Mine - Northern Cape) (Author 2020)

# Introduction

Today, most buildings are constructed using concrete and steel. However, concrete contributes 5 to 8% of global CO2 emissions (the fourth single biggest contributor of greenhouse gases) while steel produces a total of 4% of global CO2 emissions (GABC 2019). Steel is by far the most energy-intensive product to produce per volume. Timber, on the other hand, is the only renewable construction material that produces 98% less carbon to manufacture than steel. It is also the only construction material that absorbs CO2 as opposed to producing it (Green 2019).

In recent years, timber construction technology has made huge progress and mass timber or engineered wood is beginning to show promising signs as a rival for steel and concrete. Timber products such as laminated veneer lumber (LVL), laminated strand lumber (LSL) and cross laminated timber (CLT) have been developed for use in mass timber buildings. Not only does a mass timber building have the benefit of environmentally friendly construction; it also has the advantage of pre-manufacturing and on-site assembly.

In the South African built environment, the shortage of skill is a major concern. The latest figures for 2019 indicate that over 60% of the unemployed population have a qualification level of less than a matriculation certificate, while 53.8% of employed workers only have a matriculation certificate (Department of Higher Education and Training 2019). This places enormous stress on the construction sector as most of the work in this sector is skill intensive.

High-tech design tools such as BIM and virtual design construction (VDC) can help to alleviate this problem (Volk, Schultmann & Stengel 2014). A mass timber building allows the professional team to completely model and machine building elements with the help of computer numerical control (CNC) machines. This method drastically limits construction time and allows for minute building tolerances. Its most important benefit is that it allows construction workers with limited skill to assemble the building instead of constructing the building, which can be skill intensive. A simple philosophy can be applied: "If an element is drawn in the virtual model, it is constructed on site" (Milestone 2017).

This dissertation will also investigate how the gap can be bridged between limited local skill and the high-tech design tools of the Fourth Industrial Revolution. This investigation will take the form of an article within the dissertation and will be used to strengthen the argument to promote mass timber construction in the South African built environment.

# Dissertation objective

The objective of this dissertation is to promote timber construction in the South African built environment; to expose the benefits of mass timber construction in our socioeconomic context; to highlight the hidden potential of the forestry sector; as well as to establish a healthy timber culture in South Africa.

Considering the above, this research will investigate a mass timber building proposal located south of the Pretoria CBD. The project is designed completely using locally available engineered wood products that are premanufactured for assembly on site with little skill required. Furthermore, this mass timber building proposal will act as a landmark for mass timber construction awareness to illustrate its relevance in the Fourth Industrial Revolution in a developing country such as South Africa.

## General issue/intention

The building industry is responsible for 30–40% of all greenhouse gasses, mainly due to the excessive use of concrete and steel. Timber is the only sustainable and carbon-free construction material (GABC 2019).

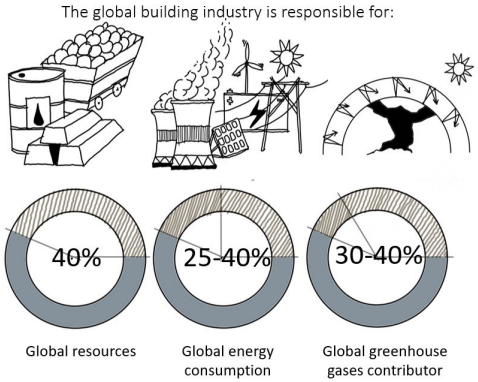



**Figure 8:** Construction industry, global influence (GABC, 2019)

## Local issue/intention

In South Africa, 54% of employed workers only have a matriculation certificate. The building industry consists of a large amount of unskilled labour (Department of Higher Education and Training 2019:49–56). A premanufacturing design approach could therefore be used as leverage to utilise unskilled labour in the making of buildings where skill becomes less important, enabling them to experience a sense of meaning and self-satisfaction in their daily endeavours (Sennett 2008:19–21).

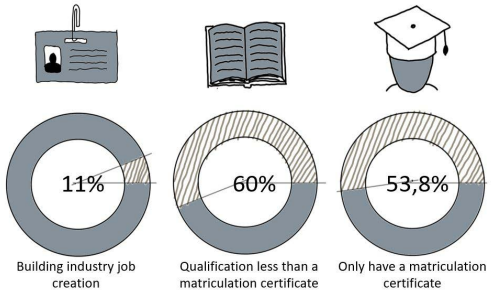



**Figure 9:** Education vs unemployment(Department of Higher Education and Training, 2019)

## Architectural concern/intention

The architectural intention of this project is to promote the use of pre-manufacturing design principles, engineered wood products and high-tech design tools – as facilitator – in order to enable previously disadvantaged unskilled workers to participate in the act of making their own buildings (Benton 2009:36), thereby creating meaning in their endeavours.

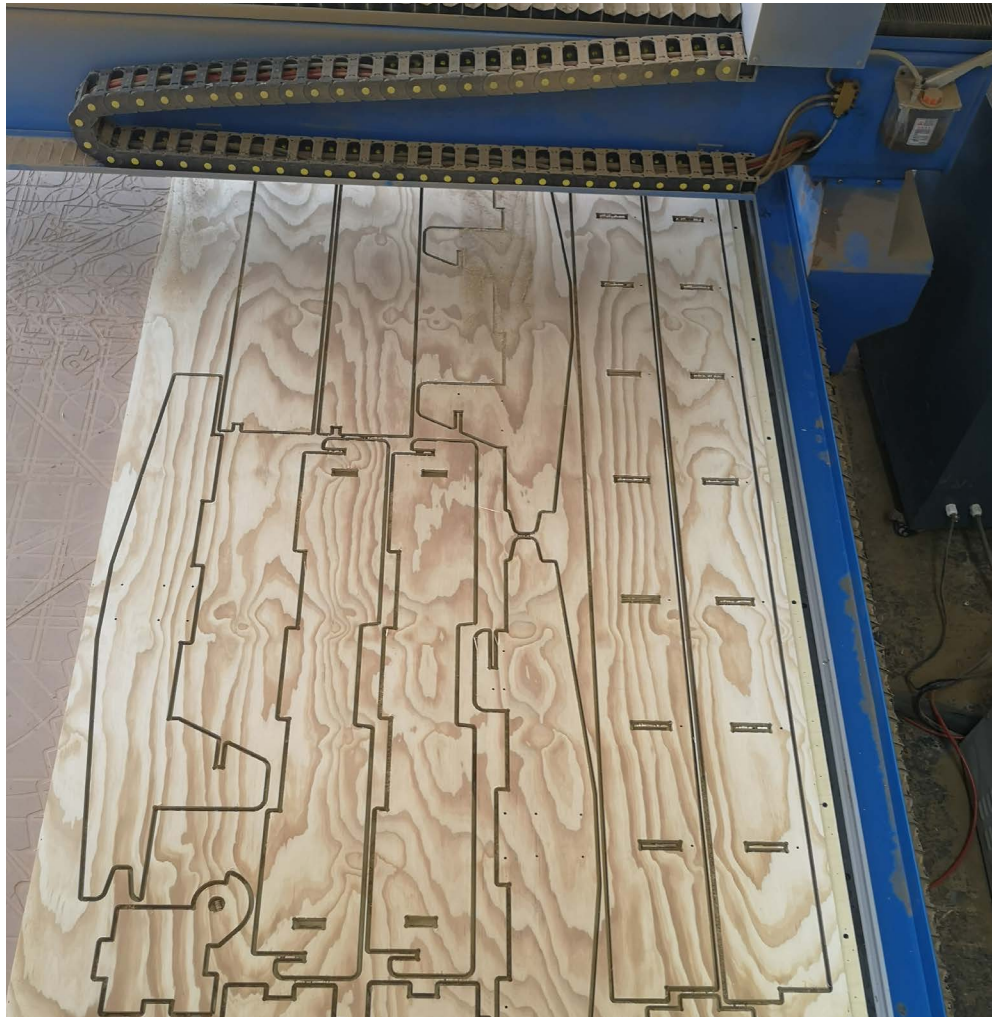


**Figure 10:** Components being machined to be assembled (Author 2020)

# Dissertation limitations

The proposal of a mass timber building anywhere in South Africa may seem controversial, as it is a common misconception that there is not enough timber available in the country and that the timber that is available is of a low standard (Mpakati-Gama 2012). These misconceptions are based on public opinion, material culture as well as a lack of timber knowledge in our society (Van der Heever 2017).

This dissertation identifies these claims as a limitation to the outcome and feasibility of investigating and proposing mass timber building in South Africa. Therefore, a feasibility study and research were carried out to determine whether our forestry sector can support the idea proposed by this dissertation; that is, to build a mass timber building in South Africa.

## Timber availability in South Africa: The hidden potential of the forestry sector

The forestry sector in South Africa consists of 1.2 million hectares of commercial plantations. These plantations cover 1% of the total land mass of South Africa. This may seem like a small number when compared to timber-rich countries such as those in North America and Europe.

A comparison was made with developed countries in the southern hemisphere that practise mass timber construction. The forestry sector in Australia consists of 1.9 million hectares of commercial plantations while New Zealand's forestry sector consists of 1.7 million hectares of commercial plantations (Godsmark & Oberholzer 2019). Both these countries share similar climatic conditions to South Africa. This is important to note because the performance of timber is largely influenced by the climate in which it grows (Teischinger 2016:6).

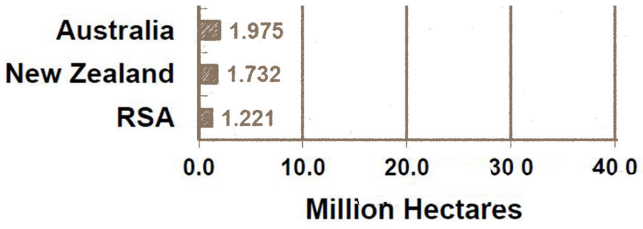
Several case studies from these two countries have shown that mass timber construction is possible even with a limited amount of plantable area for plantations. Australia and New Zealand have optimised their timber production per hectare and optimised their timber processing methods to be able to supply good quality timber for engineered wood products (Evison et al. 2018).

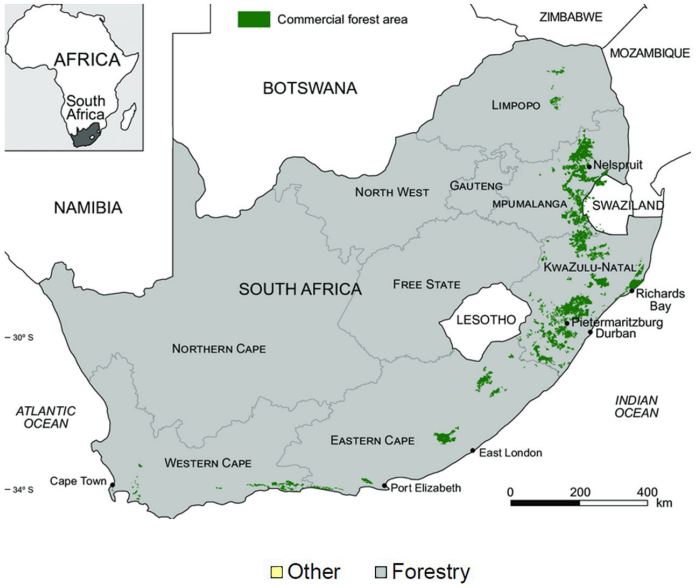


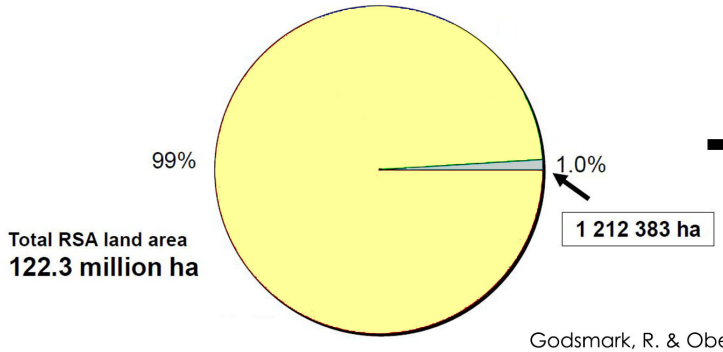
**Figure 11:** Sappi plantation, Mpumalanga (Author 2020)

Global South

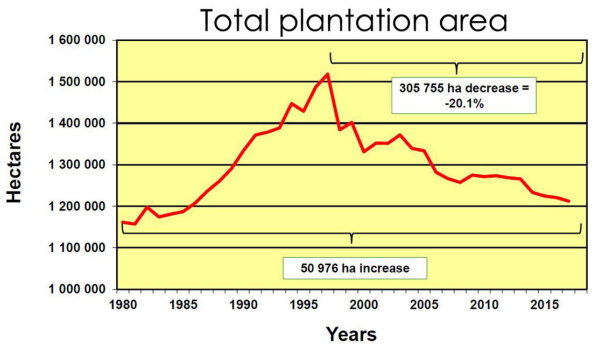
Forestry in South Africa: Land use




Production







Additional 1690ha afforestation area per year



50% Pine forests (required for CLT)

Godsmark, R. & Oberholzer, F., 2019. South African Forestry and forest products industry 2018, Cape Town: Forestry South Africa.

**Figure 12:** Forestry in South Africa (Godsmark & Oberholzer 2019)

There are three fundamental concerns that limit the forestry production system in South Africa. Firstly, the privatisation of state timber plantations. Years ago, state plantations were the primary source of sawlogs. The standard plantation turnaround is 35 years, which is a long time for private companies to lock up their resources, especially with the high interest rates associated with this timeframe. Secondly, current afforestation practices only allow for an additional 100 000 net hectares for afforestation. This is less than the net 140 000 hectares proposed by the Department of Trade and Industry. Thirdly, newly afforested areas are targeted by small plantation growers; however, without state support most of these small growers cannot supply large quantities of timber for downstream demands (Pogue 2009:135).

Primary processing and sawmilling require certain skills. Large sawmilling companies provide skill development systems, but alas, the more than 500 micro mills do not possess the necessary skills required to process lumber on a large scale. As a result, these mills start to fall out of the forestry value chain. If they were incorporated in the value chain (through skill development), these micro mills could prove of great benefit for secondary processes, supplying products such as engineered wood (Pogue 2009:144).

A critical change in the forestry value chain needs to be made. Currently, the traditional production system does not accommodate local plantation communities. Ultimately, the success and quality of the timber output equates to community-based growers. The realisation of this requires a holistic timber production paradigm approach. The development of complementary business support and the demand for high quality timber products is thus very important in this regard (Pogue 2009:146).

## The quality of South African timber: Better than you think

Timber is a natural product; therefore, the properties of the final product are dependent on a wide range of factors other than just climate and water. There are a wide range of possibilities for tailoring and enhancing wood properties along the entire wood process chain, from tree breeding and silvicultural measures to specific technological manipulations.

However, most manipulations today are focused on reducing shrinkage and swelling, increasing resistance to fire and increasing defences against a biological attack. Additionally, new novel modifications can be applied to improve the mechanical properties of wood, such as impregnating the cell wall with resins or inorganic compounds (Teischinger 2016:6).

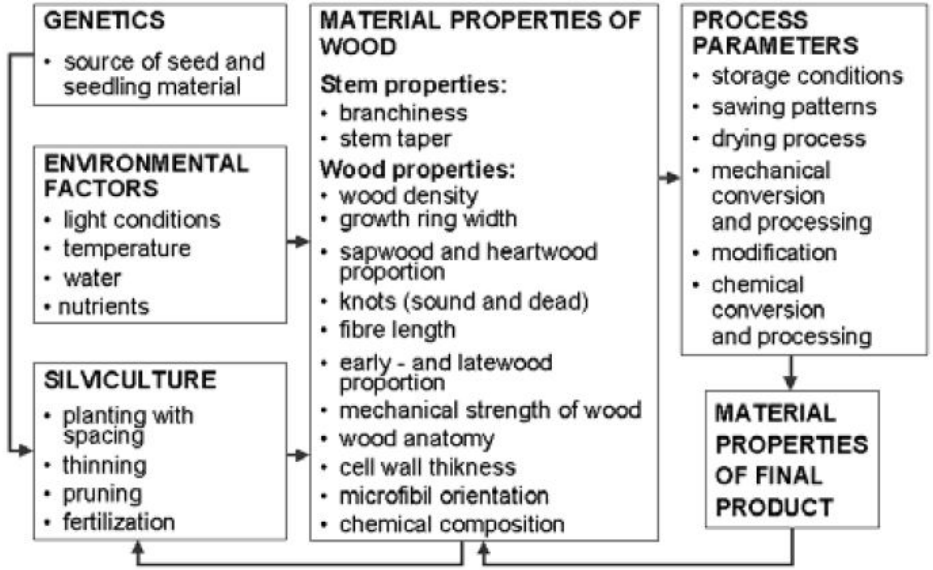



**Figure 13:** Timber properties modification solutions (Teischinger 2016:7)




FSC

**Plantation, Not natural forest**

plantation timber is a net producer of trees resulting in afforestation

SATAS

**Strength & Durability**

Timber with the SATAS or SABS stamp comes from audited, quality controlled sources.

**Fire Safety**

Timber performs very predictably in fire conditions and 2hr fire rating is achievable, especially with Mass Timber.

$CO_2$

**Carbon Store**

Combination of carbon sequestration in growing trees and the long term carbon storage in wood.

**Figure 14:** Common timber misconceptions (Author 2020)

construction in developed countries in 2020



TIMBER



construction in SA in 1800's

construction in SA in 2020



**Figure 15:** South Africa's static use of timber ( Green 2019)



Figure 16: Pretoria's building landscape dominated by traditional construction methods ( Author 2020)

# Article title

**The gap between limited local skills and high-tech design tools in the South African built environment**

## Abstract

The South African construction industry is an important role-player in job creation. In 2019, the industry provided 11% of jobs in the country (CIDB 2019:12). This figure includes skilled, semi-skilled and unskilled labour, of which the unskilled labour pool is the largest. The minister of Public Works and Infrastructure, Patricia de Lille, states in the CIBD annual report that the next few years will be crucial for South Africa's development, as we will need more than just a burst of speed to meet the goals of the National Development Plan (NDP) Vision of 2030 (CIDB 2019:4).

The Fourth Industrial Revolution has improved society in several ways and the construction industry is no exception. Every day new materials and building techniques are developed to assist designers and construction workers to complete construction projects as cost-effectively as possible and with more efficiency (Diaz 2016:2-3). Although developed countries reap the benefits of these technological advancements, developing countries such as South Africa fall behind. This is mainly due to the low skill level, as well as the lack of awareness of alternative construction materials in the country (Maddock & Maroun 2018).

One current architectural discourse is engineered wood. Although the idea of mass timber construction has been around since the 1990s, it is still a relatively new concept in the South African built environment. Thus far, only a handful of small projects relying on some aspects of engineered wood have been completed, but none have been built completely using mass timber. Not only does a mass timber building offer ecological and environmental advantages, but it also offers immense skill-based advantages because timber allows for component manufacturing and assembly, which in turn allows unskilled workers to complete a wider scope of tasks.

This dissertation aims to challenge local legislation regarding timber construction, empower unskilled workers to make complex/large-scale buildings, change public opinion about timber construction, as well as create a stronger timber culture in South Africa. In addition, this could help meet the demands of the NDP for 2030.

## Problem statement

**General: Disconnect between technology and skill**

Developing countries such as South Africa appear to have fallen behind to a certain extent in terms of fully utilising high-tech design tools. Several challenges are experienced in this respect such as unemployment, lack of skills, difficulty adapting to alternative building methods, insufficient awareness of alternative construction as well as financial implications (Maddock & Maroun 2018).

**Local: Missing opportunities in the construction industry**

There is a tremendous gap in the South African built environment regarding the use of timber and mass timber construction. This is mainly due to the lack of a timber culture and the influence of the use of dominant materials such as steel and concrete used globally.

**Architectural: Building manufacturing**

The construction process, as stated by the Joint Building Contracts Committee (JBCC), involves an outdated construction approach, where consultants and contractors are disconnected from each other (JBCC 2014). Furthermore, this approach does not accommodate a "making" approach but is instead optimised for a building "construction" approach.

## Introduction - Background information

The latest figures for 2019 indicate that over 60% of the unemployed population have a qualification level of less than a matriculation certificate while 53.8% of employed workers only have a matriculation certificate qualification (Department of Higher Education and Training 2019).

The Construction Industry Development Board (CIDB) views construction labour as all persons involved in physical construction work. This includes skilled, semi-skilled and unskilled labour. Skill can be described as the ability to perform a certain task to a high level of competence (Shah & Burke 2005). The skills required by the construction industry entail the ability to understand the construction process and plan accordingly, to work efficiently in large construction teams and to adapt, learn and use new materials and methods. Unskilled labour, however, lack most of these attributes as well as relevant qualifications, thus limiting the potential of the construction industry as a whole (Shah & Burke 2005).

According to the CIDB (2019), the issue of limited skill is directly linked to the standard and relevance of institutions and programmes such as Further Education and Training (FET) colleges. The curriculum of these institutions does not cater for the needs or required standards of the construction industry and can therefore be judged as almost irrelevant. This issue of limited skills is also a result of the problems in the education system, such as low matric pass rates. Additionally, South Africa's maths and science results are extremely poor (Modisaotsile, 2012) but these subjects are nevertheless required in order to be admitted for higher education in most of the construction trades such as electrical or plumbing courses.

## Research question

How can the gap between limited local skill and high-tech (CNC & BIM) design tools be bridged within the South African built environment?

## Article statement

Considering the above research question, this article will investigate certain issues including questioning the processes and methods followed to construct a building, as well as how high-tech design and manufacturing tools can be utilised to address the major concern of limited skill. The investigation and findings of this article will act as a basis for the broader theme of the dissertation of timber construction and the proposal of a mass timber building in Pretoria.

## Significance of the study

This study aims to provide an alternative solution to building construction. It accordingly proposes alternative construction processes that have been tried and tested in other countries in North America and Europe. Such new processes could address challenges such as limited skills better than the current legislation. This study also aims to emphasise the large gap in the timber construction industry in South Africa, which faces problems like unemployment, low skills and global warming. Current thinking about how we make buildings needs to be reconsidered and mass timber construction can be suggested as a viable solution.

# Literature review

## The global construction industry

### A brief historical overview

From the dawn of architecture, humankind was intrigued and inspired by the materials they used to physically express their ideas and which allowed them to create a building or space (Frampton 2001:2–3). Timber was one of the first materials to be used for building construction, one example being the timber temple of Hera (Hekatompedos) in Samos, Greece, constructed in the mid-8th century BC (Burkert, 2013). Parallel to the use of timber was the use of stone, mainly because of its compressive strength and durability characteristics. Later, the Romans would invent and perfect the use of concrete to create structures never imagined before, such as the Pantheon in Rome constructed in 113–125 AD. The use of concrete allowed for a 43.3-metre span dome capping the rotunda (Jones 2015:182–184). These spans would later be improved as technological knowledge progressed during the Gothic and Renaissance periods.

Fast forward to the Industrial Revolution where a new material was emerging that would change the course of the construction industry for centuries to come – the industrialisation of steel in the 19th century. The potential of this material was explored by pioneer architects like Henri Labrouste (1801–1875). Steel is prominent in his design of the Sainte-Geneviève library in Paris (1850). The barrel-vaulted roof was made up of lightweight iron sheets supported by thin ribs, resting on cast iron columns (Frampton 2001:46).

Joseph Monier's (1823–1906) invention of reinforced concrete in 1849 allowed architects and engineers to develop structural systems like François Hennebique's (1842–1921) reinforced concrete construction system (see Figure 1) and later Le Corbusier's Dom-Ino structural system. This involves the use of thin reinforced concrete slabs and columns to create a free plan interior. The use of steel and reinforced concrete by architects became common and dominated the construction industry for nearly three centuries, leaving the research and development of their counterparts, such as timber, in their wake.

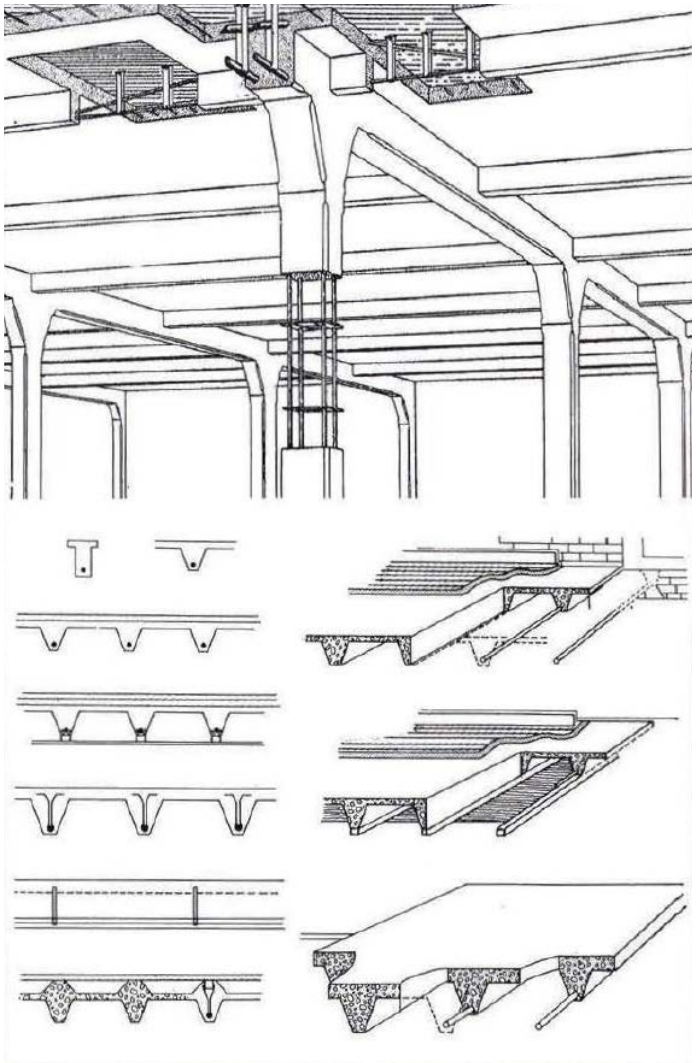


**Figure 17:** Hennebique's reinforced concrete system (Frampton 2001:122).

# The use of timber

The use of timber as a structural component can be traced back between one and three million years. Primitive shelters belonging to Peking Man, in what is now China, used timber slats to build dome-like shelters dug in a shallow pit into the earth to protect them from the elements (Smith & Snow 2012:504). Although not contemporaneously, timber construction methods evolved through the ages to what we are accustomed to today, the timber frame method. In the 19th century, methods developed such as George Washington Snow's balloon frame construction system, which is regarded as the first prefabricated building system (Frampton 2001:102). Architects like Frank Lloyd Wright (1867–1959) explored these methods and created modular systems to improve building construction and reduce construction time and material wastage, as can be seen in the summer cottage for George Gerts in Whitetail, Michigan, built in 1902, as well as his famous Usonian houses build across the United States from 1934 to 1958 (Frampton 2001:117).

Various events contributed to the steady decline in the use of timber as the main structural material. The most noteworthy is timber's combustible characteristic. Urban densification during pre-Renaissance periods caused many great urban fires. Historic fires such as the Great Fire of London (1666), the Great Chicago Fire (1871) and the Boston Fire (1872) fuelled the tendency to use more non-combustible materials such as bricks, concrete and steel. These events also resulted in governments passing legislation that limited timber buildings to heights of only four storeys, irrespective of their construction method (Smith & Snow 2012:505).

Urban densification in the 20th century demanded higher buildings to accommodate the influx of people moving to the cities. Because of height restrictions and public perception, architects and engineers resorted to the emerging materials of the time: concrete and steel (Glaeser & Kahn 2003). This led to rapid research and development of these materials and leaving timber only for furniture, interior cladding or ornamentation (Green 2019).

The use of timber as a main structural component in high-rise buildings was not realised during the 19th and most of the 20th century, until 1990. A new concept was developed by European and North American companies, mass timber construction (MTC). MTC utilises engineered wood products such as cross laminated timber (CLT), laminated veneer lumber (LVL) and laminated strand lumber (LSL). This may be used for the entire construction of a building, comprising all the structural and aesthetic elements.

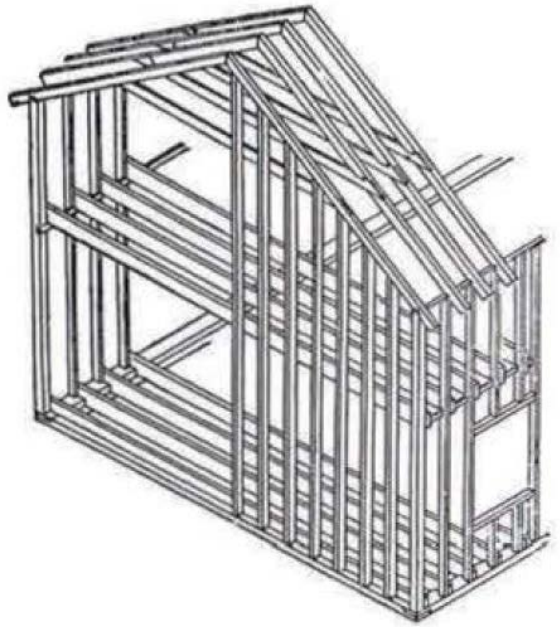


**Figure 18:** George E. Woodward, balloon framing system (Frampton 2001:102).

Various mass timber buildings are being built in Europe and North America, with some reaching heights of more than 10 storeys; for example the Stadthaus at 24 Murry Grove in England, built in 2008 by Waugh Thistleton Architects. This was the first high-rise mass timber building in the world that was completely premanufactured and assembled on site, consequently reducing construction time to 49 weeks as opposed to 72 weeks (if the building were to be built out of conventional materials, such as steel and concrete). This building stores more than 181 tonnes of carbon. Additionally, by not using concrete, a further 125 tons of carbon are saved from entering the atmosphere (Waugh 2012).

With legislation being the one major hurdles for tall wood construction, the LifeCycle Tower, which is a concept in development that proposes a 30-storey mass timber skyscraper set to be built in Austria, challenges local authorities to re-examine legislation. Considering the entire carbon footprint and lifecycle, the building aims to be the ultimate, most sustainable building ever constructed. By using prefabrication modules, the construction time of this building will be reduced by 50% as opposed to traditional building techniques (mgb Architecture + Design 2012:30-32). The emerging use of mass timber buildings internationally serves as a valuable example to follow in South Africa.

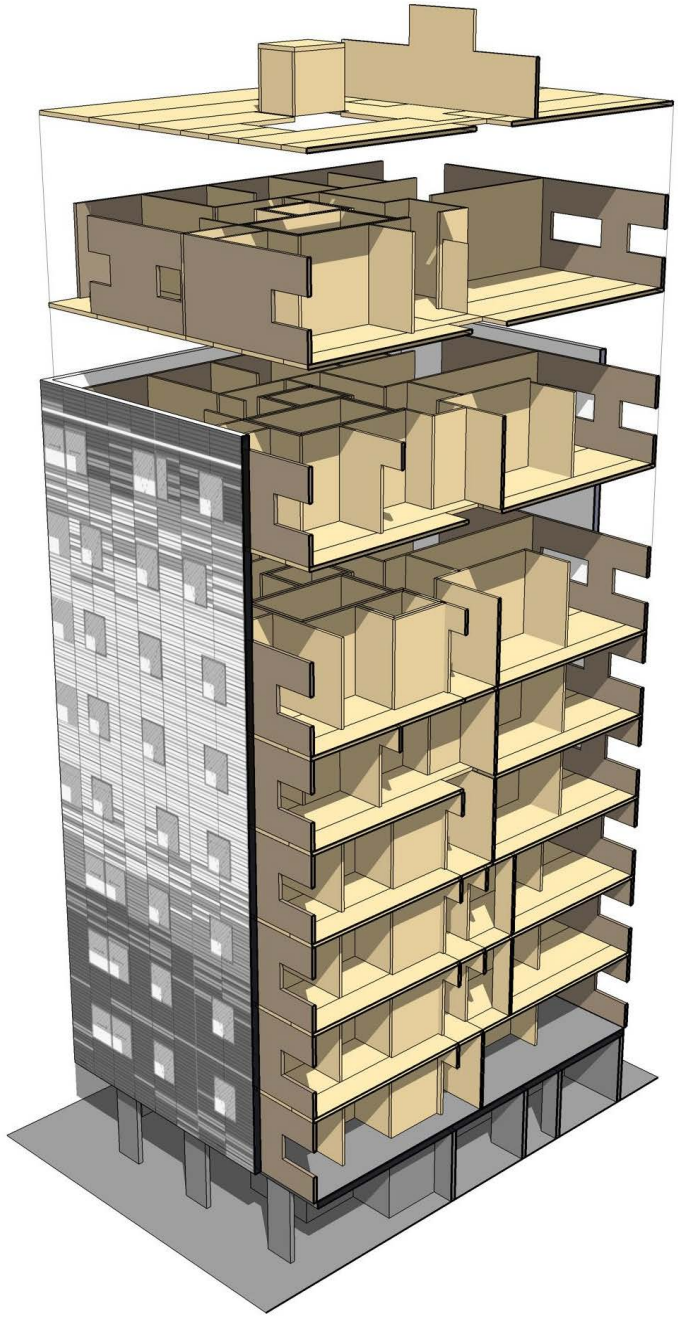


**Figure 19:** 24 Murry Grove CLT assembly (mgb Architecture + Design 2012:30)

# The South African construction industry

## A brief historical overview

Architecture in South Africa has been dominated by international influences due to its long colonial past. These influences can be traced back to European countries such as Germany, Holland and Britain. One of the first influences, following the occupation of the Cape by the Dutch in the form of the Dutch East India Company in 1652, was Dutch-Flemish which evolved in a regional architecture known as Cape Dutch. This style comprised thick stone or masonry walls and a thatched gabled roof.

During the mid-19th century, the British Victorian style dominated the built environment with Victorian patterns expressed with corrugated sheet metal and cast iron as the main construction materials. The new prosperity of gold attracted talented architects like Herbert Baker (1862–1946), who designed famous administrative buildings like the Union Building (1909) in Pretoria. Influenced by the international neoclassical style, built with sandstone as the main construction material.

During the 1920s, influences from international contemporary movements influenced the built environment such as the Modern movement of the early 20th century, which involved the use of reinforced concrete and steel as the main construction materials. These materials along with masonry and glass (because of their availability) would be used as the main construction materials for the rest of the century. In addition, new thinking and influences such as the International style, Little Brazil movement and Regionalism all make use of these materials as a result of their availability, as well as past experience, knowledge and familiarity in the industry. The use of timber as a main construction material was very limited and mostly reserved for use in roof trusses, interior cladding and decorative elements (Prinsloo 1995:302–304), contributing to the decline in a timber culture.




**Figure 20:** Mounts Bay Hotel, Pritchard Street in 1909, showcasing the iconic use of cast iron molds of the Victorian style(Business Tech 2015).



**Figure 21:** House Jooste, Pretoria, 1956, Karel Jooste. Exsessive use of concrete and brick - Regionalism influence (Author 2019)

# South Africa's static use of timber

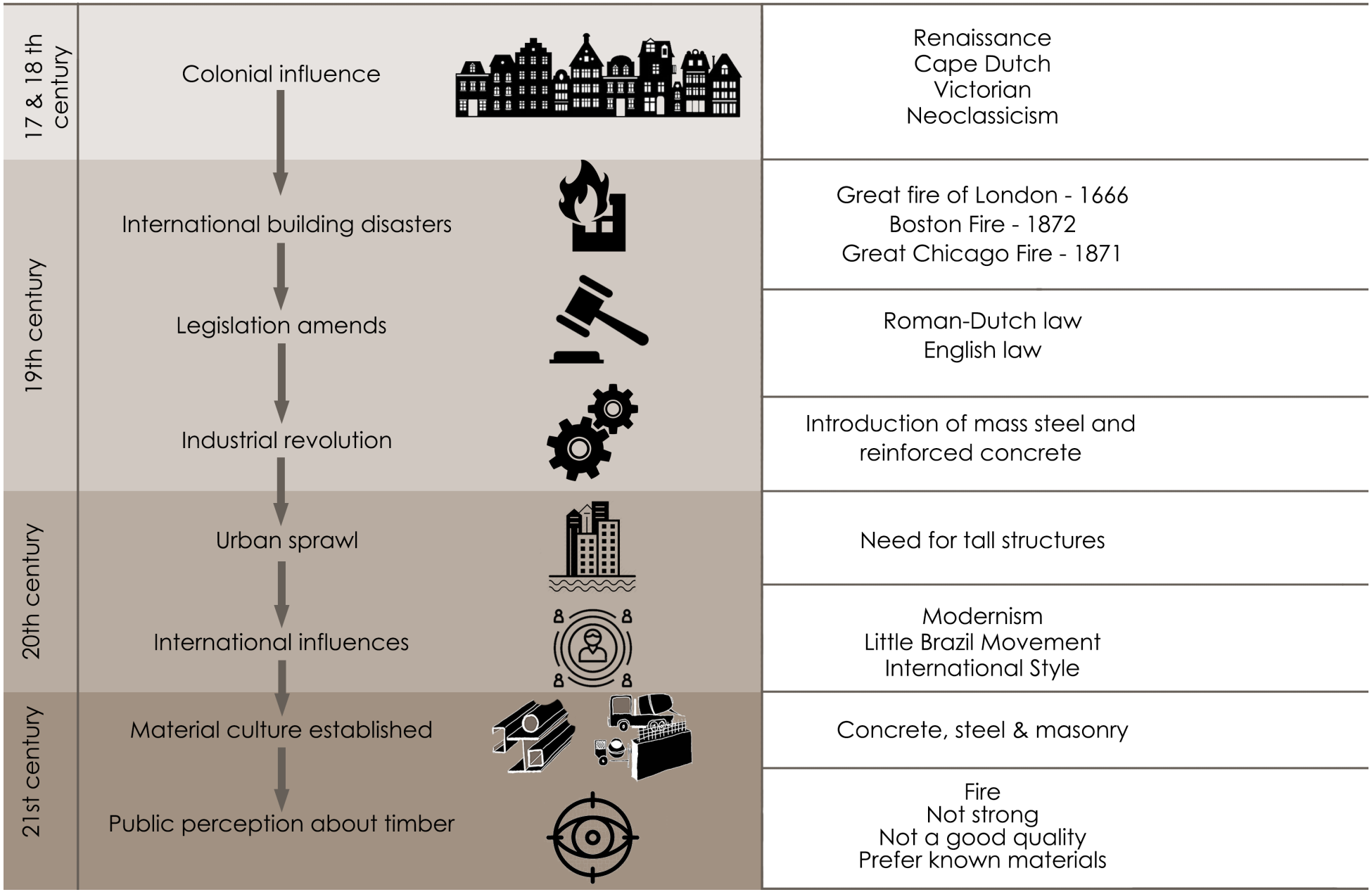



**Figure 22:** South Africa's static use of timber (Author 2020)

## Local challenges

Currently, the South African built environment comprises a few skilled workers and consultants and a substantial number of unskilled workers with an education level of matric or less. This places a lot of pressure on the industry much of the work involved is skill intensive.

Other factors relating to skilled worker shortages include the ageing workforce. Research indicates a 30% influx of skilled artisans leaving the workforce (Mukora 2008). These losses of skilled workers are not being filled by a new workforce. This is due to prospective students who are discouraged because they did not obtain a matriculation certificate or had very poor maths and science results (Department of Basic Education 2019:16-18).

This statistic is one of the main reasons why innovative building methods or materials face various hurdles within the South African context; there simply aren't enough skills in the construction workforce pool for architects to specify such methods/materials. The workforce of most contractors consists of workers with limited skills, leading them to resort to known methods that are tried and tested. These contractors rarely overstep the boundaries to explore new materials and methods of construction unless they are given the opportunity (Maddock & Maroun 2018). This phenomenon also explains the building industry's strong conservative belief in traditional materials such as concrete, steel and masonry. This results in limited opportunities to explore alternative construction materials such as engineered wood.

It is also noted that newly developed construction materials and techniques have resulted in a change of demand in certain skills and, in some cases, new skills. According to the Department of Education (2018), the technological advances in the construction industry lead to an ever-changing ecosphere of newly required skills. Curriculums need to be updated, which will redefine the skill requirements for the construction industry (Windapo 2016:3).

## The building process

Building processes in South Africa are governed by entities such as the Joint Building Contracts Committee (JBCC). Current legislation and building contracts are not compatible with pre manufacturing principles (Green, 2019) as they are optimised for traditional building techniques which require predominantly onsite operation in order to construct a building. Moreover, the consultants and contractors are disconnected from each other and the only line of communication between these two stakeholders is the project manager (PM) who is responsible for all the communication and information between the consultants and the construction team. This approach can have serious consequences such as the misinterpretation of important information, which can result in the project being completed past its due date or over budget (JBCC 2014).

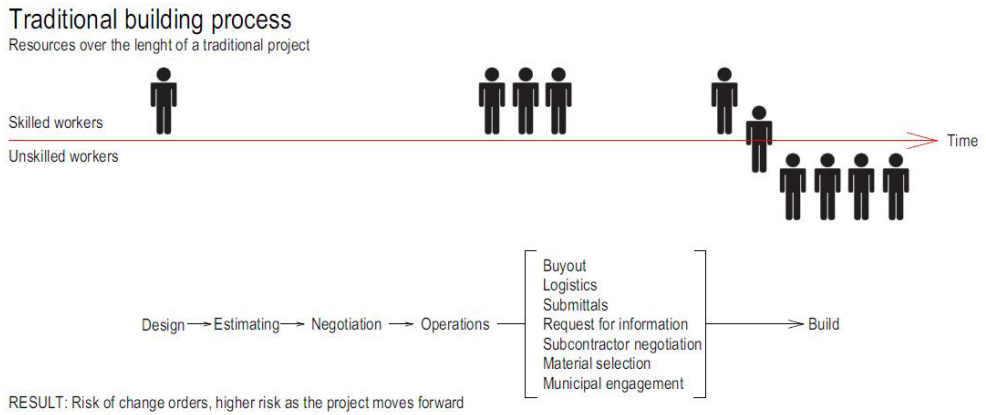



**Figure 23:** Traditional building process indicating skilled and unskilled workers at each project stage (adapted from Katerra.com)

Furthermore, this process disconnects the designers and builders from one another. Traditionally, architects and engineers would design the building and start to issue construction documentation, without the input of the building contractor. This method disconnects the design phase from the building phase. Also, the amount of resources and people required are utilised in the end (build) phase instead of being spread out evenly between all the phases. This can result in a high risk of change orders (Green 2019).

Katerra, a US-based company, has devised a strategy for a building automation process designed around the use of mass timber construction and building manufacturing automation. This process distributes most of the resources at the beginning of the project to mitigate the risk of change orders as the project progresses. The entire project is created with the aid of a building information management (BIM) program, which is used by all consultants to test building performance and loads, project sequencing, time management and project costs. All these are extremely important aspects and possible issues related to the project are discussed and resolved before the groundwork commences, thus mitigating risks.

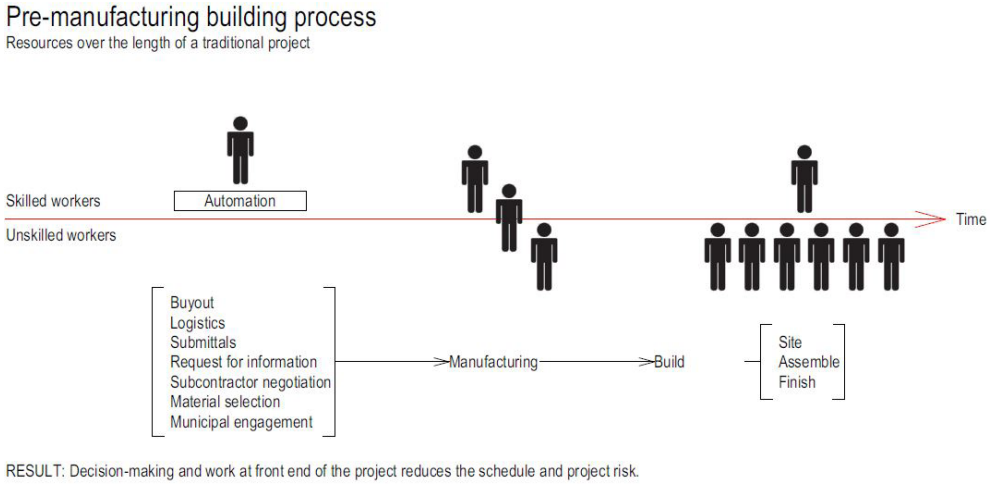



**Figure 24:** (Bottom left) Pre-manufacturing building process, indicating skilled and unskilled workers at each project stage (adapted from Katerra.com 2020)

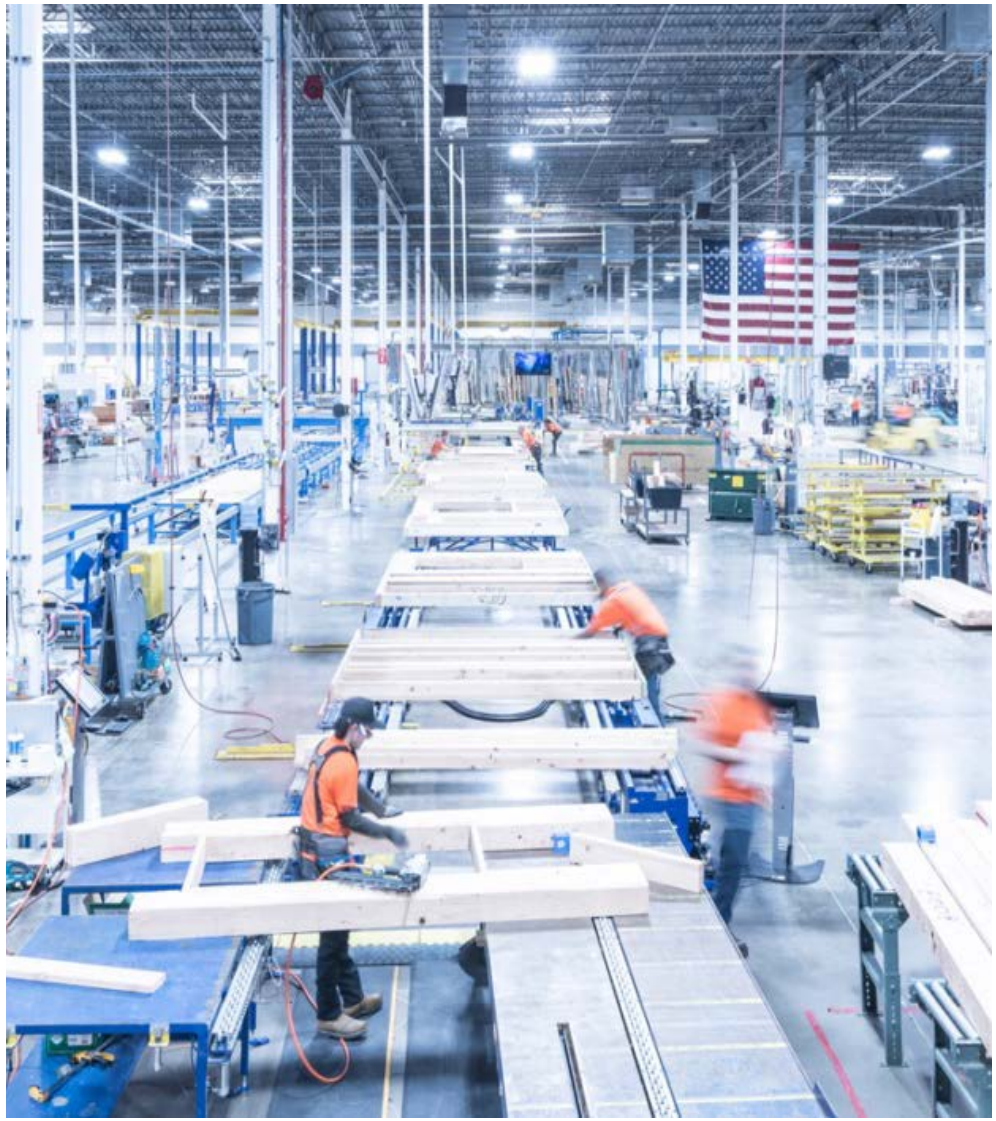


**Figure 25:** Katerra digital fabrictation workshop (Katerra.com 2020)

# A South African case study

**Future Africa, Dining Hall, Earthworld Architects, Pretoria, 2018**

Finding a mass timber building case study in South Africa is impossible, simply because there has never been a mass timber building constructed in South Africa in the 30 years of the existence of engineered wood. There are, however, a handful of projects which have been completed using engineered wood and the principles of pre-manufacturing. One such project is the recently completed Dining Hall of the Future Africa campus in Pretoria, completed in 2018 by Earthworld Architects. The principal architect, André Eksteen, saw the immense potential of pre-manufacturing with timber. This allowed him to design a relatively complex structure that was completely designed and "built" in the digital realm of the BIM environment, machined with the help of computer numerical control (CNC) machines and assembled by unskilled workers.

A series of portal frames were used to create the structural system. These portals were constructed out of three layers of 22 mm plywood boards, cut on a CNC machine and assembled off site for installation on site. The build took only 90 days which included manufacturing and assembling the entire structure. The main advantage was that the manufacturing and erection process could happen simultaneously. The contractor assigned to the project had a degree in graphic design but was a joiner and carpenter by trade. This was the first building he had ever built. His team consisted of eight workers, who were all unskilled (Gunter 2020).

The integration of BIM software operated by one skilled architect allowed the manufactured building components to be assembled by unskilled workers, thereby capitalising on the large number of unskilled workers to a ratio of 1:8.



**Figure 26:** Future Africa dining hall plywood portal frames (Author 2018)

## Hout Bay house, HWZ International, Hout Bay, 2015

The Hout Bay house was the second CLT house designed and constructed in South Africa with the aim of promoting the use of CLT and timber construction as a sustainable material for housing. The house is a showcase which is accessible to the public. The main aim of this house is to establish the way in which engineered wood performs in the climatic conditions of the Western Cape. The entire house was pre-manufactured in a factory and assembled in just 28 days. Local unskilled helpers were able to assemble the entire house with the help of two CLT construction professionals. Test results also indicated that thermo-treated pine can withstand the elements in the Western Cape. The carefully designed CLT wall and roof systems have cavities and overhangs which can deal with the high humidity of the Cape (HWZ International 2015).



**Figure 27:** Hout Bay house built in 23 days (HWZ International 2015)



**Figure 28:** CLT house dry fitted in the factory for (Smily 2019)

# Research methods and design

Two focus groups are identified as major role players in any construction project: the professional team (architect) and the contractor (construction workers). Accordingly, two different questionnaires were sent to each focus group to identify the current state of the built environment. Additionally, 23 significant buildings were analysed to determine common or new trends used in the construction industry.

This research adopted an overarching or a mixed method (Creswell 2009). It followed a quantitative approach with the use of structured questionnaires, which were sent to several architects in South Africa via Google Forms, as well as qualitative approach that used face-to-face interviews with workers in the construction industry. These included entrepreneurs who get work from the street such as in front of hardware stores. The questions that were formulated for each of the two questionnaires/focus groups were obtained from the literature review where the current state of the built environment was identified. This highlighted important questions that needed to be clarified.

A third method was also undertaken. A desktop study of prominent buildings that have been built in the last 20 years in South Africa was conducted and the following criteria were formulated for selecting and analysing these buildings:

- Buildings had to be located in Gauteng for ease of access to these buildings.
- The buildings had to be publicly accessible in order to allow them to be inspected or there had to be enough information published about the building to analyse it via a desktop study.
- The buildings had to have been built between 2000 and 2020.
- The buildings had to have won the SAIA award for excellence or an award for merit.

The buildings were analysed according to Laughier's principles of the primitive hut, according to which Laughier divides and analyses buildings into three main elements: the column, the entablature and the pediment (Laugier 1755). These elements were adapted in order to be relevant within the context of this study. The adapted elements whereby the selected buildings were analysed are the floor, the wall and the roof.



**Figure 29:** Laugier's primative hut: The column, entablature and the pediment (Laugier 1755).

## Research methods limitations

A number of limitations were identified

**Age groups and experience.** No way was found of contacting a architects in a certain age group with a specific number of years of experience; instead any architect was able to fill in the form. It might have been more beneficial if only architects with 10 years of experience or more could have filled out the forms. However, due to the national COVID-19 crisis this was simply not possible, as I was unable to meet architects in person. I therefore resorted to an electronic medium. One can, however, accept the survey responses provided by more experienced architects into account. For the purposes of this study I used all the feedback, as the results were generally the same.

**Focus group two: unskilled workers.** I was able to approach several workers in person before the national lockdown but was alas unable to interview as many workers as I have hoped for. Most of these workers were found in front of hardware shops and feel a bit intimidated when approached. They feel as if they are being violated in some way or they might get into trouble. Taking the university's ethical guidelines into account, I was only able to interview about 70% of the people that I approached. Although this limited the amount of information, I was still able to get enough information to make an informed conclusion.

**Building analysis.** This study only focuses on award winning buildings in Gauteng. It might have been more beneficial to widen the scope and include more building categories like simple residential dwellings, office blocks and commercial buildings to obtain more detailed information. However, this would have been impossible, given the time, resources and manpower required to inspect such a wide range of buildings. Therefore, the study only focused on award winning buildings which had received an award for a good reason. A simple approach was taken: if a prestigious building did not utilise innovative building or alternative construction materials such as engineered wood, what are the chances that a normal dwelling or office block would utilise these methods or materials?

## Research findings

The three data collection methods conducted revealed interesting results. The three studies will each be analysed individually in order to identify the initial findings.

**Structured questionnaire completed by the architects**

The study identified that professional architects acknowledge that the construction industry in South Africa has changed over the past 20 years. They also acknowledge that various new innovative materials and construction methods are available for use. However, most respondents revealed that these new techniques and materials can sometimes be difficult to incorporate in their designs owing to the lack of awareness of new materials and methods, as well as the limited local skills in the country. They also highlighted that the quality of work is not always on par. Most would describe the quality of work as average.

Almost 90% of the architects responded that they already use BIM software to facilitate their designs and documentation. In the light of the use of innovative materials this is a positive result, as BIM programs are the pioneer programs being used for alternative building construction, techniques and building component manufacturing (Volk et al. 2014:1–2). Most of the respondents also said that they are eager to learn more about BIM software and the benefits it has to offer.

Architects prefer a mix of both traditional and innovative building materials and techniques, depending on their own design philosophy, material availability and client requests.

Ninety per cent of architects responded that they had knowledge of engineered wood products, but they seldom specify these materials, as they are unknown among contractors as well as clients. Both contractors and clients prefer more traditional materials they are accustomed with, both in terms of material performance and durability.

**Semi-structured questionnaire administered to the construction workers**

The construction workers interviewed ranged from skilled to semi-skilled craftsmen. Most respondents revealed that they were skilled in more than one trade, on average up to three trades. This reflects the context of the South African economy and the healthy sense of entrepreneurship, where an individual is willing to expose themselves to various trades to enhance their chances of getting work.

Ninety-three per cent of the interviewed workers said that they had acquired their skills from a relative or someone they knew. None of these respondents had received any form of formal education. This highlights the lack of institutions where people can learn essential skills relevant to the construction industry in this country (Windapo 2016), as well as the lack of opportunities to study at such an institution.

Most of the construction workers did not have any knowledge of alternative construction methods or materials, knowing only the basic uses for materials. For example, concrete is only used for floor slabs and foundations, bricks are the only material used to construct walls, and timber is the only material used for roof trusses. This identifies the large gap in awareness of the use of alternative building methods and materials, as well as why architects cannot specify the use of these methods and materials.

In addition, these workers had no knowledge of engineered wood products, mainly because they had not been exposed to these materials or they had never been given the opportunity to work with these materials. Timber construction was seen as an elite trade far out of their reach.

**Building analysis: findings**

A total of 23 buildings were analysed, all according to the categories indicated above. These buildings are considered elite buildings in the South African built environment and yet they show signs of mostly having used traditional materials and construction methods. There are however exceptions: the use of innovative methods and materials used can be seen in roofs and walls, where the design of such a system greatly benefits the building's thermal and environmental performance.

In only a few projects (less than 10%) was the use of timber as the main construction material identified. The use of timber is surpassed by the use of more traditional and perhaps more regional materials such as bricks and concrete. This indicates the large gap in the awareness of the use of timber for building construction. Of the five main building materials (concrete, bricks, timber, glass and steel), timber is the material with the lowest total embodied energy and is a completely renewable source (Ching 2014:p. 421). The use of timber should therefore be encouraged to be used.

It is also evident that innovative materials and methods are only applied to buildings of this calibre (as identified in the category by the set limitations). Most of the buildings in our built environment make use of traditional methods and techniques (CIDB, 2019) that do not benefit from the use of innovative methods and materials.

# Findings discussion

## The link between limited skill and high-tech design

### Decline in construction skills

It is evident in this study that there has been a rapid decline in construction skills. To make matters worse, the building industry has not seen significant change in terms of the adaption of new materials or methods to change the way we think about limited skills. Public perception and a conservative approach to traditional building materials make it impossible to explore new means of confronting the problems of limited skills. Consequently, there is no opportunity to explore new materials like engineered wood and construction methods like pre-manufacturing and building in the current built environment. We lack a broad sense of material culture. Material culture, as Sennett (1943–) describes it, "provides in sum a picture of what humans beings are capable of making" (Sennett 2008:15). The bigger the scope of material culture, the bigger the possibilities to consider in the making of our buildings.

The architects interviewed indicated that the overall craftsmanship in the country is deteriorating. These days most people complete work just for the sake of getting paid for the job. In earlier days being a craftsman in your trade was considered the ultimate accomplishment. Today, society has changed so much that the carpenter and the doctor don't work next to each other anymore as they did centuries ago in classic Medieval and Renaissance cities. Craftsmen these days are located outside the realm of the inner city. At different moments in history, practical activity has been degraded, separated from so-called higher pursuits. Technical skills have been removed from the imagination (Sennett 2008:21). Emerging technologies can assist the designer to enable unskilled workers to participate in the act of making once more.

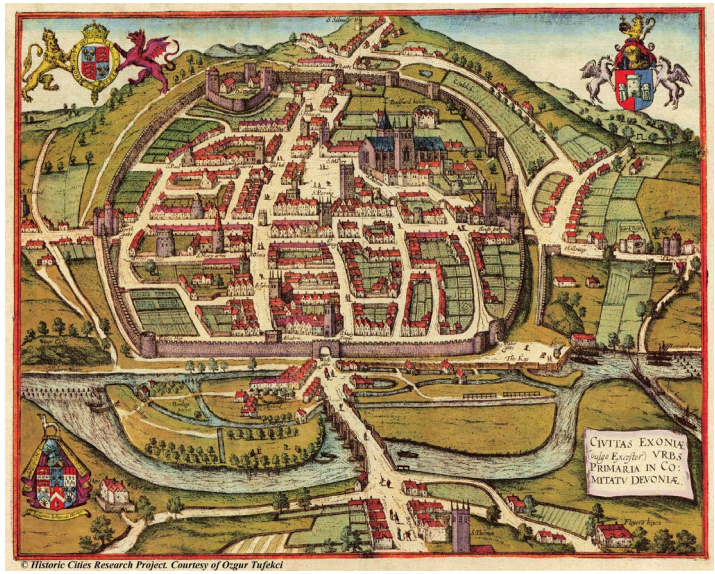



**Figure 30:** Medieval city where the craftsmen are located in the inner city (Taschen 2011).




**Figure 31:** The seal of a master craftsmen during the 5th and late 15th century (Taschen 2011).

# Bringing back meaning to the making of a building: enabling an unskilled worker to be a craftsman

It is certainly possible to get by in life without dedication. Anyone can claim that they are the master of their craft. Sennett describes individuals who complete a task merely for the sake of completion as not worthy of the title of craftsman (Sennett 2008:20). Being a craftsman means to have a skill developed to a very high degree. Acquiring such a level of skill requires immense dedication and diligence. This comes with a reward, both personally and socially. C. Wright Mills (1916–1962) explains:

> The labourer with a sense of craft becomes engaged in the work in and for itself; the satisfactions of working are their own reward. The detail of daily labour is connected in the worker's mind to the product; the worker can control his or her own actions at work; skill develops within the work process; work is connected to the freedom to experiment. Finally, family, community, and politics are measured by the standards of inner satisfaction, coherence, and experiment in craft labour (Wright Mills 1951:220–223).

When interviewing the unskilled construction workers, one prominent phenomenon surfaced. There is a strong will among unskilled workers to learn about their trade or to learn new skills from other trades. Although very limited, they reveal a sense of pride in their work. But because of the competitive market and the limits on their skills, the instinct to survive is bigger than the instinct to produce good work. The labourer struggles to become fully engaged in their work, therefore failing to gain any satisfaction out of their labour.

Bringing back the meaning in the making of a building is an extremely important intangible aspect that is missing from our current construction endeavours. Unskilled workers do not get the opportunity to be involved in the more intricate phases of a building's construction, because due to their skill level the design or construction method does not allow them to be. When a labourer can gain a sense of self-satisfaction, only then will they pursue the ideal of a master craftsman and ultimately be inspired to enhance their skill and bring back a strong sense of meaning in construction and making.



**Figure 32:** A master craftsman being engaged in his work (Baxter 2019).

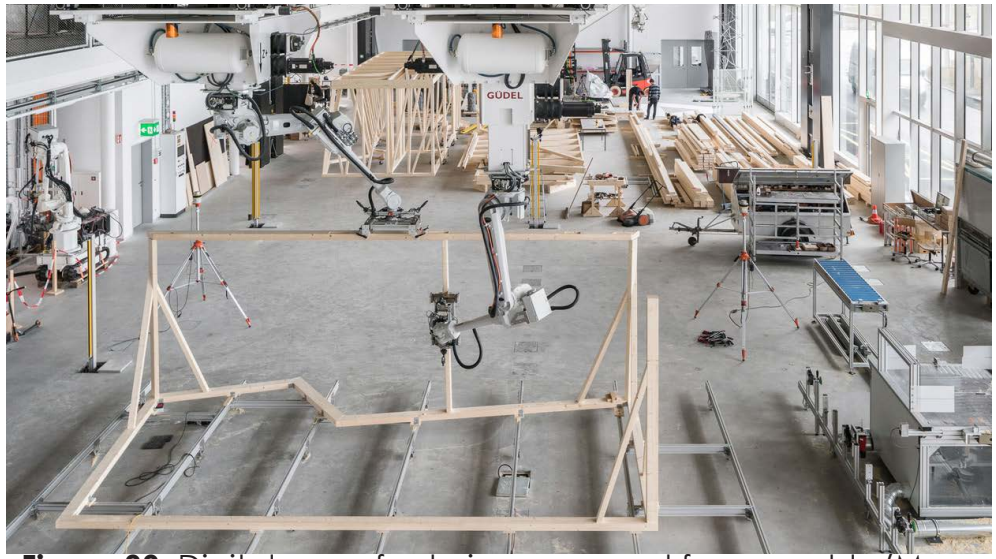



**Figure 33:** Digital manufacturing prepared for assembly (Menz 2016).

## Art, craft and technology and the skill they entail

As terms, art and craft overlap as they are both considered to be forms of creativity. A third concept, technology and how technology is used to achieve or aid an individual in their pursuit of art or their craft, may also be considered a skill/craft. Richard Sennett (1943–) explains in his book ‚The Craftsman (2008), that a conductor, artist, carpenter and lab technician are all considered craftsman because they are dedicated to good work for its own sake. “They all represent the special human condition of being engaged” (Sennett 2008:20).

Art and craft were founded centuries ago. Back then it was the mediation between the head and mind to enable the artist or craftsman to produce a tangible object/work. But in recent years, since the beginning of the Industrial Revolution, this notion is thought be in jeopardy (Sennett 2008:25–27) because the means of producing and making can now also be accomplished by using machines and technology. Although these machines can produce work that is far more accurate and detailed than most artists or craftsmen, they still require some sort of input/data on what to do. Therefore, operating a machine or program may also be considered a craft in its own right, just like a conductor or lab technician. Technology will never replace the human connection of being engaged in art or craft, but it can be used as a third tool apart from the mind and hand to assist in the making of meaningful things.

Art is considered to be the expression of emotions while craft is considered to be a form of work completed to a high level/ standard. It results in a tangible output (Baldwin 2017). In the context of this study, art and craft are a single entity. With technology, the hand and mind is used as a tool to achieve these goals of manufacturing and making in a meaningful and economic way.

All media used to create, whether it be virtual/BIM design, laser cut, metalwork, CNC woodwork, 3D printed ceramics, painting or glasswork, can be considered either as utilitarian or artistic. The notions of art and craft are intertwined. The degree of invention and creativity and their investment of beauty and the inspiration of emotion embodies art, but each is expressed through their craftsmanship (Baldwin 2017).

## Rethinking the making of buildings: the pre manufacturing approach

Pre-manufacturing is not a newfound 21st-century idea. Architects like Frank Lloyd Wright and Le Corbusier explored the possibilities of pre-manufacturing in their respective eras. In Le Corbusier’s essay titled “Le Modulor” (1948) he states the following:

> Building should be the concern of heavy industry, and the component parts of houses should be mass – produced.
> A mass – production mentality must be created:
> A frame of mind for building mass – produced houses,
> A frame of mind for living in mass – produced houses,
> A frame of mind for imagining mass – produced houses (Smith 2012:219).

This normative approach was adapted to tie in with the argument of this study.

> Building should be the concern of *manufacturing*, and the component parts *should be machined to be assembled*.
> To *enable anyone to be part of the making where skill becomes less important.*
> *An assembly* mentality must be created:
> A frame of mind for building *prefabricated structures*
> A frame of mind for living in *prefabricated structures*
> A frame of mind for imagining *premanufactured buildings.*

Frank Lloyd Wright's Usonian houses proved the fundamental advantages of the premanufacturing building approach. The idea of pre-manufacturing was further explored by the Usonian automatic houses (1951–1956), which allowed the owner of the house to be involved in the making of their home, cultivating a deeper connection between the building and the user to create meaning through making (Frampton 2001:102–118).

The same approach is followed in this study. Engineered timber was identified as the medium through which premanufacturing can occur to enable unskilled workers to be involved in the making of the building. The idea was that they would not only be engaged during the making process but that it would also promote a sense of self-satisfaction and create meaning.

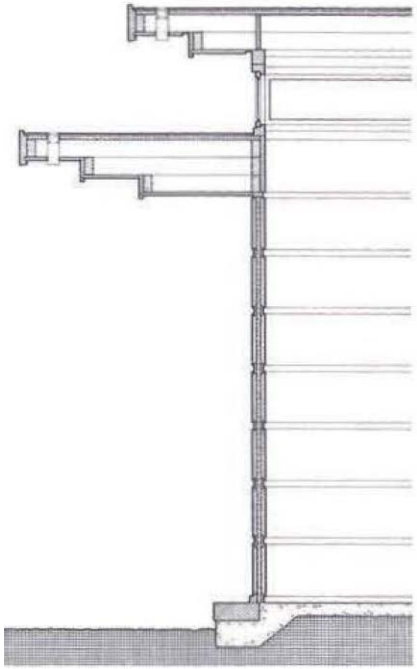


**Figure 34:** Frank Lloyd Wright's Usonian house using standard timber elements to ease construction time (Frampton 2001:117).

## Mass timber construction: the pre-manufacturing building process

Mass timber buildings offer many advantages. Engineered timber can be machined by CNC machines using BIM design programs such as Rhino, Grasshopper, Revit and ArchiCAD. This method of design enables building component manufacturing and pre-manufacturing and allows for efficient and affordable prototyping, as well as small building tolerances. An entire building can be developed and designed in the digital realm in a BIM environment, where simulations can be conducted to obtain data such as structural and room temperature simulations, material quantities and component cut lists, all before construction has started, thus mitigating the risk of the project being over budget or late (mgb Architecture + Design 2012:36).

A further benefit is that any element or structural component can be modelled and detailed to the finest and most precise perfection. A simple approach can be followed: if a component is modelled in the 3D BIM model, then it will be built. These modelled elements can be exported to various formats for 3D printing, laser cutting or CNC cutting. Building elements can be machined and manufactured the same way cars are manufactured on production lines, where efficiency is everything (Hager, Golonka & Putanowicz 2016). Building elements arrive on site and the building is assembled instead of being built.

With the advent of CAD and modelling software, many professionals have struggled to make the shift to relying solely on these programmes to do their work, finding mastering this skill challenging at first. As time progressed, however, the usability of these programs developed a more user-friendly interface – with some training almost any professional individual can operate and fully utilise them (Kostic et al. 2012), thus limiting the skill level required for building manufacturing. Skill is only required to model

these elements with much less skill needed to assemble them, thus limiting the number of skilled staff required and capitalising on unskilled labour to assist in the assembly of buildings.

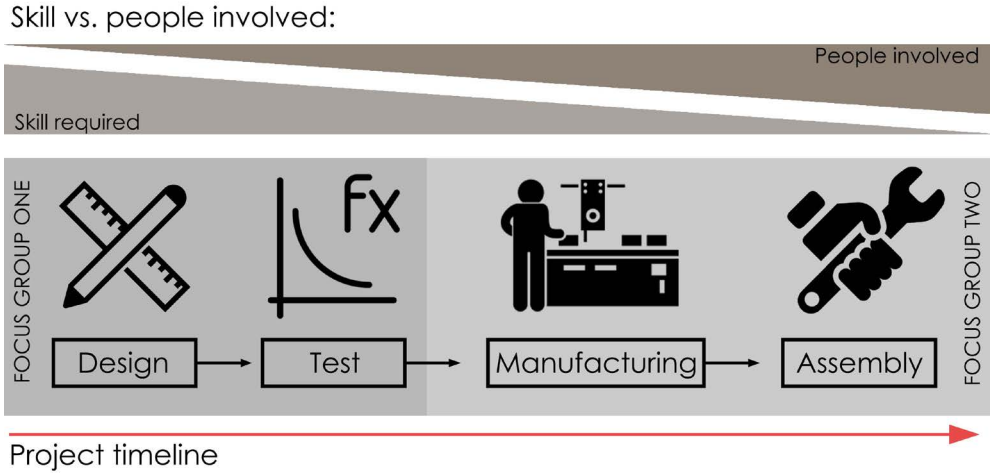



**Figure 35:** Limited skill as potential (Author 2020).

## Article conclusion

The way we approach construction has remained the same for decades, as have legislation, building contracts and building procedures. What has changed is the availability of skills and funds and a deteriorating education system. We need to change the way we think about building construction.

Technology and manufacturing using engineered wood and various other materials as a medium leads to skill becoming less important, thus enabling anyone to be part of the building process and allowing for a wider scope of people to participate in the act of making.

For this large group of workers, construction has become merely a completing a job just for the sake of surviving. It has lost the intangible aspect of being engaged, creating meaning for the labourer who invests their time and effort in their daily work.




**Figure 36:** Unskilled workers advertising their skills in front of a hardware store (Author 2020).

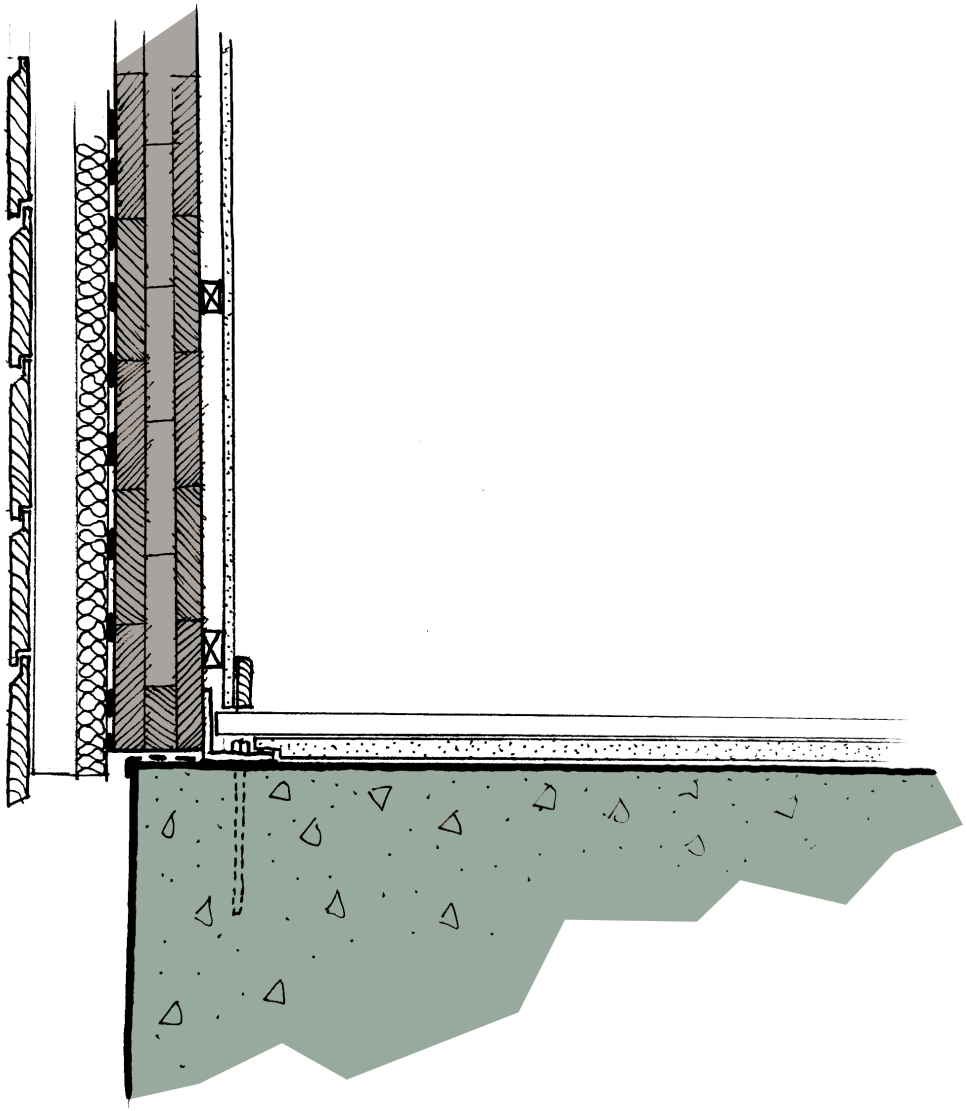


**Figure 37:** Typical floor connection (Author 2020).

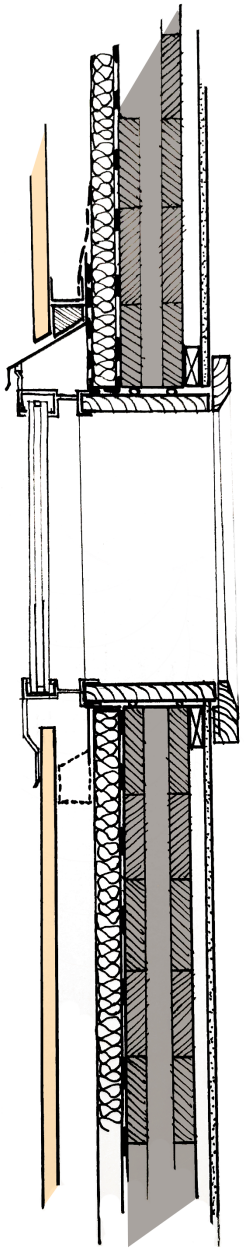


**Figure 38:** Typical window frame detail (Author 2020).

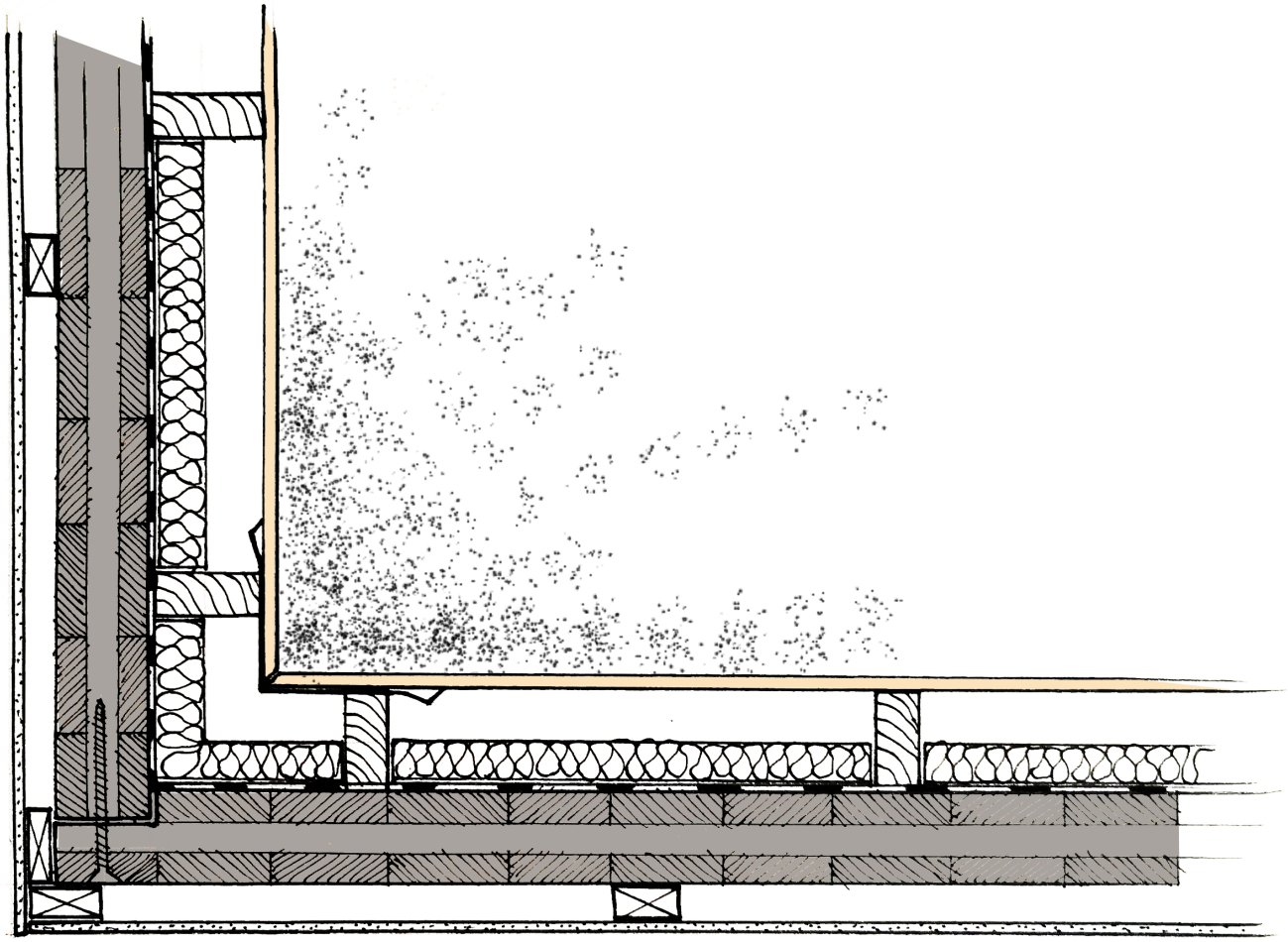


**Figure 39:** Typical corner connection detail (Author 2020).

# Timber vs concrete

Louis Kahn (1901–1974) described concrete construction as an "inelegant procedure of work whereby you have to build one structure in order to cast another" (Frampton 2001:212).

Several studies have been done to compare mass timber construction with traditional concrete and steel construction. The sustainability of mass timber and advances in timber engineering have started to attract more and more interest worldwide, resulting in engineered wood products becoming a more cost-competitive solution (Forsythe 2015: 4).

The material properties and characteristics of engineered wood compared to concrete show promising results. A standard five-layer CLT panel has an average density of 480 kg/m3 as opposed to concrete density of 2400 kg/m3 (Waugh 2012). This results in a lighter structure that can limit the need for heavy lifting equipment on site and uses smaller foundations. The lightweight nature of timber is advantageous in poor soil conditions, contributing to reduced pilling or smaller foundation footings, thus influencing the overall cost and time of the project (Forsythe 2015:13).

Timber's profound benefits for pre-manufacturing and on-site assembly give it a substantial edge in construction time when compared to concrete. Three case studies were consulted to compare the construction time of the same building, one with concrete and the other with timber. On average, the results showed that constructing a mass timber building is 32% faster than a concrete building (Forsythe 2015:22).

A similar approach was taken to compare the construction cost of timber vs concrete, with a mass timber building proving to be more cost-effective as opposed to a concrete building. In total, an estimated 2.2% can be saved when considering a mass timber building (Forsythe 2015:26).

Estimate No.01 - Brickwork Structure
COST SUMMARY
09 July 2019

| | Element | Ground Floor (231m2) | | First Floor (192m2) | | TOTAL | % | Rate / m² |
|---|---|---|---|---|---|---|---|---|
| | | Amount | Rate / m² | Amount | Rate / m² | | | |
| 1.01. | Preliminaries | R 305 816 | R 1 324 /m² | R 254 184 | R 1 324 /m² | R 560 000 | 15% | R 1 324 /m² |
| 1.02. | Alterations | R 106 480 | R 461 /m² | R 14 050 | R 73 /m² | R 120 530 | 3% | R 285 /m² |
| 1.03. | Substructure | R 18 113 | R 78 /m² | R 0 | R 0 /m² | R 18 113 | 0% | R 43 /m² |
| 1.04. | Structural Frame | R 0 | R 0 /m² | R 414 007 | R 2 156 /m² | R 414 007 | 11% | R 979 /m² |
| 1.05. | Ground Floor Construction | R 2 500 | R 11 /m² | R 0 | R 0 /m² | R 2 500 | 0% | R 6 /m² |
| 1.06. | External envelope | R 195 065 | R 844 /m² | R 304 321 | R 1 585 /m² | R 499 386 | 13% | R 1 181 /m² |
| 1.07. | Roofs | R 19 374 | R 84 /m² | R 249 848 | R 1 301 /m² | R 269 222 | 7% | R 636 /m² |
| 1.08. | Internal divisions | R 59 784 | R 259 /m² | R 149 696 | R 780 /m² | R 209 480 | 6% | R 495 /m² |
| 1.09. | Floor finishes | R 160 723 | R 696 /m² | R 219 660 | R 1 144 /m² | R 380 383 | 10% | R 899 /m² |
| 1.10. | Internal wall finishes | R 28 650 | R 124 /m² | R 146 100 | R 761 /m² | R 174 750 | 5% | R 413 /m² |
| 1.11. | Ceilings & Soffits | R 97 480 | R 422 /m² | R 122 957 | R 640 /m² | R 220 437 | 6% | R 521 /m² |
| 1.12. | Joinery & Fittings | R 8 600 | R 37 /m² | R 156 950 | R 817 /m² | R 165 550 | 4% | R 391 /m² |
| 1.13. | Plumbing and drainage | R 64 458 | R 279 /m² | R 129 317 | R 674 /m² | R 193 775 | 5% | R 458 /m² |
| 1.14. | Electrical installation | R 139 173 | R 602 /m² | R 115 677 | R 602 /m² | R 254 850 | 7% | R 602 /m² |
| 1.15. | Balustrading | R 0 | R 0 /m² | R 100 720 | R 525 /m² | R 100 720 | 3% | R 238 /m² |
| 1.16. | External Works | R 131 150 | R 568 /m² | R 0 | R 0 /m² | R 131 150 | 4% | R 310 /m² |
| 2 | Sub-total (Excluding VAT) | R 1 337 365 | R 5 789 /m² | R 2 377 487 | R 12 383 /m² | R 3 714 852 | 100% | R 8 782 /m² |
| 3 | Contingency Allowance (5%) | R 66 868 | | R 118 874 | | R 185 743 | | |
| 4 | TOTAL CONSTRUCTION COSTS (EXCL. VAT) | R 1 404 233 | R 6 079 /m² | R 2 496 361 | R 13 002 /m² | R 3 900 595 | | R 9 221 /m² |

**Table 1:** Concrete cost comparison (Smily 2020)

Estimate No.02 - Cross Laminted Timber
COST SUMMARY
09 July 2019

| | Element | Ground Floor (231m2) | | First Floor (192m2) | | TOTAL | % | Rate / m² |
|---|---|---|---|---|---|---|---|---|
| | | Amount | Rate / m² | Amount | Rate / m² | | | |
| 1.01. | Preliminaries | R 218 440 | R 946 /m² | R 300 020 | R 1 563 /m² | R 518 460 | 14% | R 1 226 /m² |
| 1.02. | Alterations | R 106 480 | R 461 /m² | R 14 050 | R 73 /m² | R 120 530 | 3% | R 285 /m² |
| 1.03. | Substructure | R 18 113 | R 78 /m² | R 0 | R 0 /m² | R 18 113 | 0% | R 43 /m² |
| 1.04. | Structural Frame | R 0 | R 0 /m² | R 682 228 | R 3 553 /m² | R 682 228 | 18% | R 1 613 /m² |
| 1.05. | Ground Floor Construction | R 2 500 | R 11 /m² | R 0 | R 0 /m² | R 2 500 | 0% | R 6 /m² |
| 1.06. | External envelope | R 196 958 | R 853 /m² | R 272 638 | R 1 420 /m² | R 469 596 | 13% | R 1 110 /m² |
| 1.07. | Roofs | R 14 550 | R 63 /m² | R 369 895 | R 1 927 /m² | R 384 445 | 10% | R 909 /m² |
| 1.08. | Internal divisions | R 55 441 | R 240 /m² | R 87 833 | R 457 /m² | R 143 274 | 4% | R 339 /m² |
| 1.09. | Floor finishes | R 158 563 | R 686 /m² | R 199 790 | R 1 041 /m² | R 358 353 | 10% | R 847 /m² |
| 1.10. | Internal wall finishes | R 27 650 | R 120 /m² | R 73 030 | R 380 /m² | R 100 680 | 3% | R 238 /m² |
| 1.11. | Ceilings & Soffits | R 98 460 | R 426 /m² | R 26 980 | R 141 /m² | R 125 440 | 3% | R 297 /m² |
| 1.12. | Joinery & Fittings | R 8 600 | R 37 /m² | R 156 950 | R 817 /m² | R 165 550 | 4% | R 391 /m² |
| 1.13. | Plumbing and drainage | R 64 458 | R 279 /m² | R 129 317 | R 674 /m² | R 193 775 | 5% | R 458 /m² |
| 1.14. | Electrical installation | R 139 173 | R 602 /m² | R 115 677 | R 602 /m² | R 254 850 | 7% | R 602 /m² |
| 1.15. | Balustrading | R 0 | R 0 /m² | R 53 392 | R 278 /m² | R 53 392 | 1% | R 126 /m² |
| 1.16. | External Works | R 131 150 | R 568 /m² | R 0 | R 0 /m² | R 131 150 | 4% | R 310 /m² |
| 2 | Sub-total (Excluding VAT) | R 1 240 536 | R 5 370 /m² | R 2 481 800 | R 12 926 /m² | R 3 722 336 | 100% | R 8 800 /m² |
| 3 | Contingency Allowance (5%) | R 62 027 | | R 124 090 | | R 186 117 | | |
| 4 | TOTAL CONSTRUCTION COSTS (EXCL. VAT) | R 1 302 563 | R 5 639 /m² | R 2 605 890 | R 13 572 /m² | R 3 908 453 | | R 9 240 /m² |

**Table 2:** CLT cost comparison (Smily 2020)

# SA timber vs the world

There is a general belief that timber produced in South Africa is of low quality and unsuitable for elaborate structural applications (Van der Heever 2017).

As mentioned before, CLT panels in South Africa are manufactured using SA pine (Pinus radiata) or eucalyptus (Sulinga grandis). A recent study done by HWZ International compared SA pine with European spruce (Picea abies). Spruce is the main material used for engineered wood in Europe. Both materials were tested according to the mechanical characteristics of each species.

Although the table above clearly indicates that European spruce is superior in almost every category when compared to SA pine, the variance between the two species is not that large, thus pine is adequate for the intended purpose. On 11 May 2020, SABS approval was granted for SA pine grades 7, 10 &14 timber to be used in the manufacturing of CLT panels, as highlighted in SANS 8892 (SABS 2020).

One major advantage that SA pine CLT has over spruce CLT is that the former can take a pressure impregnated treatment to protect against mould, fungus and insect attack. This is not possible with European CLT, owing to the nature and structure of the spruce that is used (Smily 2020).

*Table 1: Mechanical characteristics of south African pine and European spruce*

| | Compression parallel to grain (MPa) | Mean static bending strength (MPa) | Modulus of elasticity (MPa) |
|---|---|---|---|
| Pinus pinaster | 39 | 80 | 8 800 |
| Pinus patula | 39 | 69 | 11 350 |
| Picea abies | 46 | 78 | 11 900 |
| Pinus radiata | 41,9 | 80,7 | 10 200 |
| Pinus elliotii | 56,1 | 112 | 13 700 |
| Pinus taeda | 49,2 | 88 | 12 300 |

Table 2 ranks the species according to each criterion.

*Table 2: Ranking of the species*

| Ranking | Compression parallel to grain (MPa) | | Mean static bending strength (MPa) | | Modulus of elasticity (MPa) | |
|---|---|---|---|---|---|---|
| 1st | Pinus elliotii | 56,1 | Pinus elliotii | 112 | Pinus elliotii | 13700 |
| 2nd | Pinus taeda | 49,2 | Pinus taeda | 88 | Pinus taeda | 12300 |
| 3rd | Picea abies | 46 | Pinus radiata | 80,7 | Picea abies | 11 900 |
| 4th | Pinus radiata | 41,9 | Pinus pinaster | 80 | Pinus patula | 11 350 |
| 5th | Pinus patula | 39 | Picea abies | 78 | Pinus radiata | 10200 |
| 6th | Pinus pinaster | 39 | Pinus patula | 69 | Pinus pinaster | 8800 |

**Table 3 & 4:** Characteristics of pine vs spruce(Timber institute 2018:2)

# Engineered wood products

This dissertation will explore the various engineered wood products available on the market to construct a mass timber building as follows.



**Cross-laminated timber (CLT)**
CLT is an engineered wood panel made by arranging and gluing layers of dimension lumber. Each layer is perpendicular to the next. CLT panels typically consist of three, five or seven layers. The dimensions of CLT panels are limited only by transportation constraints but they are typically up to 12 m long and up to 2.4 m wide. CLT panels are typically used for floors, walls and roofs (Canadian Wood Council 2016:20).



**Glulam**
Glulam is made by gluing together laminations of solid-sawn lumbers that are specifically selected and positioned based on their structural strength and appearance characteristics. Glulam is typically used for beams and columns and can be manufactured in curved sections (Canadian Wood Council 2016:20).



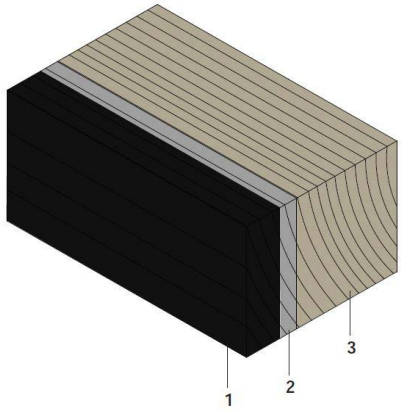
**Laminated veneer lumber (LVL)**
Standard LVL is made from layers of veneer laid parallel to each other and bonded together with moisture-resistant adhesives. LVL is typically used for beams and headers in residential and commercial construction (Canadian Wood Council 2016:20).

# Fire performance of timber: The perfect fire-resistant material

In 1952, Auguste Perret (1874–1954) wrote in his book titled, Contribution à une théorie de l'architecture (Contribution to a theory of architecture): "In the beginning architecture is only wooden framework. In order to overcome fire, one builds in hard material. And the prestige of the wooden frame is such that one reproduces all the traits, including the heads of the nails" (Frampton 2001:125–127). Back in 1952, timber-framed houses (balloon frame houses) were limited to two storeys in height because of the fire rating and combustible nature of the material due to the small timber element sizes they used.

Engineered wood such as CLT provides excellent fire resistance. This is due to the massive sizing of these timber elements. Thicker timber elements provide better fire resistance as these members, when exposed to fire, char at a predictable rate, allowing the inner structural core to function at full capacity when exposed to a fire (Dagenais, White & Sumathipala 2013:13).

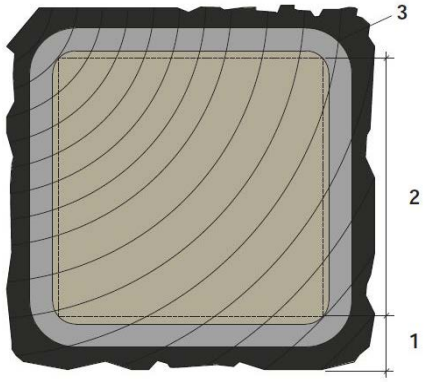
Steel performs extremely unpredictably during a fire because, depending on the amount of heat, steel members can yield at any point in time during a fire (Green 2019). By contrast, a tree's natural defence mechanism to protect itself during a wildfire is to char the outer exposed layer to protect the inner core. One of the main advantages of mass timber exposed to fire is that the timber will start to char at a predictable nominal charring rate of 38 mm/hr (Dagenais et al. 2013:36). Therefore, the exact time of structural failure can be calculated in the event of a fire. The required fire rating of a mass timber building is determined by the structural timber sizes or the addition of fire-rated gypsum boards.




**Charring Diagram**

1 Char layer
2 Pyrolysis zone
3 Normal wood

**Figure 40:** Charring diagram of a structural timber panel (mgb Architecture + Design 2012:112–113).




**Charring Structural Design Diagram**

1 Sacrificial layer (char layer and pyrolysis zone; no structural capacity)
2 Residual section (structural capacity retained)
3 Rounded corner

**Figure 41:** Charring diagram of a structural timber column (mgb Architecture + Design 2012:112–113).

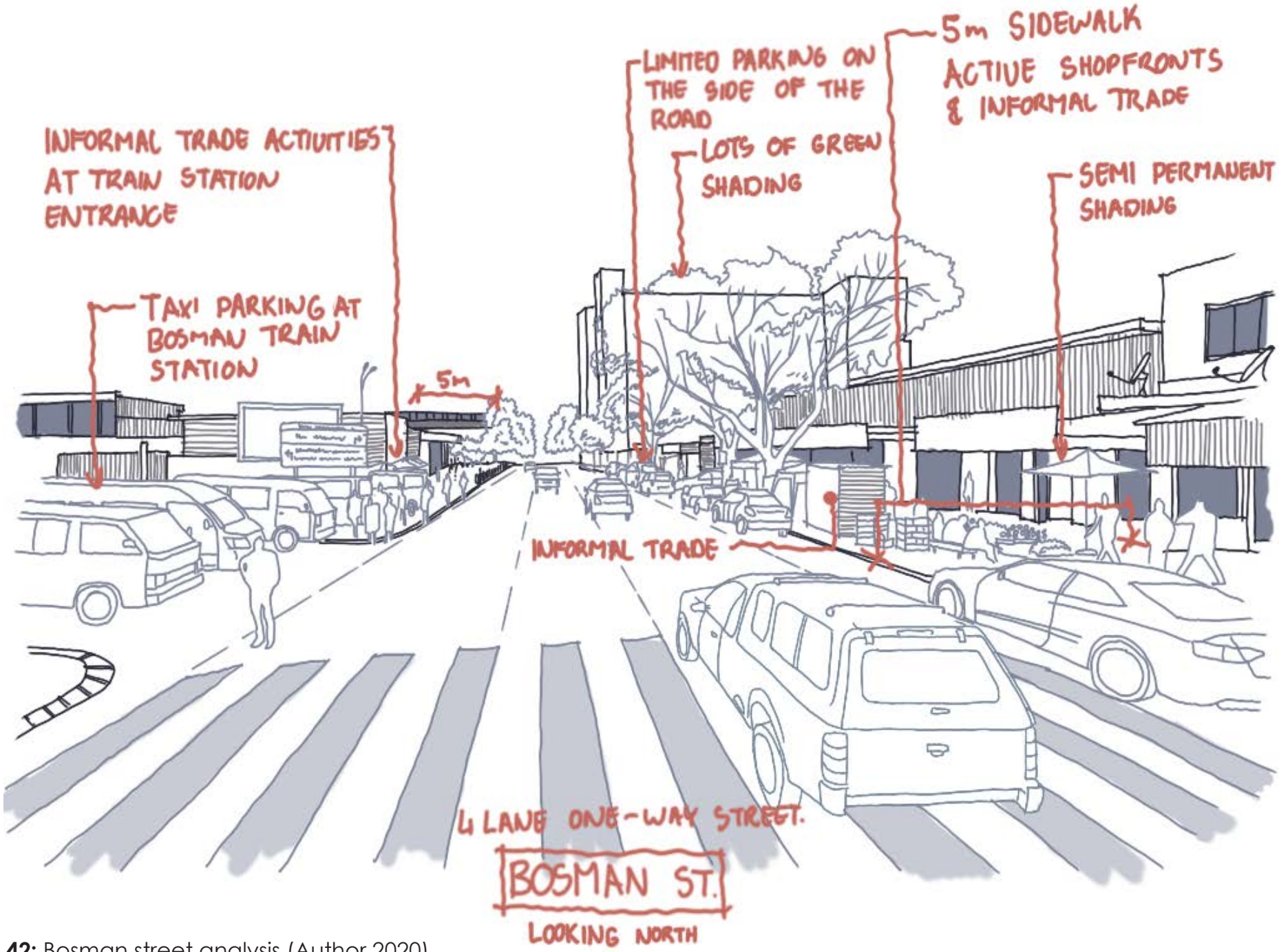



**Figure 42:** Bosman street analysis (Author 2020)

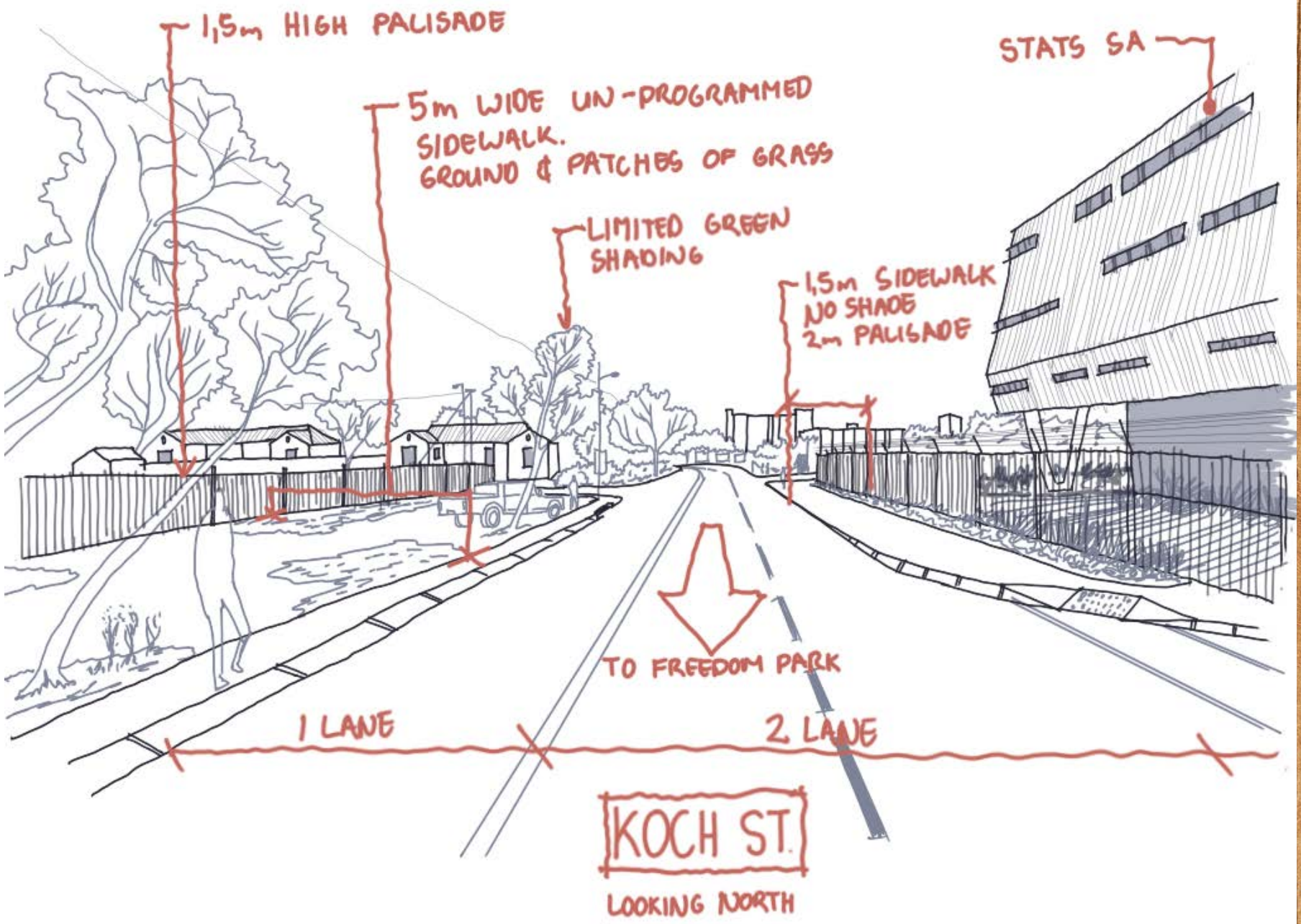



**Figure 43:** Koch street analysis (Author 2020)

# Program

**Formulation of the main program**

The minister of Public Works and Infrastructure, Patricia de Lille, states in the CIBD annual report that the next few years will be crucial for South Africa's development, as: "We will need more than just a burst of speed to meet the goals of the National Development Plan Vision (NDP) of 2030" (CIDB 2019:4).

Parallel to limited local skill are the technological advances in the construction industry. In the light of the 2030 NDP, these tools, methods and materials can be utilised to achieve the goals for rapid and effective development (Mpakati-Gama 2012:269).

The SABS annual report of 2019 acknowledges that it is important to involve third-party management and certification bodies to enhance R&D locally in order to stay competitive globally. South Africa continues to drive the localisation of procurement, the provision of product and systems certification services and product development in the construction industry. This will be critical in supporting the industrialisation effort as well as the creation of a globally competitive industrial capacity in the country (SABS 2019:25).

The SABS aims to support small, medium and micro enterprises (SMMEs) which play a vital role in economic growth and job creation. The SABS provides support through two units: the Design Institute (DI) and the SMME unit. The DI's aim is to stimulate development and manufacturing in the country through engineering and product design. The SMME unit aims to guide small to big business and departments to meet product and service requirements as per SANS and ultimately provide certification (SABS 2019:30). These two support streams can be utilised to increase awareness and to assess and procure the use of alternative construction methods and techniques, particularly to enhance the use of the most underutilised construction material in South Africa – timber.

R&D facilities located in Pretoria are disconnected from the public realm. Most of these facilities (CSIR, Agrément, NRF & Department of Science and Technology) are located at Persequor Park in Pretoria East, disconnected from the inner city and the SABS.

In South Africa, there are no research and development facilities that focus solely on researching timber construction and skills development. Agrément (an entity of the Department of Public Works), in agreement with the SABS, is the only company that tests and issues procurement certificates for alternative building construction for third-party developers. In the year 2018/2019, Agrément issued 27 approval certificates for new alternative construction systems and materials (Agrément 2019:106). However, none of the approved systems involved the use of engineered timber or timber design manufacturing.




**Figure 44:** Locating existing R&D facilities in Pretoria (Author 2020)

## The main program

A timber construction R&D facility will be developed that will consists of open plan offices, a laboratory and a workshop for material testing, assembly and procurement. This facility will collaborate with researchers from the Department of Science and Technology, the CSIR, the NRF, Agrément and the SABS to explore the construction technology of the future by way of interdisciplinary collaboration (Menz 2016:2).
(Insert diagram for the main programme)

## Sub programs/functions

Facilities such as a cafeteria, public workshops, bathrooms and outdoor seating provides a public interaction platform.

Considering already mentioned concerns about the lack of a timber culture in South Africa, this scheme proposes to pique the pedestrian's curiosity to learn more about mass timber construction by subconsciously making him/her aware (Affendy 2014) of this technology by way of movement routes, viewing decks and pause spaces (parks).

## Client user profiles

*Researchers – between 25 and 60 years of age*. These are educated researchers that conduct work in labs, offices and collaborative rooms. They are employed full time from 8 a.m. to 5 p.m. weekdays.

*Lab assistants – between 19 and 60 years of age*. They assist the researchers in the labs to conduct experiments, handle research supplies, as well as to clean the laboratories.

*Workshop assistants – between 19 and 60 years of age*. They assist the researchers in the workshops to build prototypes, handle material logistics, as well as cleaning the workshops.

*Salvokop pedestrians – their age ranges from 10 to 80 years.* These people are pedestrians coming from the CBD or Salvokop. They require a convenience store/canteen and a public space to relax and meet with colleagues/friends in between their commute. They use the public space on a 24-hour cycle and the workshops on occasion for public workshop days, normally on weekends.

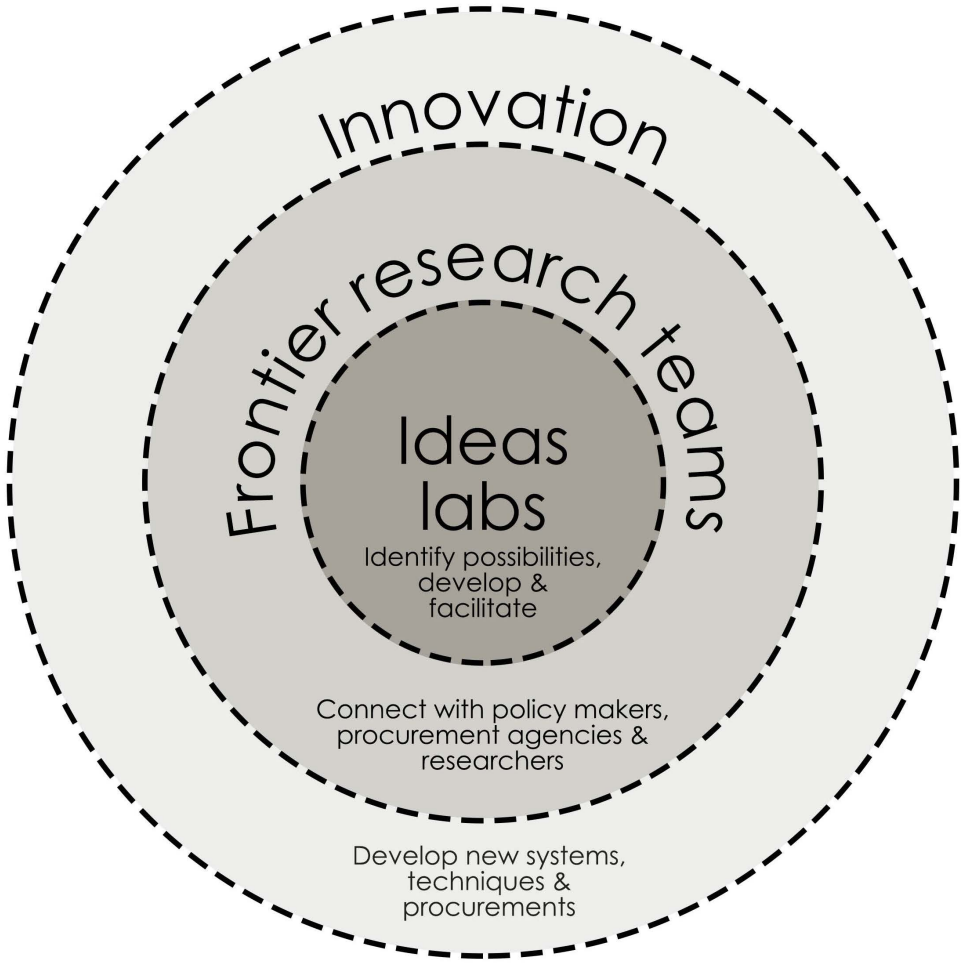



**Figure 45:** Formulation of the main program(Author 2020).

# Site
## Choosing a site

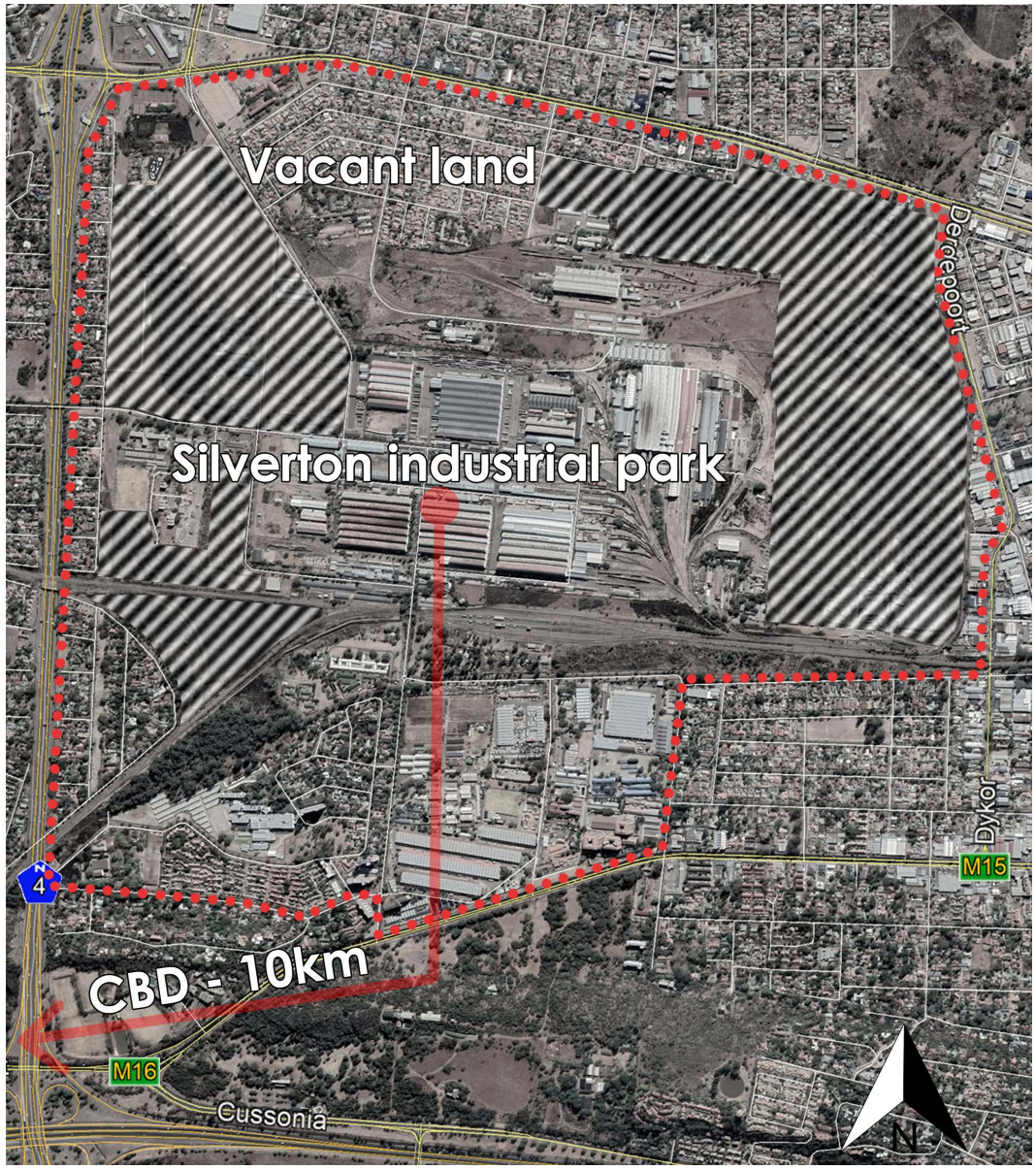



**Figure 46:** Silverton industrial park – site limitations and opportunities (Author 2020).

Three initial site locations were considered. During the investigation a site selection criteria were developed as follows: the site should

- be located in the CBD, close to policymakers and procurement entities
- provide opportunities for public interaction
- provide logistical support for material delivery
- be located within the social realm of the inner city
- be large enough to accommodate all the proposed programmes
- provide several entrances to separate dangerous activities (workshops) from safer activities (parks, cafeteria etc.).

**1. Silverton Industrial area**

This area was initially considered, mainly because the main programme would have been a factory producing building components. Therefore, a factor typology was explored. This area also provides a lot of open land to utilise.

It was soon realised, however, that this was not the correct main programme nor the correct site for the scheme, as this area is disconnected from the inner city and would have been able to fit the purpose of timber construction awareness.

## 2. UNISA Sunnyside Campus

The second site considered is located closer to the CBD. The UNISA Sunnyside campus consists of a lot of vacant land and buildings to the south of the campus. In particular, a tall vacant apartment block was identified. The scheme would thus lean towards an adaptive reuse resolution. Although this would have yielded enough depth and complexity, this was not the main focus of the dissertation.

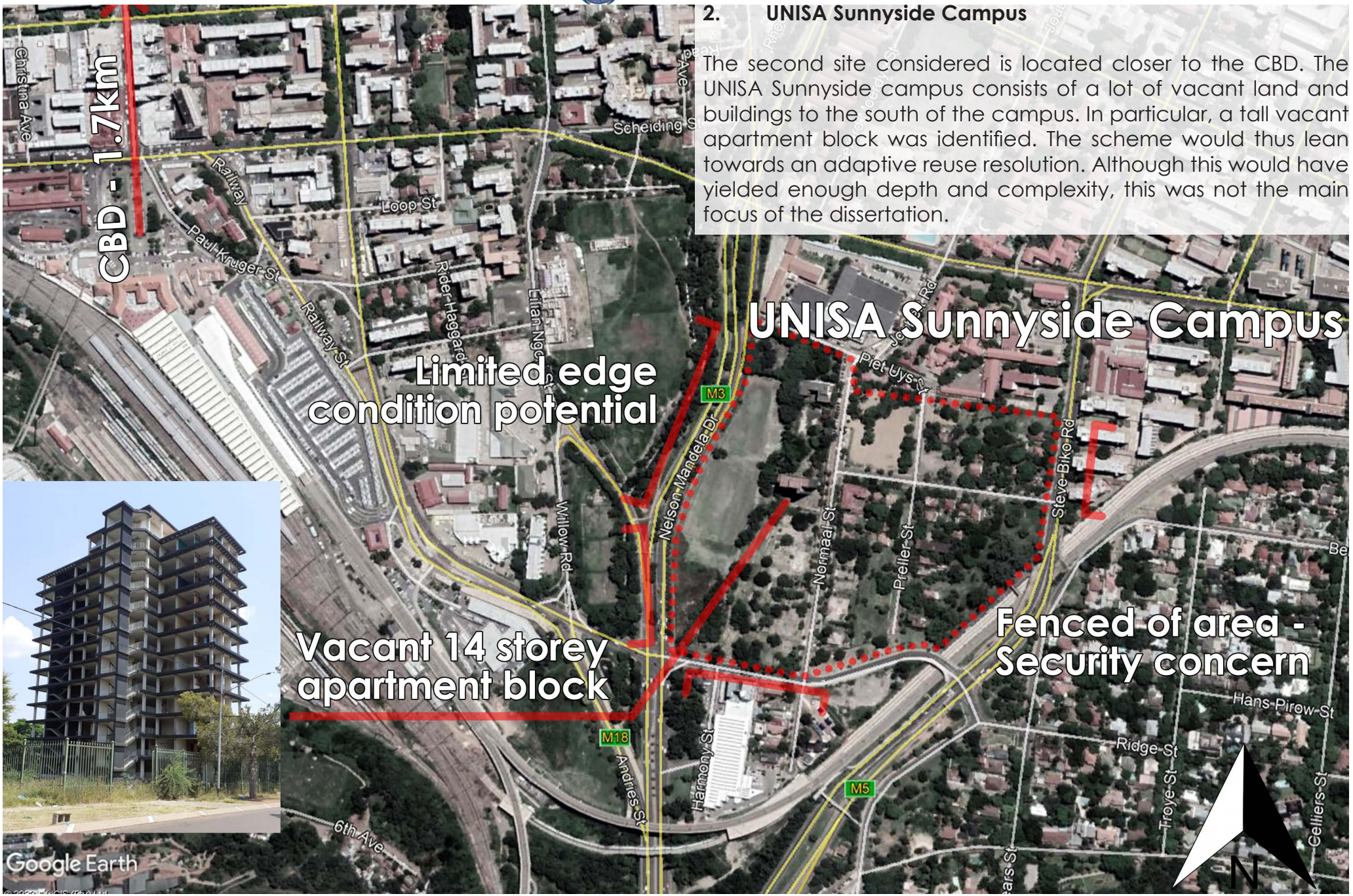



**Figure 47:** UNISA Sunnyside Campus – site limitations and opportunities (Author, 2020)

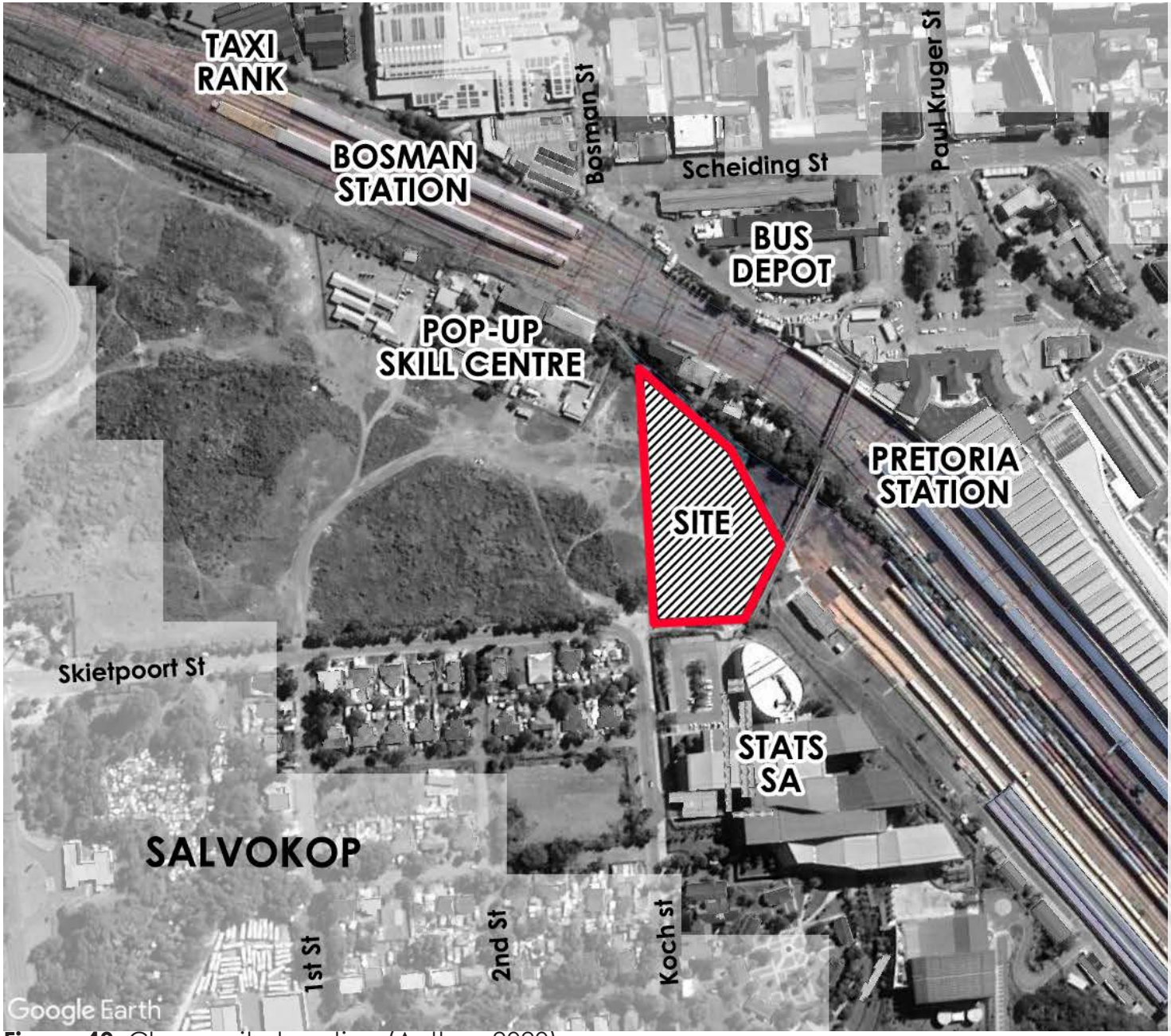
## 3. Sammy Marks Square

The third site considered is located in the CBD. Sammy Marks Square is in an extremely busy, pedestrian-rich area with ample opportunity to respond to pedestrian movement and behaviours. Because of the high foot traffic, this location would have been ideal for public exposure. Alas, the size of the site was not adequate for the proposed programme. Site requirement research also indicated that, with the proposed programme, this site would have faced major material logistical issues. It was concluded that this was not the correct site for this kind of programme.




**Figure 48:** Sammy Marks Square – site limitations and opportunities (Author 2020)

# Chosen site: Salvokop, Pretoria – Reasons for choosing this site




The site is bordered in the north by an unused railway line which can be used for material logistics. The site borders a very busy footbridge which connects anchor destination points to one another, such as Freedom Park and the Salvokop precinct to the south of the railway to Pretoria Train Station and the CBD to the north of the railway. This flow of people is an effective good design informant in proposing a public space and additional access routes to the proposed building. The POP-UP skills centre is located 100 m from the site. This facility could be used to introduce cooperative training programmes and workshop sessions.

A large area of vacant land is located to the west of the site. This was recently acquired by the Department of Public Works to be developed as part of the Salvokop precinct development (Gerber 2019). This development will result in a number of government bodies (the main policymakers) being located close to the site. The site is also a good location for a landmark as it enjoys a lot of exposure due to the proximity of the train station as an anchor destination, making it suitable for introducing the public to mass timber construction as well as for creating a timber culture.

**Figure 49:** Chosen site location (Author, 2020)

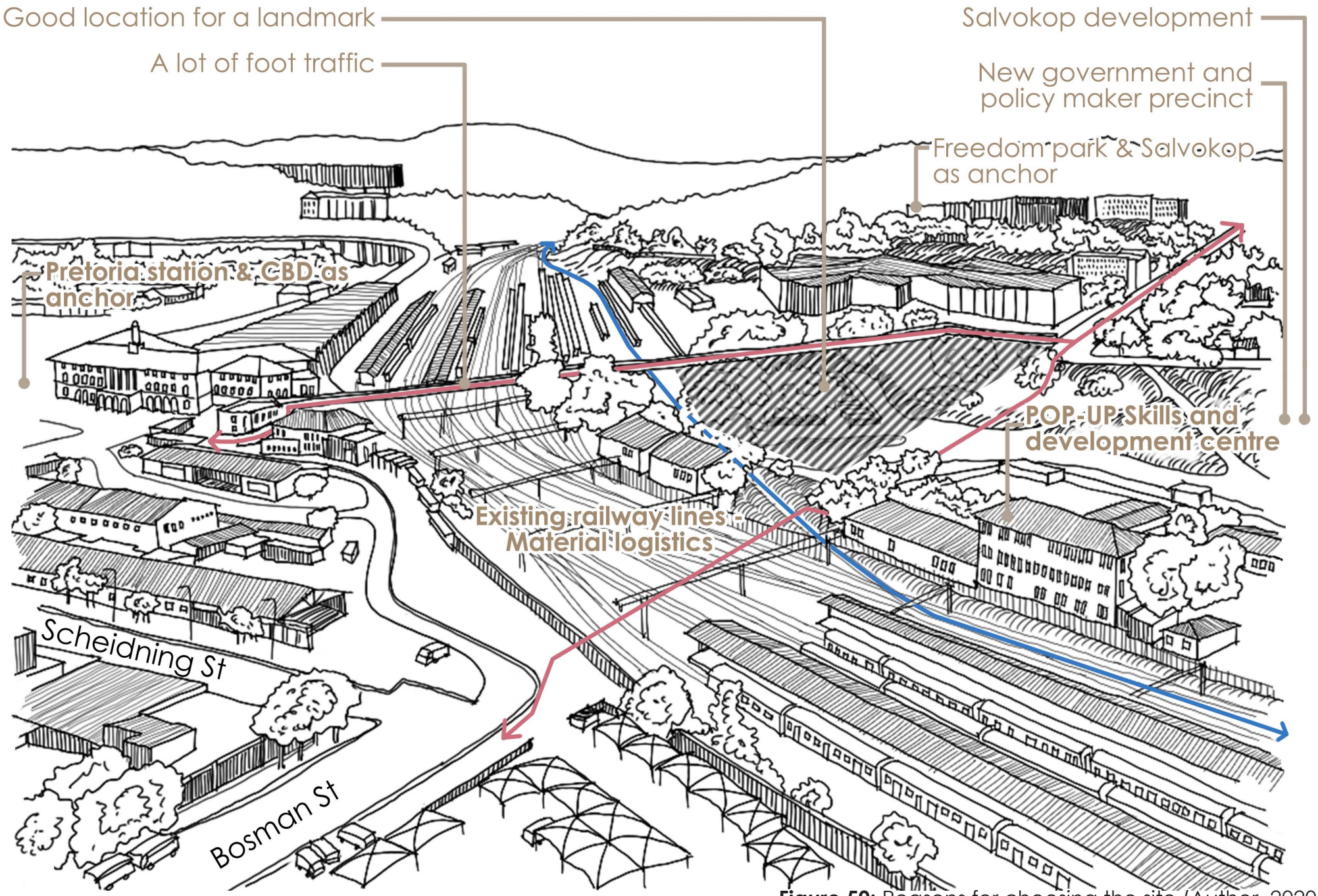



**Figure 50:** Reasons for choosing the site (Author, 2020)

# Salvokop: Historical overview

An extract from Prof. Karel Bakker's heritage report for Salvokop reads as follows:

> Salvokop is a heritage place, which as a new and accessible destination in the inner city of Pretoria commemorates the country's, region's and city's railway and railway workers' history, which provides a core heritage and environmental resource management area and urban heritage interpretation centre which focuses on cultural and educational tourism, as well as being a place in which people of all sectors of society may live, trade, work and play, but where such new development opportunities and special places will retain a dialogue with the historical landscape, where historical links with the urban context are strengthened and maintained, where accessibility the proposed larger urban spatial initiatives create a legible dialogue with the precinct initiative's own local dialogue between new and old and where the opportunities inherent in the Station Precinct restructuring development, the Freedom Park National Legacy site, the Paul Kruger Street Spine, the Gautrain Rapid Rail System initiative as well as future urban initiatives, are incorporated as new urban layers that respond to and evolve from the existing historical urban pattern (Bakker 2004).

Salvokop, lying south of the Pretoria CBD, is rich in history. The area has seen much development during late 19th century and the 20th with the establishment of NZASM (Nederlandsche Zuid-Afrikaanse Spoorweg Maatschappij) in 1887 and later the South African Railways and Harbours (SAR&H) association established in 1910 (Pelser, 2013:13). Since the beginning of the 21st century, however, the area has become a haven for immigrants and homeless people alike. Many of the buildings built in the 20th century have been demolished leading to what can today be observed as large areas of vacant land. These buildings mainly consisted of industrial railway workshops used to manufacture parts and service train locomotives.

The only visual clues of this area's historic past can be seen in the few iconic red Kirkness clay brick houses dating back to 1948 and earlier. These row houses were built by the South African Railways and Harbours (SAR&H) association to house the workers working in the railway workshops to the north of Salvokop (Pelser 2013:14). A figure ground analysis indicates the fine grain footprint of these houses (Next page).



**Figure 51:** Salvokop historic residential houses (Author, 2020)

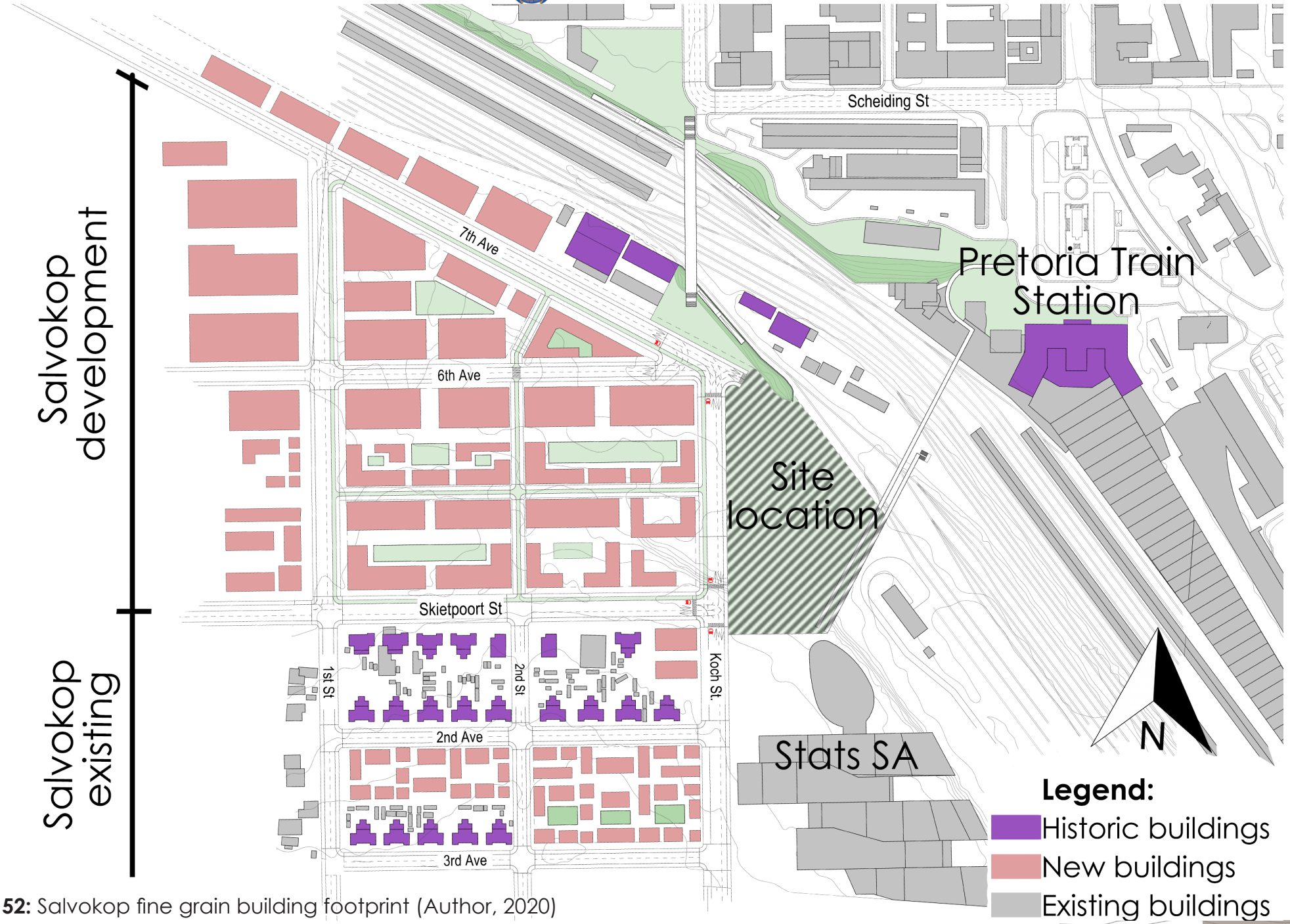



**Figure 52:** Salvokop fine grain building footprint (Author, 2020)

Apart from the row houses, two other historically significant sites can be identified: the Railway Engineers Offices next to the railway to the north and the NZASM village to the east of Salvokop. The recently completed STATS SA building was built over part of the NZASM historic village but some of these houses have been restored and are now the best-preserved historic structures in Salvokop. The Railway Engineers Office building is currently occupied by the POP-UP skills and development centre. A few additions have been made to the building such as covered parking, a gate house and storage containers, which have had a dramatic impact on the southern façade of the building.

The only entrances to the Salvokop precinct are a vehicular route (Skietpoort Street) and a pedestrian bridge crossing the railway line to Pretoria Station. A second pedestrian bridge was also once located next to the Railway Engineer Office Building, as can be seen in a map dating 1948. This bridge has since been demolished.

It is important to note that some of the historical buildings that were demolished included the so-called Skittle Alley, Shooting Gallery building and the Salvokop recreation grounds (Pelser 2013:13). A site analysis study has shown that Salvokop lacks public urban parks and recreation areas. Freedom Park could offer many outdoor and recreation activities but is completely fenced off for security reasons.

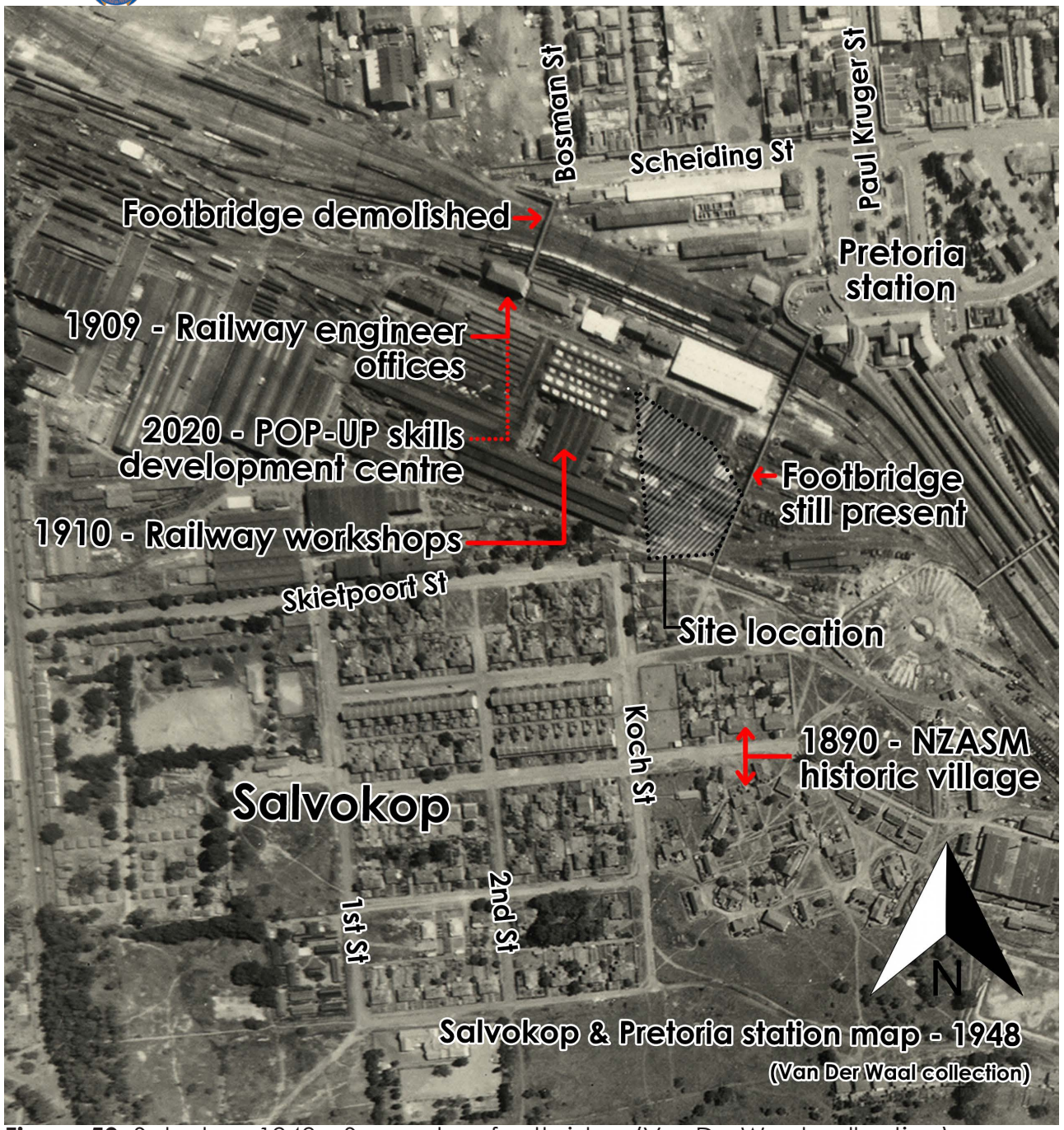



**Figure 53:** Salvokop 1948 – Secondary footbridge (VanDerWaal collection)

# Salvokop development

In December 2019, the minister of Public Works announced that a R18 billion development was planned for the Salvokop precinct set to start in April 2020. This development would include several government bodies to be relocated, as well as mixed-use residential and commercial buildings, and a medical and education centre. The development was planned for constructing in the large area of vacant land to the north of Salvokop and sought to attract investors as well as potential residents to this new precinct (Gerber 2019).

It was not possible to obtain detailed plans or an updated urban vision for this development from the Department of Public Works. A rational approach was thus followed to create a possible urban framework for this new development (see next page). The street grid was extended to the north of Salvokop to meet up with a new proposed street positioned parallel to the railway lines. The same urban block sizes were used as the existing block sizes, but instead of a vehicular route in between the blocks, a cycling and pedestrian route is proposed in between every four city blocks in accordance with the Tshwane 2055 urban vision, to promote pedestrian and cycling routes (Tshwane 2055, 2013). This intervention also allowed for the introduction of public green zones in between buildings to create nodes for public life as proposed by Christopher Alexander (Alexander 1977) to create more pedestrian-friendly cityscapes.

The new proposed urban fabric changes in scale as one progress northwards. With smaller building footprints and heights to the south adjacent to the existing buildings, and larger building footprints and heights to the north of the site which will house the government bodies.

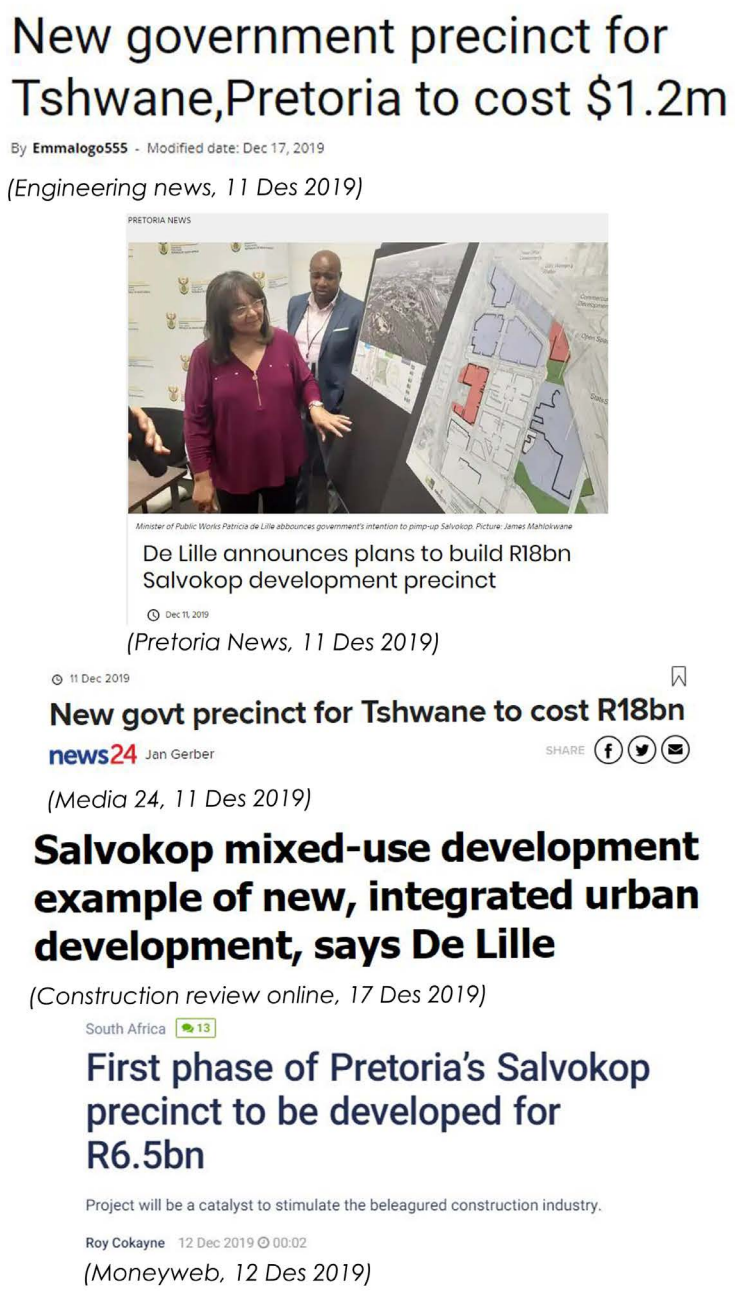



**Figure 54:** Salvokop development press release headlines

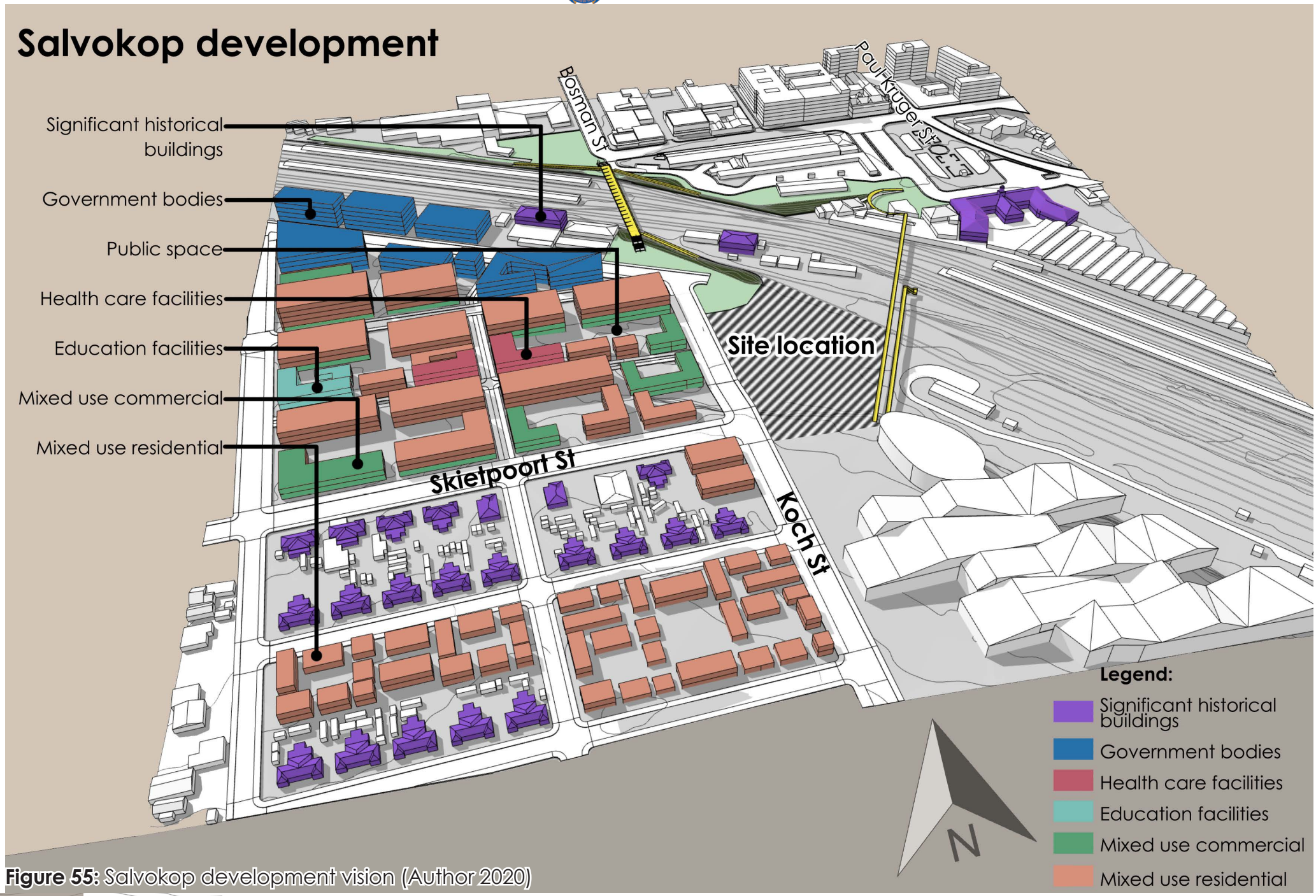



**Figure 55:** Salvokop development vision (Author 2020)

# Urban vision

The urban vision was completed in a group with two other colleagues whose sites were located on the opposite side of the railway to the north. The diagram below shows the location of these two sites in relation to my proposed site on the southern side. The three programmes were identified, relationships were established and a triangular movement route was created between the sites as shown in the diagram.

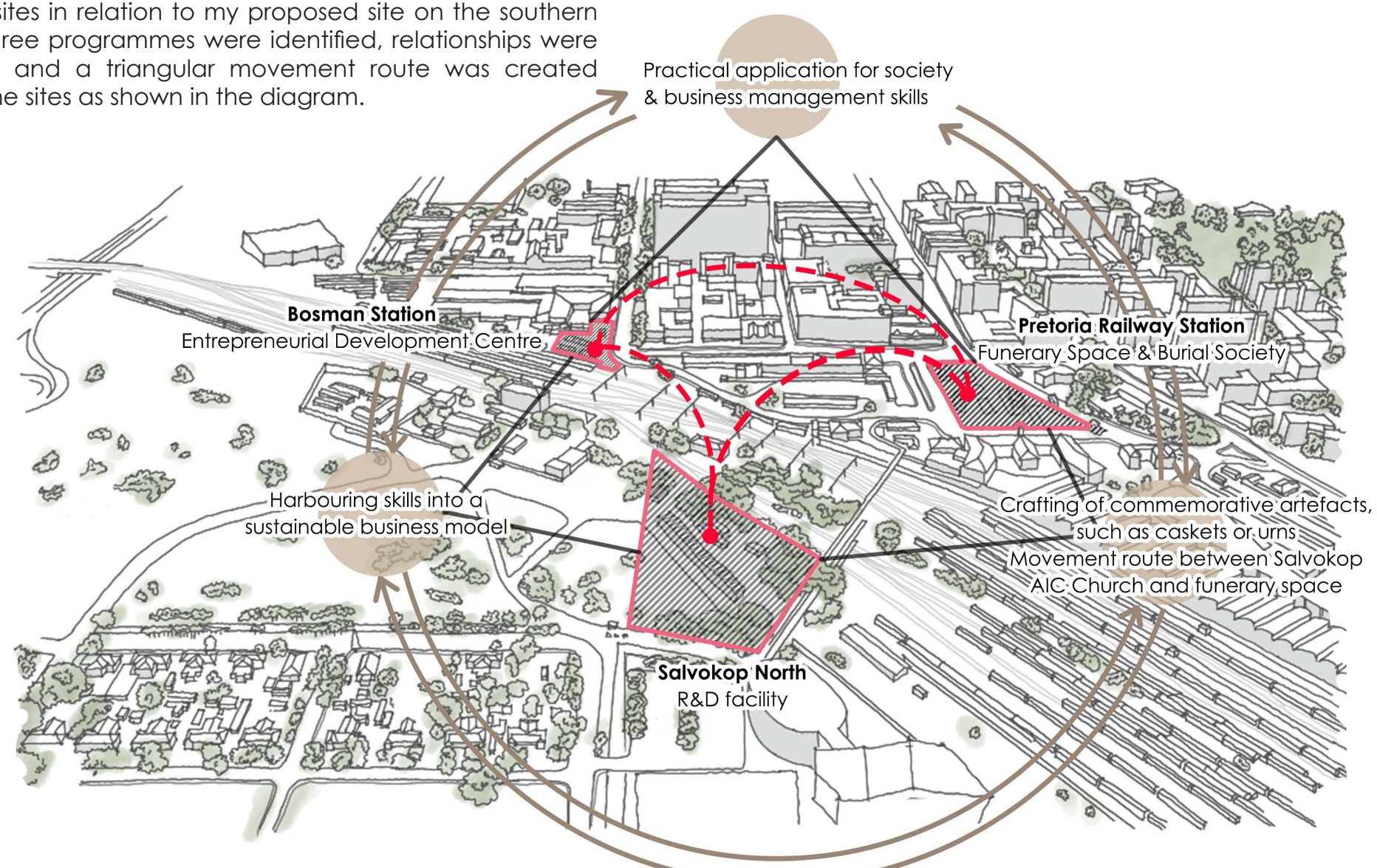



**Figure 56:** Identifying the three sites and their relationships (Author 2020)

An urban vision was developed with the main focus to promote pedestrian movement and public transport, as proposed by Jan Gehl in his book Cities for People (Gehl, 2010). The three sites were developed into large public squares (Bosman Station Square, Pretoria Train Station Square and Salvokop Square) which are connected by a promenade route and two pedestrian bridges. This urban vision proposes to reinstate the secondary pedestrian bridge that was demolished years ago, to reconnect Bosman Street with Koch Street via a five-metre wide pedestrian bridge, creating a direct pedestrian link from Bosman Station Square to Salvokop Square. A green pedestrian/cycle promenade route connects Bosman Station Square with Pretoria Station Square which run parallel to the railway line on the northern side all the way to the taxi rank on the corner of Jeff Masemola Street. The promenade route also includes an earth berm that acts as a buffer between the route and the busy and noisy railway lines. The slope of the berm allows pedestrians to sit and rest underneath the trees out of the way of the main road. Additionally, a ring road is proposed around the Salvokop development, allowing for bus and cycle routes to minimise car traffic.



**Figure 57:** Salvokop north, looking east to STATS SA (Author 2020)



**Figure 58:** Salvokop north, looking west to the Department of Defence (Author 2020)

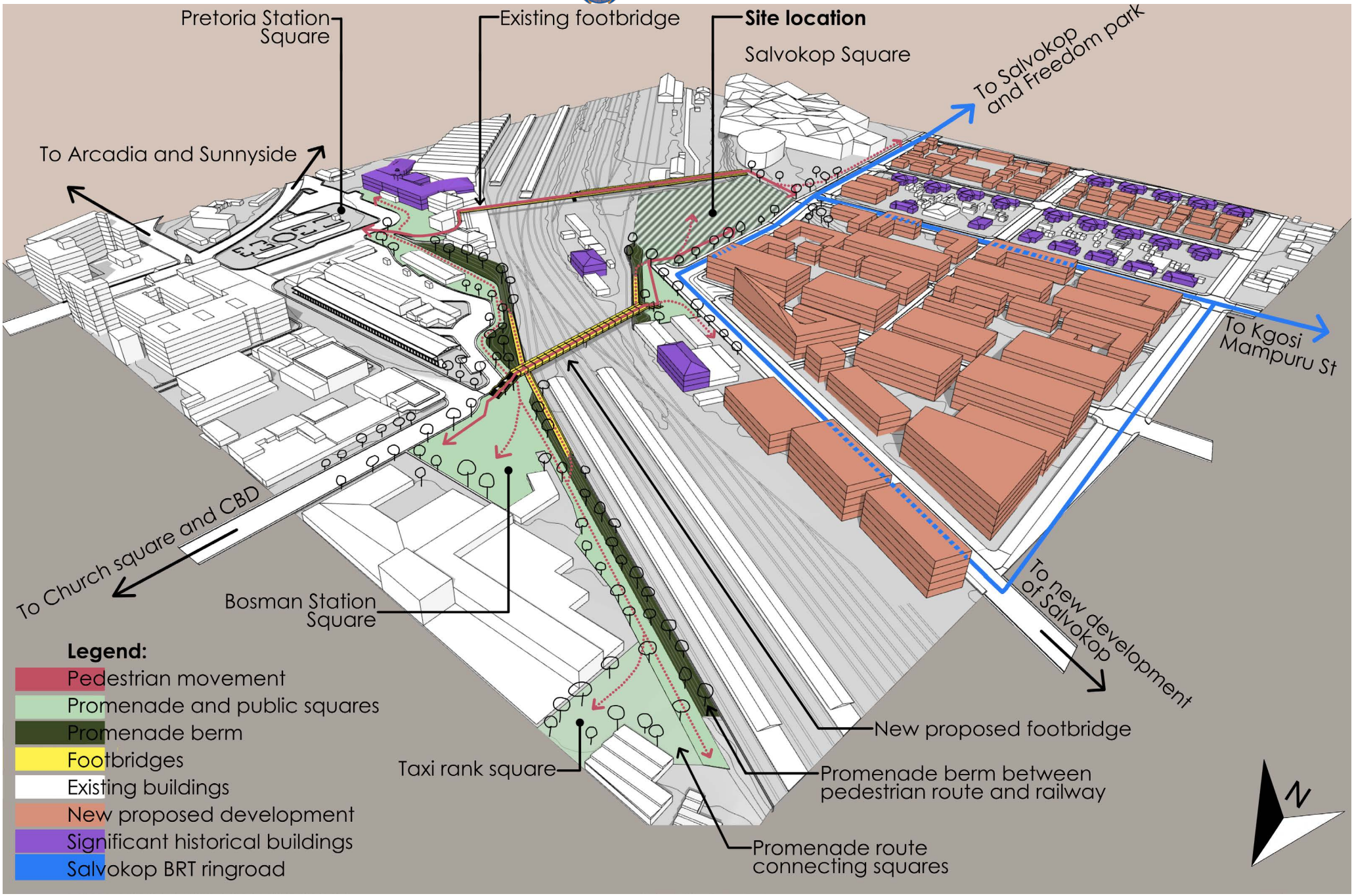



**Figure 59:** Salvokop urban vision (Author 2020)

# Site analysis

The two main pedestrian movement routes defined the eastern and western edge of the site. Three axis lines were identified that would inform the design response: the railway axis line to the north, the pedestrian bridge axis line to the east and the east–west axis (true axis) that is used to face orientate the building to the north. Noise coming from the train tracks was noted. The fine grain of Salvokop's existing buildings must be taken into consideration when considering a building footprint as a series of small masses, as opposed to a single large building footprint such as the Stats SA building.

Sight lines were identified to inform the placement of a landmark structure on the site.



**Figure 61:** Pedestrian bridge to Pretoria Station (Author 2020)



**Figure 60:** Unused railway lines (Author 2020)



**Figure 62:** Pedestrian bridge to Salvokop (Author 2020)

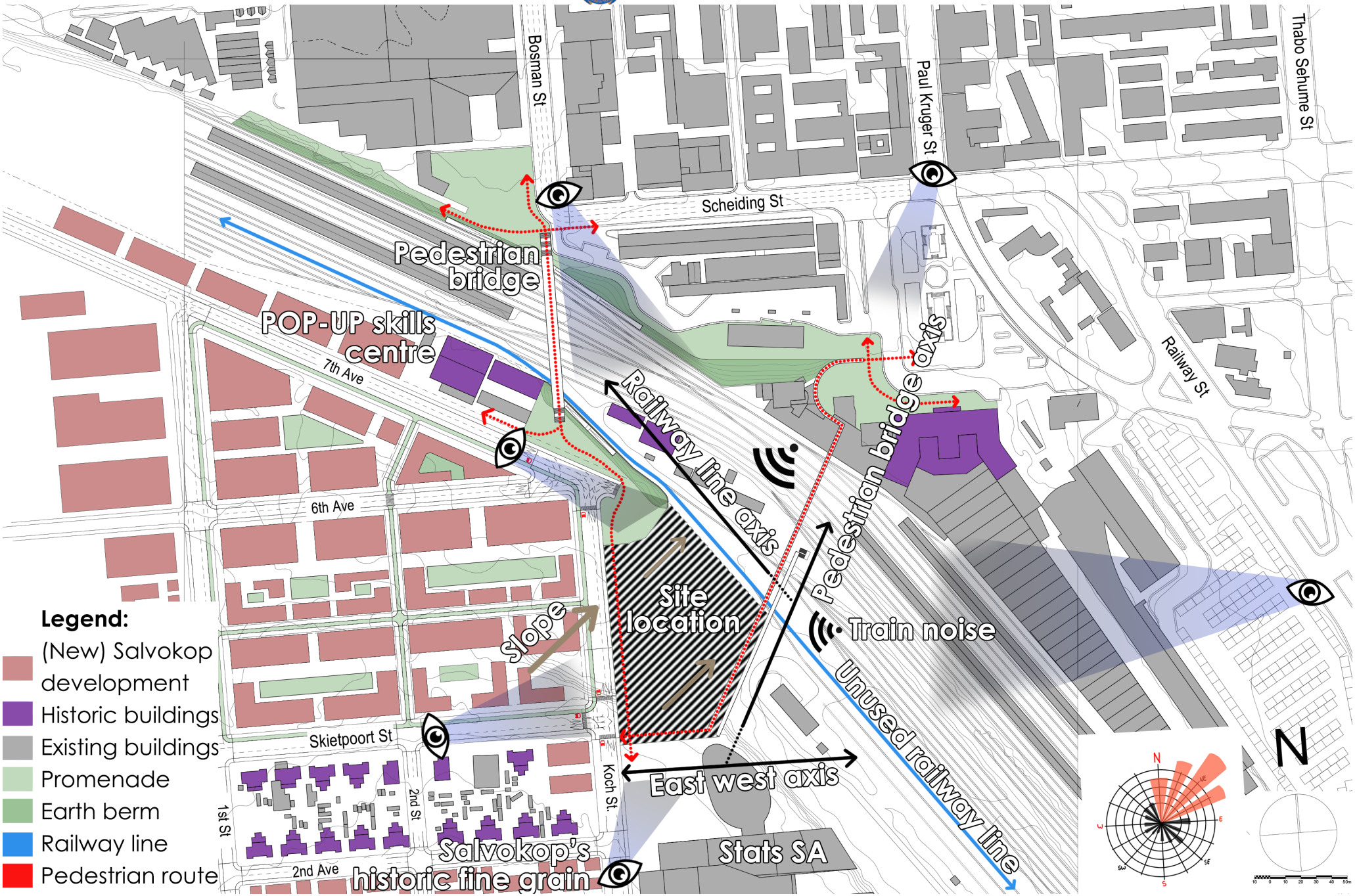



**Figure 63:** Site analysis (Author 2020)

# Precedents

## Contextual precedent

**Darling Square/The Exchange**

ASPECT Studios & Kengo Kuma Architects, 2019, Sydney, Australia

Darling Square is located on a former entertainment centre and car park. The precinct serves as a connection point for residential, commercial and community facilities and entertainment centres, which are all connected to a public square. The park serves as an extension to the circular building on the site known as The Exchange, designed by Kengo Kuma. An iconic pergola walkway, known as the canopy edge, merges with the building's timber screen, serving as a threshold between the boulevard and the lawn. Trees are also used as organic spatial devices which form a symbiotic relationship with the predominant use of timber in the building (Shuang 2020).

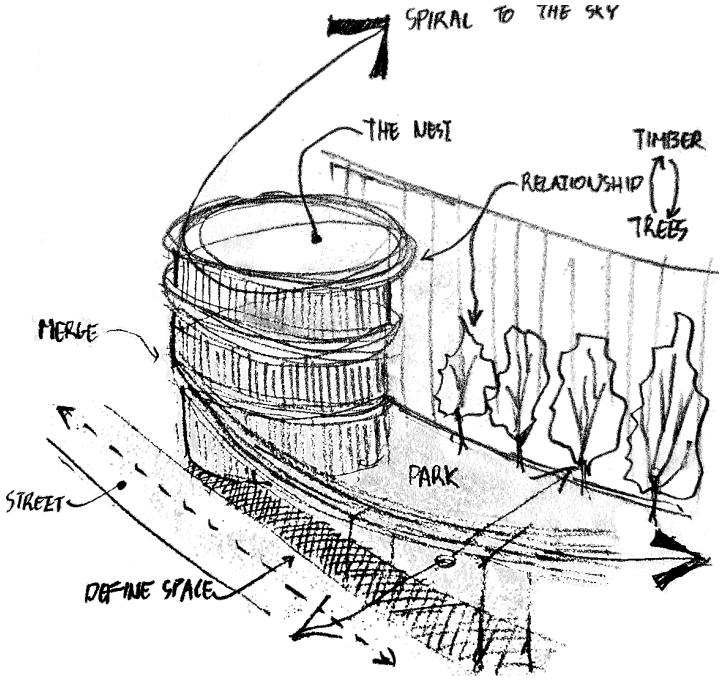



**Figure 64:** Landscape morphing into the building (Author 2020)

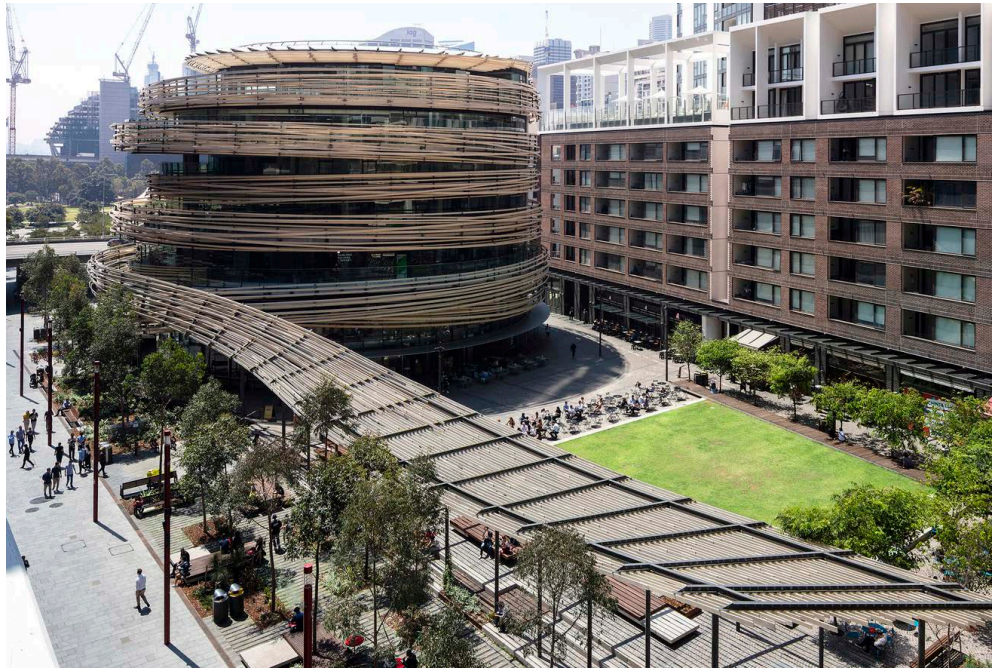


**Figure 65:** Pergola to define the edge (ASPECT Studios 2019)

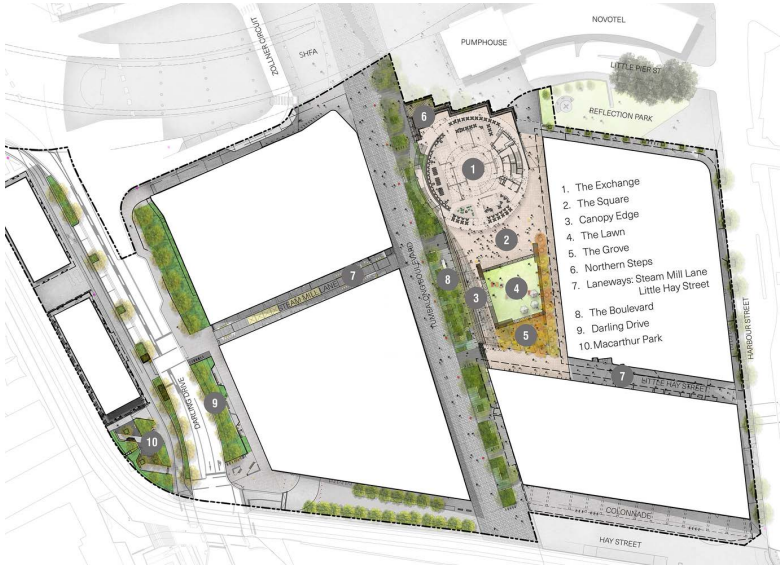



**Figure 66:** Greenery as edge condition (ASPECT Studios 2019)

# Conceptual precedent

**CLT Pavilion**

Kengo Kuma and associates, 2019, Tokyo, Japan

A temporary pavilion designed for event spaces. The structure comprises steel columns placed on a grid with pre-manufactured CLT "leaves" fixed to the column in a spiral shape. A transparent fluororesin film was used to wrap the pavilion to provide protection from the rain and wind. Light can filter down to the ground floor, creating a constant change in shadow patterns just like light would filter through the canopy of a forest (Kudo 2020).

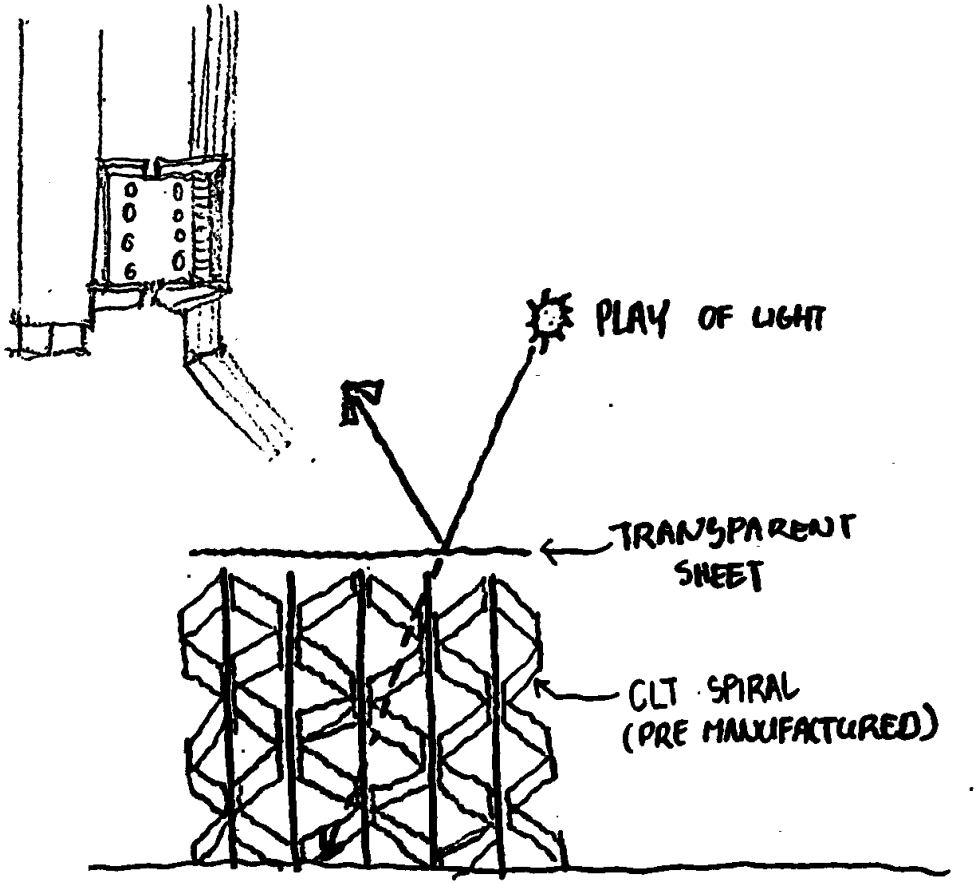



**Figure 67:** Connection detail (Author 2020)

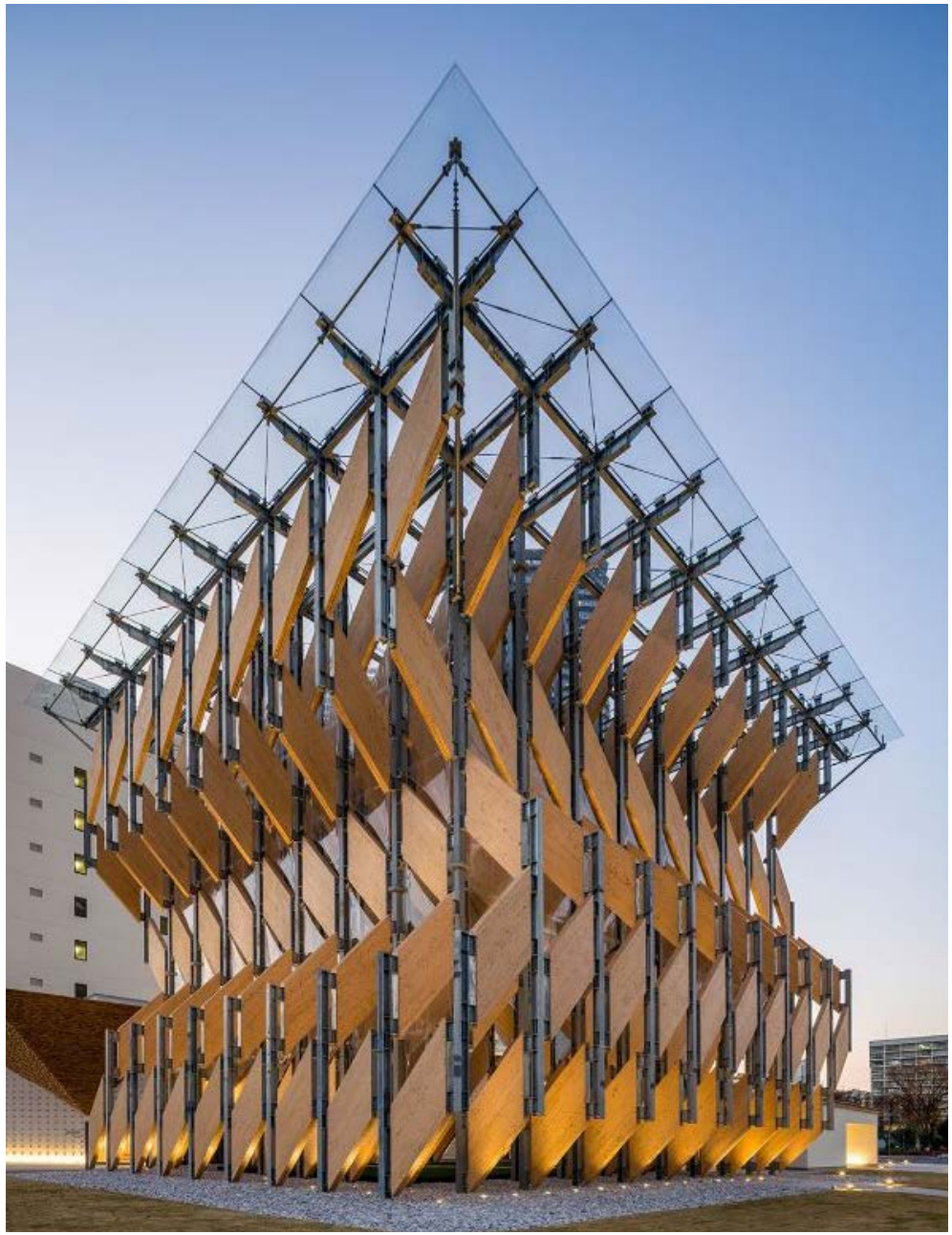


**Figure 68:** CLT Pavilion (Kengo Kuma and associates 2020)

**Nest we grow**
Kengo Kuma and associates, 2014, Takinoue, Japan

A public building to bring people together and to store, prepare and enjoy local foods. The concept for this building is an attempt to merge Western timber construction with local Japanese craftsmanship and tools. The building's structure comprises a large glulam post and beam construction, with the joints and connections influenced by Japanese carpentry. Polycarbonate sheets wrap around the building's exterior to create a microclimate for food to be preserved and prepared. This translucent screen also exposes the skeleton structure of the building's interior. A stereotomic rammed earth plinth is used to gain access to the building (Kengo Kuma & Associates 2015).

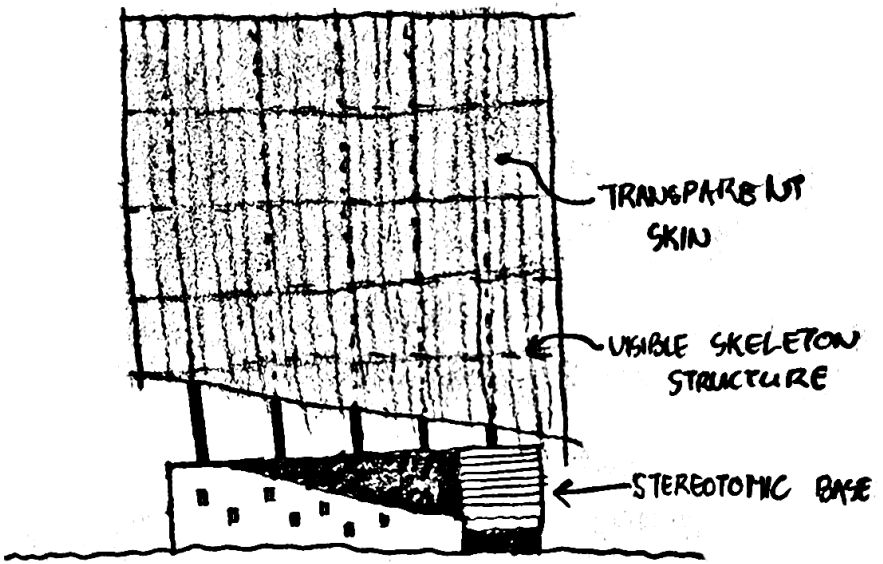



**Figure 69:** Steriotomic vs tectonic (Author 2019)

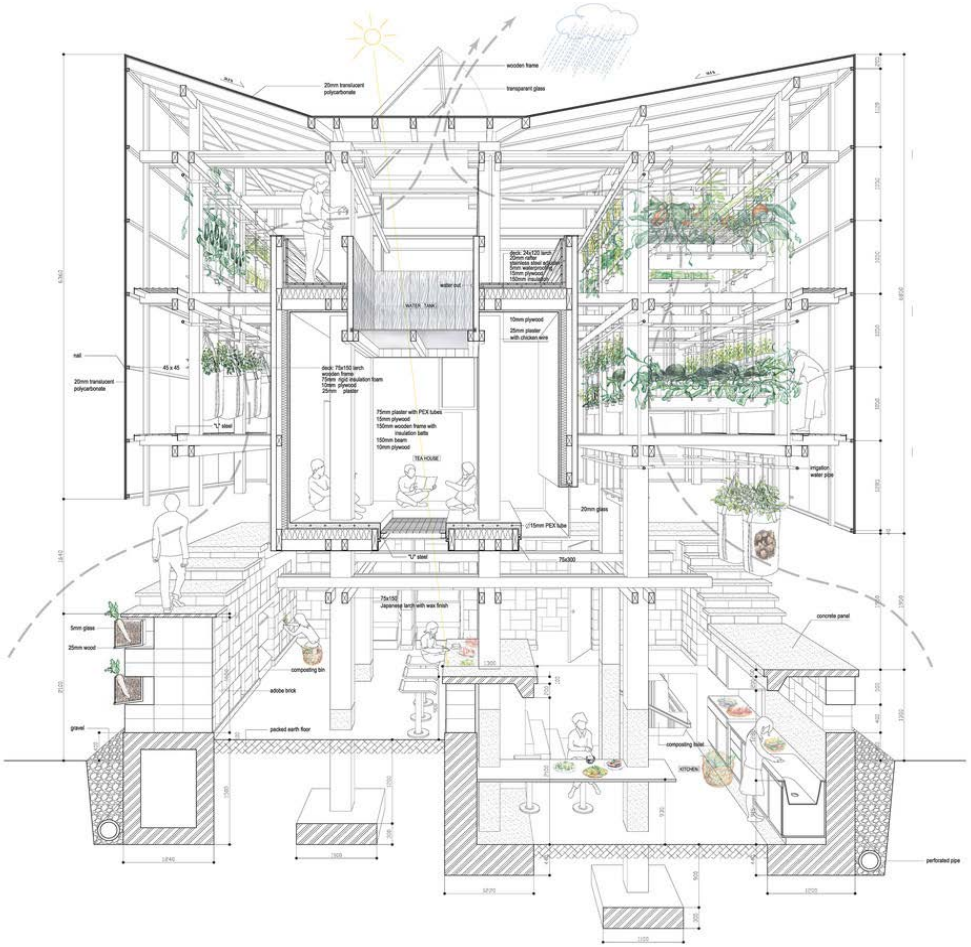


**Figure 70:** Nest we grow, use of a translucent membrane (Kengo Kuma and associates 2020)

# Formal precedent

**Renzo Piano Building Workshop**
Renzo Piano, 1991, Genoa, Italy

An office building for the Renzo Piano Building Workshop. Influenced by the slope of the site as well as the scenic view towards the Mediterranean Sea, a giant glass roof gently slopes down the hill creating for the most part a single volume across all the terraced floors. The building is completely lit by natural light filtering through the roof. Levels of natural light are controlled by hand-operated external louvres.

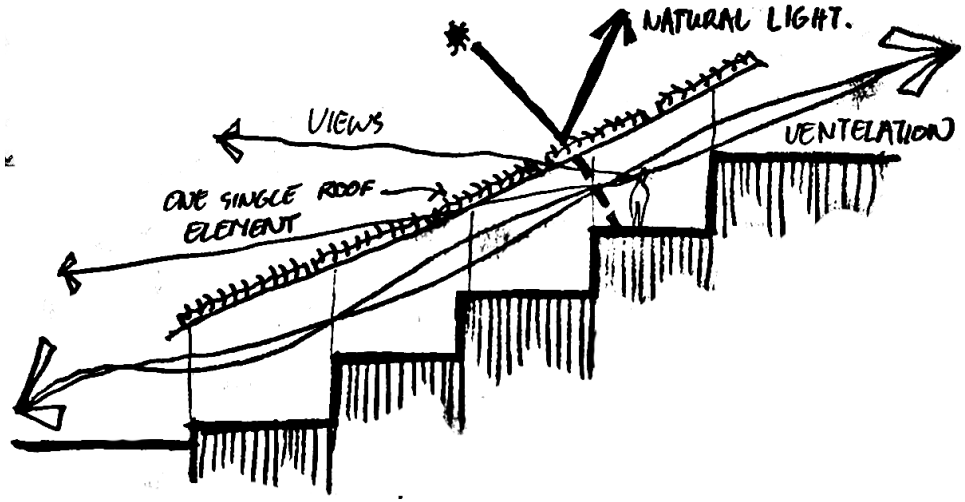



**Figure 71:** The roof as a window(Author 2020)



**Figure 72:** Renzo Piano Building Workshop (Renzo Piano 2018)

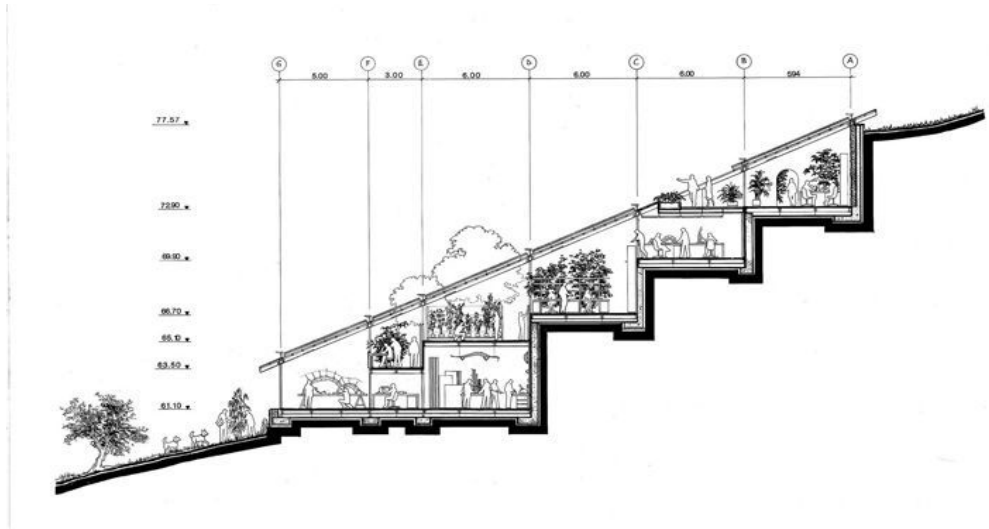


**Figure 73:** Renzo Piano Building Workshop section (Renzo Piano 2018)

# Programmatic/Functional precedent

**Archi Tec Lab**
Guido Züger, 2016, Zurich, Switzerland

A research lab and workshop focused on digital technologies and collaborative planning processes that can be used to create a new paradigm shift towards the future of construction. The building itself was designed on an existing parking block. The methods of construction used in the building relate to the main programme the building is designed for. The roof was designed with the aid of various BIM programs, used to generate information for a gantry robot that was used to assemble the complex roof trusses. These trusses comprised of 48 000 individual timber beams, all the same size and shape, assembled according to the BIM model. The facility houses a large workshop area equipped with state-of-the-art technology that allows researchers to produce full-scale prototypes for testing and procurement (Menz 2016).

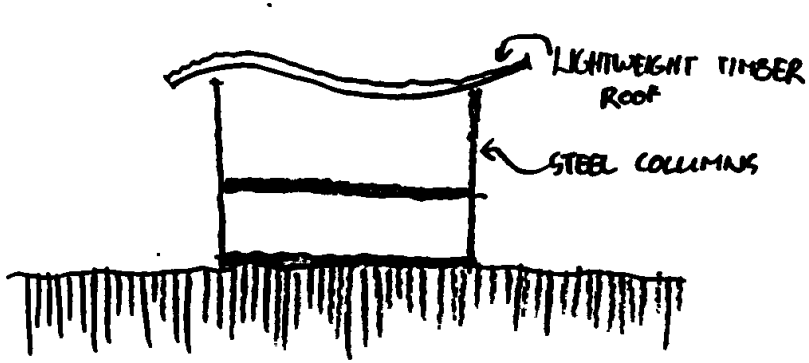



**Figure 74:** Timber truss roof on steel columns (Author 2020)



**Figure 75:** Manufacturing workshop with gantry assembly robots (Menz 2016)

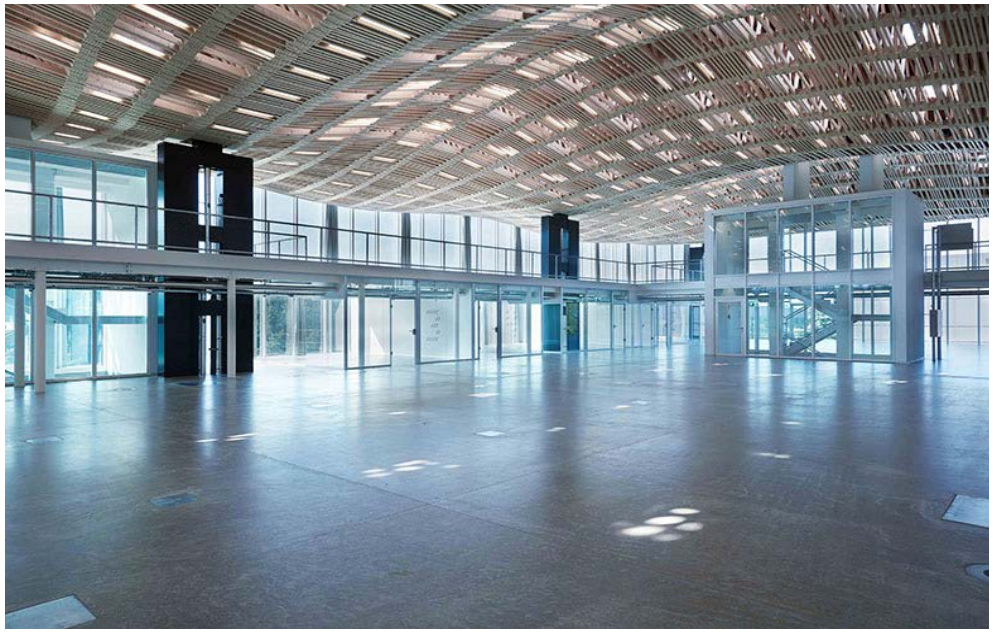


**Figure 76:** Digital manufactured timber truss roof (Menz 2016)

# Technological precedent

**Saintsbury centre**
Foster + Partners, 1978, Norwich, UK

An exhibition room designed around the principles of a free plan, to accommodate a wide range of exhibitions. The building is enclosed by a double wall system, where all the services, including restrooms, kitchens and storage rooms, are located in between the interior wall and exterior cladding. The structural system used was a web of steel members used to form portal frames to which cladding can be affixed. The service walls and roof are generous in size which enables maintenance workers to work freely without having to worry about tight spaces or hard-to-reach areas (Foster + Partners 2006).



**Figure 78:** Saintsbury centre (Foster + Partners 2019)

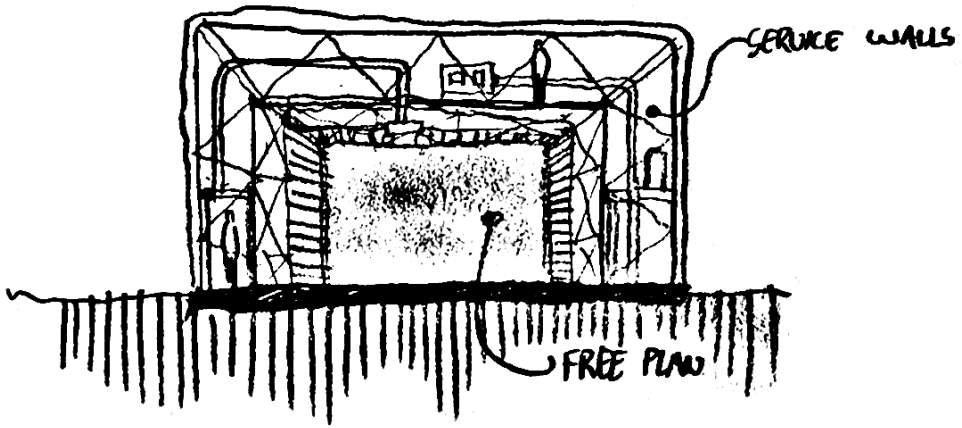



**Figure 77:** Service wall (Author 2020)

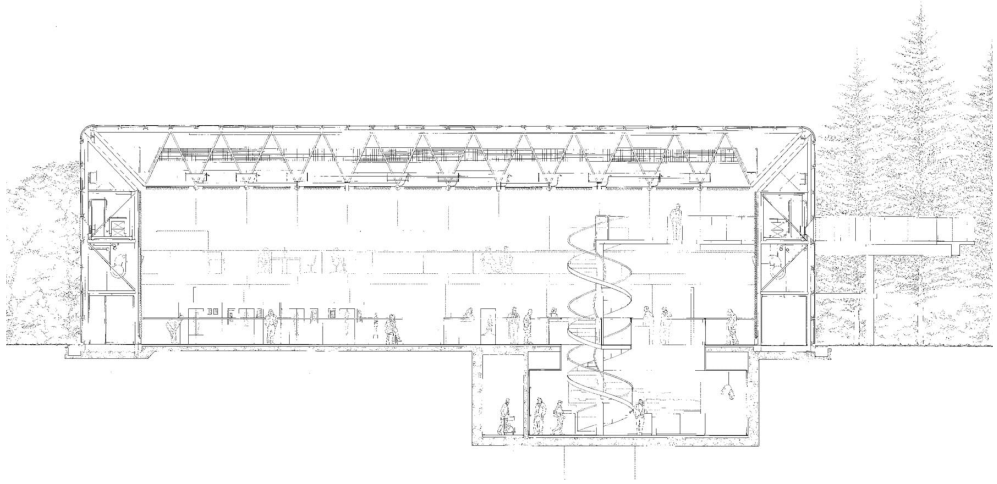


**Figure 79:** Saintsbury centre section (Foster + Partners 2019)

**Future Africa, Dining hall**
Earthworld Architects, 2018, Pretoria, South Africa

A dining hall for the new innovation campus at the University of Pretoria. The building's structural system comprises plywood timber portals. These portals consist of three layers of 22 mm Birch ply components bolted together. These components were completely pre-manufactured with a CNC machine of a drawing created with a BIM program. This allowed the architect to use unskilled labour to assemble the entire structure of the building with precision and speed in mind. The material properties of the plywood outmatch those of steel by weight and structural movement if similar steel members were to be used for the same application (Gunter 2020).

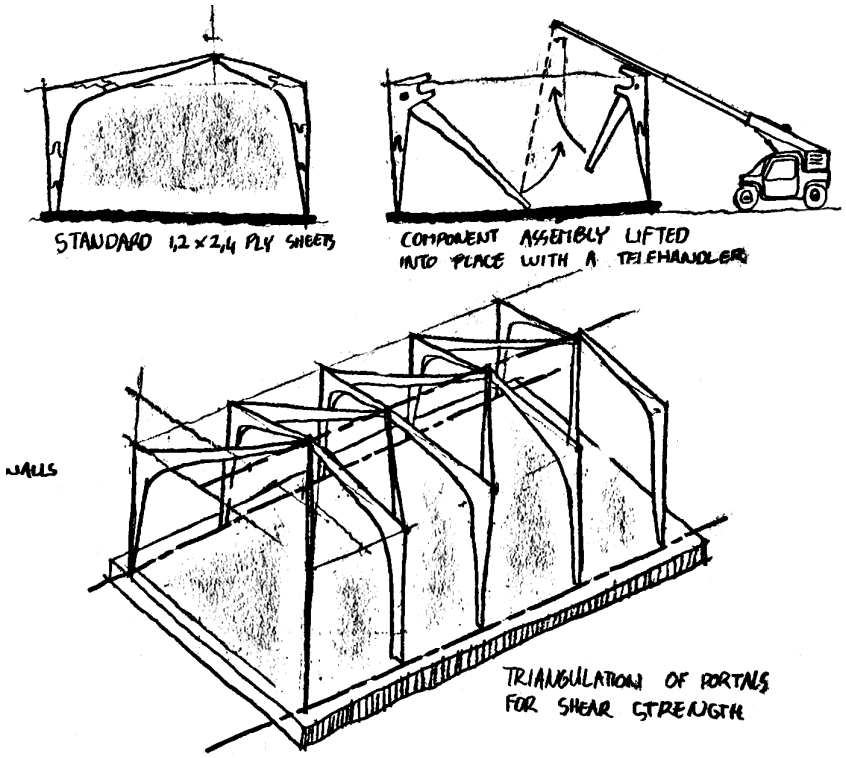



**Figure 80:** Assembly process (Author 2020)

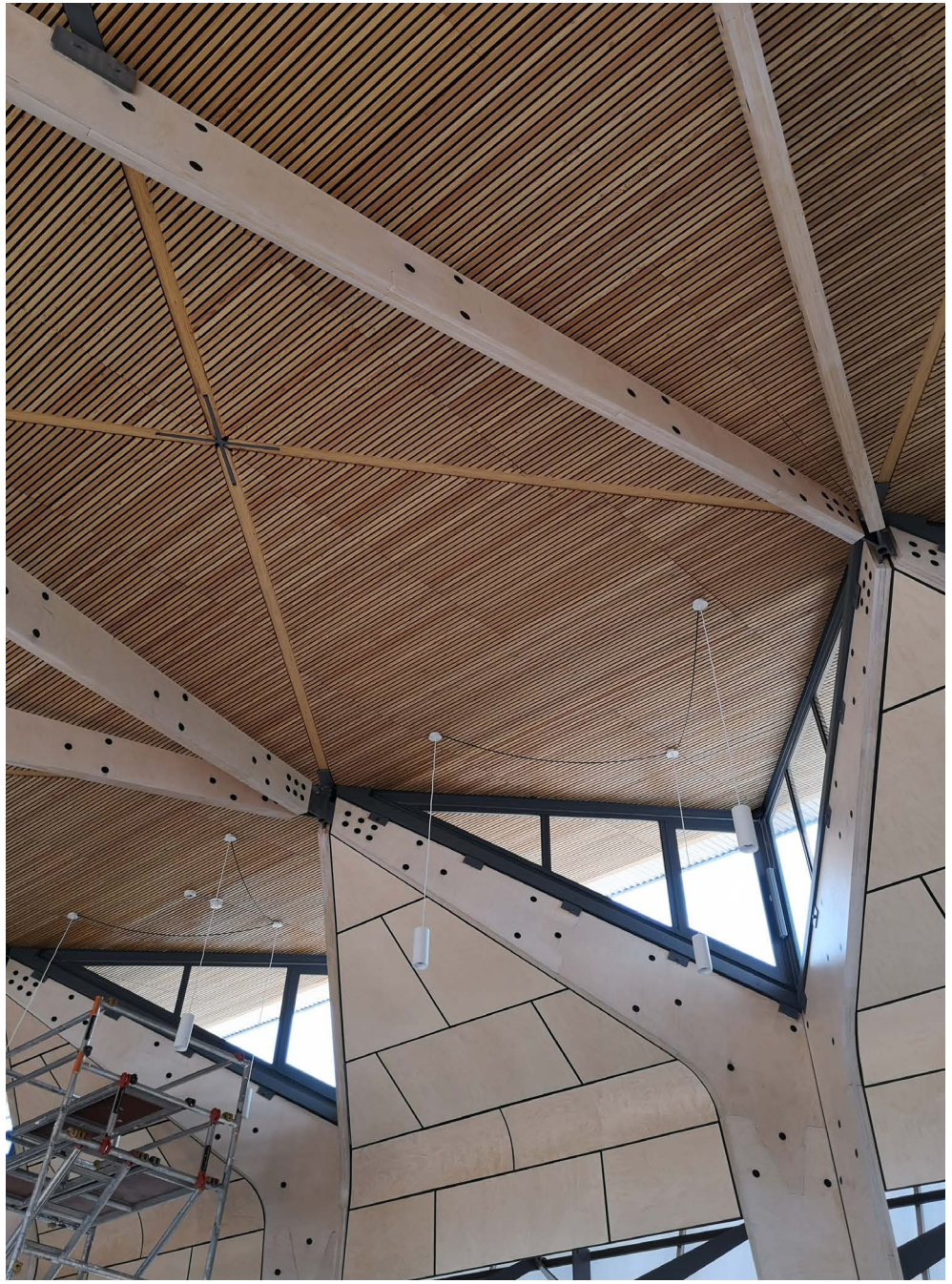


**Figure 81:** Portal frame connections (Author 2018)

# Programatic planning
## Area schedule

| Salvokop Tower : Area schedule | | | | |
|---|---|---|---|---|
| **Program** | **Sub functions** | **Qty** | **Approx area required (m2)** | **Total area (m2)** |
| **Information and reception** | Reception desk | 1 | 6 | 6 |
| | Staff bathroom | 1 | 45 | 45 |
| | Staff room | 1 | 60 | 60 |
| | Kitchenette | 1 | 8 | 8 |
| | Caretaker's office | 1 | 12 | 12 |
| | Maintenance storage | 1 | 50 | 50 |
| | Lift & staircase lobby | 1 | 7 | 7 |
| | Material storage | 1 | 100 | 100 |
| | | | | |
| **Research labs** | Lab manager office | 1 | 12 | 12 |
| | Equipment storage | 1 | 15 | 15 |
| | Labs | 2 | 135 | 270 |
| | | | | |
| **Offices** | Private offices | 2 | 13,5 | 27 |
| | Kitchenette | 3 | 6 | 18 |
| | Open plan offices 1 | 1 | 180 | 180 |
| | Open plan offices 2 | 1 | 145,8 | 145,8 |
| | Circulation and discussion areas (40%) | 1 | 163 | 163 |
| | | | | |
| **Research workshops admin** | Workshop manager office | 1 | 12 | 12 |
| | Equipment storage | 1 | 30 | 30 |
| | Staff room | 1 | 60 | 60 |
| | Kitchenette | 1 | 6 | 6 |
| | | | | |
| **Research workshop** | CNC machine | 3 | 14 | 42 |
| | Lamination press | 2 | 12 | 24 |
| | Sanding station | 2 | 4 | 8 |
| | Planeing station | 2 | 4 | 8 |
| | Pull saw station | 2 | 5 | 10 |
| | Assembly station | 4 | 4,5 | 18 |
| | Hand tool storage | 2 | 3 | 6 |
| | Circulation (70%) | 1 | 595 | 595 |
| | Outdoor workshop | 1 | 445 | 445 |
| | | | | |
| **Inner courtyard** | Public bathrooms | 1 | 54 | 54 |
| | Circulation | | | 0 |
| | | | | |
| **Lecture rooms** | Sound lobby | 2 | 4 | 8 |
| | Main seating (50 seater) | 2 | 158 | 316 |
| | Podium | 2 | 35 | 70 |
| | Equipment storage | 2 | 10 | 20 |
| | | | | |
| **Cafeteria kitchen** | Food prep | 2 | 4,5 | 9 |
| | Cooking area | 2 | 2 | 4 |
| | Dry storage | 1 | 25 | 25 |
| | Cold storage | 1 | 25 | 25 |
| | Washing | 1 | 4 | 4 |
| | Waste | 1 | 30 | 30 |
| | | | | |
| **Cafeteria: serving** | Seated (100 people) | 1 | 156 | 156 |
| | Take away | 1 | 4 | 4 |
| | | | | |
| **Viewing deck** | Lookout platform | 1 | 81 | 81 |
| | | | Total: | 3188,8 |

**Table 5:** Room requirements and sizing (Author 2020)

# Programming

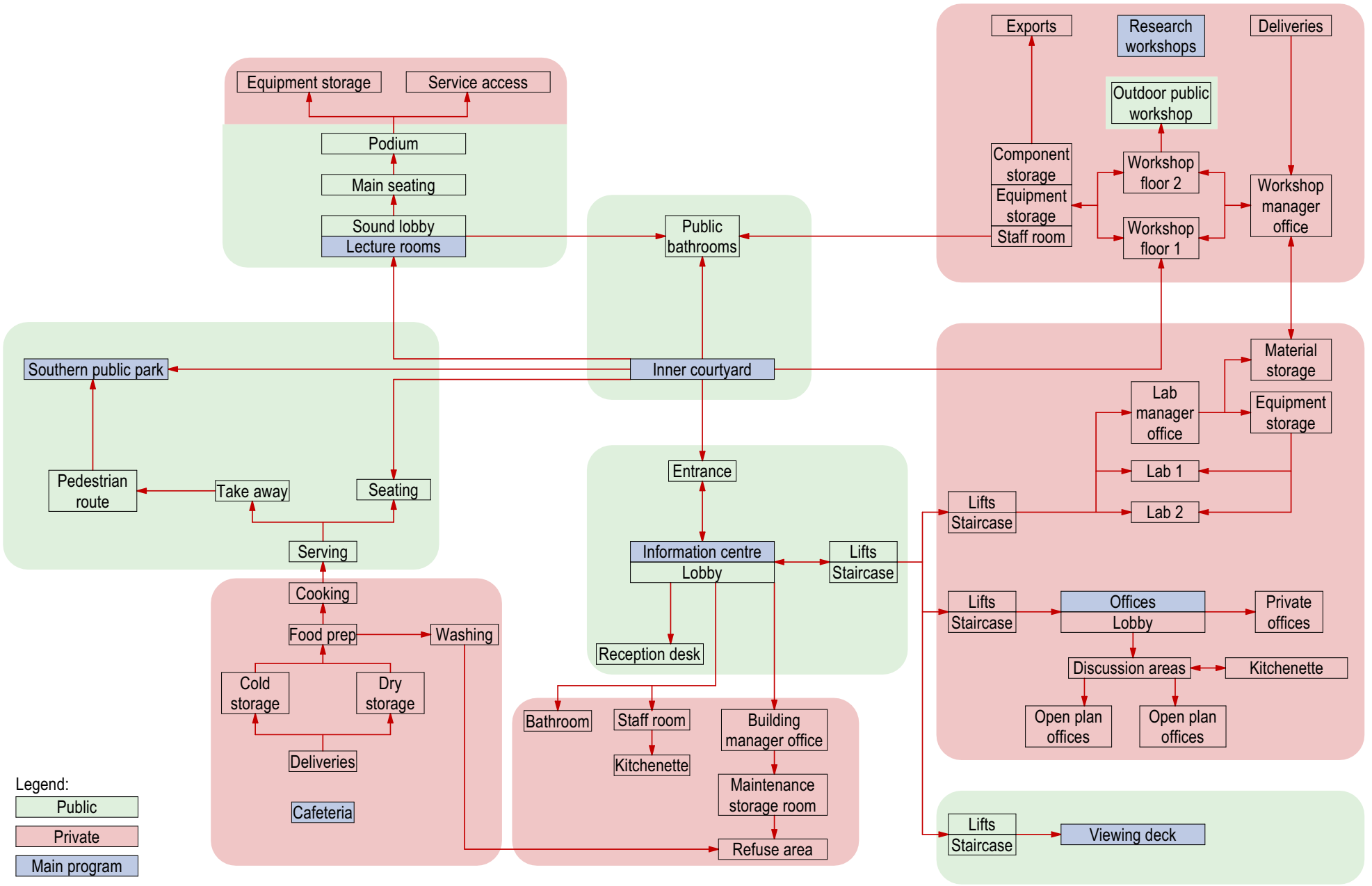



**Table 6:** Programming and zoning (Author 2020)

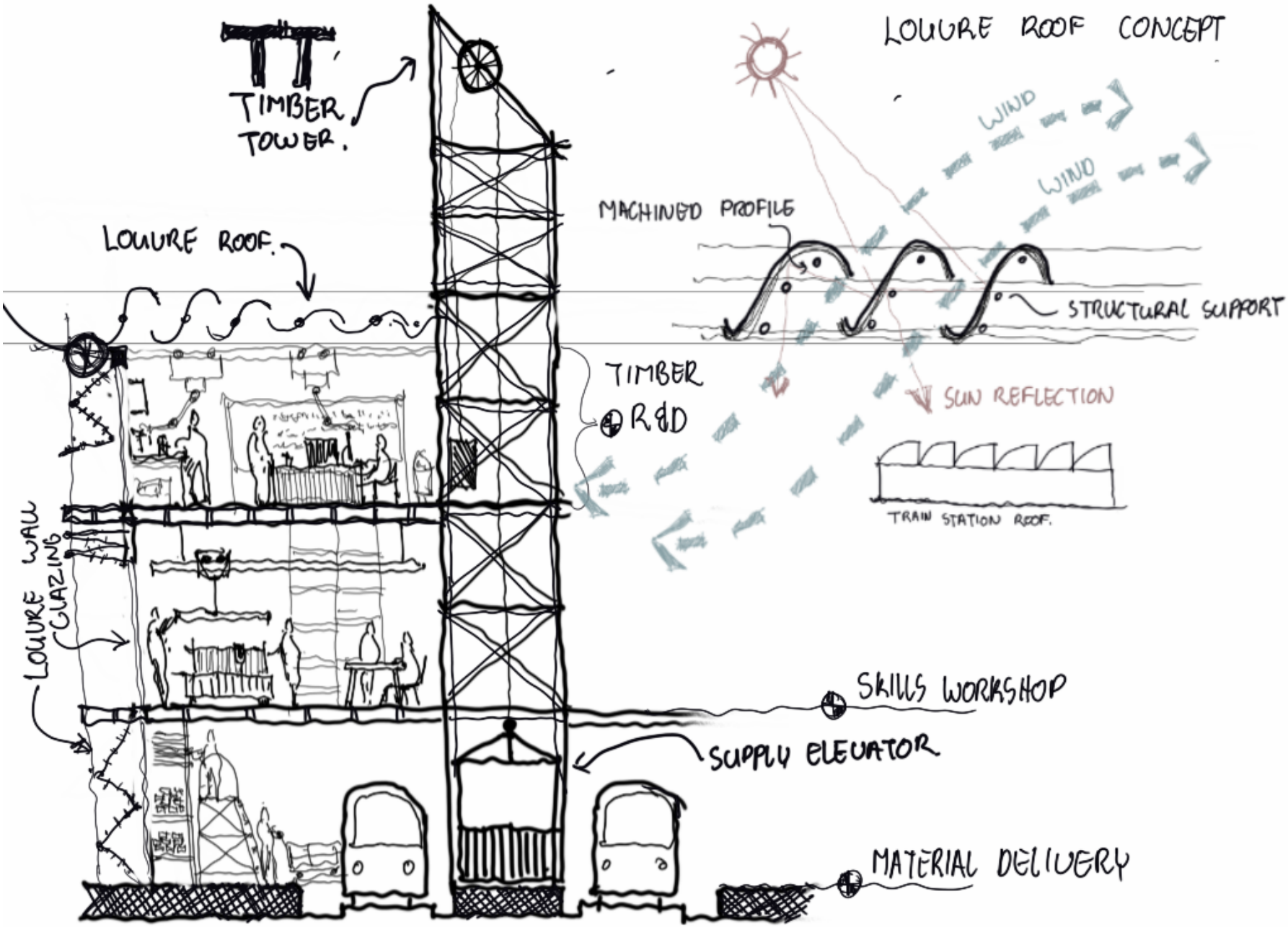
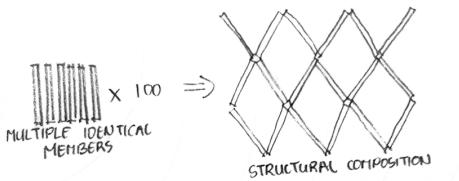


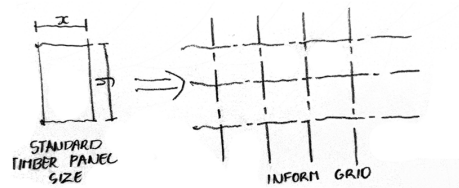

**Figure 82:** First conceptual sketch (Author 2020)

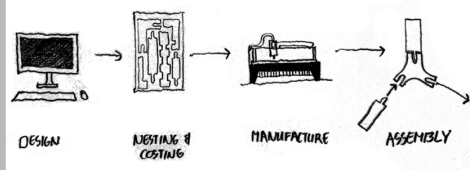
# Conceptual generators

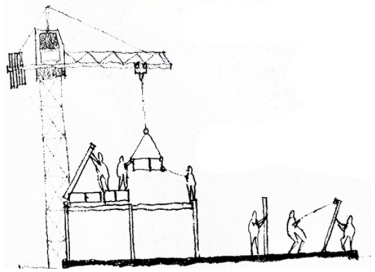
## Technology

- Repetition
- Layout
- Manufacture
- Assembly



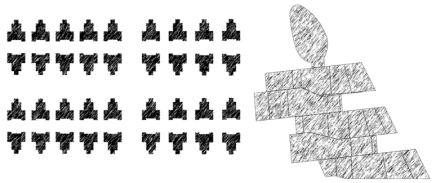



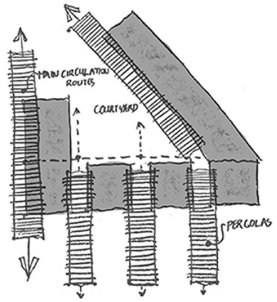



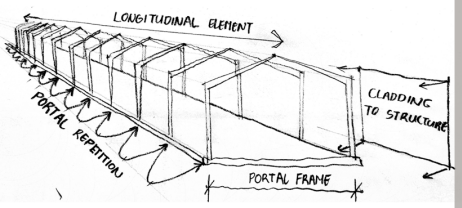



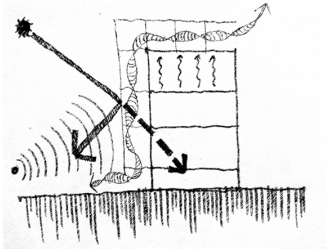
## Contextual

- Footprint
- Edge conditions
- Historical typology
- Climate



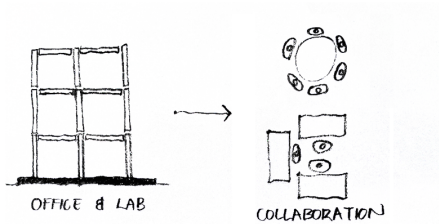


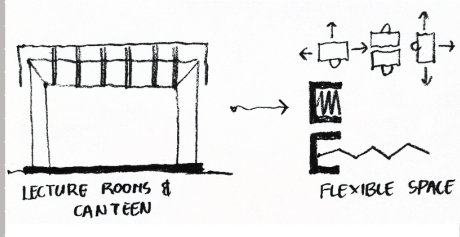



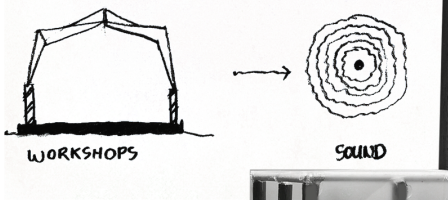



## Program

- Offices & Lab
- Lecture rooms
- Workshops




## Landmark

- Structure
- Tectonic
- Transparency

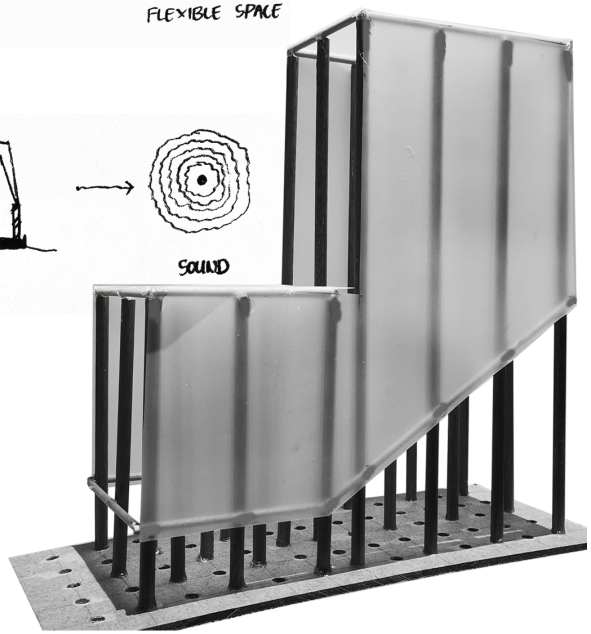


**Figure 83:** Four conceptual generators (Author 2020)

# Four conceptual generators

Four conceptual generators were used to inform the design outcome:

## 1. Technology

Technology plays a significant role in this dissertation. Much of the theory discussed has investigated material technology and manufacturing technology and how high-tech can be used to bridge the gap in limited local skills. Technology also plays an important role when considering the design of the building, in which ultimately the aesthetic look of the building will be a result of what is made possible by the technology used to make the building. This can be categorised into four main sub generators.

### 1.1 Modularity – using the same member to give form

The "lost decade" of the 1990s, when Japan's economy stagnated, resulted in a decline in novel architectural opportunities in the country. Unlike his counterparts, Kengo Kuma (1954–) saw this crisis as an opportunity to find and engage with small-scale craftsmen, which resulted in his iconic way of practising architecture today. He moved his focus from the big picture to focus on the individual small members he would use to make a building, all of which are identical in size, and are repeated. These members are very basic with a few notches or pockets carved into them that guide the builder to assemble all of the elements to create a seemingly complex structure. Although skill is required to design these members to interlock with one another, not as much is required to assemble them (Goodwin 2019). A similar approach would be used in the design of the proposed R&D centre. A series of identical members and systems (floor, truss, wall) will be used and repeated to create form and structure.

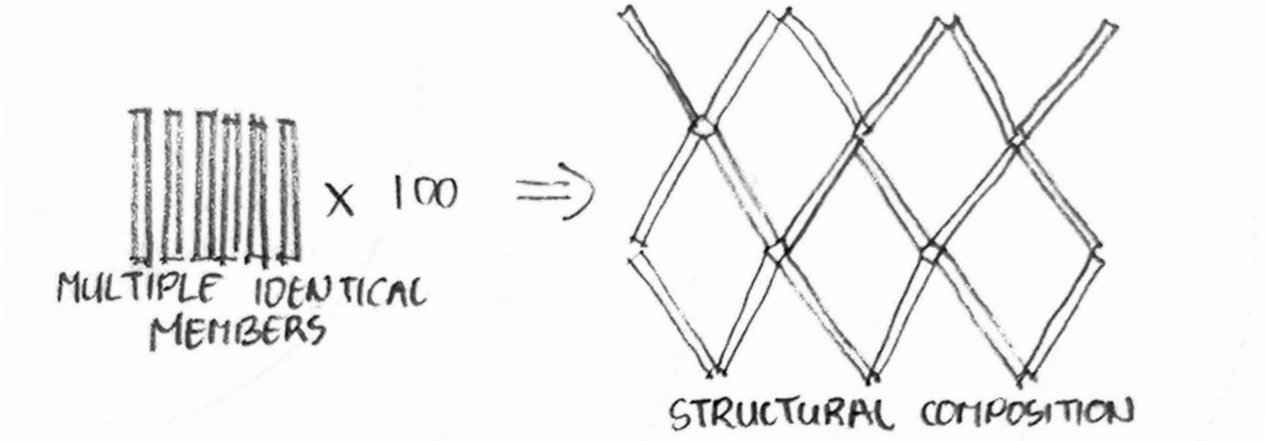



**Figure 84:** Repetition of identical members (Author 2020)

## 1.2 Layout – grid defined by standard dimensions

Some engineered timber products such as CLT and plywood are only available in standard panel sizes. In South Africa, CLT panels are manufactured in 8 m x 2.85 m sizes, although longer panels can be manufactured on request (Smily 2020). These sizes were used to explore possible member sizes that would offer the best economical use of one sheet of CLT with the least amount of material wastage.

Once a viable solution was identified a possible structural composition was explored that would determine the floor-to-ceiling dimensions (4.2 m) as well as the building's grid lines.

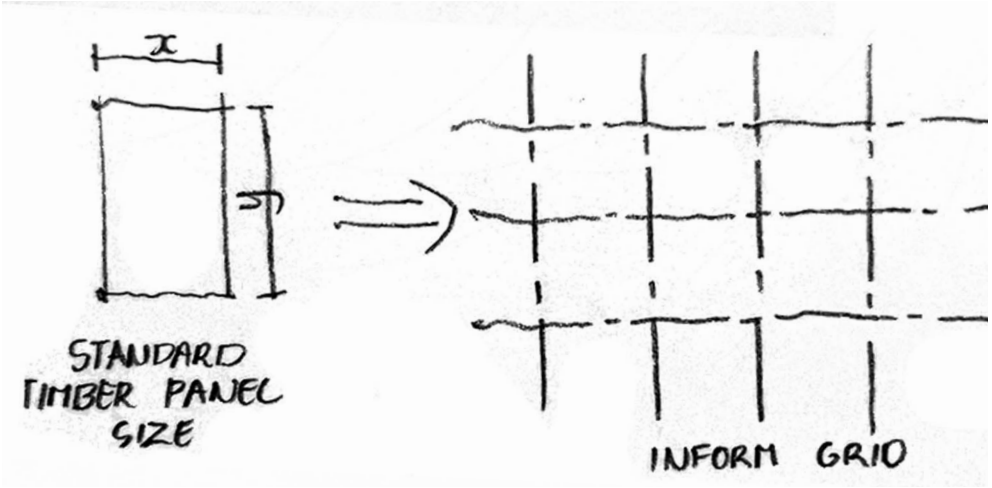



**Figure 85:** Standard panel sizes to inform the grid and floor levels (Author 2020)

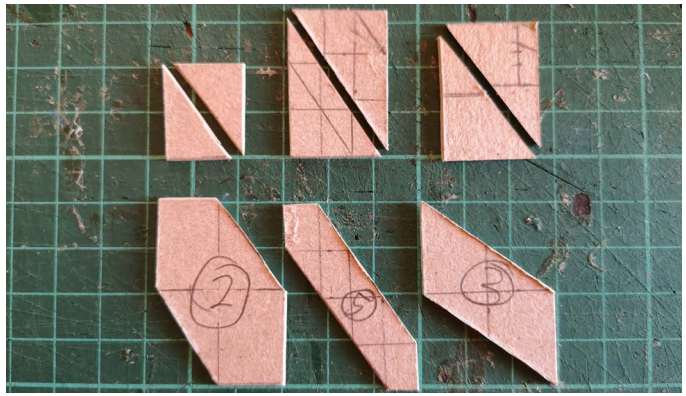


**Figure 86:** Possible cut-outs explored on one CLT sheet with material wastage (Author 2020)

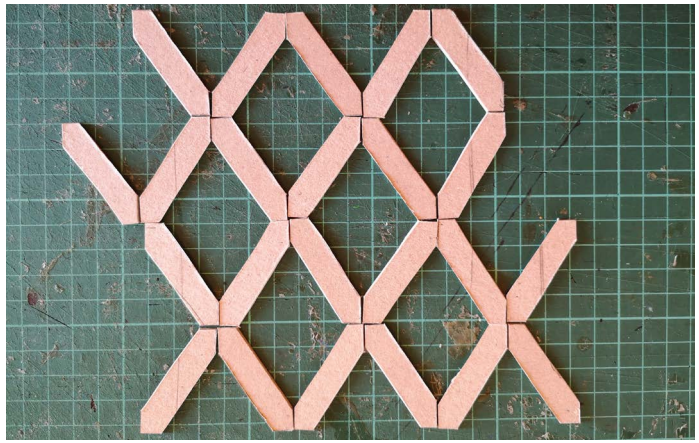


**Figure 87:** Possible composition of multiple members and grid layout confirmation (Author 2020)

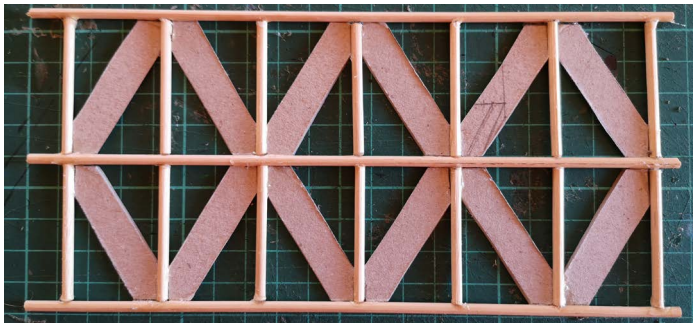


**Figure 88:** Floor to ceiling heights & grid established (Author 2020)

## 1.3 Manufacture – a pre-manufacturing making approach

As noted in the dissertation article (chapter 3), Le Corbusier states that architecture should be the concern of mass manufacturing and component parts (Smith 2012). Influenced by this paradigm, other pre-manufacturing theories and local precedents such as the Hout Bay House and Future Africa, Dining hall, as well as the material being explored to construct this building, a pre-manufacturing making approach was adopted whereby almost all the components required in the building would be pre-manufactured and installed on site.

Although this dissertation is structured around high-tech design tools and machinery, certain delimitations have to be made because not all these technologies are feasible in South Africa. Therefore, construction technologies such as virtual design construction (VDC), 3D printing construction and robotic fabrication are not considered to influence the design outcome. Instead, local technologies that are currently being used in our built environment are identified, the main technology being a CNC machine. The use of this machine has many advantages: it is compatible with most BIM programmes being used by architects and engineers and it can cut a variety of engineered wood products.

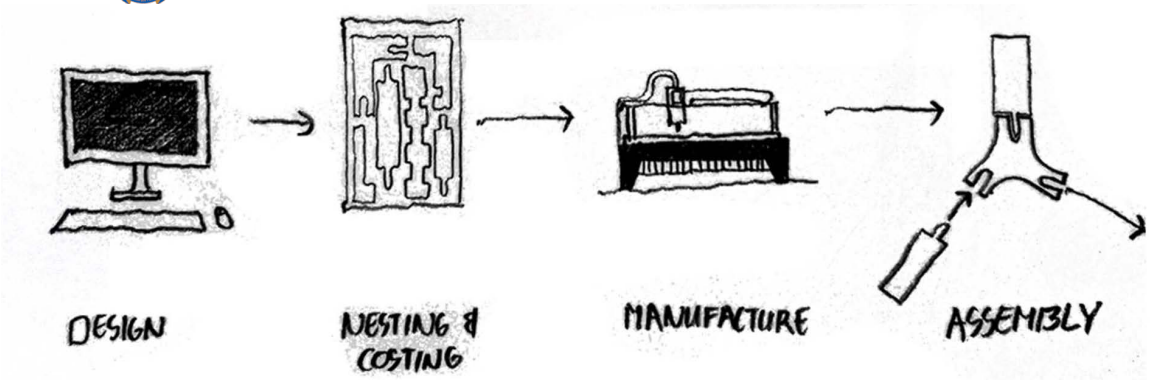



**Figure 89:** Pre-manufacturing design approach (Author 2020)

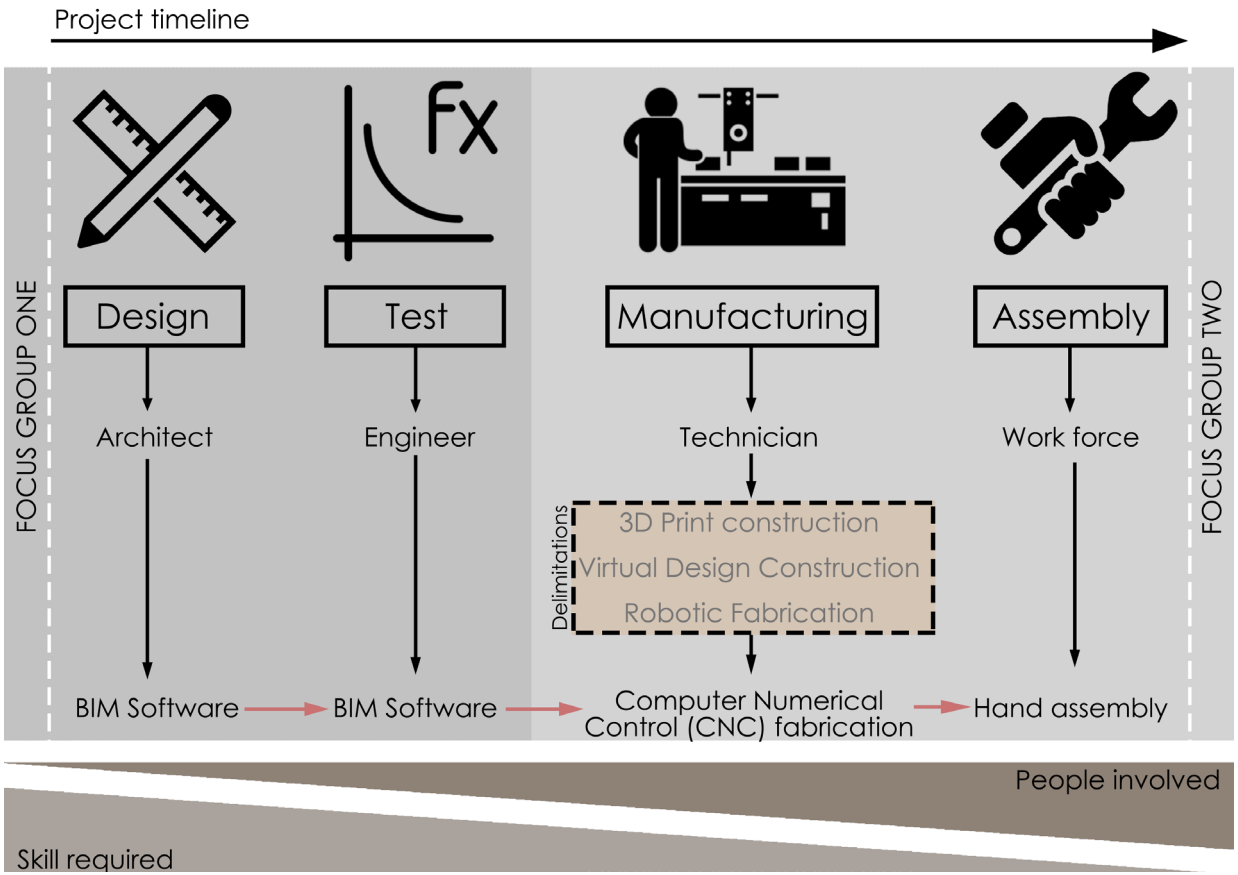



**Figure 90:** Pre-manufacturing design approach, identifying manufacturing deliminations (Author 2020)

### 1.4 Assembly – empowering unskilled workers

Because of the pre-manufacturing nature of the design most building members/components will be light enough to lift and install by hand without the need for heavy lifting equipment. This allows any unskilled worker to engage with the project on a deeper level to distil personal satisfaction and pride, to be acknowledged for the good work they are doing as well as to create a strong sense of comradery among the team (Awan, Schneider & Till 2011).

Components will be delivered by train or truck, unloaded, and then assembled where required. Ramp scaffolding will be erected to allow workers to carry building components to higher levels. Heavy components will inevitably be lifted by crane, but the need for this will be limited, reducing the overall cost of the project (Steyn 2017).




**Figure 91:** Human scale component assembly (Author 2020)

## 2. Context

Salvokop's context was analysed by investigating the urban fabric, responding to street edges, investigating the historic typology, as well as considering the climatic conditions of the site.

### 2.1 Urban fabric – fragmenting the building mass

A figure ground study of Salvokop's existing historical urban fabric (residential homes) has revealed many small building footprints, as opposed to the recently completed Statistics SA building which consists of one massive building footprint. This design informant led to an exploration of a series of smaller elements (footprints) clustered together to give the building form. The exploration has dealt with four main building elements/ footprints: the timber tower, the workshop wing, the knowledge transfer wing and the in-between atrium. These elements are also individually defragmented to give a large building, which could easily dominate the landscape, a smaller appearance to blend in with the context (Ching 2015).

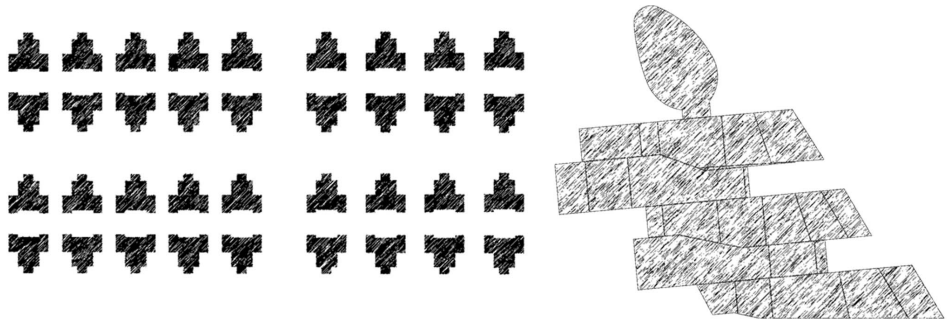


**Figure 92:** Historic building footprint vs Statistic SA footprint (Author 2020)

## 2.2 Historic typology – exploring the use of a portal frame.

As mentioned previously, Salvokop was previously characterised by a dominant industrial building typology. In most industrial buildings the use of portal frames are evident. These frames are designed to meet certain parameters and are then mass produced, all identical, to be installed in a repeated longitudinal axis line. These members form the structural component of the building on which the cladding is fixed to (The Steel Construction Institute 2012). This has influenced the use of longitudinal "wings" to rethink and apply the use of a portal frame machined out of engineered wood that allows for the repetition of mass-produced elements to be installed for different functional and structural requirements.

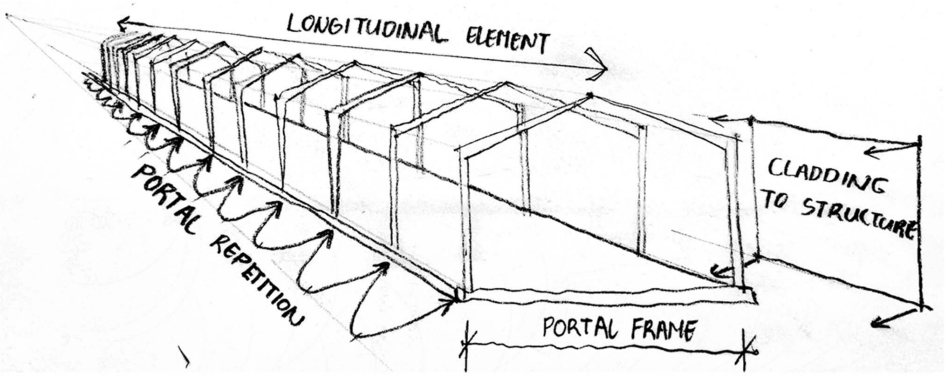



**Figure 93:** Repetition of the portal frame as main structural element (Author 2020)

## 2.3 Climatic conditions – introducing a second skin

Salvokop is located in the Northern Steppe climatic zone with a great deal of solar radiation and moderate humidity levels. In the summer, solar gain into the building should be limited but is desirable during the winter months. Western and eastern facades receive strong solar radiation during the morning and afternoon and should be dealt with either by thermal mass or other screening devices (Holm 1996).

This design informant has led to the exploration of a translucent second skin to the building's façade, to minimise solar heat gain during the summer. Because timber cannot offer thermal mass, a building plenum with a rock store will also be introduced to heat and cool the building. Mechanical ventilation, with the aid of the cavity created in between the building and the second skin, will be used to transfer the air to the desired rooms. The second skin will thus perform multiple roles, to protect against solar radiation, act as an air cavity, house all the building's services as well as provide an aesthetical appearance to generate curiosity among the public.

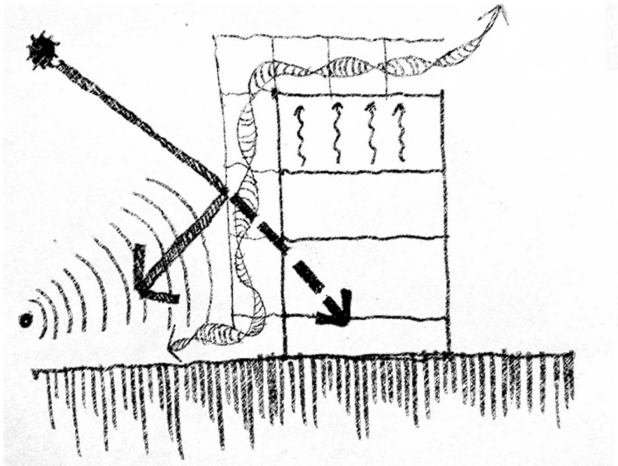


**Figure 94:** Environmental considerations impacting the building (Author, 2020)

## 2.4 Street edges – the edge as catalyst

According to Jan Gehl (2014), the edge of a building is the place where the building and the city meet (Gehl & Svarre 2013:75). In this case, Koch Street to the west connects directly to the main entrance of the new proposed building. Integrated pedestrian pathways and meeting places strengthen the social function of a space (Gehl & Svarre 2013:6).

A designed street edge offers a level of protection (Allers et. al. 2015:31) and promotes public interaction. The edge invites the user to use the site for social gatherings and activities such as community workshops or to rest during lunch time. The edge is not only a place for exchange but also a staying zone therefore a sensory experience is created to create pause spaces and allow the user to be drawn into the site (Gehl & Svarre, 2013: 75-76).

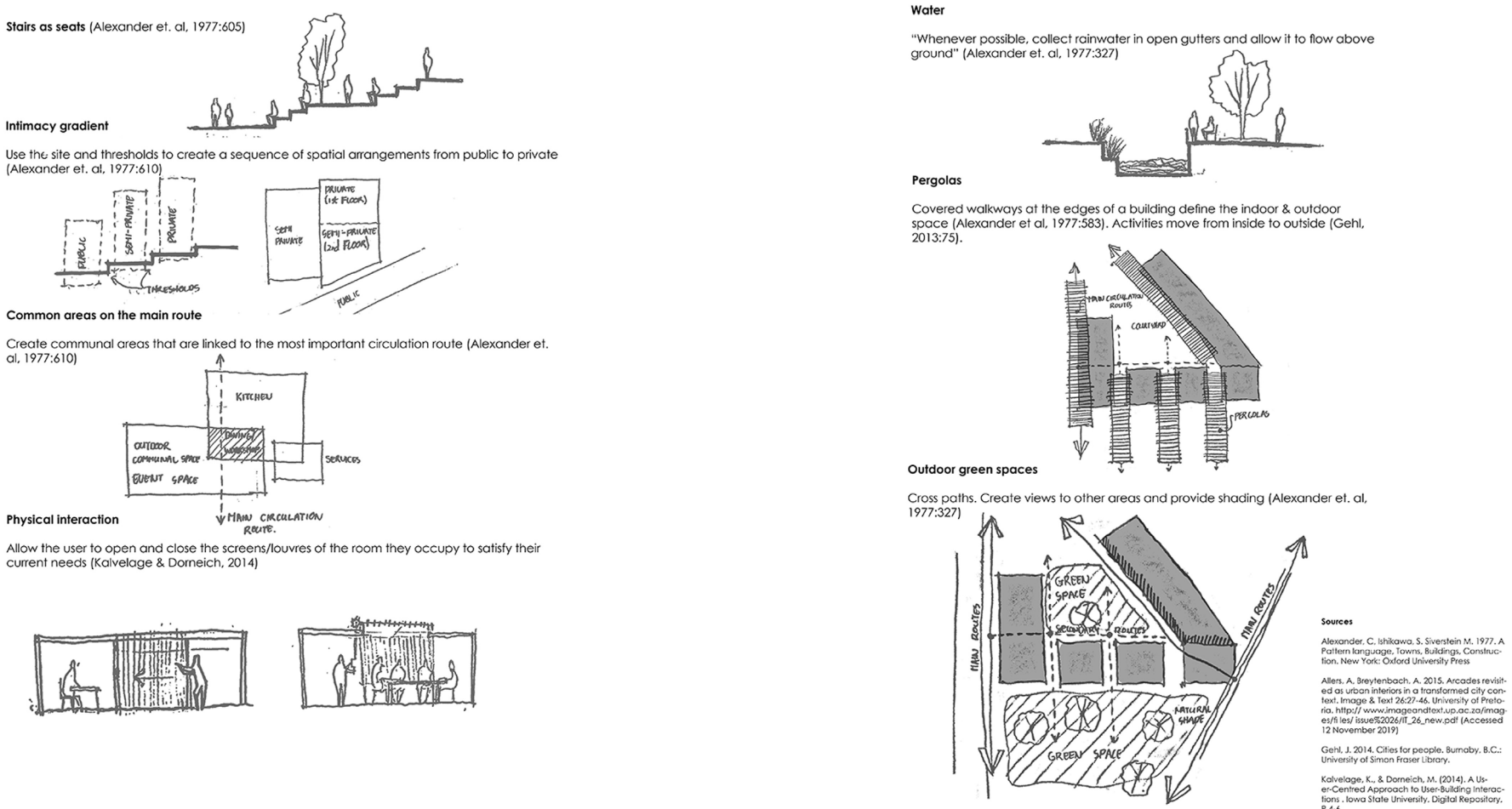



**Figure 95:** Edge condition strategies (Author, 2020)

## 3. Programme

The use of timber and its application will change according to the requirements of the programme/room where it is used.

### 3.1 Research workshops

Two characteristics of the research workshops are noise that needs to be dealt with and additional services that needs to be provided such as suction tubes, power outlets and optimised logistics for material movement and storage. An insulated CLT roof panel system will be developed to deflect and absorb noise as well as to house all the services required in the workshops. 1.5 m high brick walls will be used on the ground floor next to material movement routes to minimise collision damage with the walls as well as to protect the timber walls above from material carts and the general handling of materials.

### 3.2 Offices and laboratory

A collaborative office environment is proposed for the researchers and the laboratory. The need for flexible furniture is required to quickly set up collaborative brainstorming sessions as well as provide for private workspaces (Fisher 2005). Therefore, the timber tower (where the offices and laboratory are located) will adopt a post and beam construction system. It will consist of a series of members used for columns and beams to achieve the desired height, as well as to create a free plan layout with a central service core for circulation and amenities.

### 3.3 Knowledge transfer rooms and canteen

These areas will be publicly accessible and sometimes crowded. Therefore, large re-imagined timber portals will be introduced that can achieve long spans as well as to provide house ventilation and electrical services at regular intervals. High floor-to-ceiling heights, as well as a completely translucent roof system, will be introduced to allow natural light to flood into the space to make the room feel bigger than it actually is (Ching 2015).

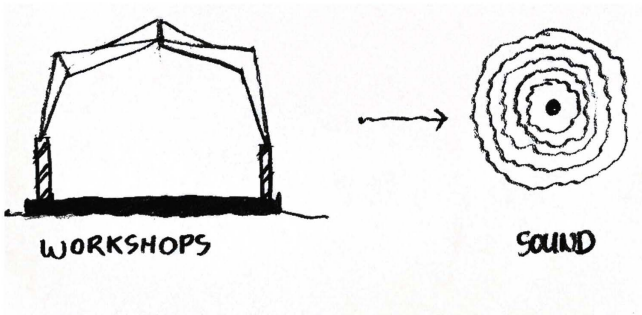



**Figure 96:** Portal frame's abstract shape used to deflect sound (Author, 2020)

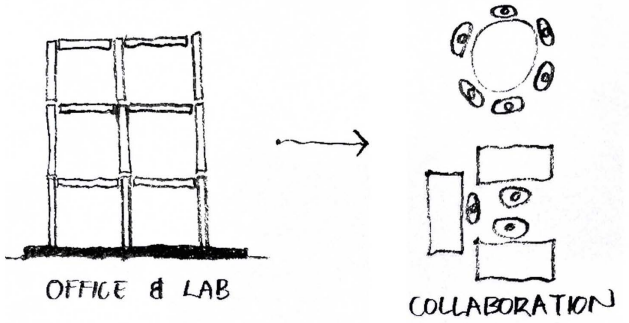



**Figure 97:** Post and beam construction to allow for verticality and a free plan (Author 2020)

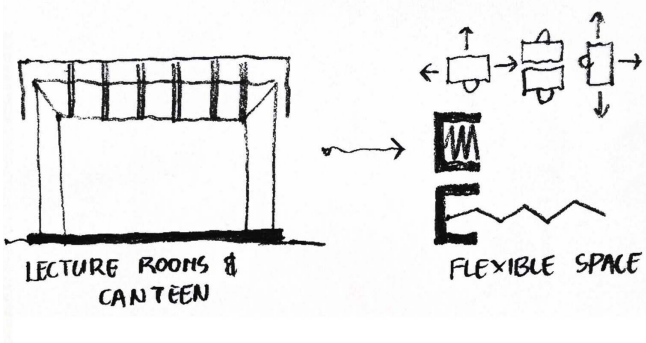



**Figure 98:** Large portal frames to provide natural light and pockets for furniture storage and shutter doors (Author, 2020)

## 4. Landmark:
## The need to build a tall timber structure

Considering that mass timber construction is a relatively new concept in South Africa, the idea of a landmark was explored to create awareness of this kind of construction. To use a landmark in this context means many different things to achieve multiple objectives. First verticality; most landmarks are tall structures in order to see it from a distance and orientate yourself accordingly. Here, a tall structure (timber tower) is proposed not only just for the sake of being tall, but also to make a political statement. As mentioned in chapter 2, legislation limits timber buildings to just two storeys in height (Rees 2018). Therefore, a tall timber tower is proposed to challenge local legislation to amend these policies, as well as to showcase the fact that the technology for tall timber buildings is available.

Secondly, the idea of a landmark will serve as a gateway or threshold to Salvokop and the new development that is proposed. A public park is also introduced to serve as a gathering point for the Salvokop community, where they can engage in social activities such as holding workshops.
Thirdly, a landmark structure of this nature will be used to create awareness of mass timber construction. The use of a translucent second skin will be used to partially cover the building but leave the structure and iconic colour tone of timber exposed. The structure will be visible from a distance to incite curiosity in the public's mind to explore this peculiar structure (Affendy 2014).

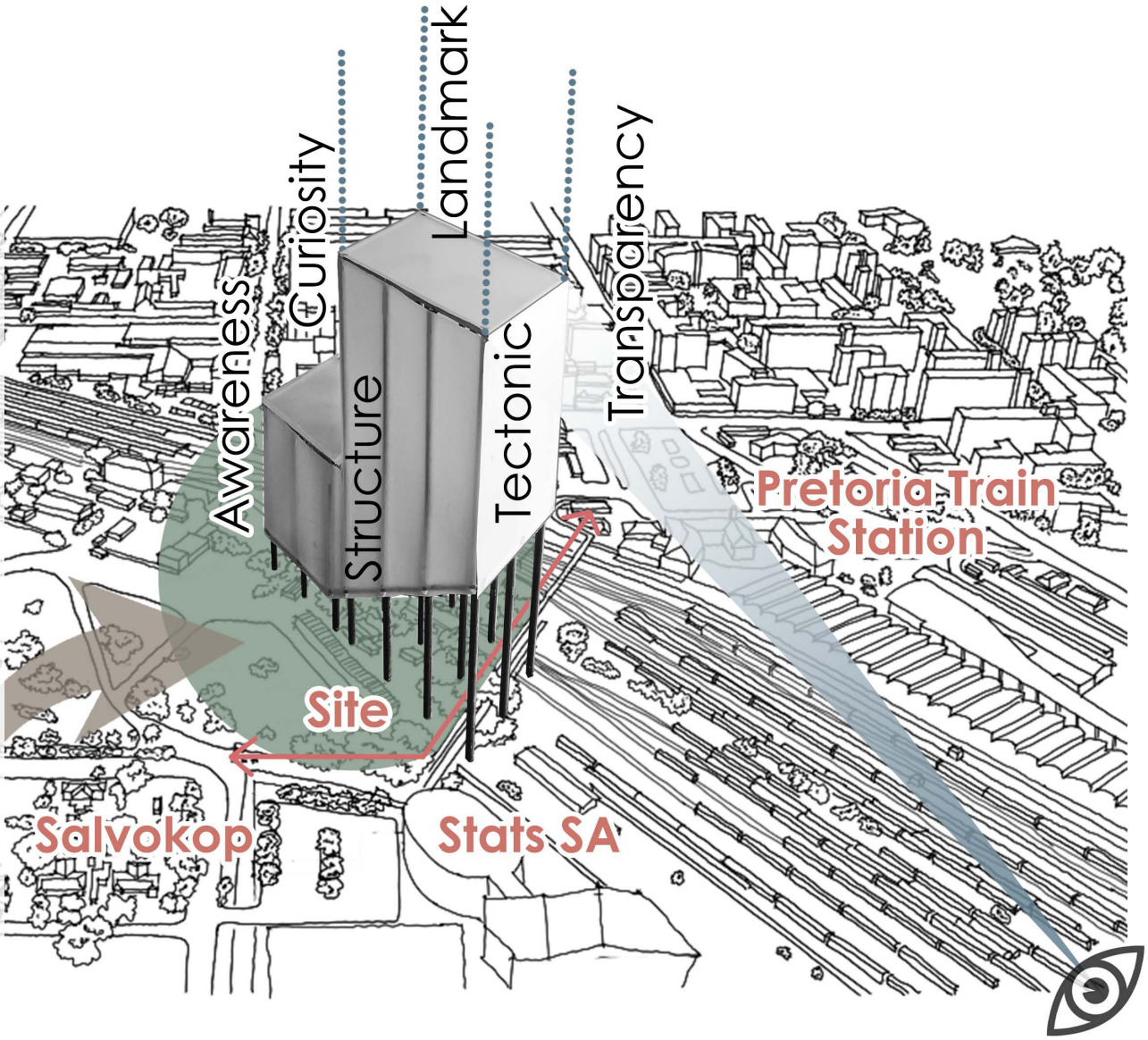



**Figure 99:** Landmark (Author 2020)

# Final architectural concept

## Making

"Architecture finds its expression in the use of structure and materials experienced through space and the effects of light" (Barker 2013:1). Craft-based design will form the basis for the architectural outcome of this dissertation. Barker describes craft-based design as: "The knowledge of buildings traditions and local materials, new technological advances, culture, climate and place. Skill is developed through a physical, hands-on approach fused with haptic sensibility that encompasses both the tangible and mythical" (Barker 2013:2).

The design outcome will be influenced by the paradigm of craft-based design or in this case, making; to be used as a tool to influence the mindset around building construction, local skill, self-satisfaction, sense of accomplishment, building culture and material culture. The final architectural outcome will be a physical manifestation of the theory on which the building was initially based.

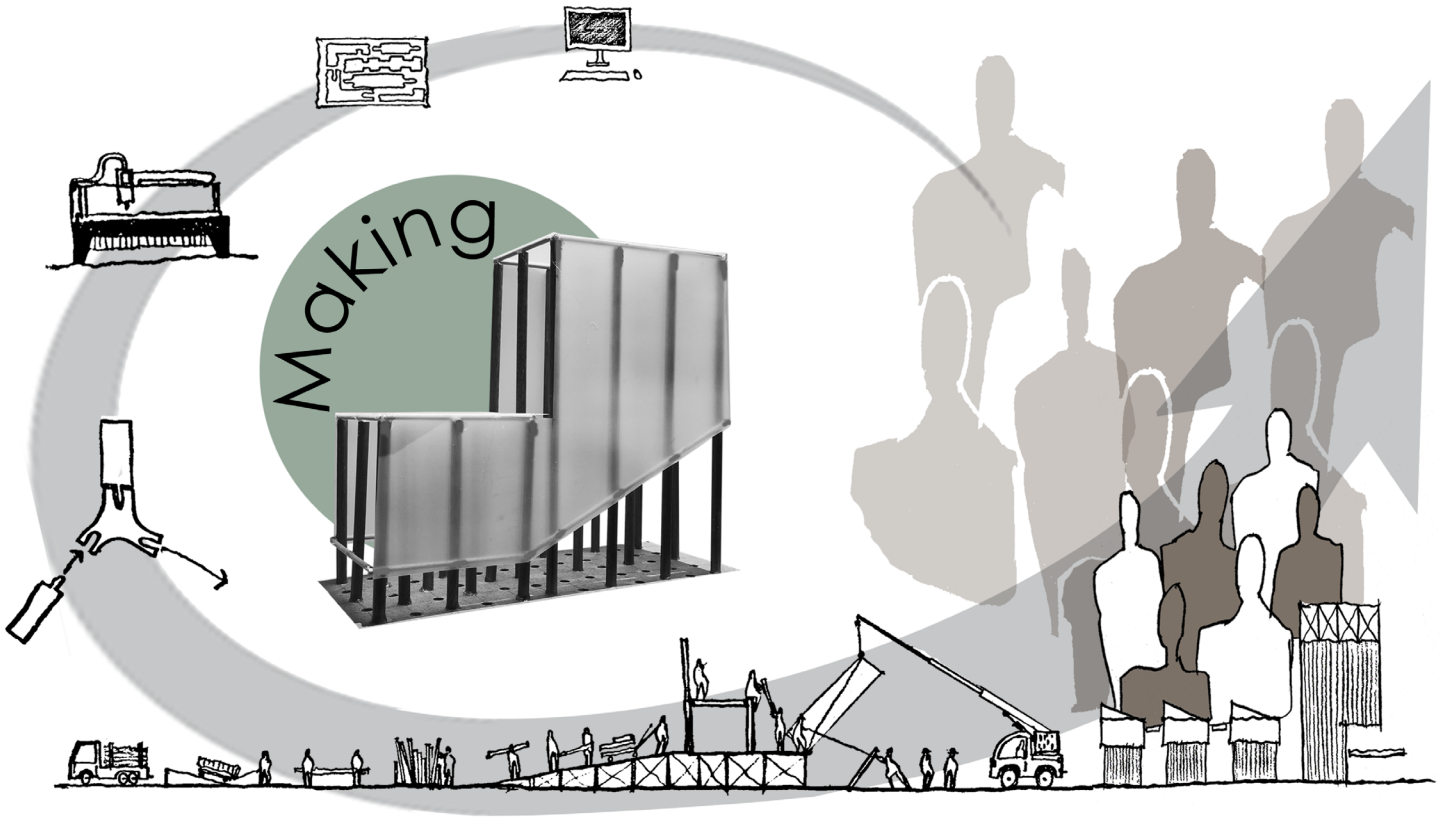



**Figure 100:** Architectural concept: making (Author 2020)

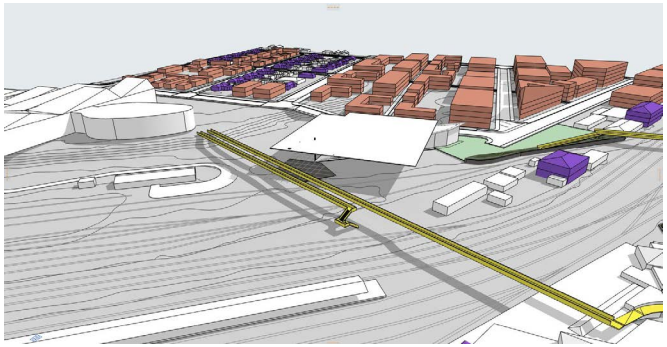
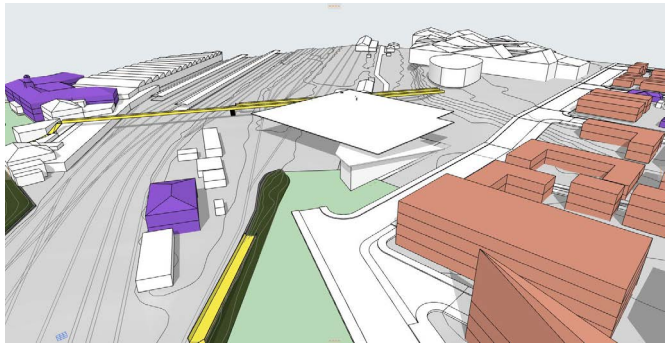
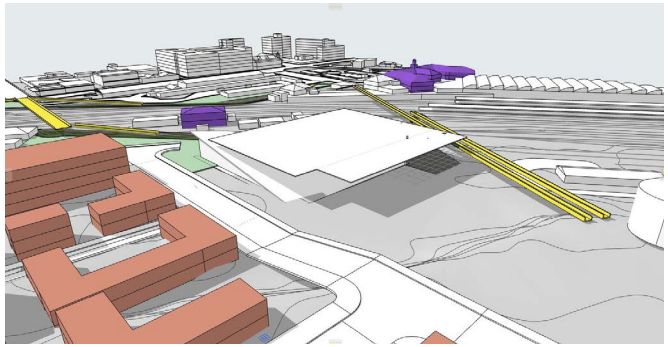




**Figure 101:** Design development 1 (Author 2020)

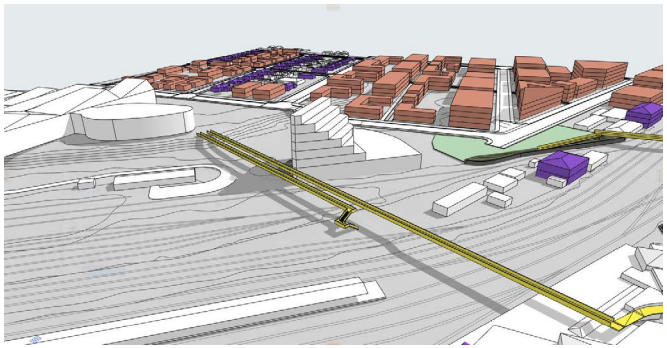
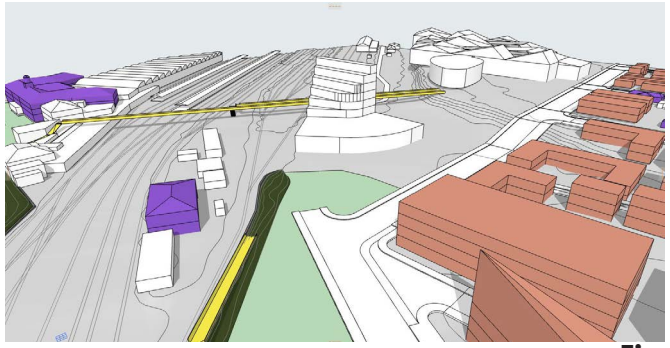
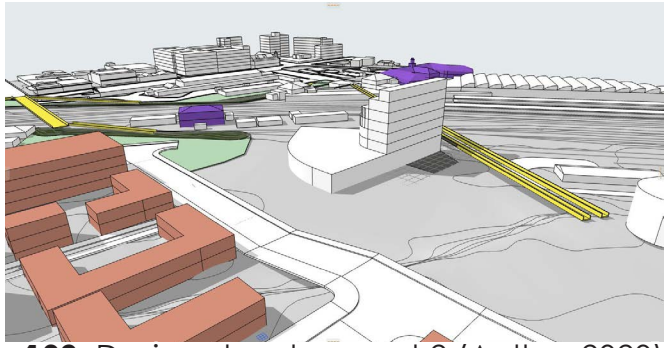




**Figure 102:** Design development 2 (Author 2020)

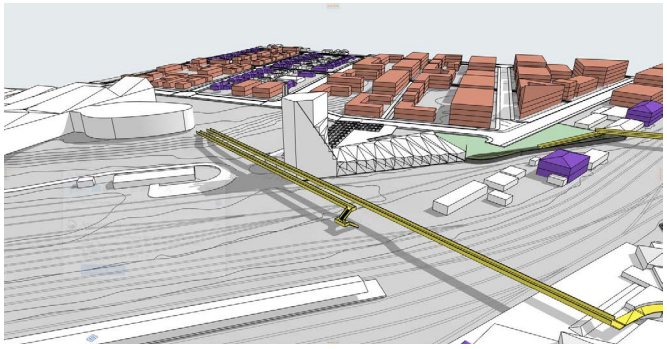
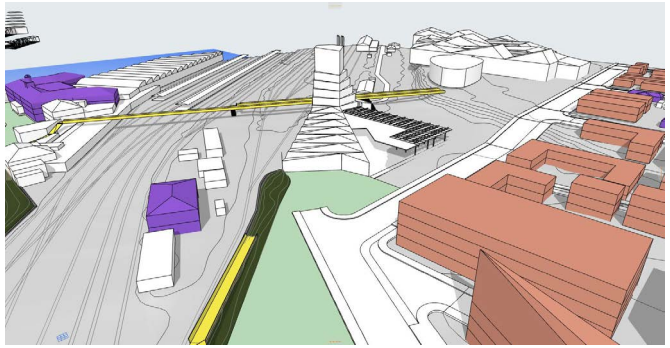




**Figure 103:** Design development 3 (Author 2020)

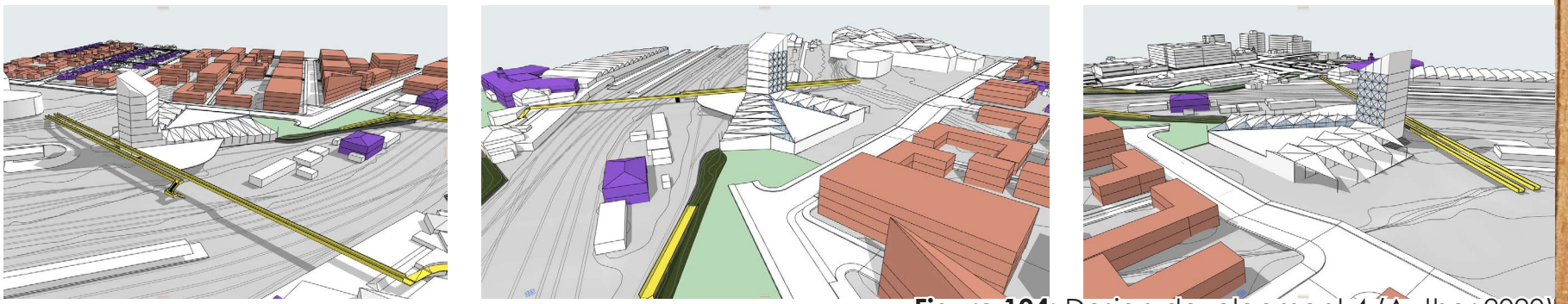


**Figure 104:** Design development 4 (Author 2020)

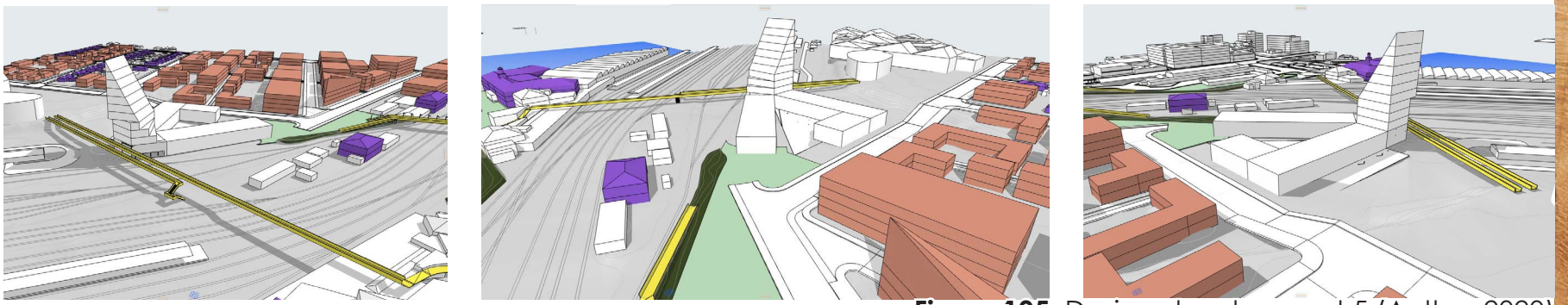


**Figure 105:** Design development 5 (Author 2020)



**Figure 106:** Design development 6 (Author 2020)

# Site analysis – design informants

The existing pedestrian bridge along with the new footbridge, as proposed in the urban vision (Chapter 5), have proven to be valuable design informants for possible access points as well as main circulation routes. Once the main circulation routes were established, programming could be planned. The northern section of the site was identified as dangerous due to the railway lines. A workshop wing is positioned next to the railway line to act as buffer between the railway and the inner courtyard, as defined by the southern wing which will house lecture rooms, ablution facilities and a canteen area.

The two main pedestrian routes are linked by means of a route located in between the two wings. This allows for direct movement through the centre of the building which will be used to create vignettes in the workshops, where pedestrians can look into the workshops on the activity occurring inside, and to subconsciously inform pedestrians about timber construction and research. Two secondary access routes also feed from the central route to access the lecture/boardrooms, ablutions, the canteen and the public park located to the south of the site.

The timber tower is located next to the pedestrian bridge to enable access from the 6 m footbridge to the ground floor. A public vertical circulation route is introduced to allow the public to ascend the timber structure towards a viewing deck on the top floor to further allow interaction with the structure.

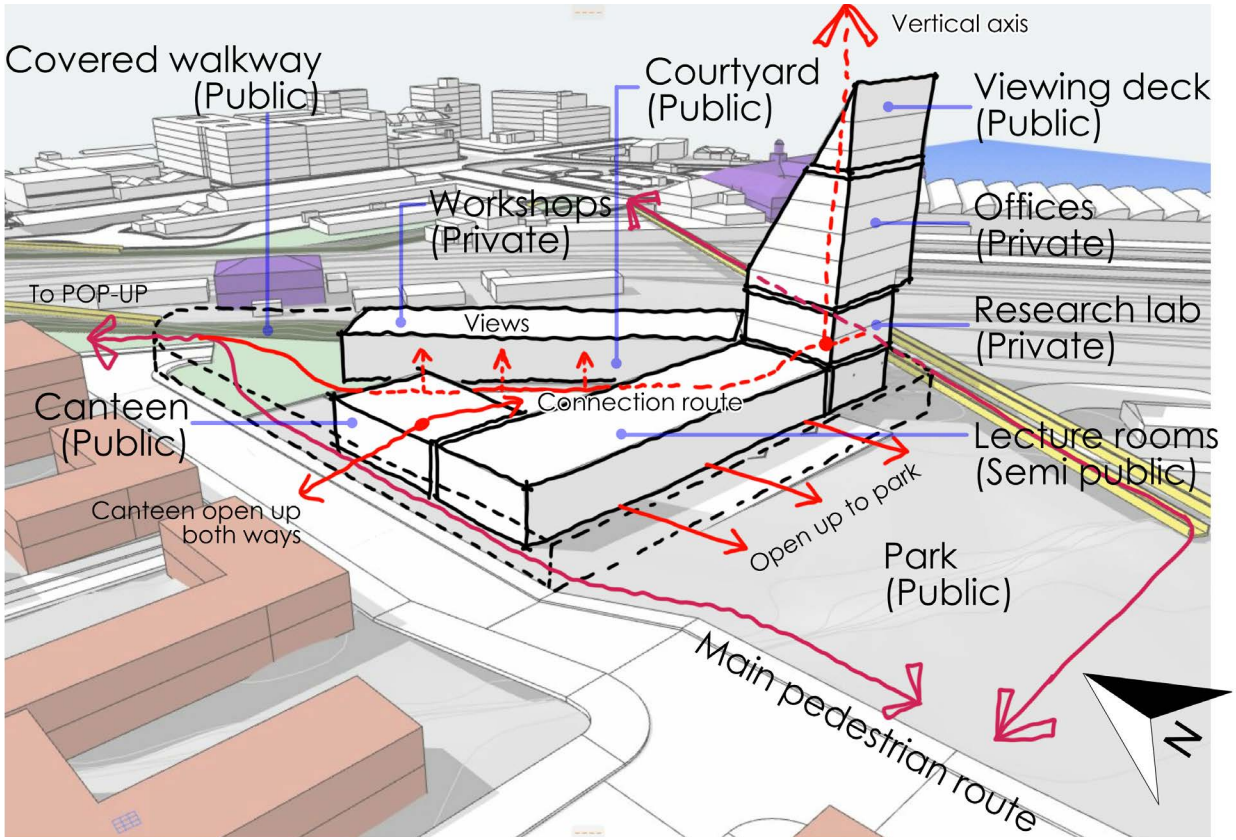



**Figure 107:** Circulation and programming (Author 2020)

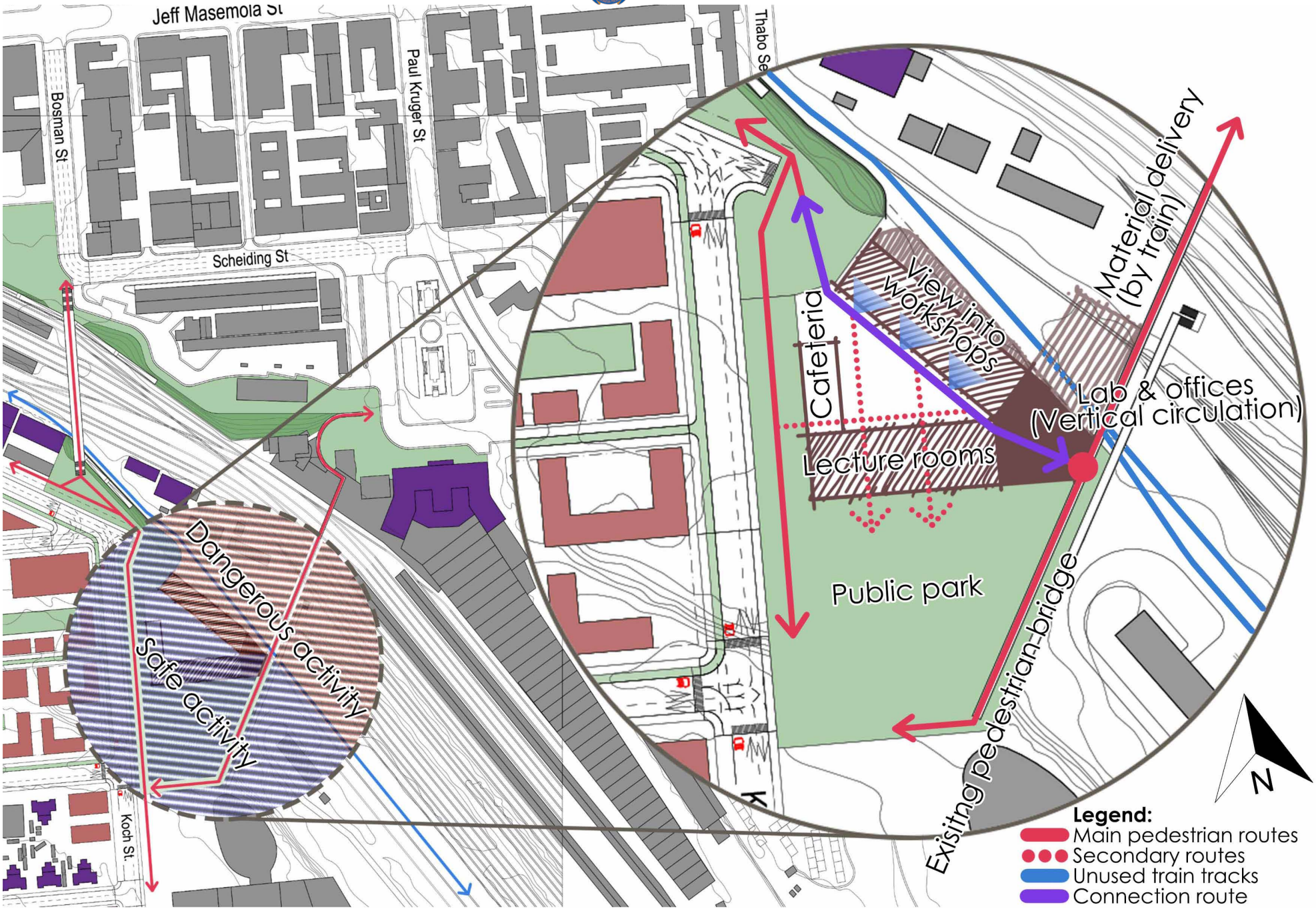



**Figure 108:** Site activity and main pedestrian routes (Author 2020)

# Investigating order through trigonometry

Three major axis lines are identified: the Railway axis line as defined by the railway line to the north of the site; the pedestrian bridge axis line as defined by the existing pedestrian bridge crossing over to the Pretoria Train Station; and the east–west axis line used to orientate a building for optimal north and southern exposure.

When considering the trigonometry, order and alignment of the grid lines, it was soon realised that the existing site conditions and the alignment of these axis lines with one another were random. Therefore, "alteration" elements are used at the railway wing to obtain the desired angles to facilitate the layout of the building footprint. Furthermore, terraces that slant to the back will be introduced to the northern façade of the timber tower to change the building face to an optimal north-facing direction.

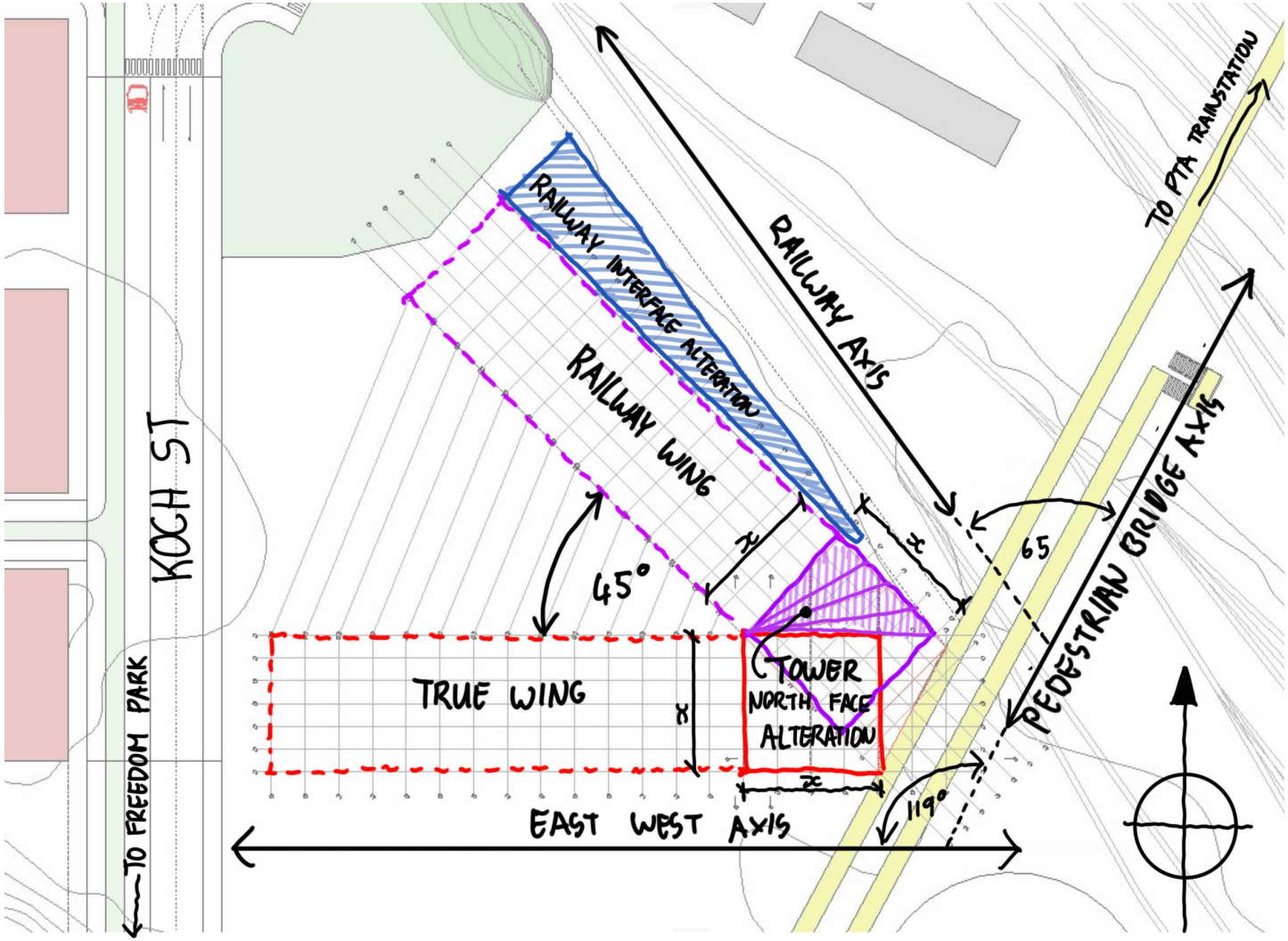



**Figure 109:** Building footprint order and trigonometry (Author 2020)

# Design iterations

This section will take a step back to illustrate the design development, concerns and considerations taken into account as described in previous chapters. A series of iterations was done to establish the form and layout of the design proposal. The final iteration has proven to be successful for the development of further details.

**Iteration 1:**
A landmark building is proposed on top of a landscape plinth, which will enable the pedestrian bridge level to become the new ground level. The plinth could possibly house the workshop's supporting programmes underneath which will include material storage and handling as well as parking.

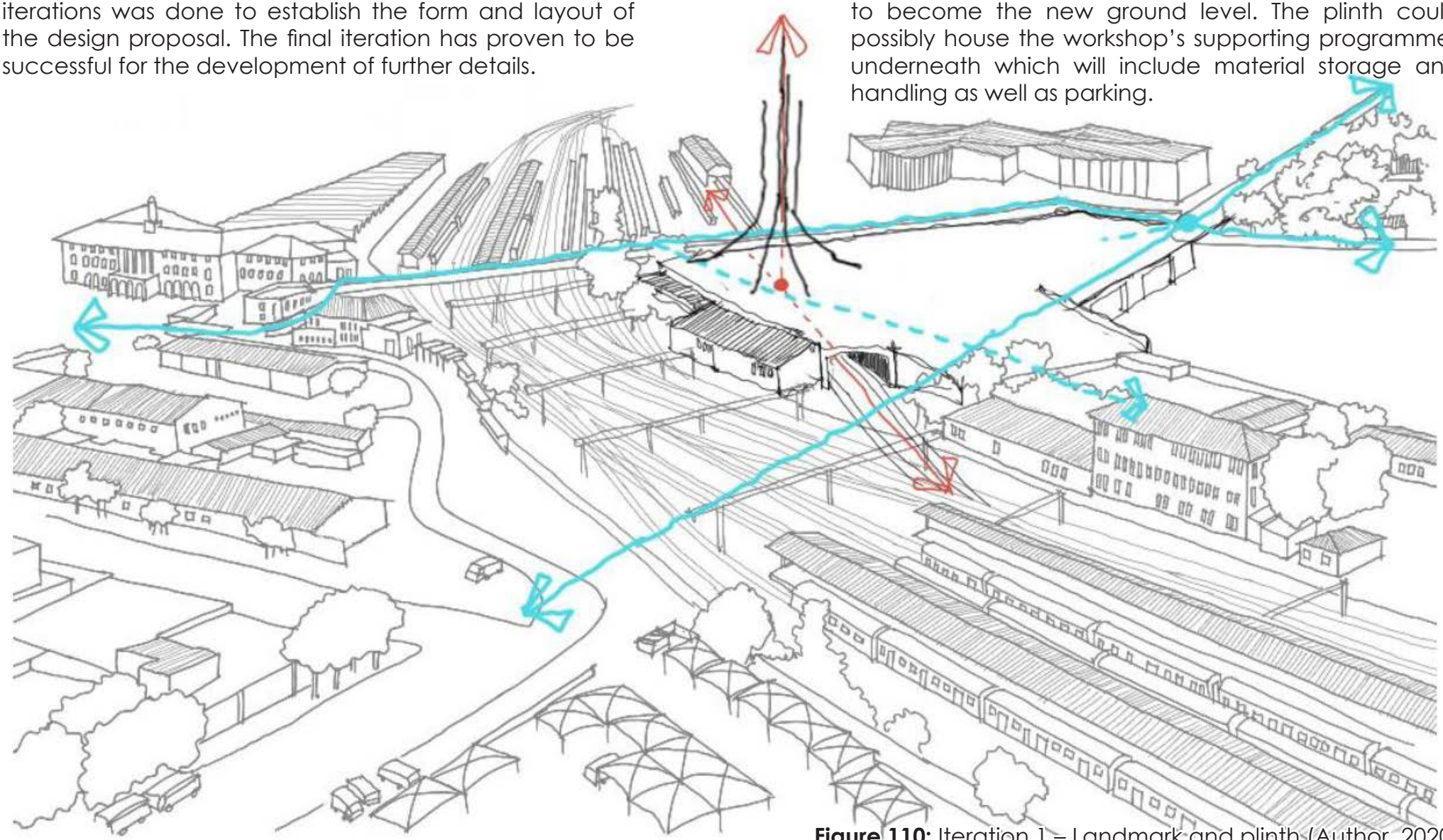


**Figure 110:** Iteration 1 – Landmark and plinth (Author, 2020)

**Iteration 2:**

The Salvokop development was explored to create an urban edge to respond to. The position of the landmark building was also further explored on the landscape plinth. Different heights were experimented with to enable accessibility.



**Figure 111:** Landmark position (Author 2020)

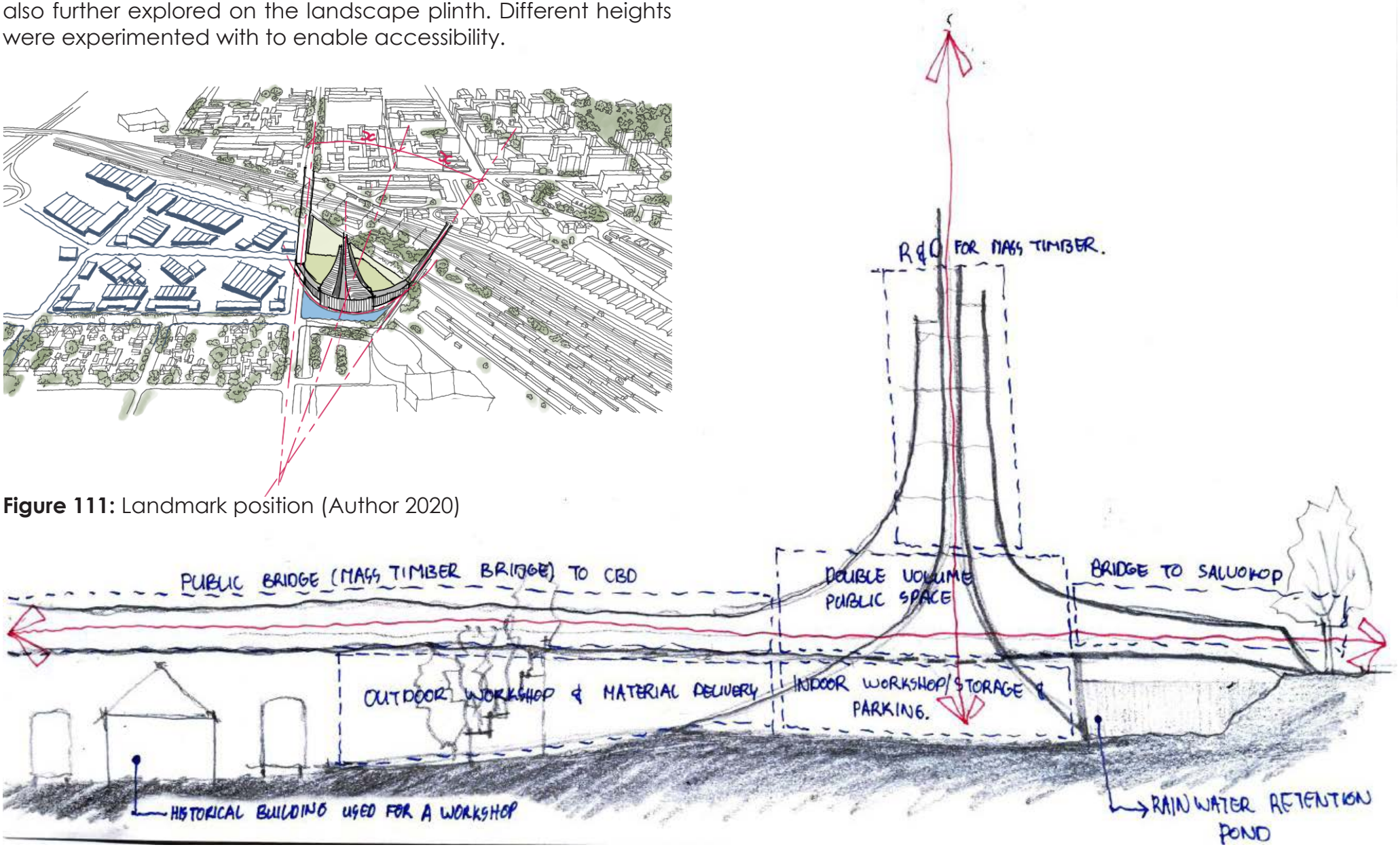



**Figure 112:** Urban edge conditions (Author 2020)

**Iteration 3:**
Scale and programming were explored. The idea of a landscape plinth was discarded, mainly because the plinth would create problematic edge conditions and would result in limited urban interaction. Circulation routes and edges were considered.




**Figure 113:** Exploring scale(Author 2020)

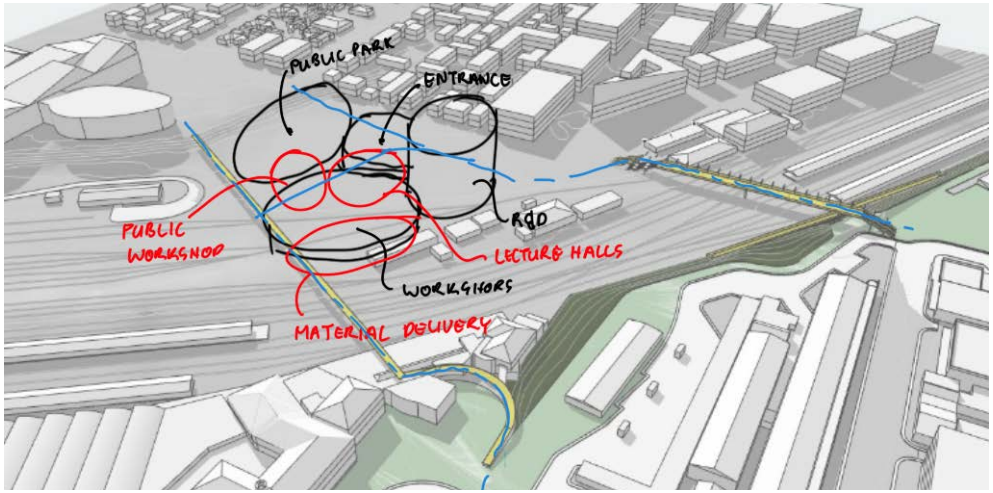



**Figure 114:** Developing site hierarchy through zoning(Author 2020)

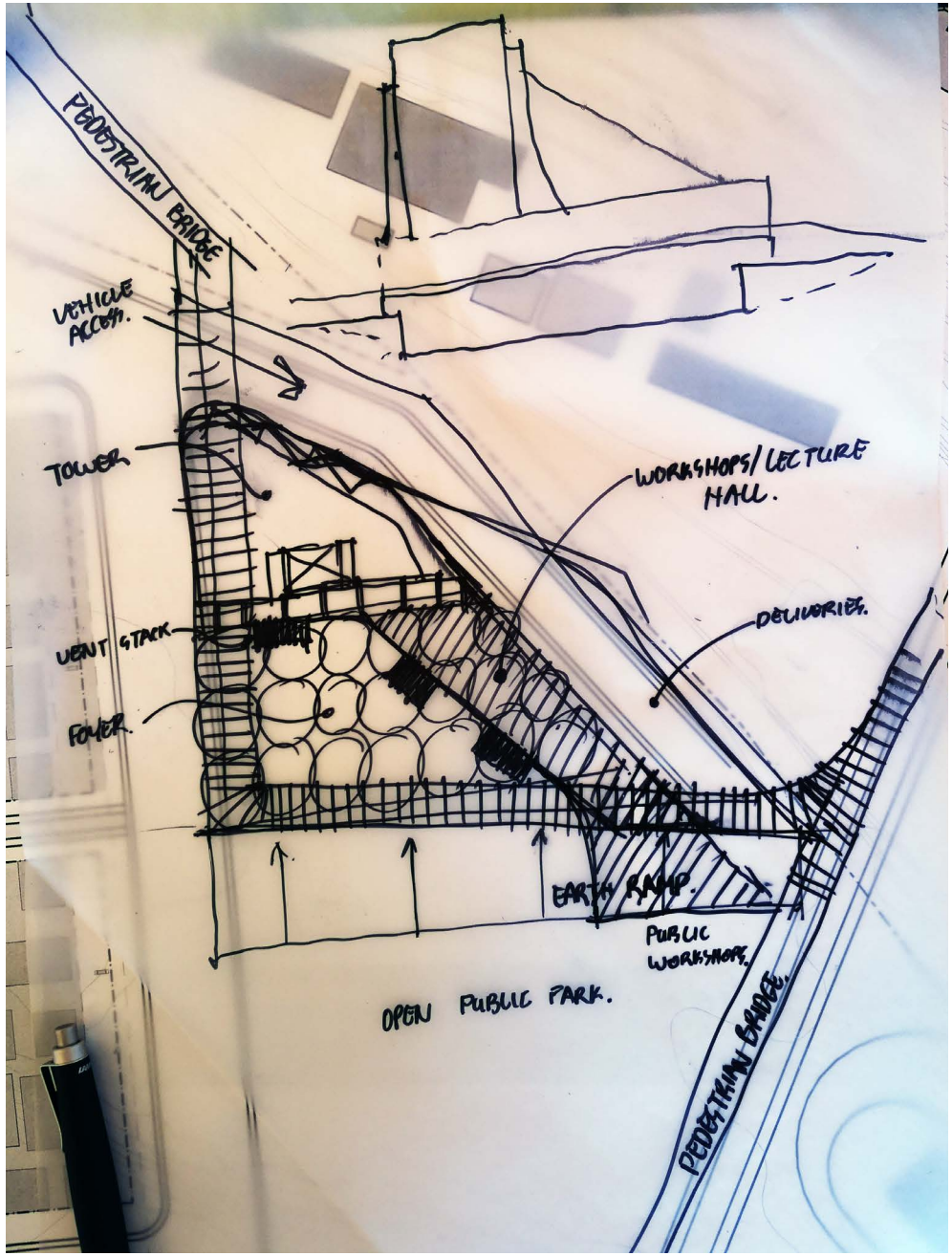



**Figure 115:** Zoning (Author 2020)

**Iteration 4:**

Scale modelling was done to explore form and the building layout. The idea of a ramp towards the north was explored to include a buffer between the railway line and the public park for protection.

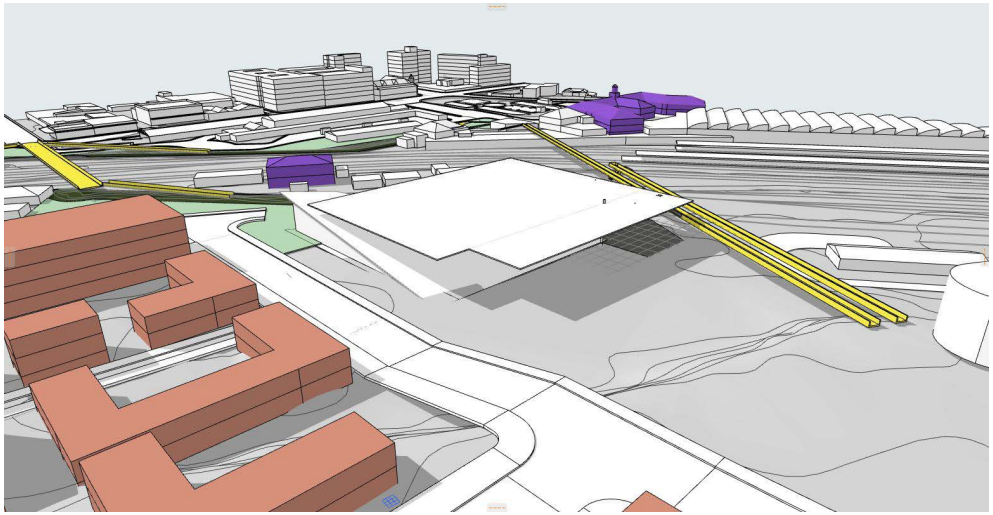


**Figure 117:** Exploring scale (Author 2020)

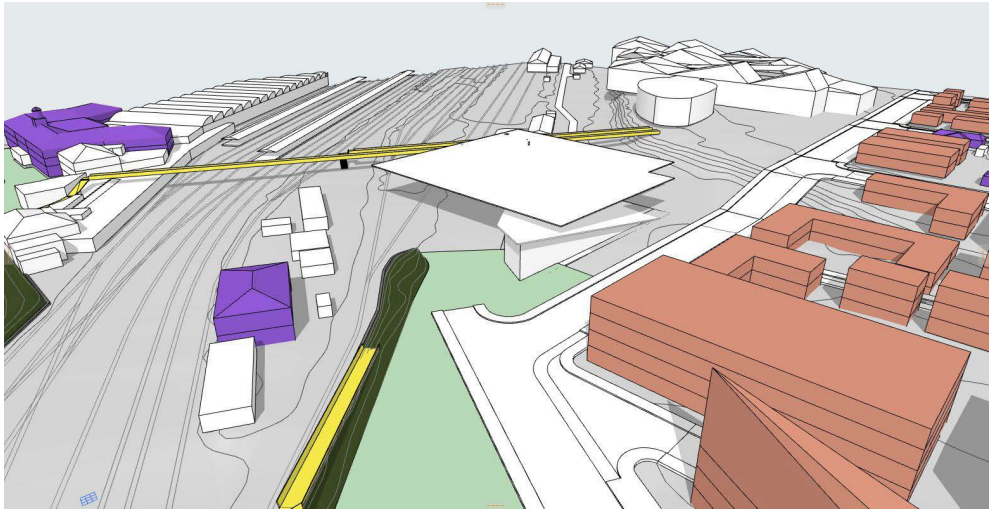


**Figure 116:** Exploring height through a ramp (Author 2020)

**Iteration 5:**

The idea of a landmark was translated into a timber tower. The location of the tower was determined, taking into consideration the shade that would be cast by such a tall structure, as well as view lines.

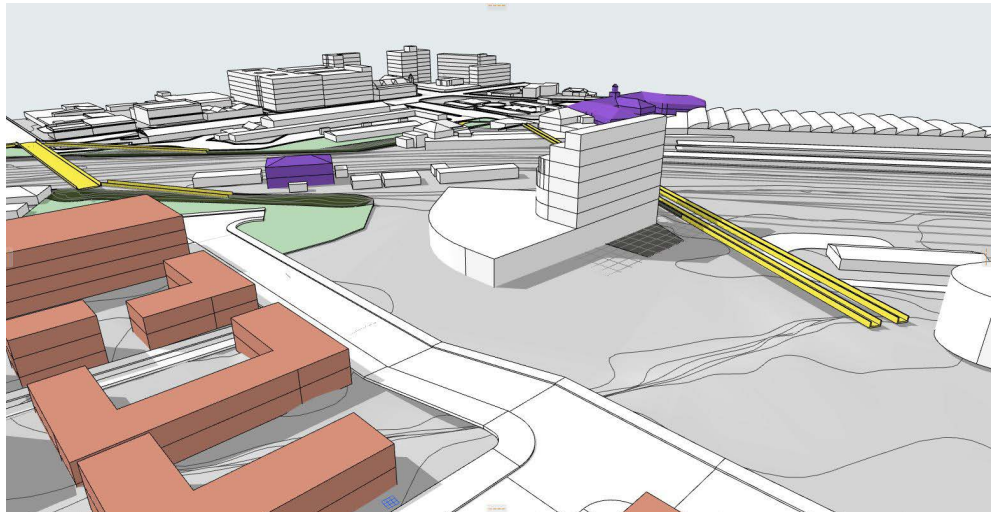


**Figure 118:** Establishing the position of the tower (Author 2020)

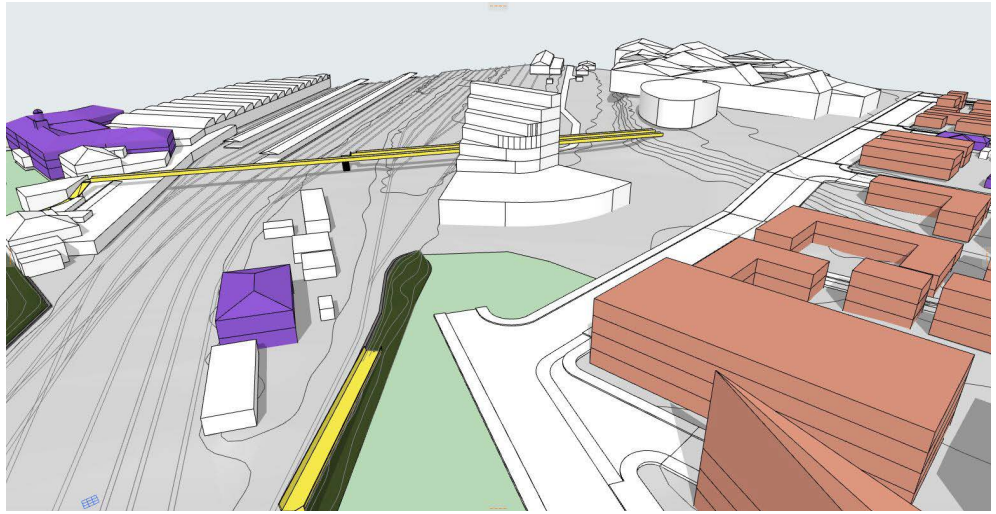


**Figure 119:** Tower as threshold against the pedestrian bridge (Author 2020)

**Iteration 6:**
Building mass was explored. The introduction of two wings stemming from the tower allowed for spaces to be defined. The railway wing responds to the railway line, which is positioned parallel to the train tracks and acts as a buffer. The second wing (true wing/southern wing) is positioned on an east–west axis in relation to Koch Street and the public park. It is also orientated for maximum northern and southern exposure.

A secondary access route from the existing pedestrian bridge is also introduced to allow movement through the core of the building.

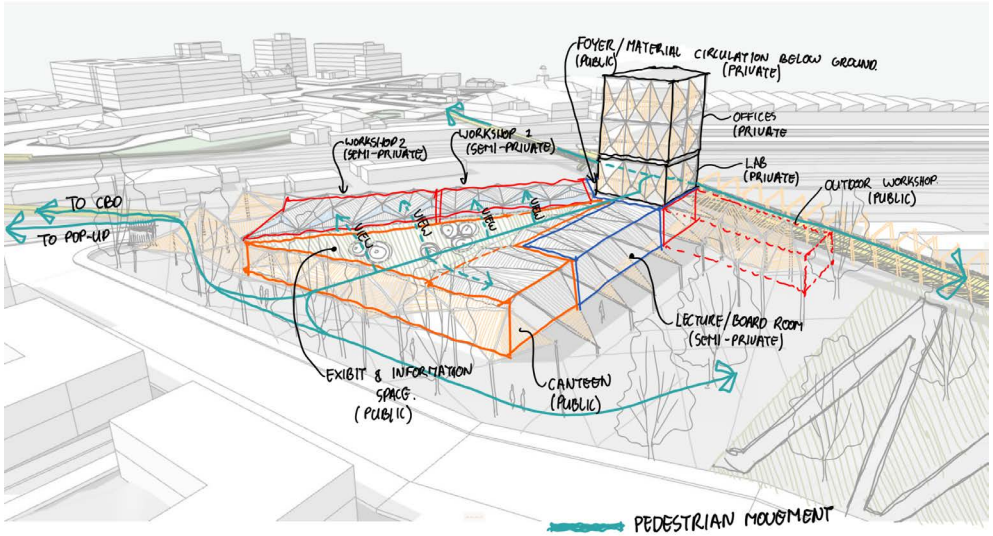



**Figure 120:** Two wings and a secondary access route (Author 2020)

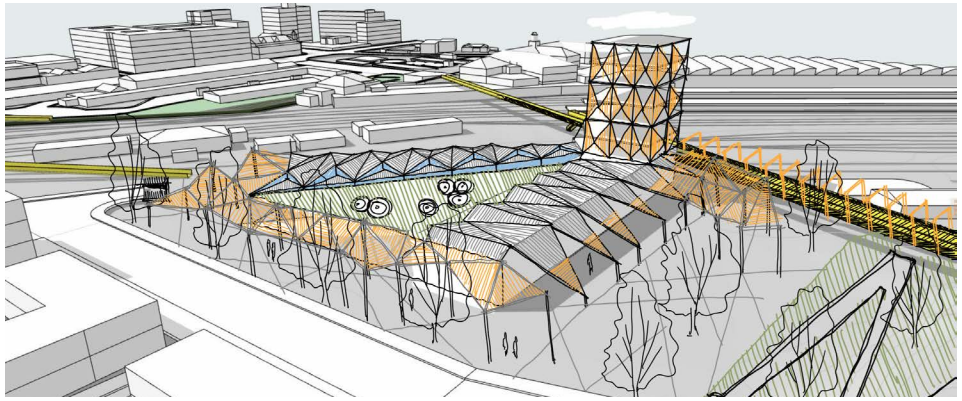


**Figure 121:** Triangulation as an architectural language (Author 2020)

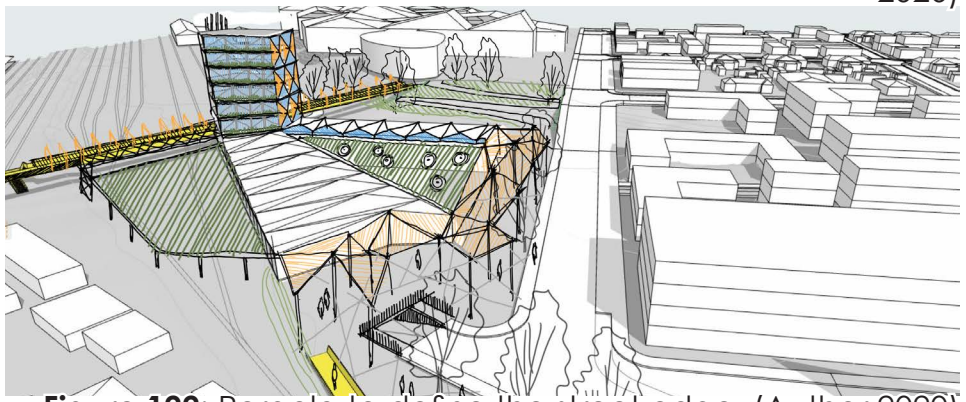


**Figure 122:** Pergola to define the street edge (Author 2020)

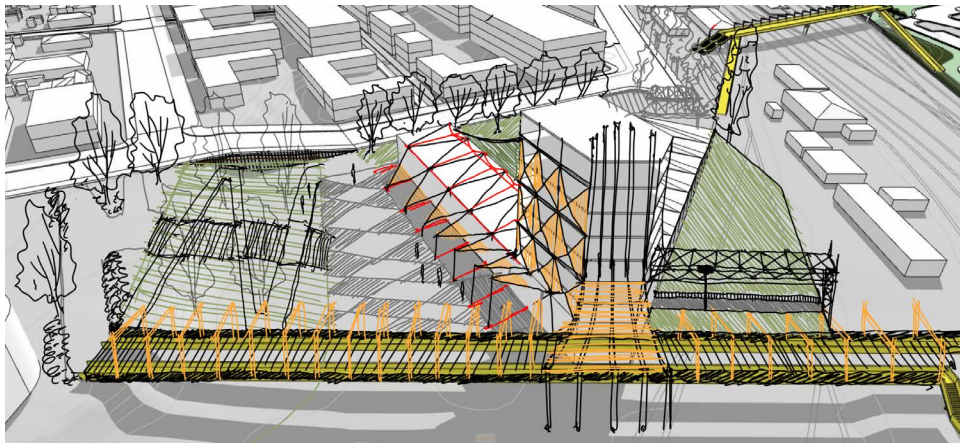


**Figure 123:** Secondary access route via the tower (Author 2020)

**Iteration 7:**

Structural systems were explored with the newly developed form. It was soon realised that with a tall timber building, the most economical way to construct would be to locate the main structural system on the outside of the building as opposed to a structural core. This informed the prominent design language that can be seen from here on – the use of triangulation.

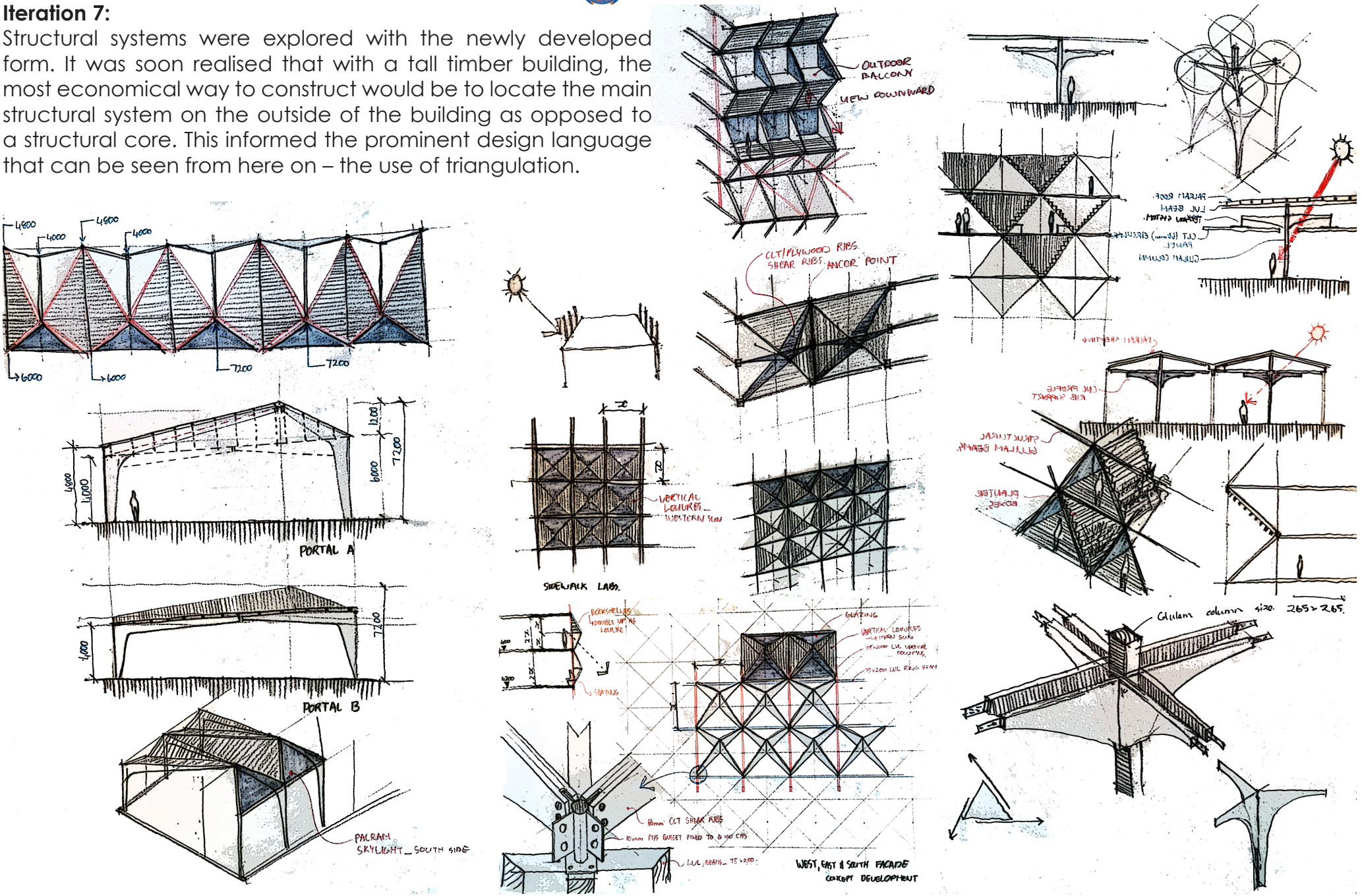



**Figure 124:** Establishing triangulation as the main structural system (Author 2020)

# July exam

**Iteration 8**

At this stage, the overall form and structural system of the building was established. Main circulation routes were defined as well as programming around these routes. From here on more focus was directed towards services, cooling and systems, as well as multiple iterations on structural systems.

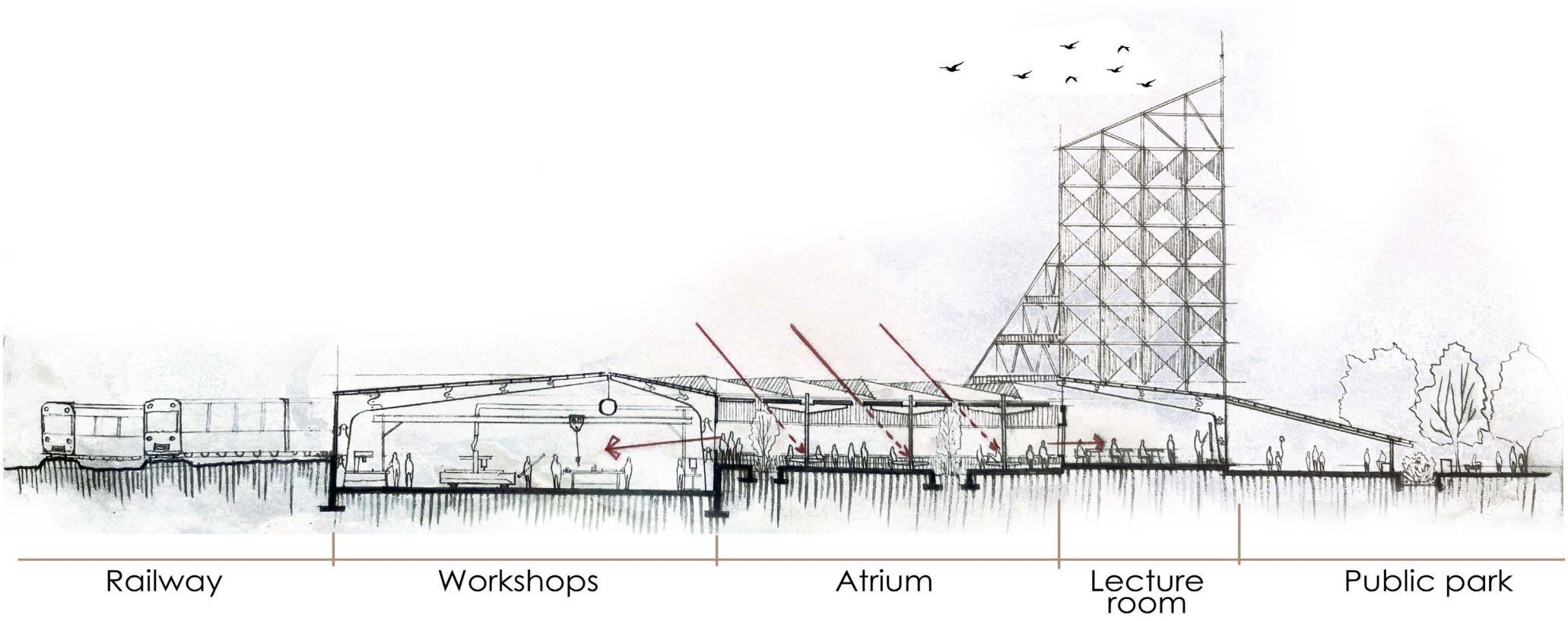



**Figure 125:** Section through the workshop, atrium and lecture rooms with the tower in the background (Author 2020)

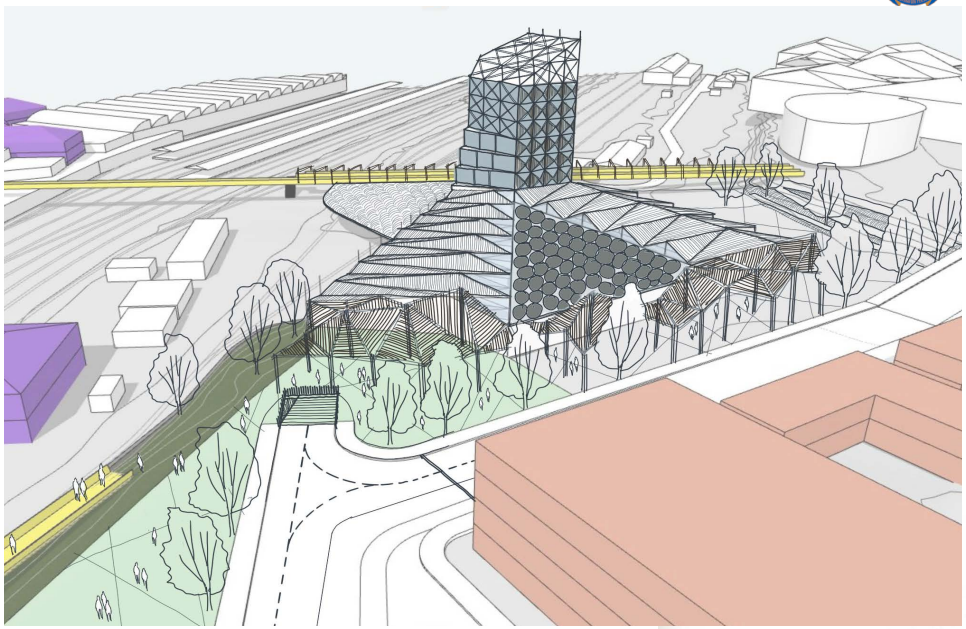


**Figure 126:** North western perspective (Author 2020)

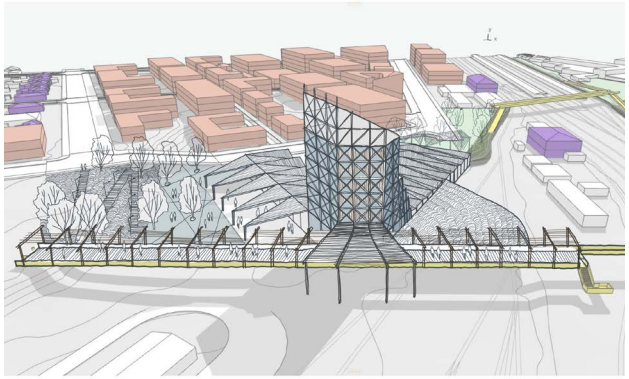


**Figure 127:** Secondary access route via the tower (Author 2020)

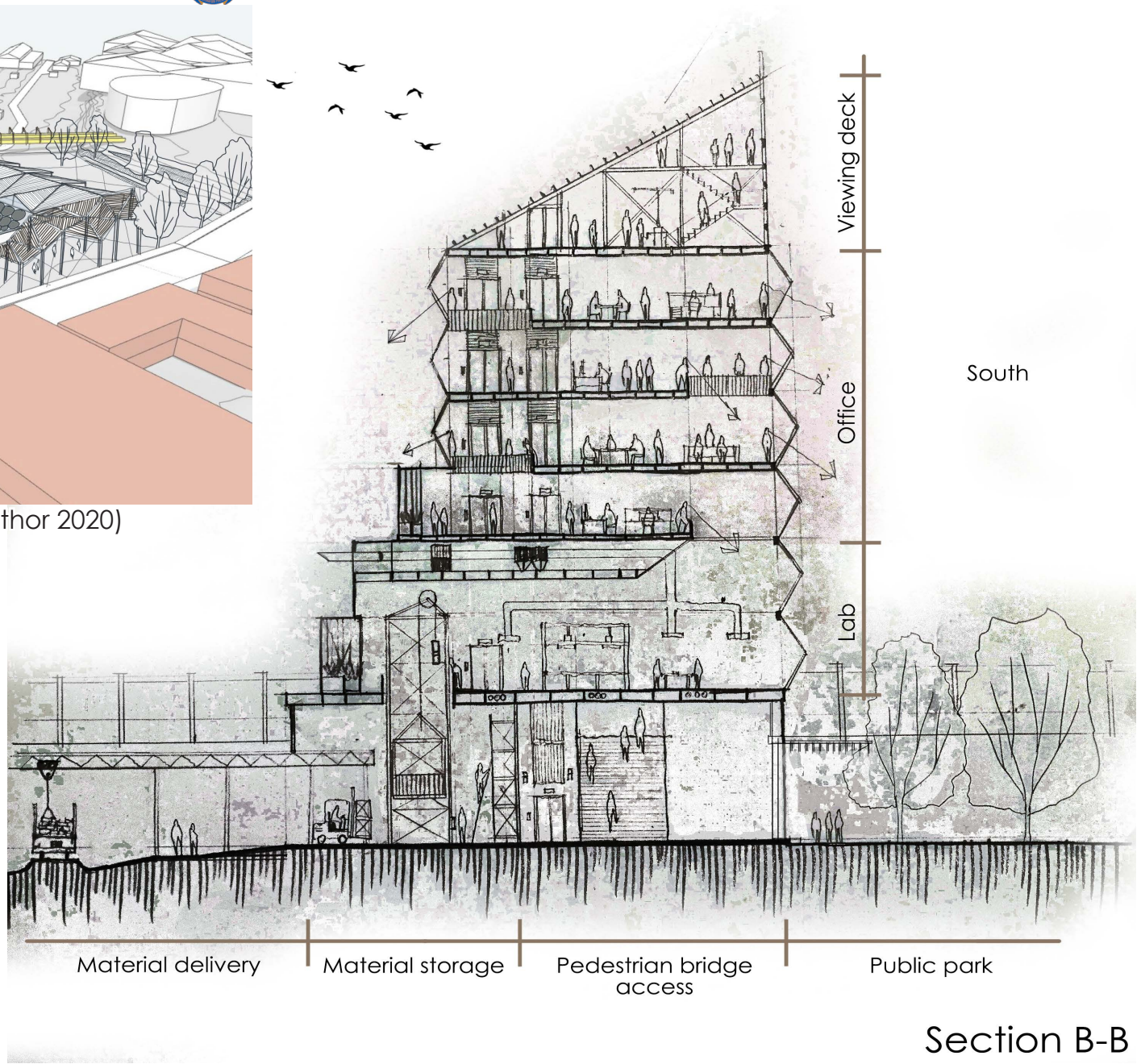



**Figure 128:** Section through the tower showing lab, office and viewing deck conditions (Author 2020)

**Iteration 9:**

Based on feedback from the July exam panel, a second skin was introduced on the east and west façade of the timber tower. This skin will be used to limit solar radiation (protecting the timber) as well as assist with air flow to cool the interior. Possible solutions were also investigated as how the two wings could gracefully merge with the tower's façade.

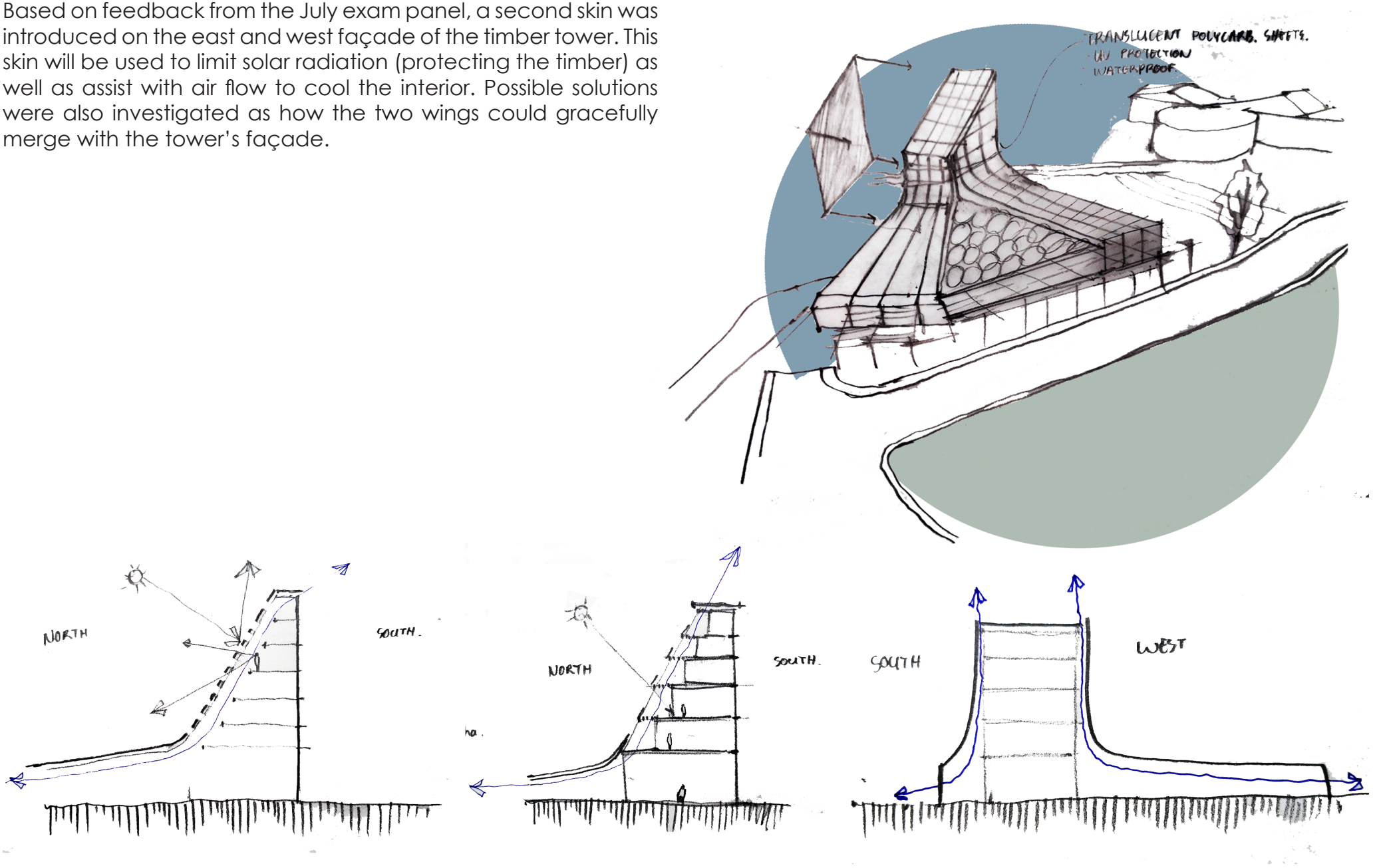



**Figure 129:** Introducing a second skin to the envelope (Author, 2020)

**Iteration 10:**

In revisiting the structural system to integrate a second skin in the envelope of the building, an in-depth study was done to explore how the materials that are going to be used can inform the design outcome. The standard CLT panel size that can be produced in South Africa is 8 m x 2.4 m. These dimensions were translated on cardboard, where various cut outs were explored, keeping in mind material wastage and the optimal use of one panel.

This resulted in a single member that can be mass produced and which will ultimately inform the grid as well as floor-level heights. A second concept model was developed to explore how CLT can be used as beams to support a roof, bearing in mind material wastage, joints and panel sizes for beam span calculations.

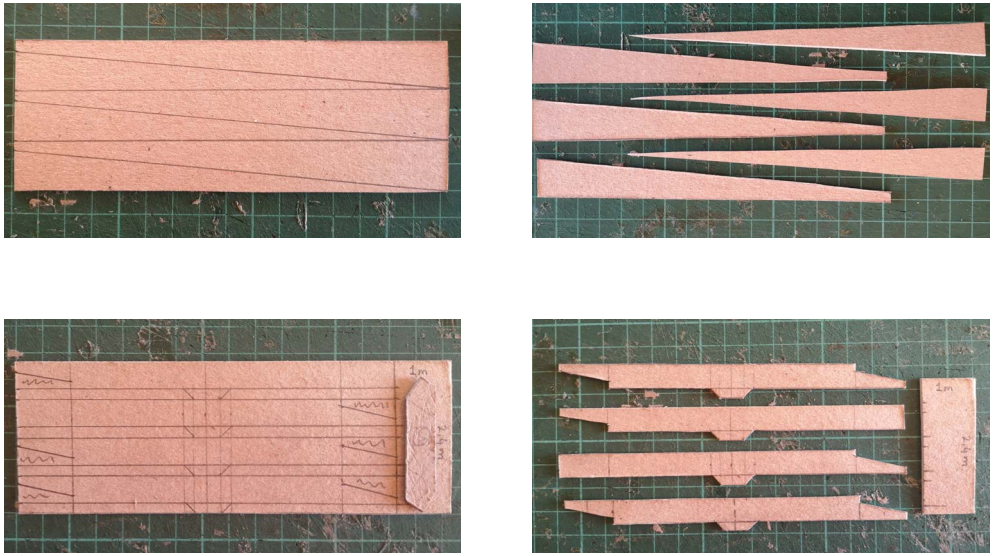


**Figure 130:** Exploring economical member cut-outs from one sheet of CLT (Author 2020)

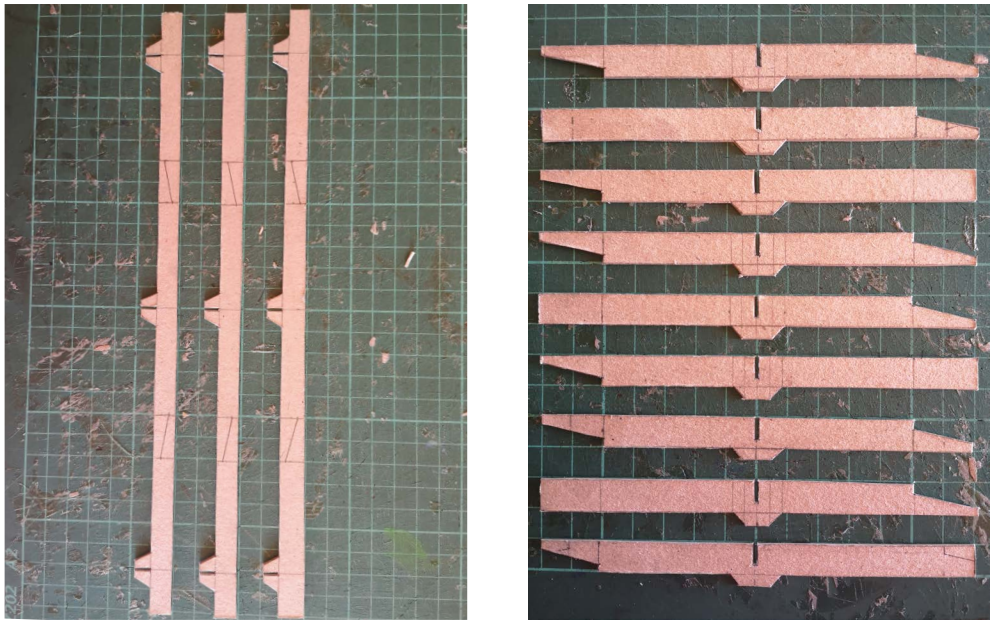


**Figure 131:** Exploring scarf joints to create a strong connection for a longer spanning beam (Author 2020).

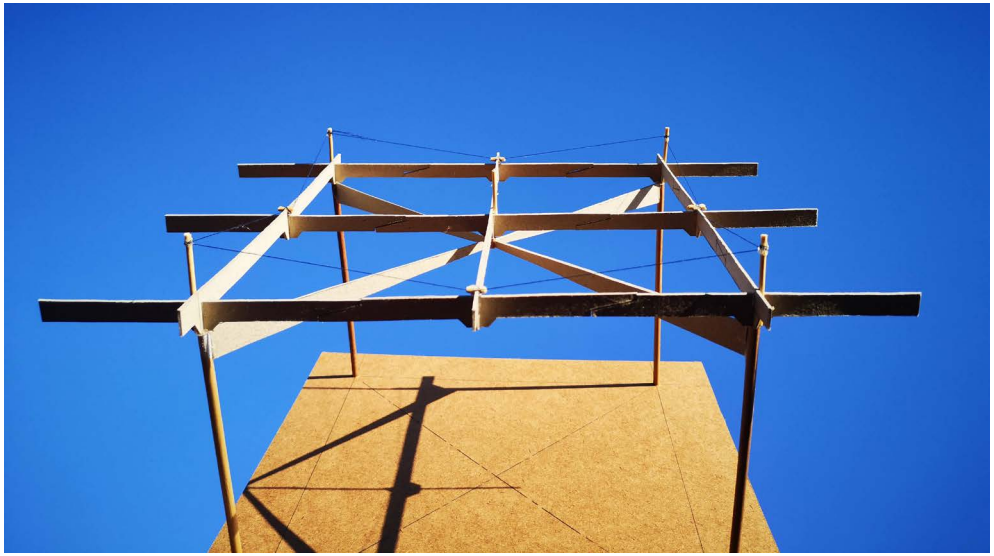


**Figure 132:** 1st Structural system developed (Author 2020).

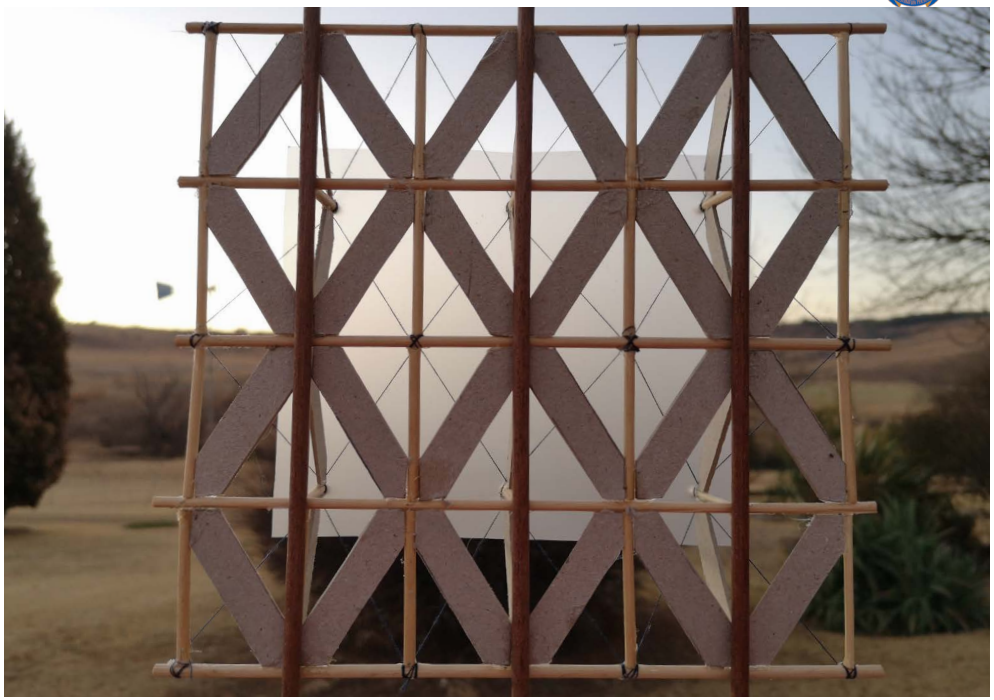


**Figure 133:** 2nd Structural system developed (Author 2020).

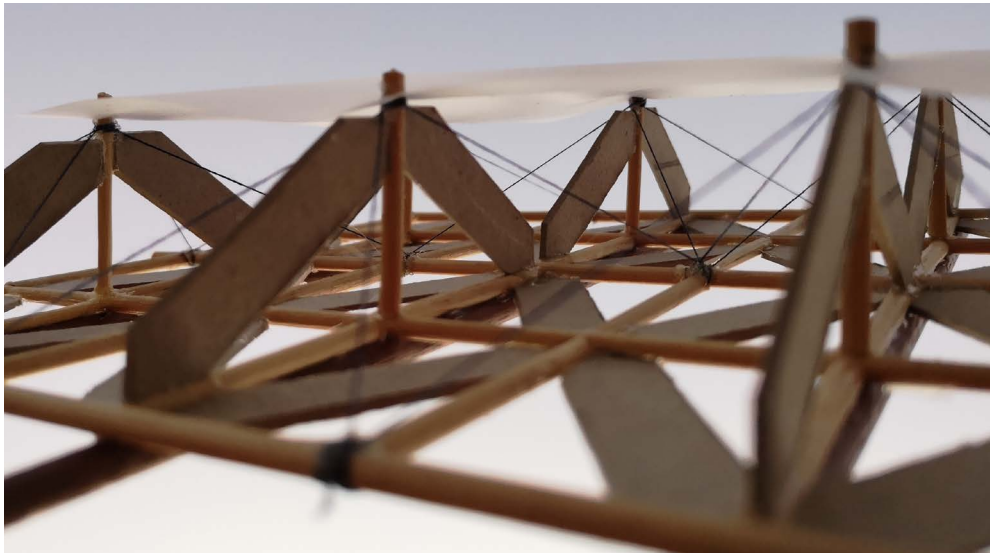


**Figure 134:** The use of cables to provide additional support (Author 2020).

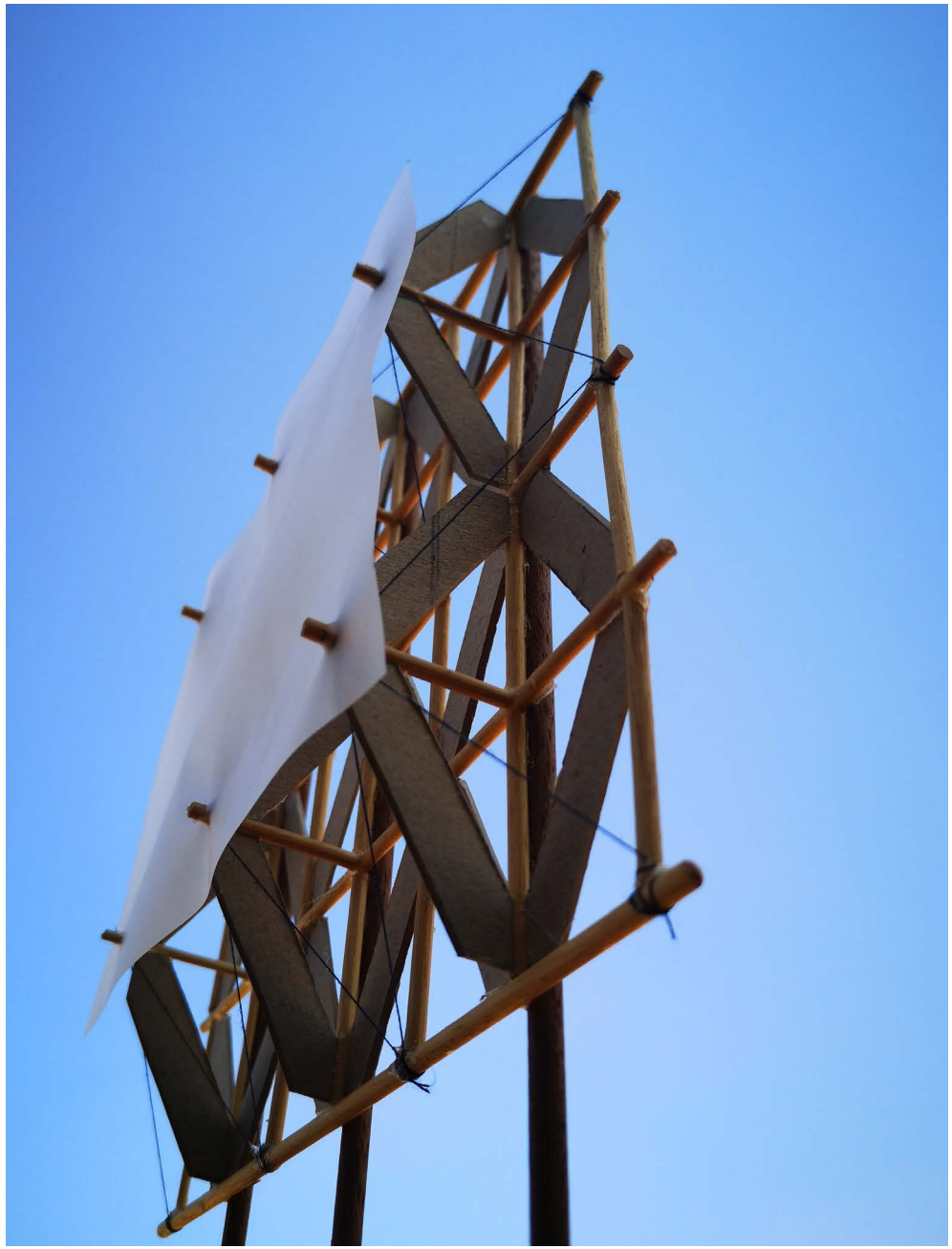


**Figure 135:** Façade system with an integrated second skin (Author 2020).

**Iteration 11:**

Addressing the geometry of the timber tower. At this stage the tower's geometry still seemed a bit bulky. Precedents like the Shard and the Renzo Piano Workshop **(page 55)** by Renzo Piano informed the shape of the tower. The north façade was sloped at a 60-degree angle that was also informed by the structural system and dimensions of a standard CLT panel size. This allowed for the weight of the building to be cut by almost by 50%, resulting in smaller structural members being required to carry the imposed loads, as well as to define the triangular aesthetic even more, with the tower becoming thinner and thinner as it ascends into the sky.

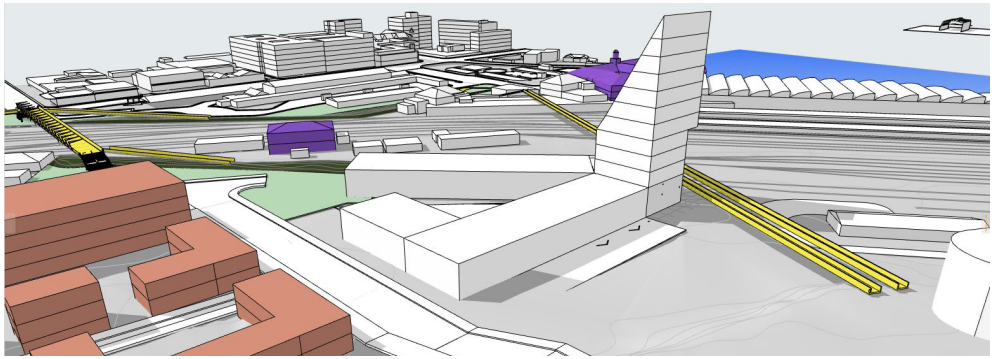


**Figure 136:** Exploring the tower's geometry (Author 2020).

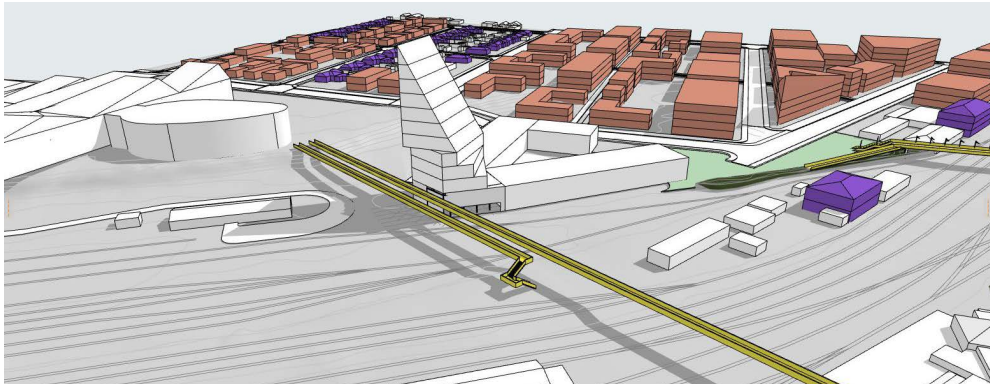


**Figure 137:** Developing the threshold (Author 2020).

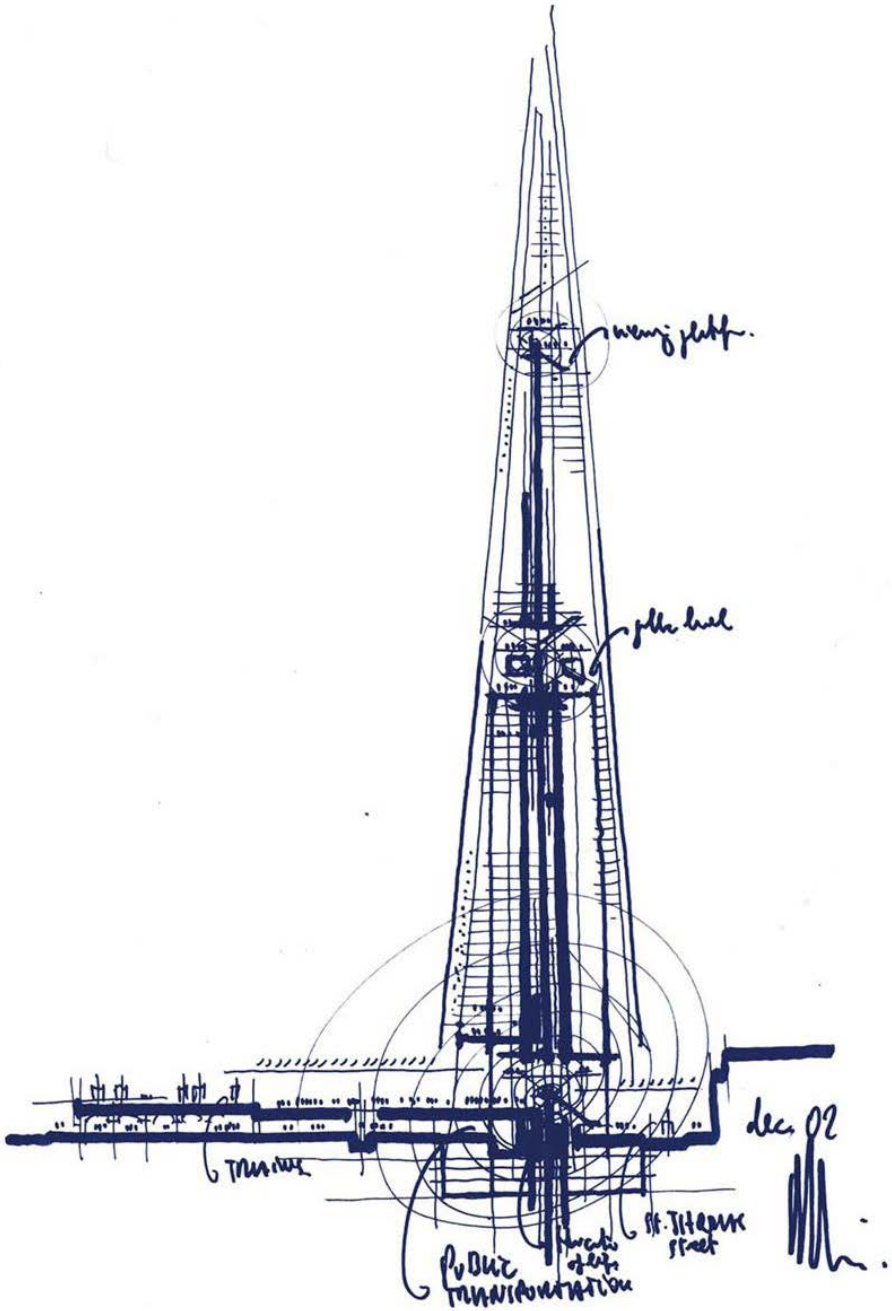


**Figure 138:** The shard conceptual sketch (Piano 2009).

**Iteration 12:**

The structural system for the second skin was refined and re-imagined for a roof system to allow the wall of the towers to merge gracefully with the roof of the southern wing. It was also discovered that the cavity created by the second skin and the building envelope allowed for the introduction of a service wall. This is similar to the service wall of the Sainsbury Centre **(page 57)**, which allows for all of the electrical, plumbing and cooling ducts to be located in one central spine, which is easily accessible to maintenance workers and out of the way of the building's interior, allowing for a more flexible open space.

A building plenum with a rock store was also introduced below the building so as to rely on mechanical cooling only instead of air-conditioning.



**Figure 139:** Tower to conference centre connection (Author 2020)

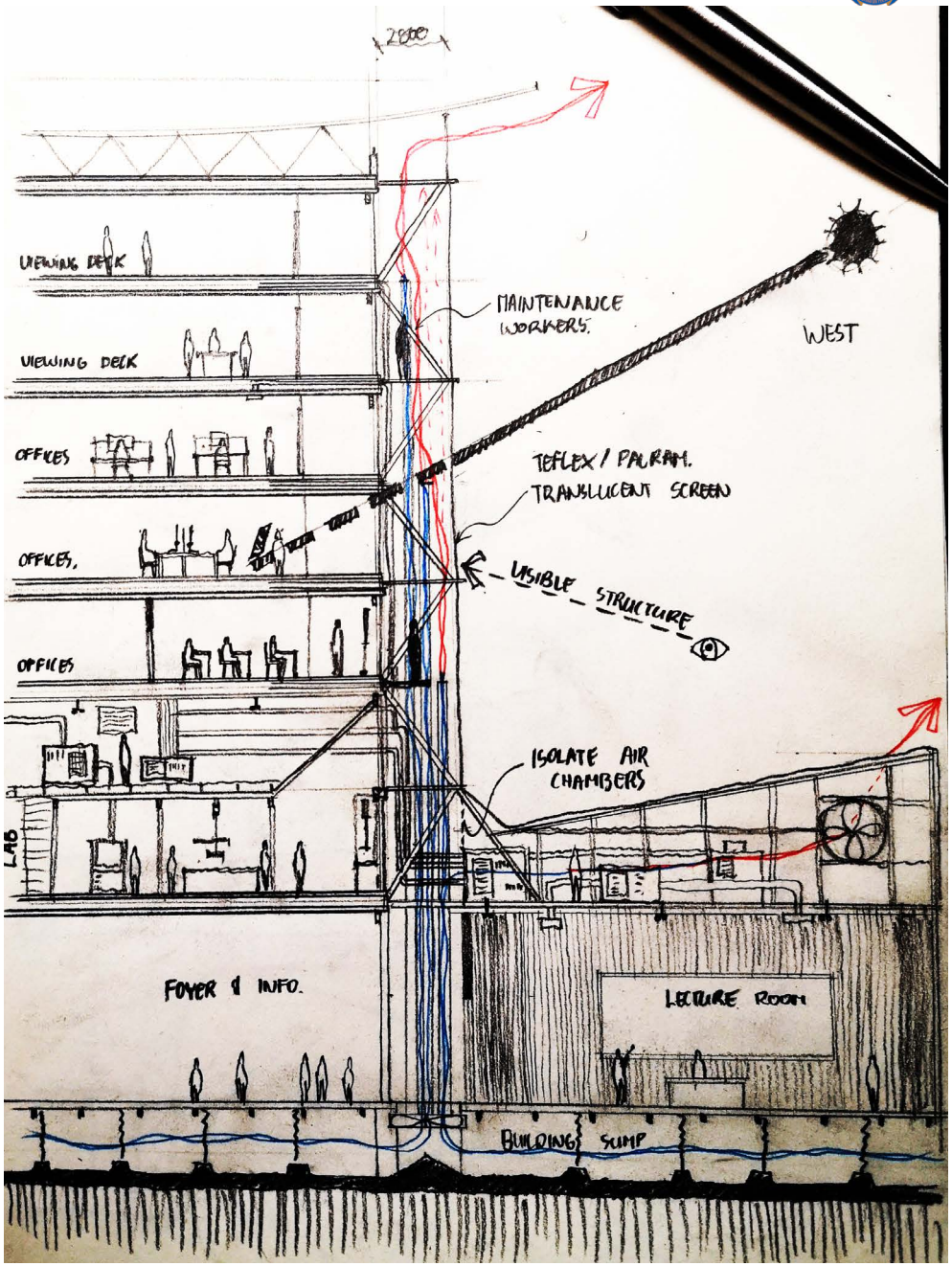



**Figure 140:** Section indicating the cooling mechanism strategy and services (Author 2020)



**Figure 141:** Front view, conference hall conceptual roof exploration (Author 2020)

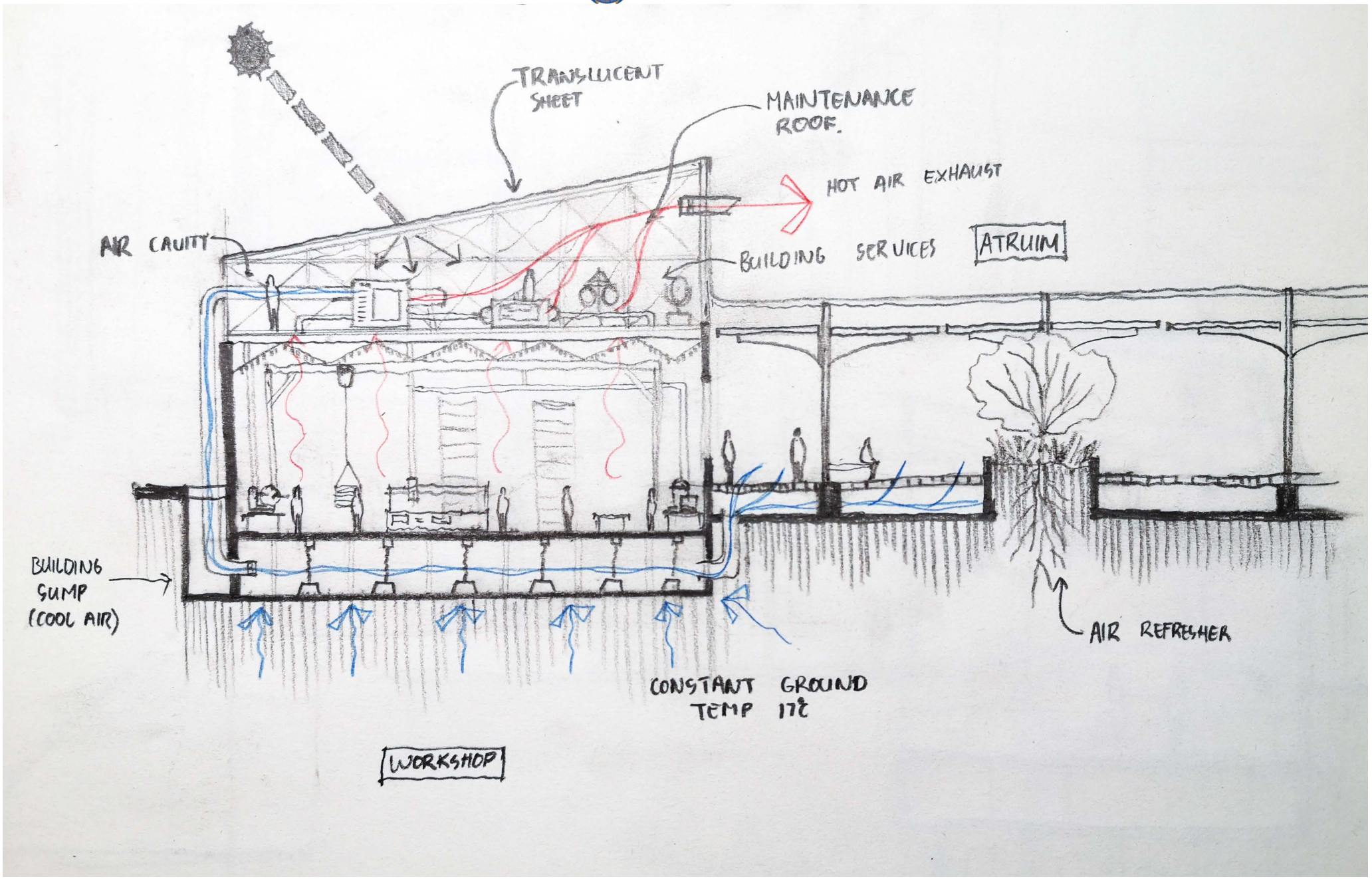
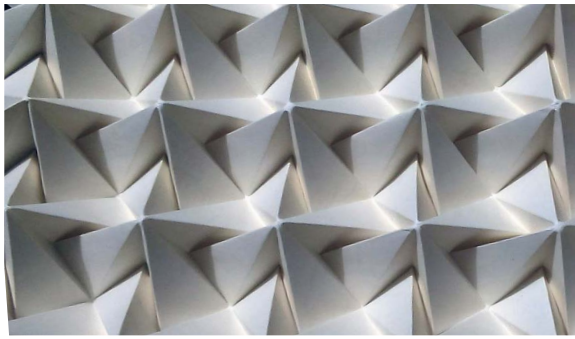
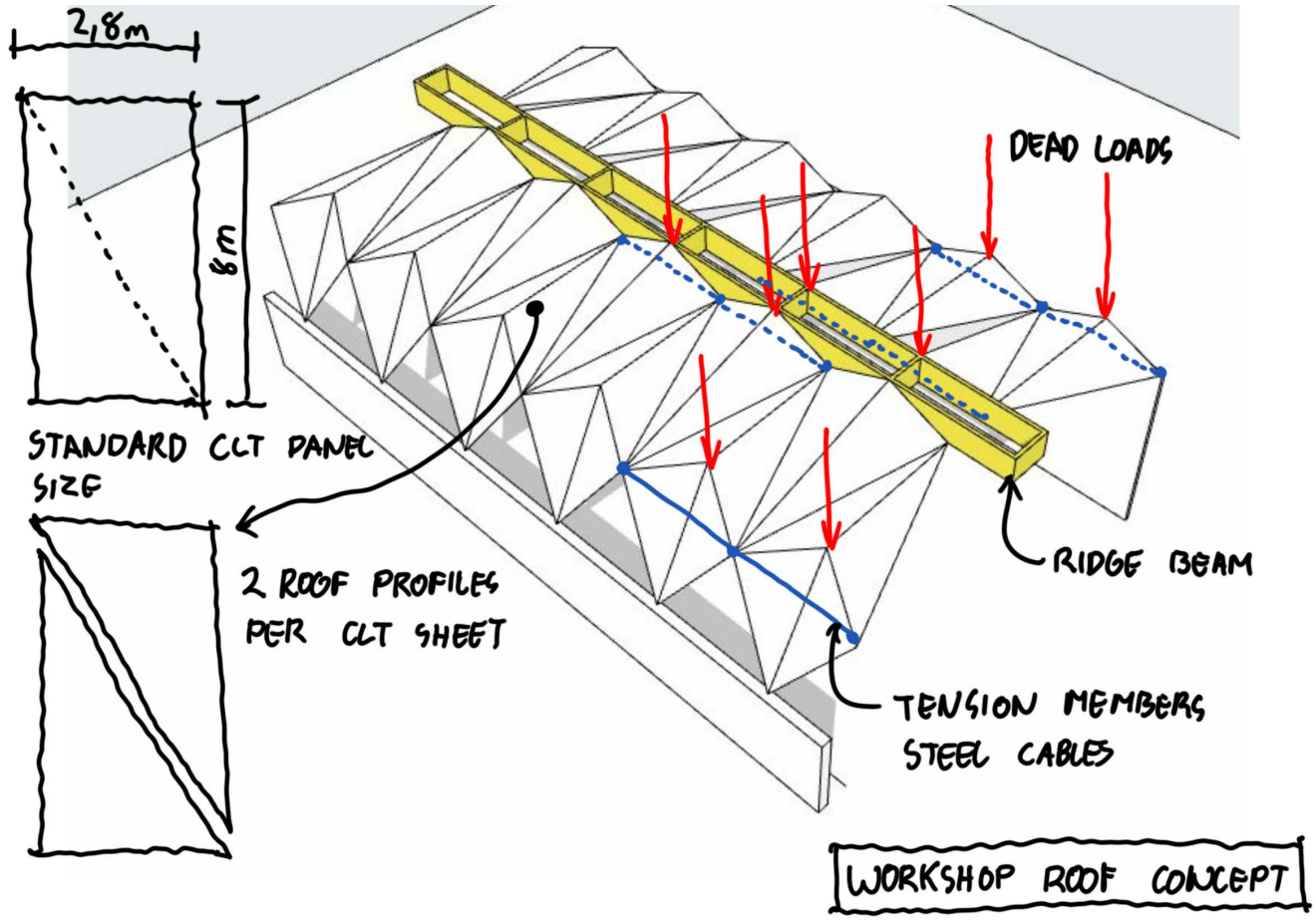



**Figure 142:** Section through the research workshop, with a heavy emphasis on services and cooling strategies. (Author 2020)

The use of timber was also re-imagined to suit the appropriate programme as discussed earlier (Chapter 6: Conceptual generators). Standard CLT panels are used for the construction of the workshop's portal frames. These panels are cut diagonally to create triangular shapes, which are then positioned next to one another at different intersecting angles to create an abstract triangular form that is inspired by origami patterns, where a single piece of paper is folded to create a very strong structural system. The abstract form that these panels create allows for sound deflection as well as a rigid structure that can span 18 m without support and sufficient head space to house all the services. This element can be pre-manufactured as a member to be mass produced and installed.





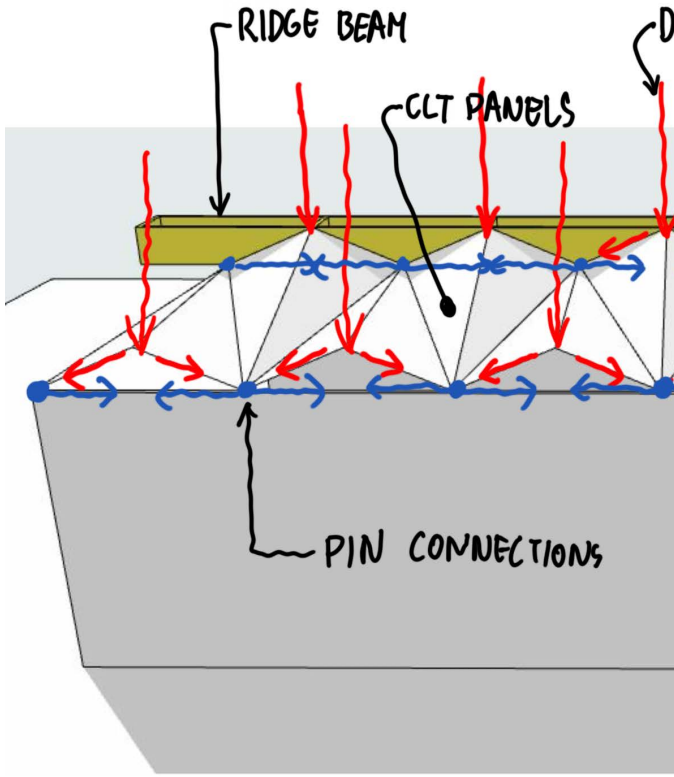




**Figure 143:** Roof structure informed by a standard CLT sheet size which is cut diagonally to create a triangular member (Author 2020).

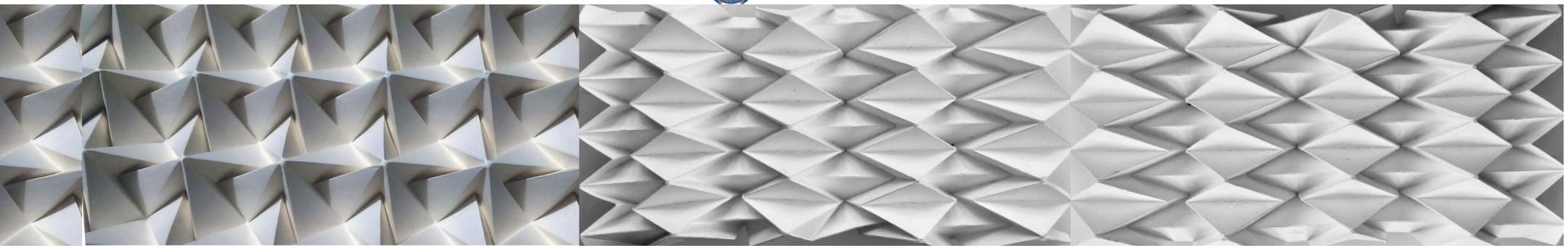


**Figure 145:** Origami patterns as a conceptual driver (Cutfoldtemplates.com 2020).

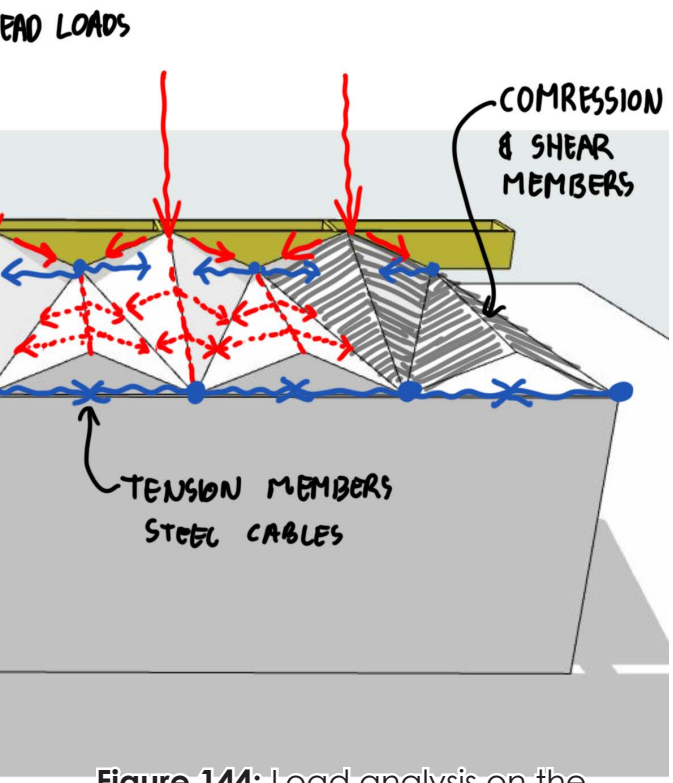



**Figure 144:** Load analysis on the structure. The unique form allows the forces to work against each other (Author 2020).

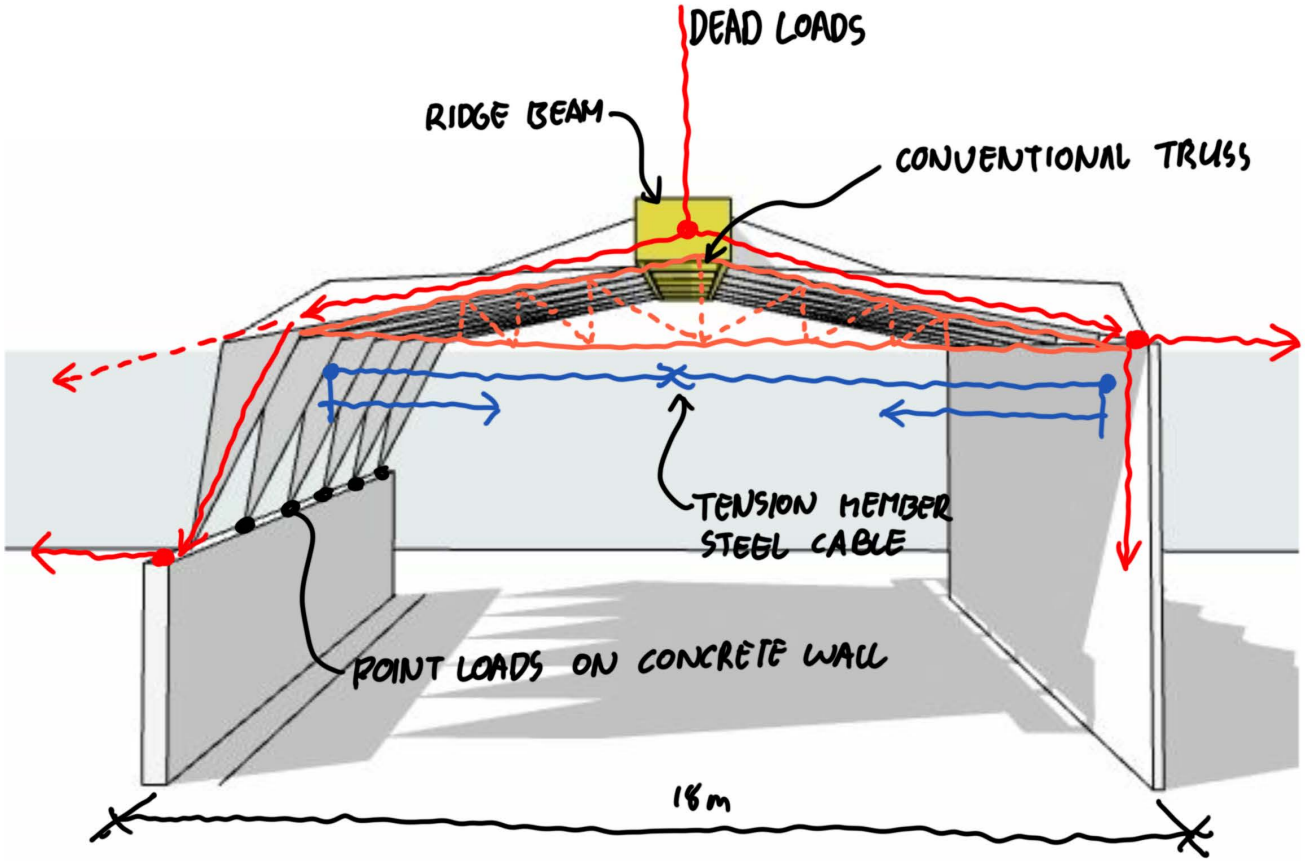



**Figure 146:** Roof system behaves just like a conventional truss which allows for a 18m span (Author 2020).

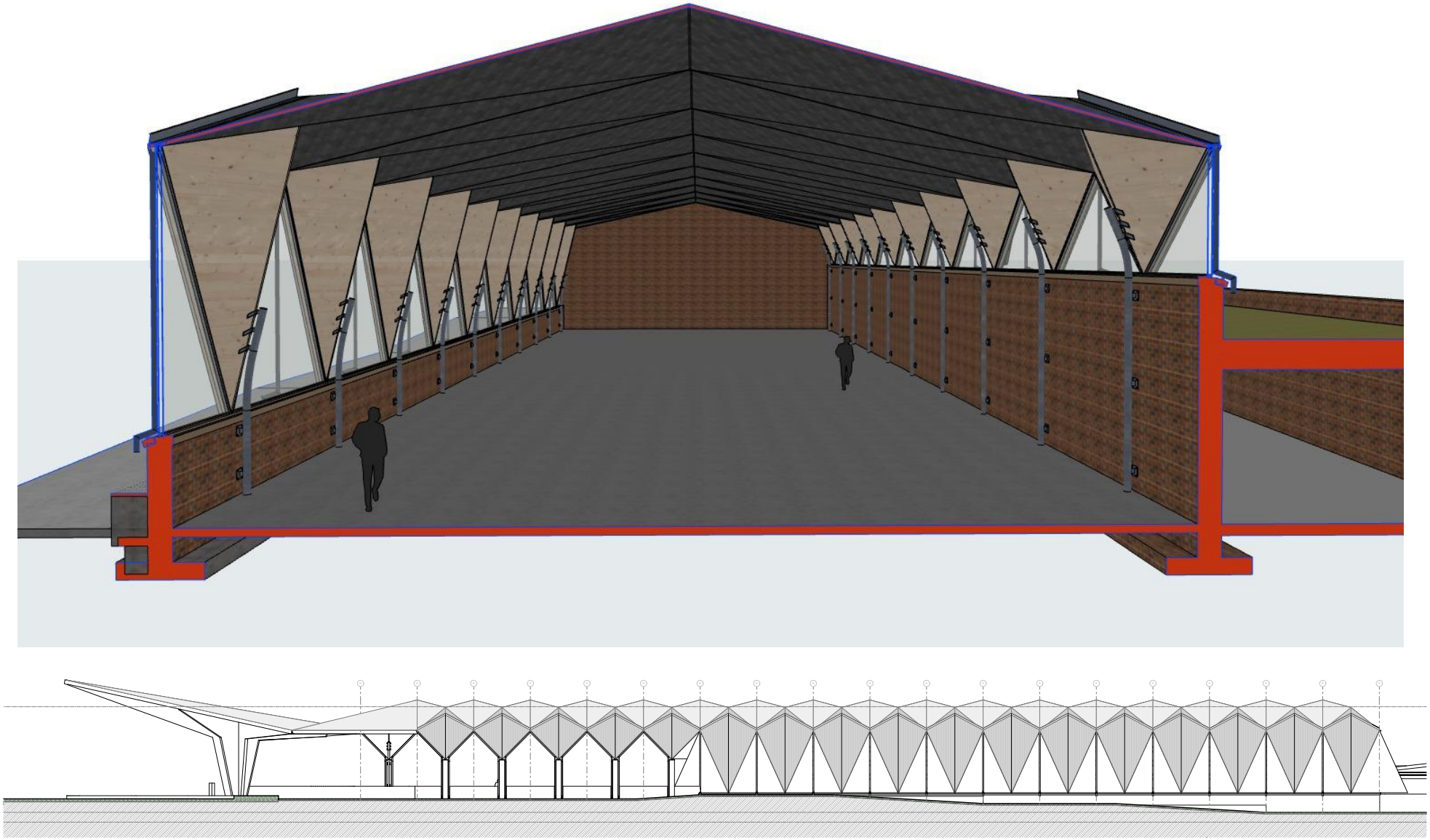


**Figure 147:** The workshop portals are fixed to a concrete wall with masonry cladding, considering the industrial program and durability of materials. Large double-glazed windows allow pedestrians to see through. To subconsciously inform them about timber construction. (Author 2020).



**Figure 148:** A phased approach is used to construct this elaborate structure. First the 150mm CHS M/S columns are fixed to the concrete walls. (Author 2020).

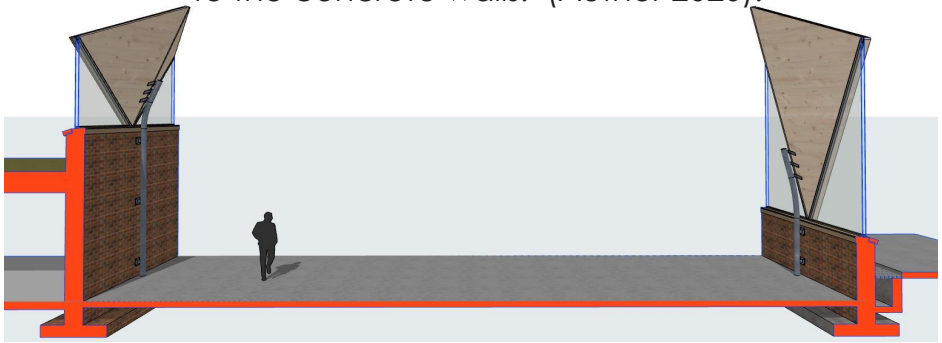


**Figure 149:** Second, the CLT composite columns are fixed to the steel columns. (Author 2020).

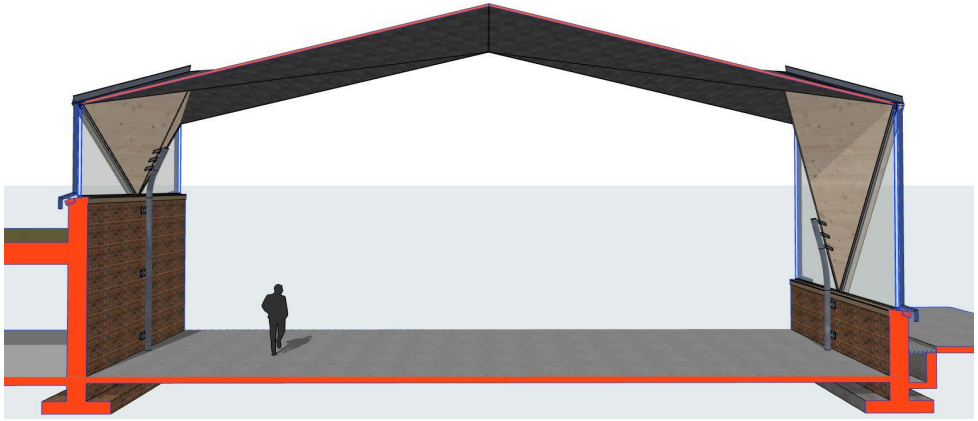


**Figure 150:** Finally, the CLT composite roof panels can be installed in place. This is then followed by the installation of window frames, gutters and the roof finish(Author 2020).



**Figure 151:** Roof structure informed by a standard CLT sheet size which is cut diagonally to create a triangular member (Author 2020).

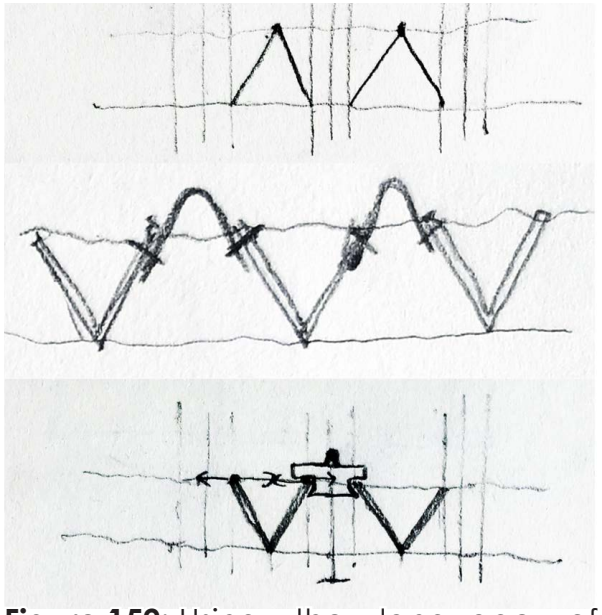


**Figure 152:** Using the language of triangulation to inform the beam's structural system (Author 2020)

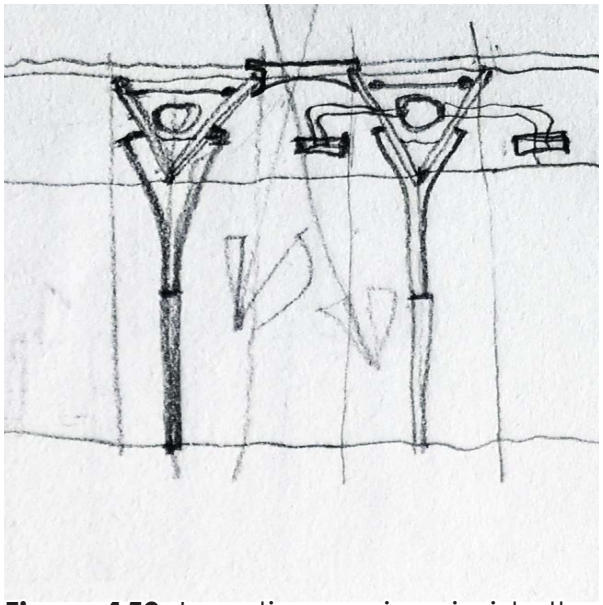


**Figure 153:** Locating services inside the beam (Author 2020)

**Iteration 13:**

A new portal system was developed to span 18 metres for the lecture and boardrooms in the southern wing, taking into account the merging of the wall of the tower with the roof of the southern wing. At first a traditional space frame was used, but it was soon developed into a V-beam system consisting of a standard 66 mm three-layer CLT panel with 220 x 100 LVL ribs fixed to the panel.

Tension cables are located on the top to prevent the beam from splitting. Four of these beams will be used next to each other to create a room. A 1 m air gap (which can be closed) between the CLT panels will allow natural light to flood into the rooms.

A third iteration introduced 220 mm CLT panels to be used as load bearing walls which allowed for the removal of some of the columns as proposed in iteration 2. This also allowed for freeing up the façade of the rooms to create a clear visual link from one side to the other. The cavity created between the V beams is used to position all the required services, out of sight.

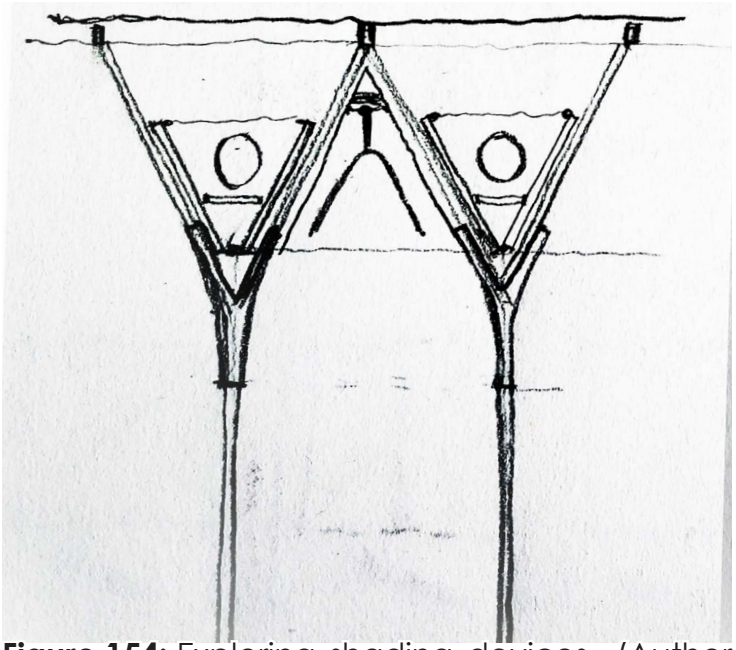


**Figure 154:** Exploring shading devices (Author 2020)

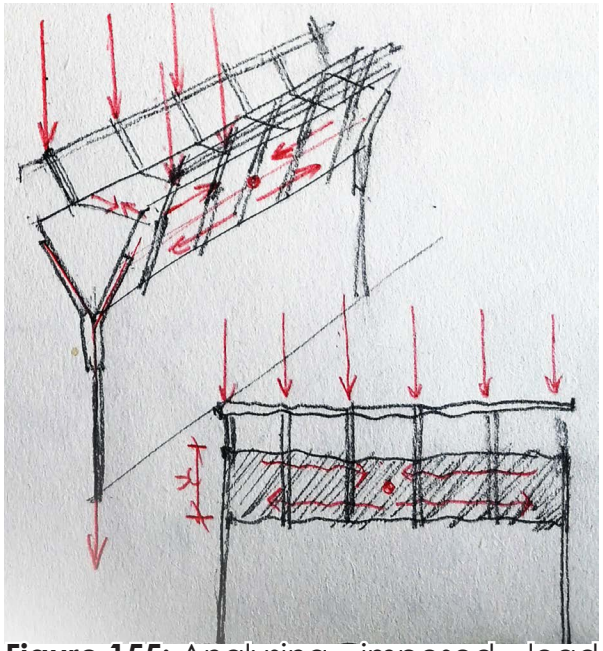


**Figure 155:** Analysing imposed load behaviour (Author 2020)

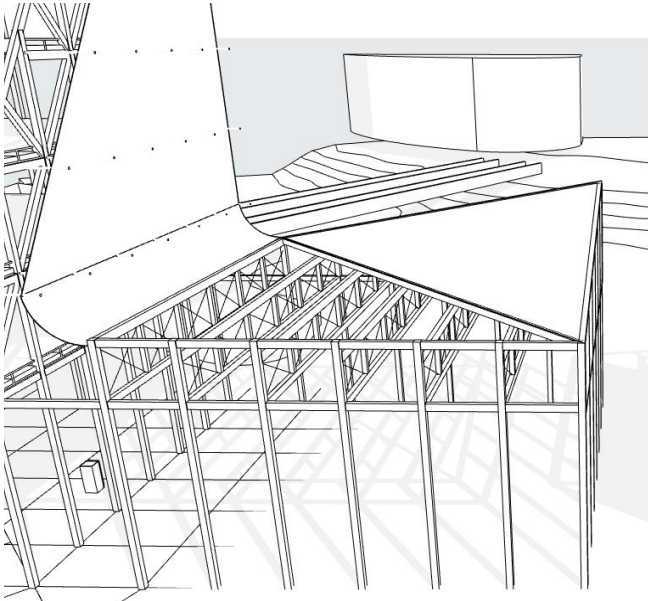


**Figure 156:** Base case, conventional timber truss (Author 2020)

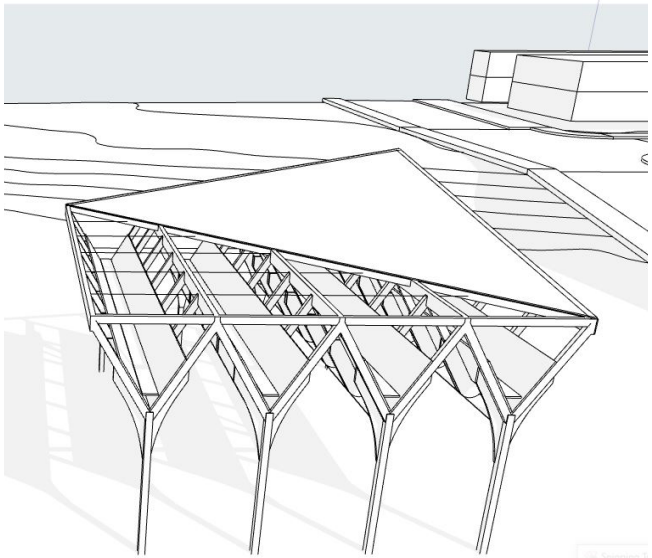


**Figure 157:** CLT beam, iteration 1 (Author 2020)

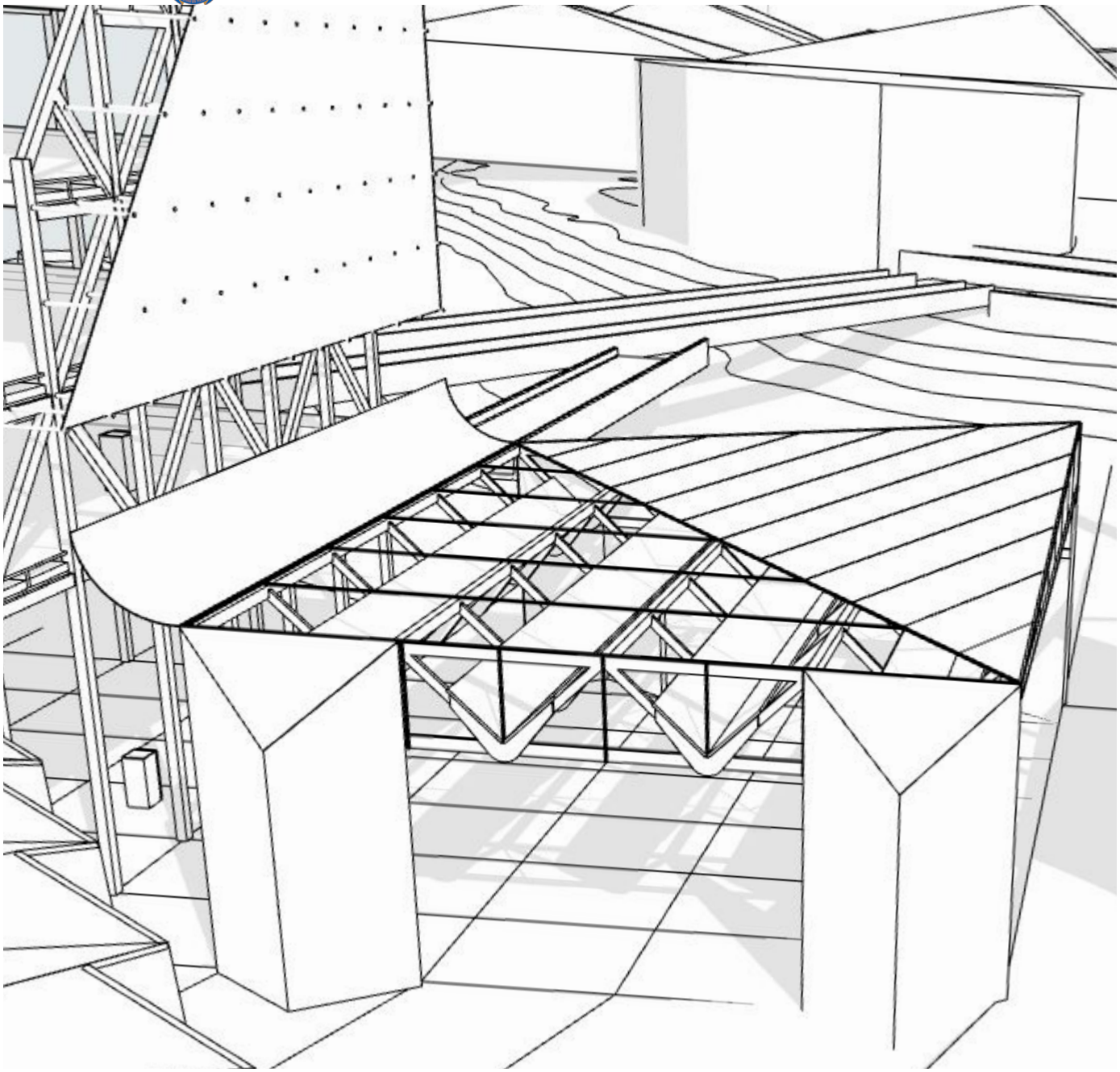


**Figure 158:** CLT beam, iteration 2 (Author 2020)

**Iteration 14:**

The floor of the timber tower consists of a CLT floor system, comprising two CLT panels divided by three floor ribs acting as beams. These ribs also create cavities for electrical and plumbing services to run through, as well as an air flow duct for cold and hot air. These floor panels will also be pre-manufactured off site and installed on site as a unit complete with insulation and service access hatches.

Terraces will be introduced on the northern façade of the offices to allow the users to step outside. This can be act as a catalyst for incidental conversations where ideas can be discussed and solutions found. This a similar concept to that used in Renzo Piano's Genoa offices. Planter boxes are used to act as a balustrade as well as to introduce greenery into the office space. The use of plants will also reinforce the concept of sustainability as this feature can be seen from a distance.

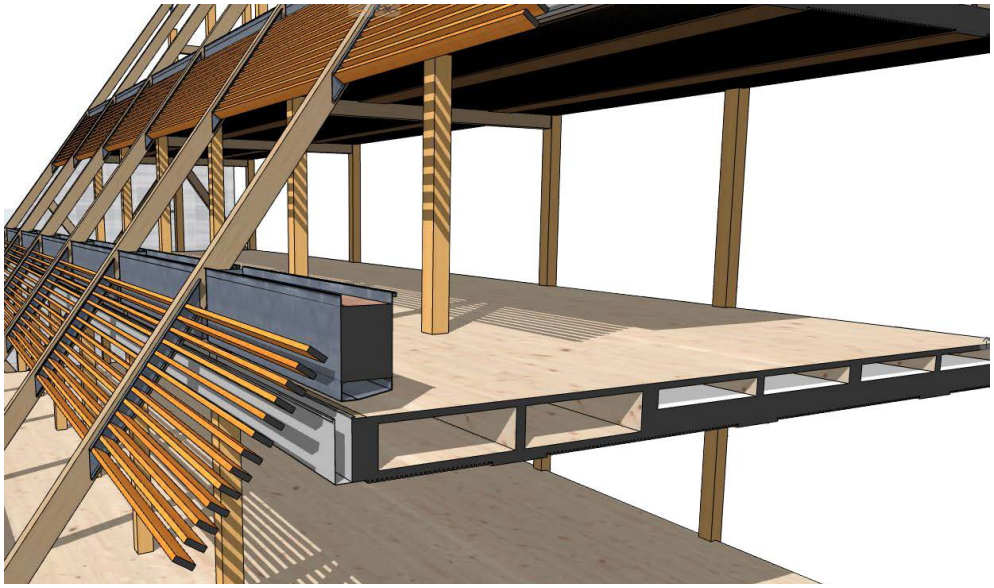


**Figure 159:** Timber tower_ Northern edge condition (Author 2020)

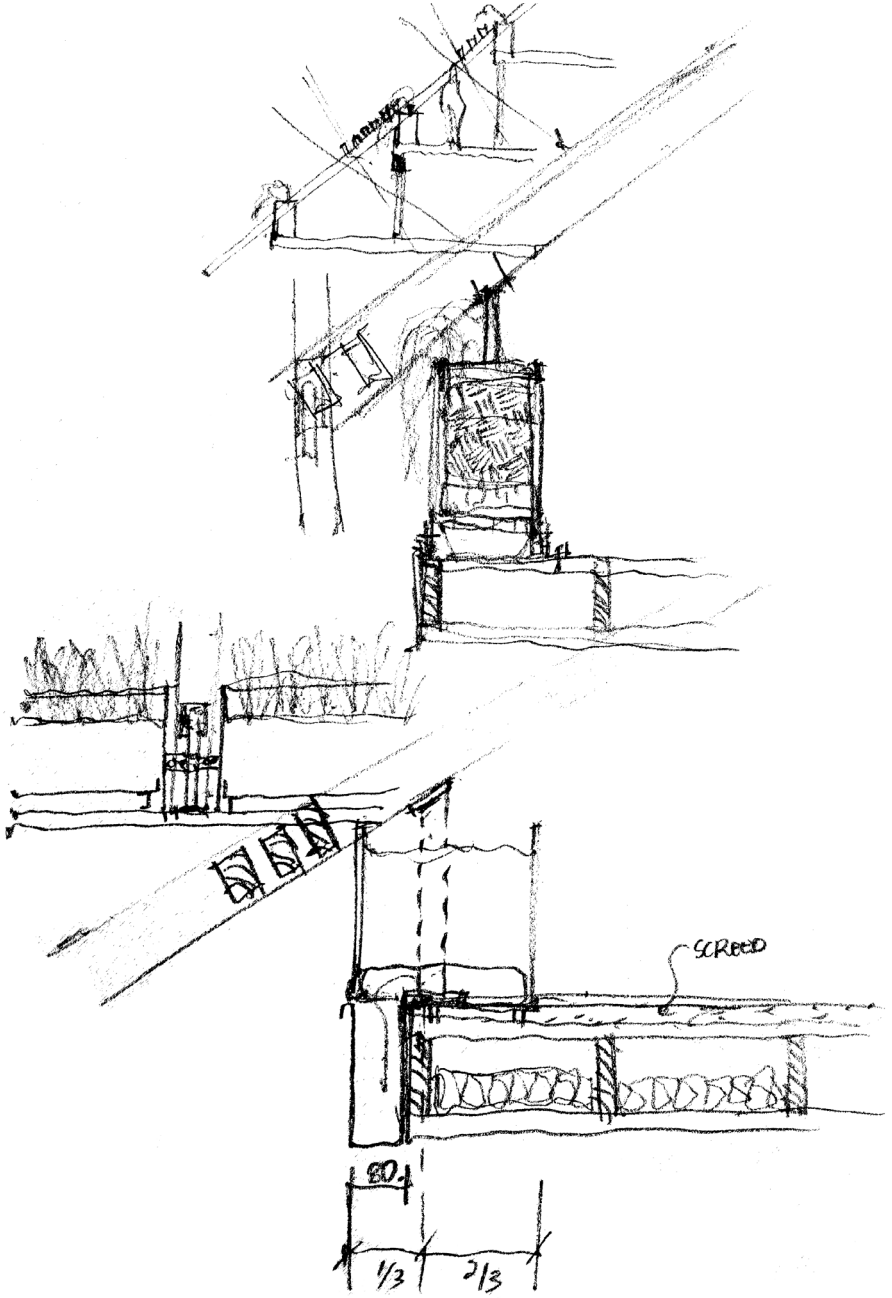



**Figure 160:** Planter box balustrade & louvre concept development (Author 2020)

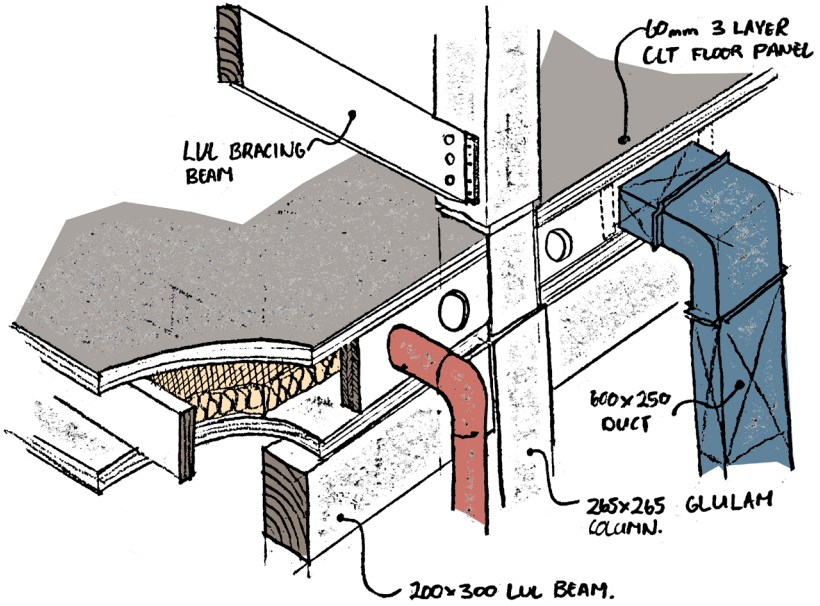



**Figure 161:** CLT floor system with integrated services (Author 2020)

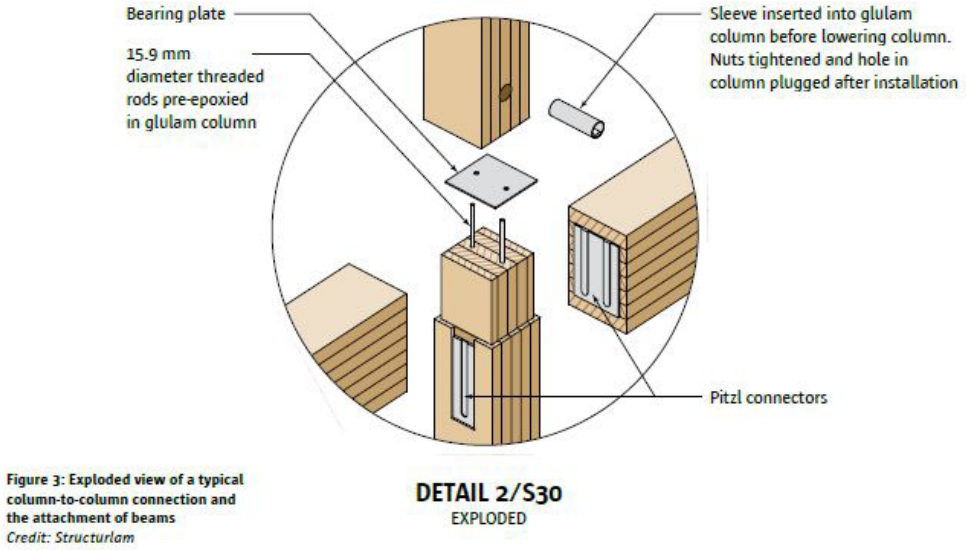



Figure 3: Exploded view of a typical column-to-column connection and the attachment of beams
*Credit: Structurlam*

**Figure 162:** Post and beam connection detail (CWC 2016)

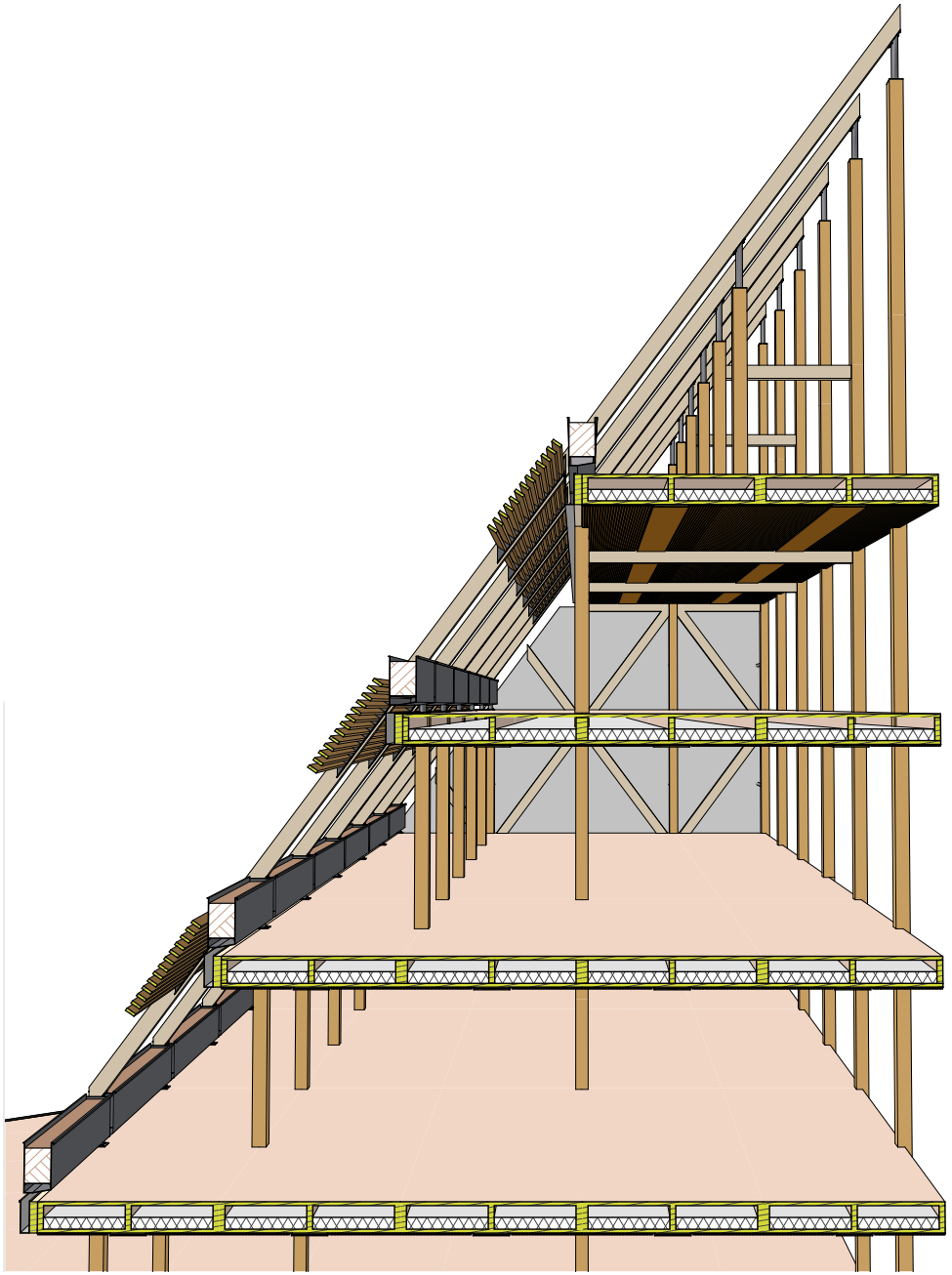
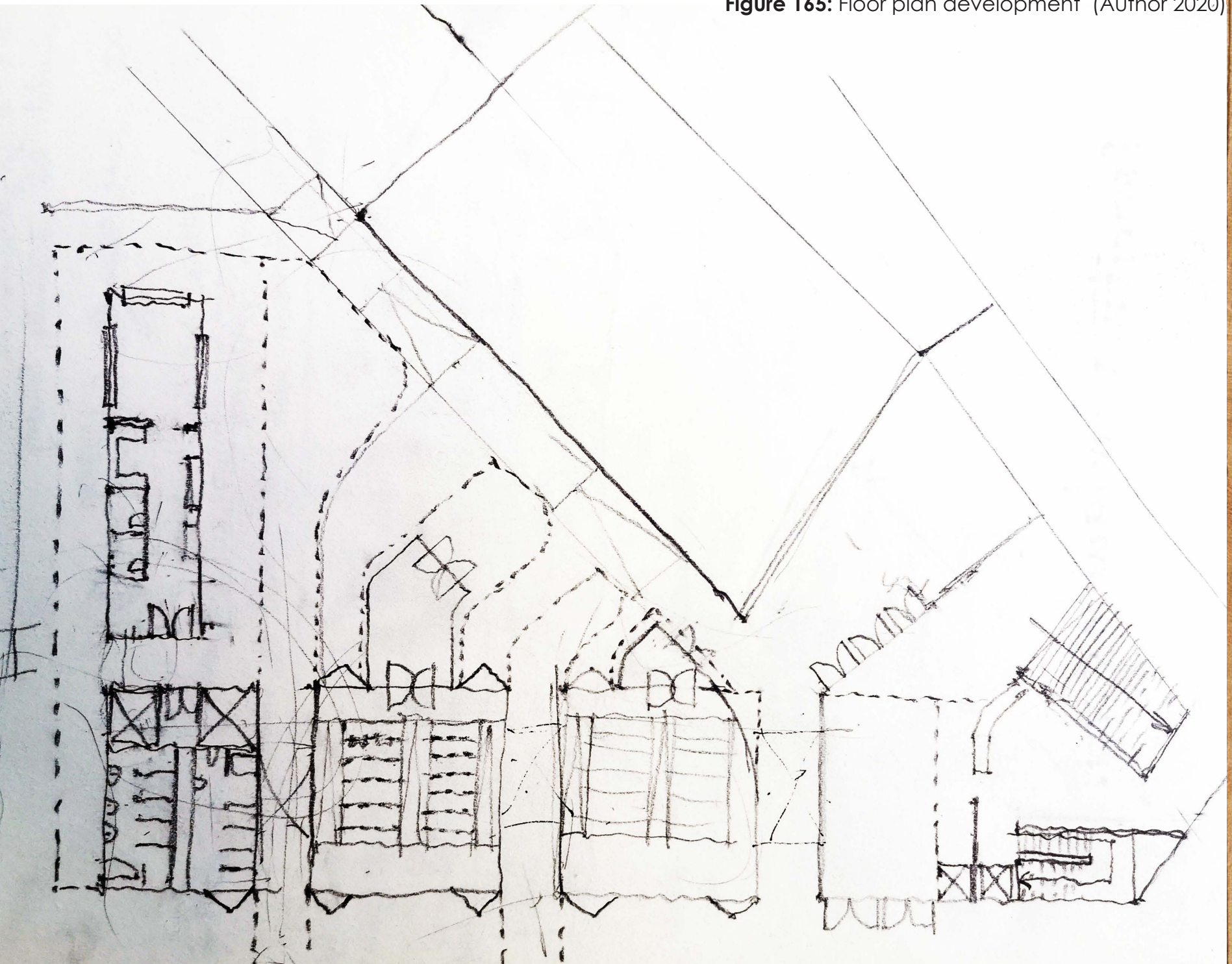


**Figure 163:** Tower's structural and floor system concept (Author 2020)



**Figure 164:** View into the inner courtyard (Author 2020)

**Figure 165:** Floor plan development (Author 2020)



# Building analysis

## Water consumption and storage

| Salvokop Tower water catchment analysis | |
|---|---|
| Effective Catchment (m2) : | 1620 |
| Runoff coefficient: | 0,9 |
| Possible catchment area (m2): | 5072 |

| Year 1 Starting with no top up | | | | |
|---|---|---|---|---|
| Month | Rainfall m | Total yield m3 | Out m3 | Remaining in tank (m3) |
| J | 0,137 | 301 | 71,404 | 230 |
| F | 0,07 | 102 | 71,404 | 31 |
| M | 0,081 | 219 | 71,404 | 148 |
| A | 0,044 | 165 | 71,404 | 94 |
| M | 0,016 | 125 | 75,616 | 49 |
| J | 0,012 | 119 | 75,616 | 43 |
| J | 0 | 101 | 75,616 | 26 |
| A | 0,003 | 106 | 75,616 | 30 |
| S | 0,028 | 142 | 75,616 | 66 |
| O | 0,068 | 200 | 71,404 | 129 |
| N | 0,088 | 230 | 71,404 | 158 |
| D | 0,123 | 281 | 71,404 | 209 |

| Year 2 starting with left over from year 1 | | |
|---|---|---|
| In m3 | Out m3 | Remaining in tank (m3) |
| 510 | 71,404 | 439 |
| 541 | 71,404 | 469 |
| 689 | 71,404 | 617 |
| 783 | 71,404 | 711 |
| 836 | 75,616 | 760 |
| 879 | 75,616 | 804 |
| 905 | 75,616 | 829 |
| 935 | 75,616 | 859 |
| 1001 | 75,616 | 926 |
| 1126 | 71,404 | 1055 |
| 1284 | 71,404 | 1213 |
| 1494 | 71,404 | 1422 |

The characteristics of the intended program informs a rather minimal amount of water required for on site use. Therefore, the idea of a retention pond and overflow reservoir was explored. To allow for the neighbouring sites to capitalize of the large roof catchment areas rather than letting the water go to waste.

A total catchment area of 5072m2 are possible but it was determined only to use the cafeteria and lecture hall roofs for catchment (1620m2) because of their position and the type of roof covering (Palram) which has a runoff coefficient of 0.9. Calculations shown that these catchment areas would prove to be more than enough for on site water consumption as well as providing a significant amount of water for of site consumption.

| Building and site water usage (1m3 of water = 1000 litres) | | | | | |
|---|---|---|---|---|---|
| Building demand | Usage litre | Times used per day (per person) | Times used per month (30,5 Days) | Oty | Total liters used (per month) m3 |
| Cooking | 100 | 3 | 91,5 | 5 | 45,75 |
| HWB | 1 | 3 | 91,5 | 16 | 1,464 |
| WC | 7,5 | 2 | 61 | 20 | 9,15 |
| | | | Total daily usage: | | 56,364 |
| | Area | Coef | | | |
| Summer irr | 3945 | 0,125 | 30,5 | | 15,04 |
| Winter irrig | 3945 | 0,16 | 30,5 | | 19,25 |
| | | | Total system demand (m3): | | 101,270 |

**Table 7:** Rainwater yield and building consumption (Author 2020)

# Water strategy

**SALVOKOP TOWER - water catchment**
**Total catchment area:**

Total possible catchment area : 5 072m²
Effective catchment area: 1 620m²
Runoff coefficient: 0.9

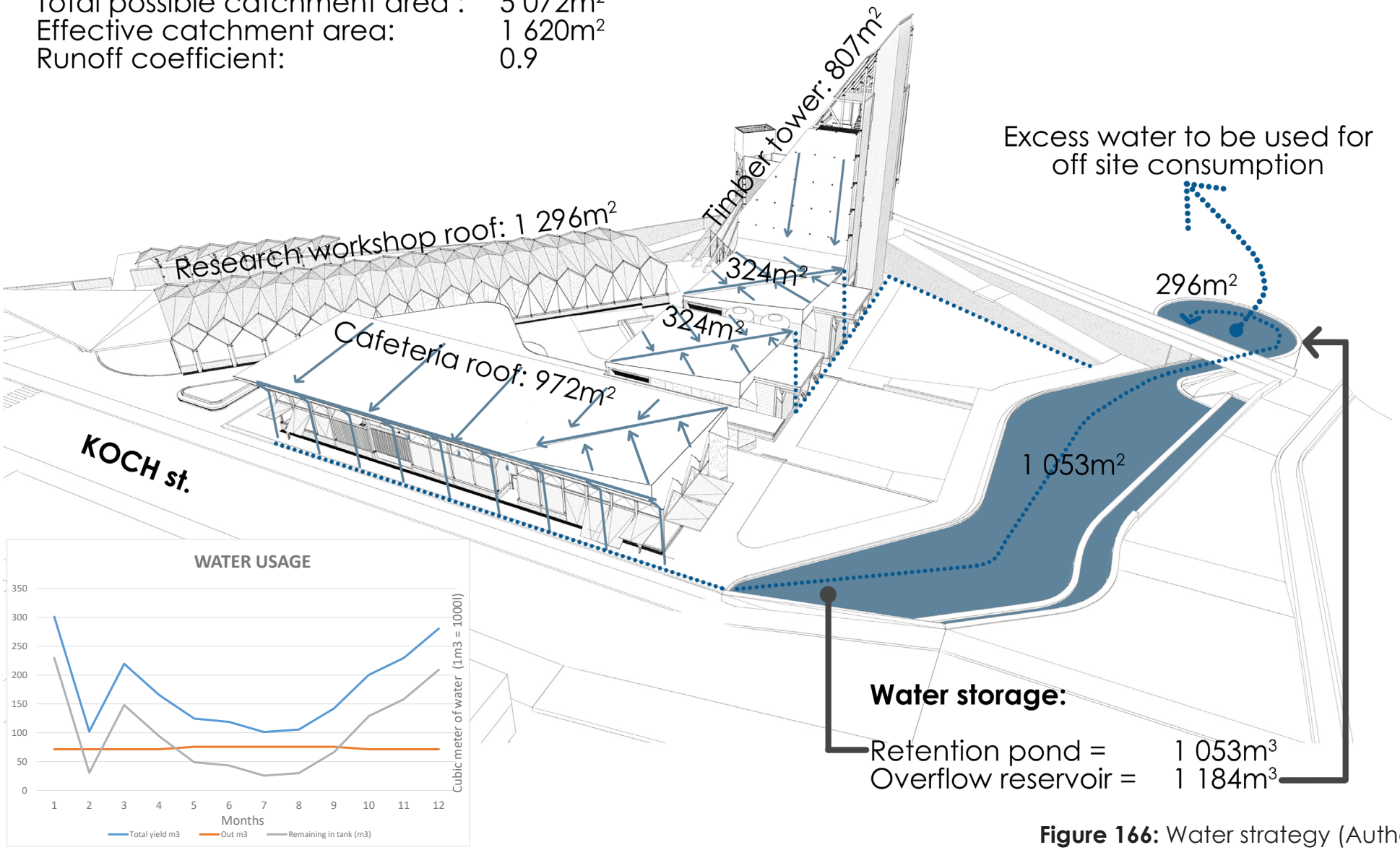






**Figure 166:** Water strategy (Author 2020)

# Electricity strategy

| Salvokop Tower: Electricity calculations | | | | | |
|---|---|---|---|---|---|
| **Workshop** | | | | | |
| *Item:* | *No. Of items* | *Power usage (Watts)* | *Ave.run time per day (hrs)* | *Ave. run time per week (hrs)* | *Watt-hours per week* |
| CNC machine | 3 | 2000 | 3 | 15 | 90000 |
| Laser cutter | 1 | 2500 | 1 | 5 | 12500 |
| Computer | 1 | 80 | 10 | 50 | 4000 |
| Power tools | 10 | 45 | 1 | 5 | 2250 |
| Dust trap machines | 4 | 150 | 3 | 15 | 9000 |
| LED lights | 50 | 5 | 2 | 10 | 2500 |
| | | | | | |
| **Cafeteria** | | | | | |
| Toaster | 2 | 800 | 2 | 14 | 22400 |
| Microwave | 2 | 800 | 2 | 14 | 22400 |
| Wifi Router | 2 | 7 | 24 | 168 | 2352 |
| Large Fridge | 1 | 1800 | 24 | 168 | 352800 |
| LED downlights (Int) | 46 | 5 | 10 | 70 | 16100 |
| Dishwasher | 2 | 2600 | 3 | 21 | 109200 |
| Alarm | 3 | 20 | 24 | 168 | 10080 |
| Cash register | 3 | 40 | 8 | 56 | 6720 |
| Kettle | 3 | 1800 | 1 | 7 | 37800 |
| Snackwich | 3 | 1700 | 1 | 7 | 35700 |
| | | | | | |
| **Lecture rooms** | | | | | |
| Computer | 2 | 80 | 4 | 20 | 3200 |
| LED lights | 36 | 7 | 5 | 25 | 6300 |
| Speakers | 8 | 150 | 4 | 20 | 24000 |
| | | | | 0 | 0 |
| | | | | | |
| **Offices** | | | | | |
| Computer | 36 | 80 | 8 | 40 | 115200 |
| LED Lights | 127 | 7 | 9 | 45 | 40005 |
| Lab equiptment | 15 | 300 | 8 | 40 | 180000 |
| Printer | 3 | 260 | 1 | 5 | 3900 |
| | | | | Total (W): | 1108407 |

| | | |
|---|---|---|
| 1 Solar panel = 250W | Total panels required | 4434 |
| 1 Solar panel size = 1.4m2 | Size required (m2): | 6207 |

**Table 8:** Electrical demand (Author 2020)

## Establishing delimitations in this study

The electrical demand of the building was calculated to calculate the number of solar panels required. A total area of 6207m2 are required to accommodate 4434 solar panels (250W). It was soon realised that some roofs due to their shape, roof finish and other secondary roof characteristics did not allow for the required roof area to install PV panels. The only feasible option would be to utilise the green roof closest to the railway.

Considering the main objective of this dissertation (to inform the public about timber construction) it was decided to delimit the focus of PV panels on the roofs. To be conscious of the technology and acknowledge the option to install PV panels in the future. But rather to focus the design of the roofs according to other informants, such as showcasing the possibilities of timber or to allow for natural light. This decision was made to avoid the possibility of designing a roof only for the purpose to accommodate PV panels, rather than to imagine new innovative ways of what a timber roof could look like.

# PV panels - roof analysis

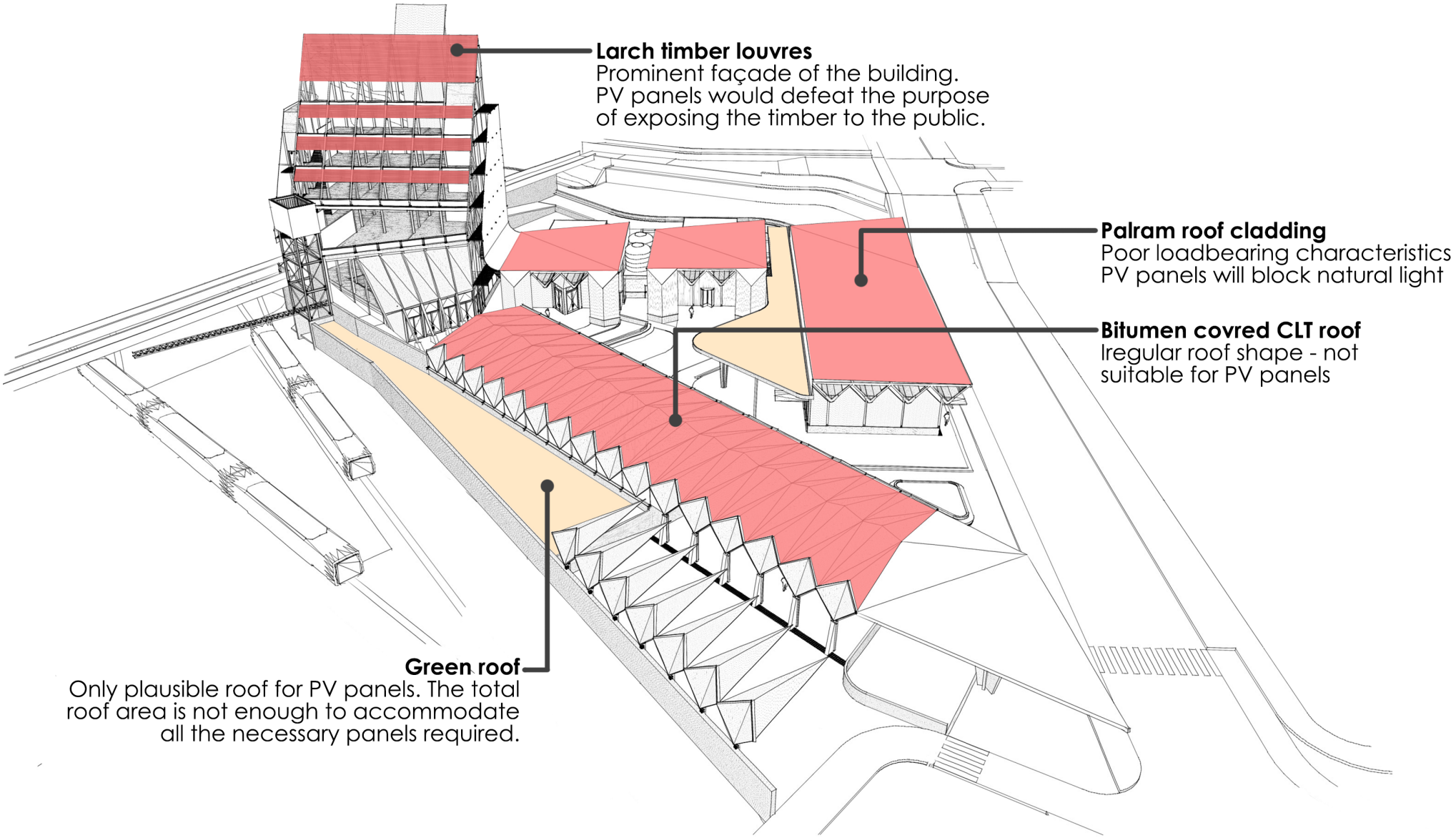



**Figure 167:** Electrical strategy (Author 2020)

# Building preformance

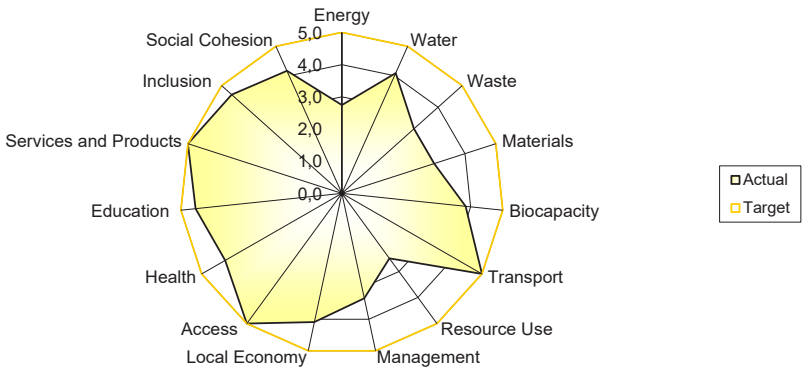
**SUSTAINABLE BUILDING ASSESSMENT TOOL RESIDENTIAL**
1,04

| | Achieved |
|---|---|
| **SB SBAT REPORT** | **3,9** |

**SB1 Project**
Salvokop Tower

**SB2 Address**
1 Koch street, Salvokop

**SB3 SBAT Graph**




| SB4 Environmental, Social and Economic Performance | Score |
|---|---|
| Environmental | 3,3 |
| Economic | 4,0 |
| Social | 4,5 |
| SBAT Rating | 3,9 |

| SB5 EF and HDI Factors | Score |
|---|---|
| EF Factor | 3,6 |
| HDI Factor | 4,3 |

| SB6 Targets | Percentage |
|---|---|
| Environmental | 67 |
| Economic | 80 |
| Social | 90 |

**Table 9:** SBAT report (SBAT 2020)

# Passive systems

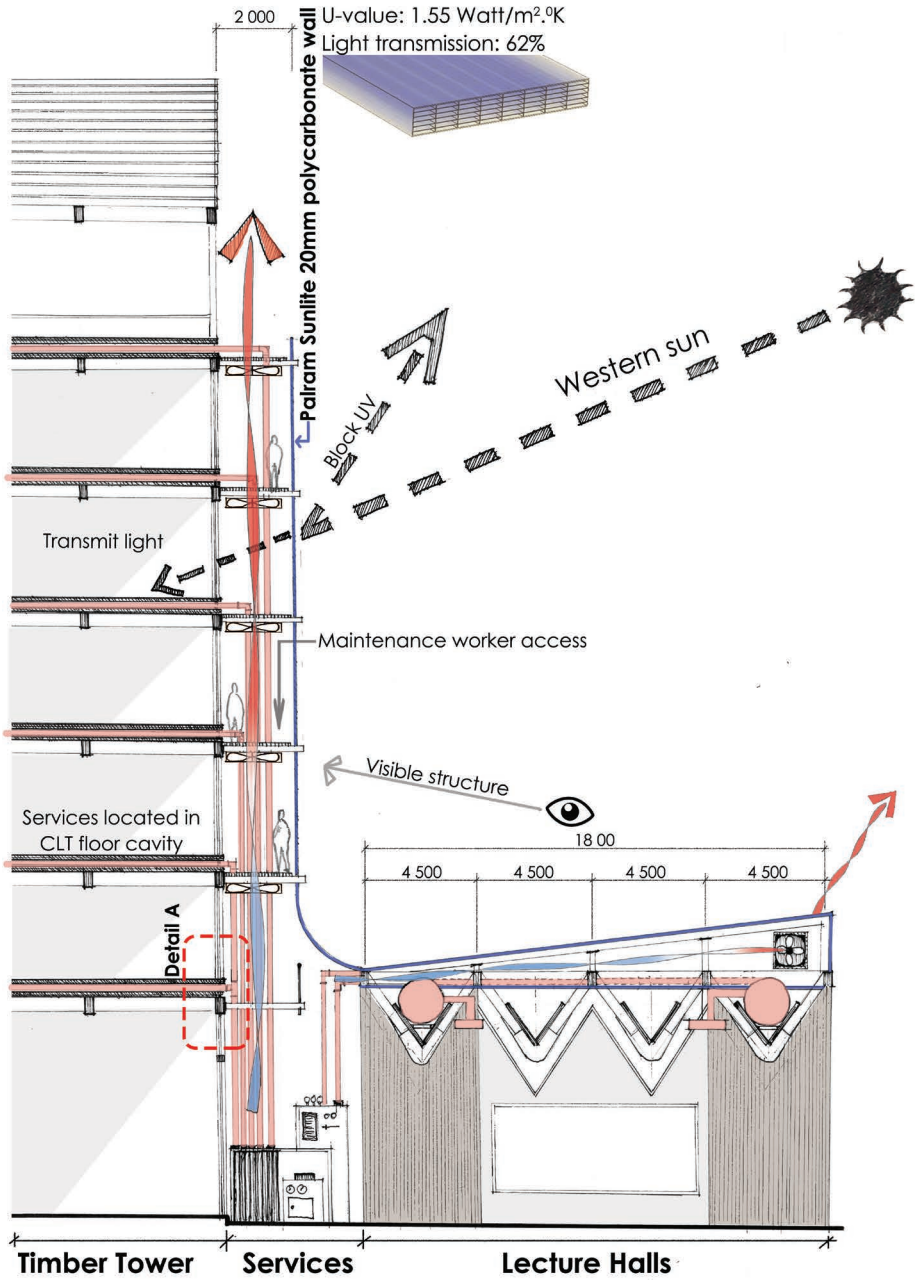



**Figure 168:** Second skin: West & Eastern facade (Author 2020)

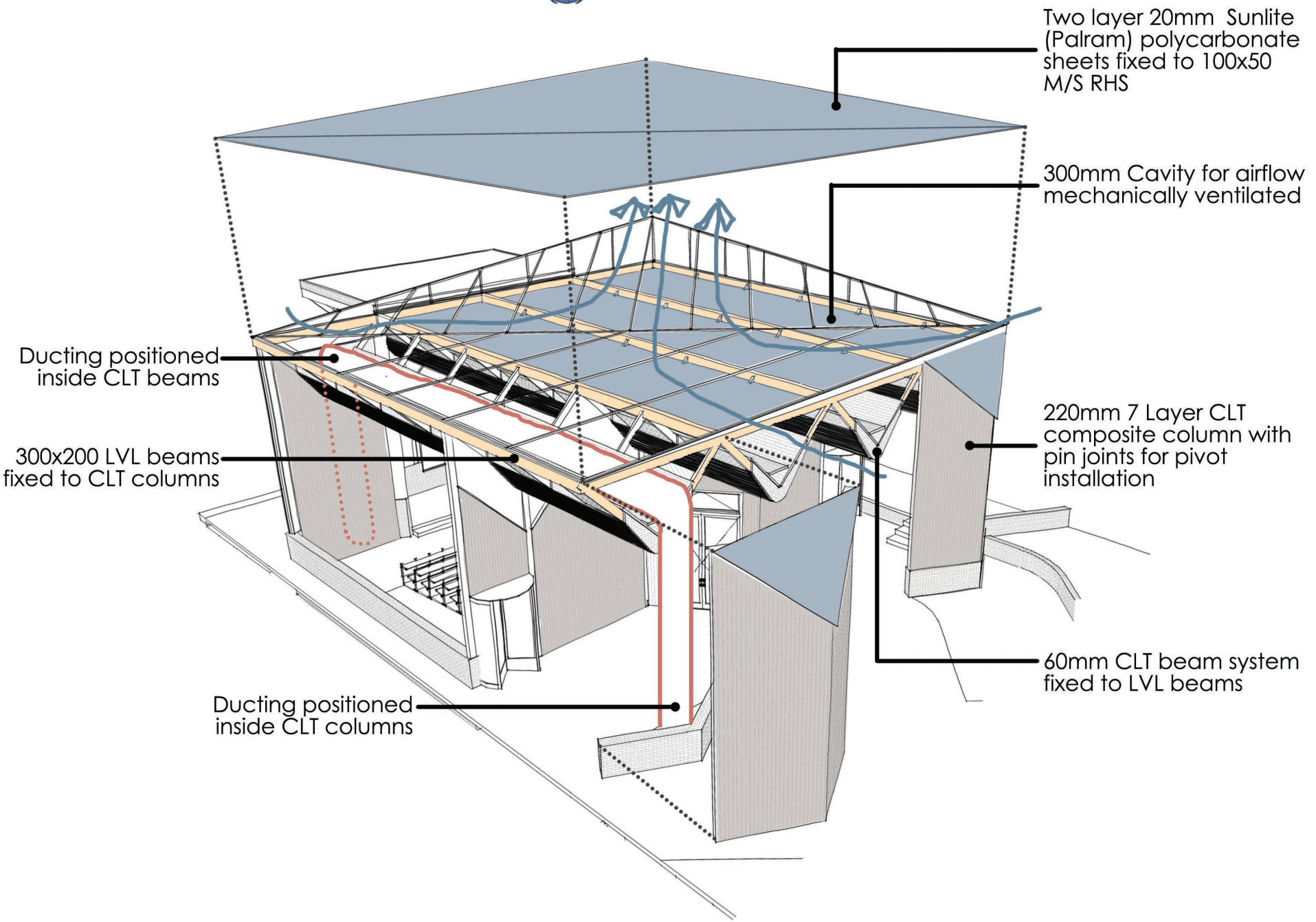
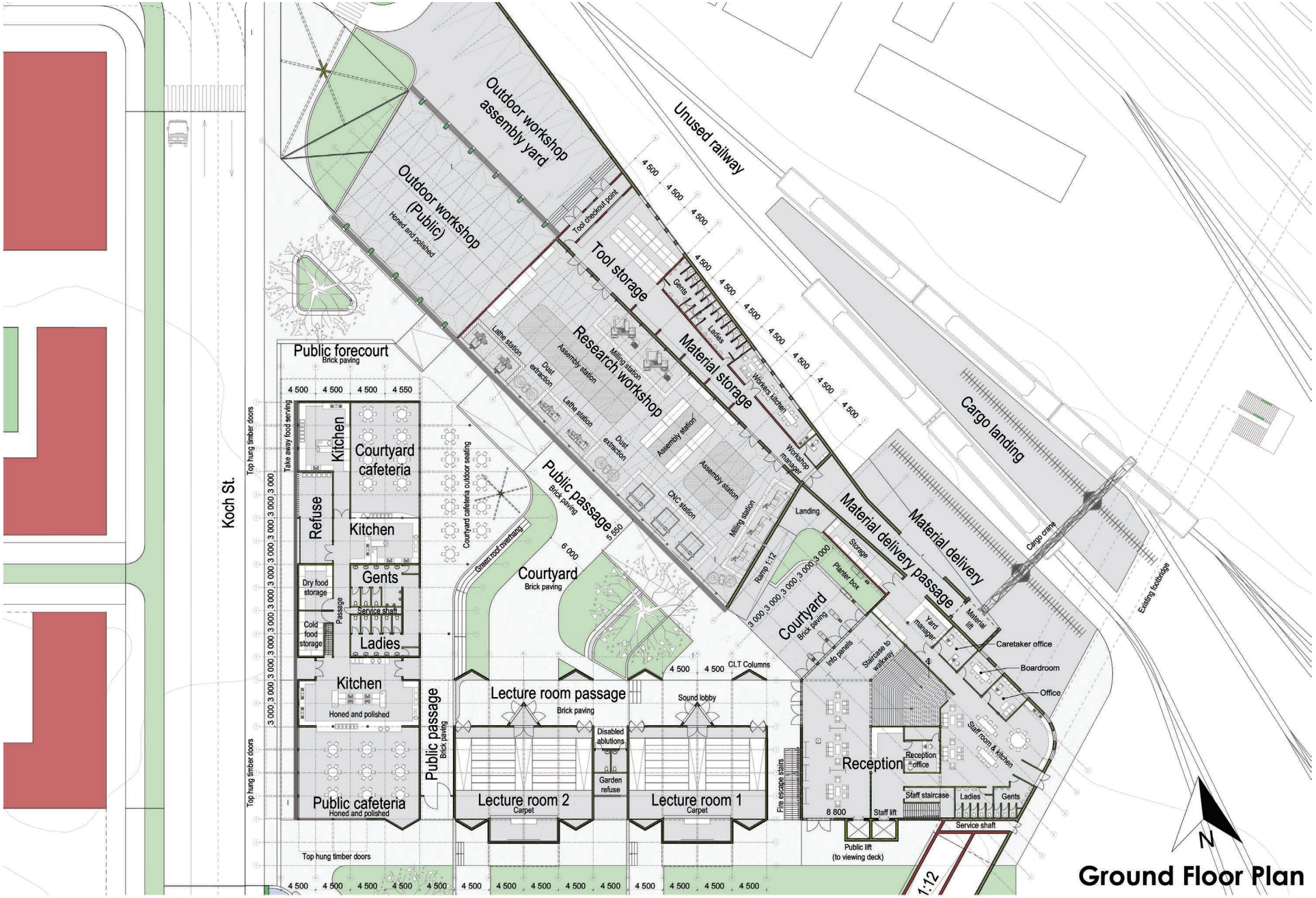
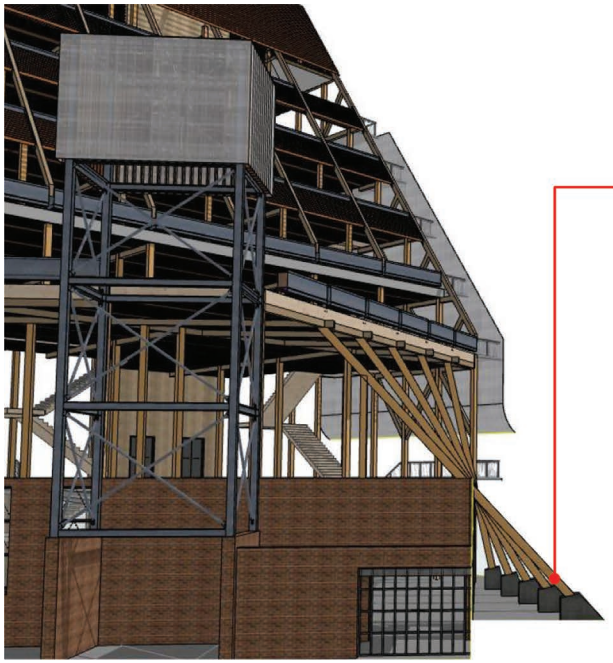



**Figure 169:** Southern wing: Passive systems (Author 2020)

# Building documentation

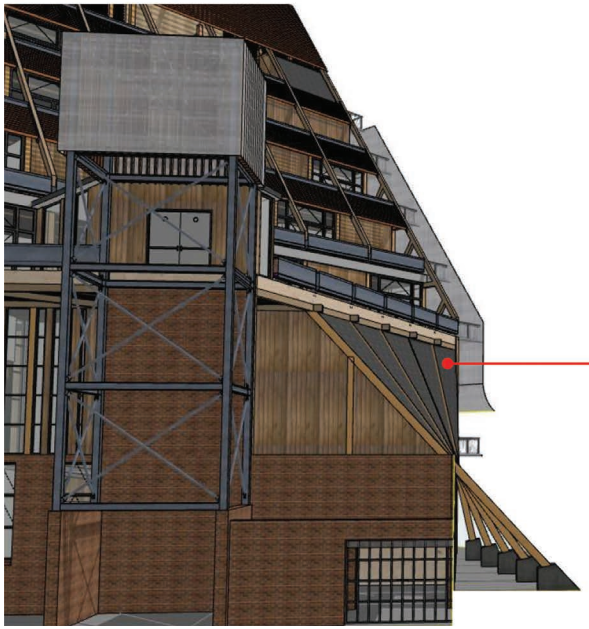
**Figure 170:** Ground floor plan (Author 2020)





x5 300x200 LVL Beams fixed to a 10mm M/S baseplate cast into 450mm high concrete stub columns @3000 cc's placed on +10⁰ increments from each other

Slanted composite wall structure



66mm 3 Layer composite CLT panel insulated with 100mm Iso therm insulation externally cladded with Sika bitumen tiles (asphalt grey)

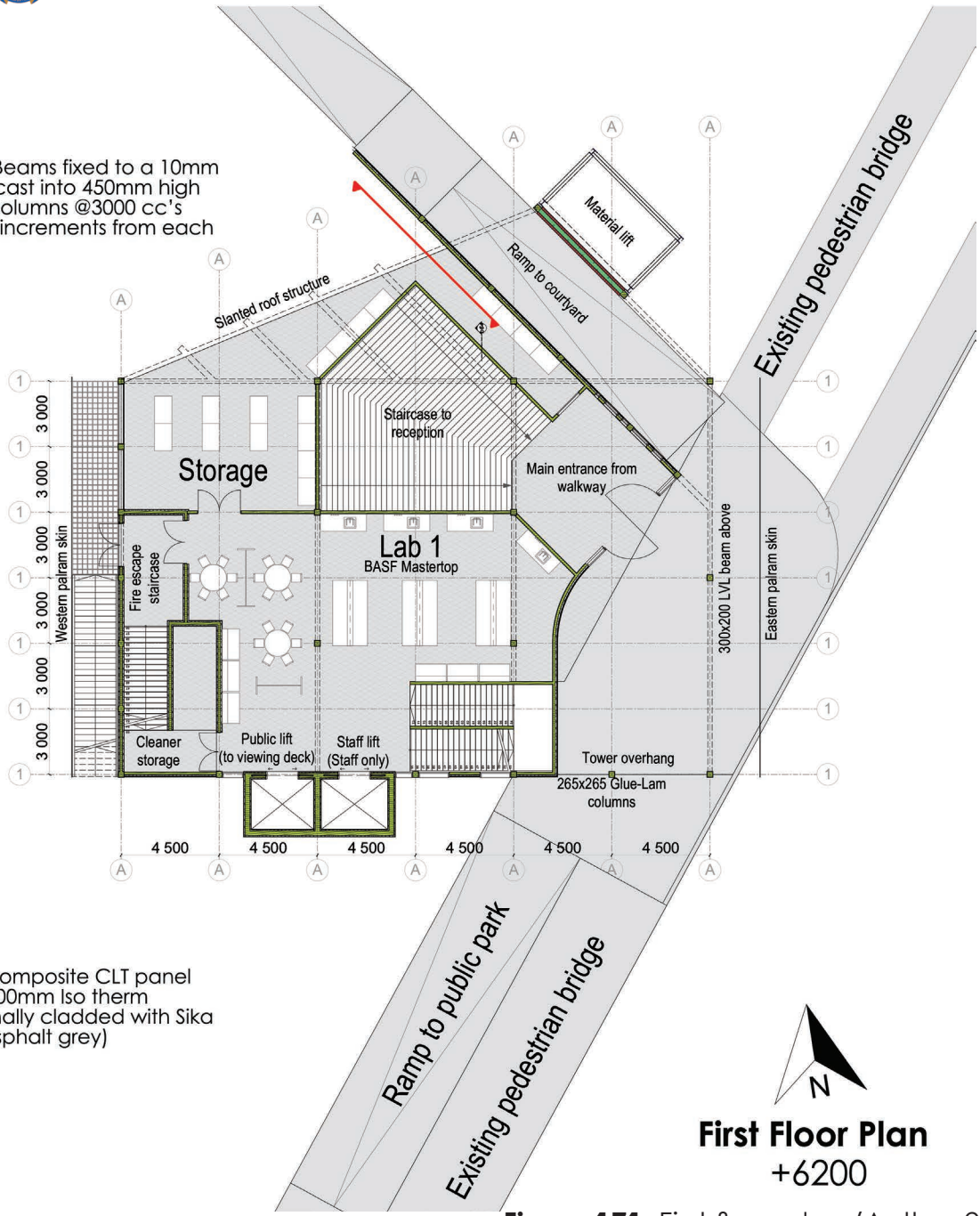



**Figure 171:** First floor plan (Author 2020)

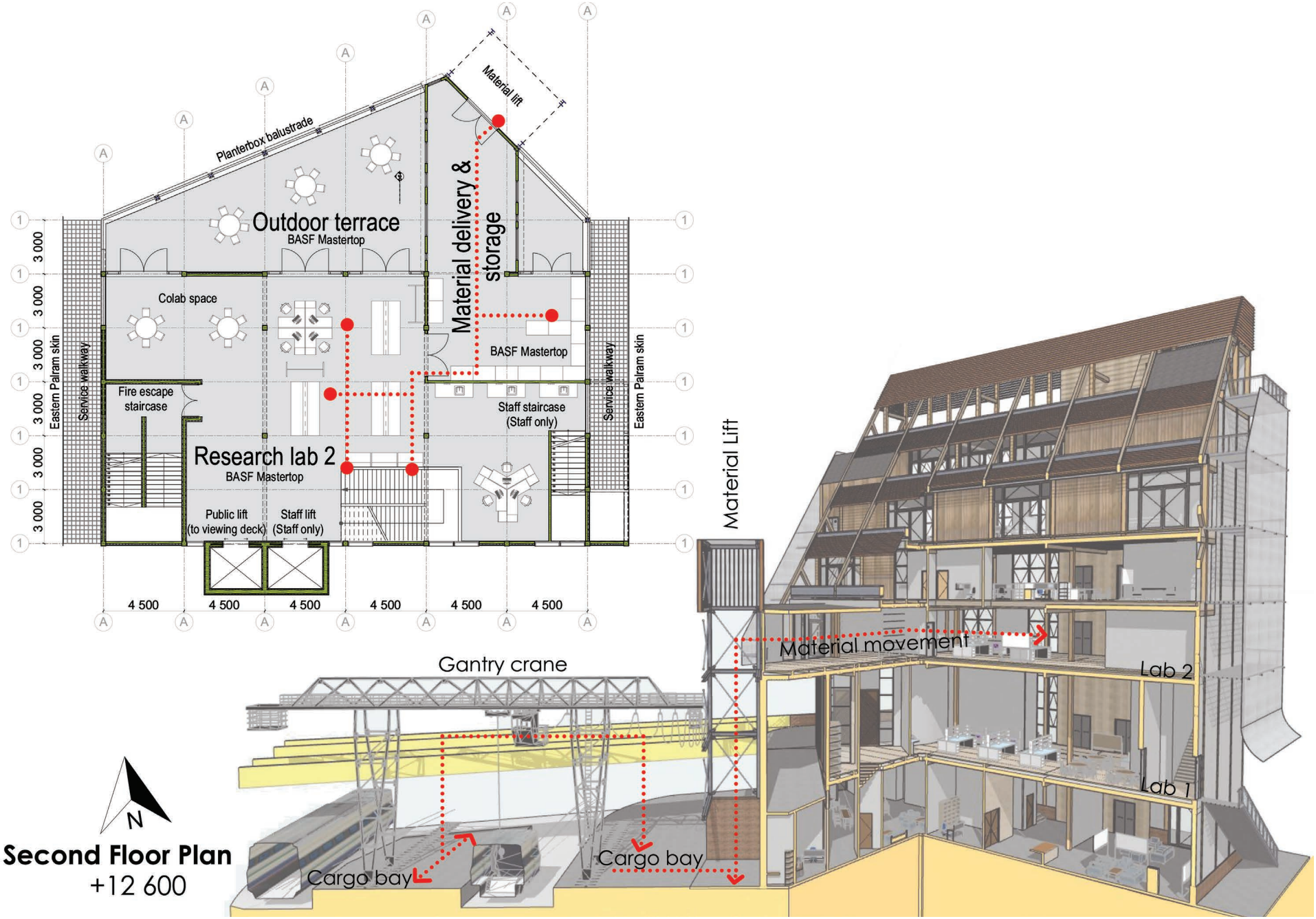
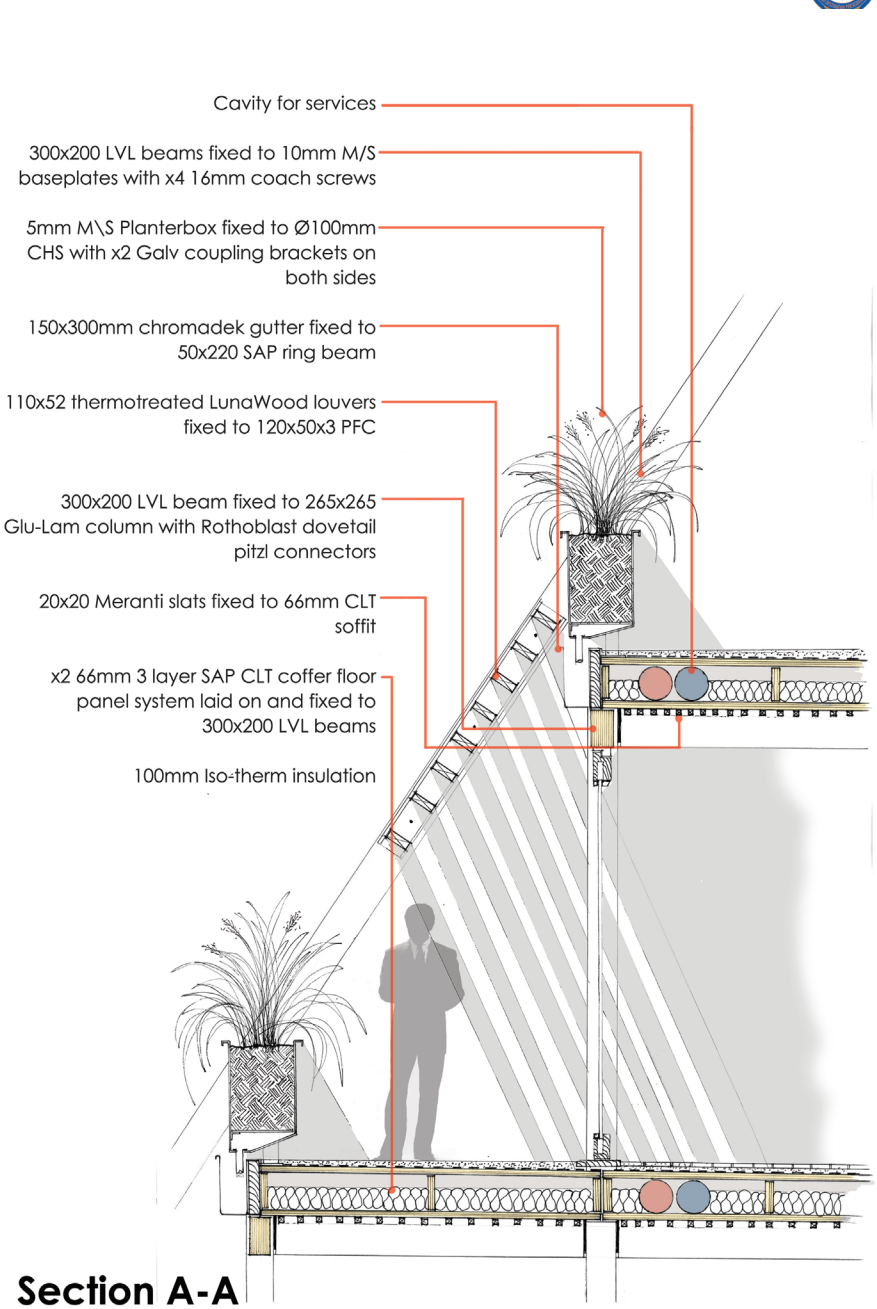
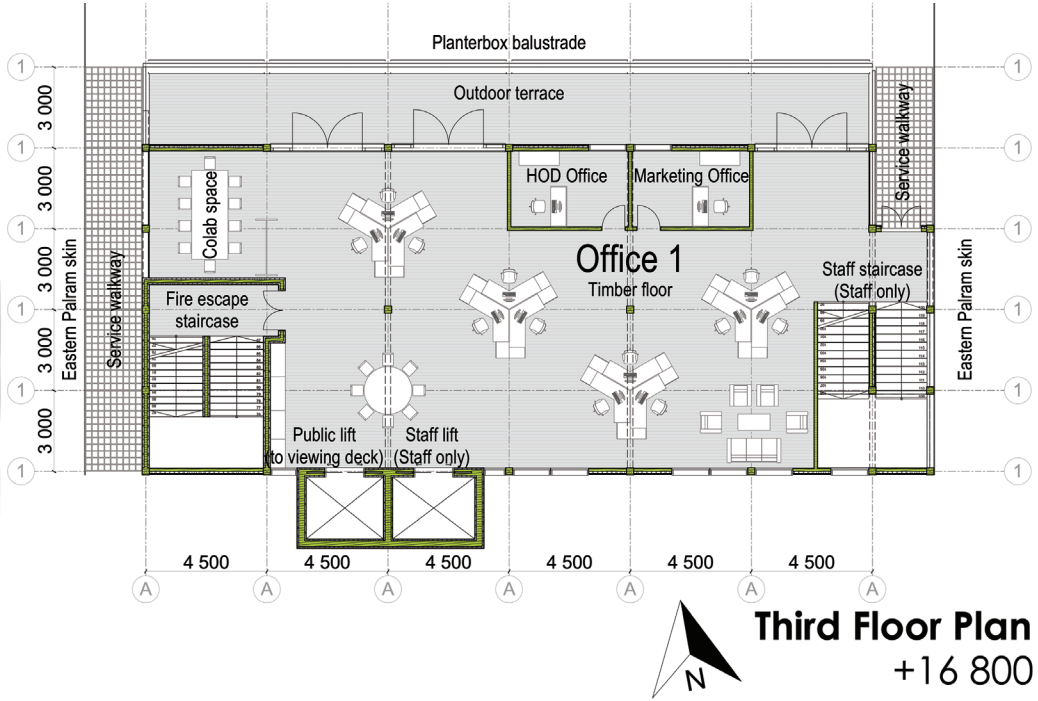



**Figure 172:** Second floor plan (Author 2020)



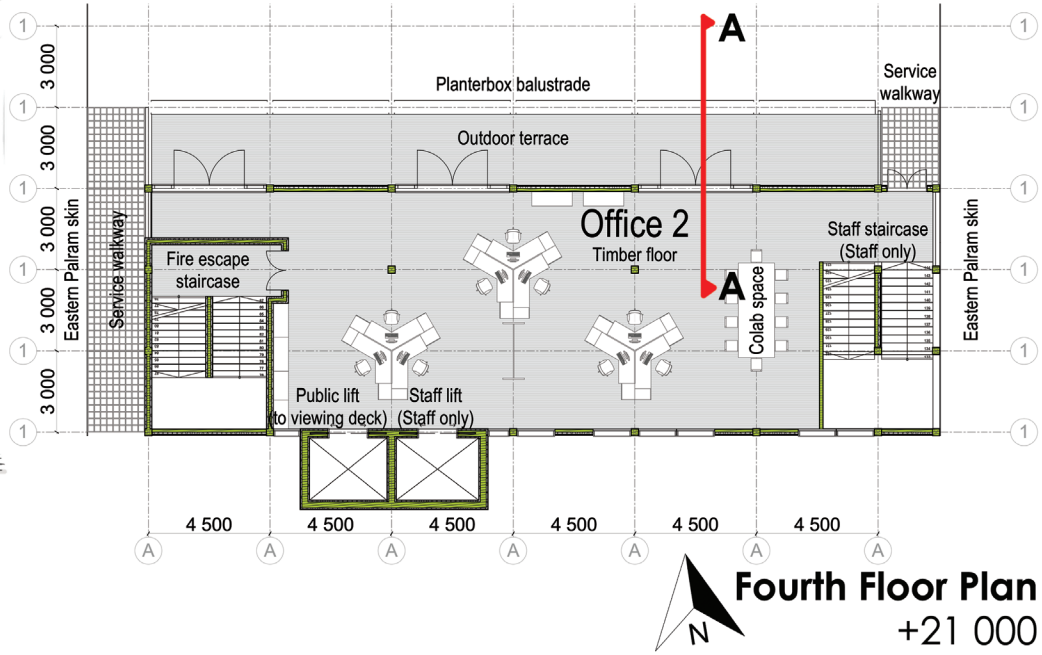
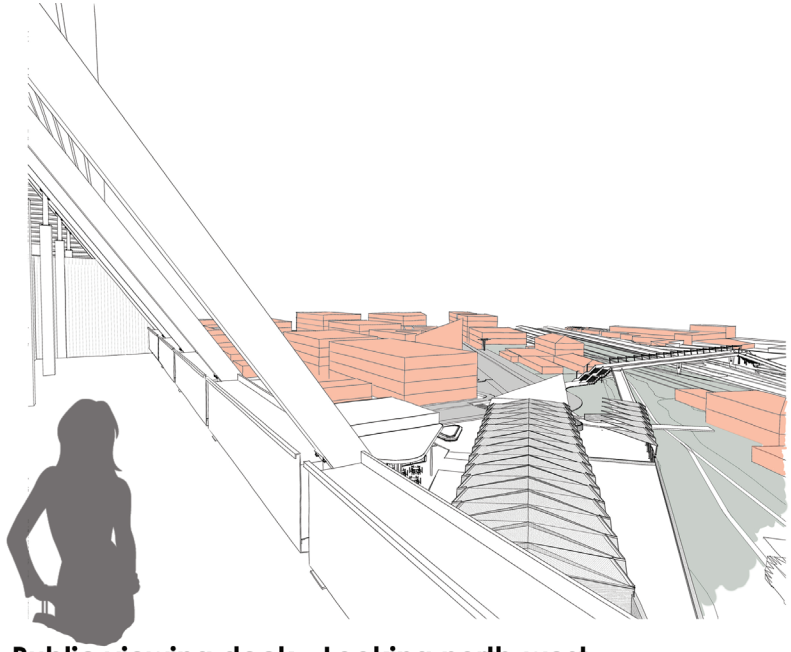
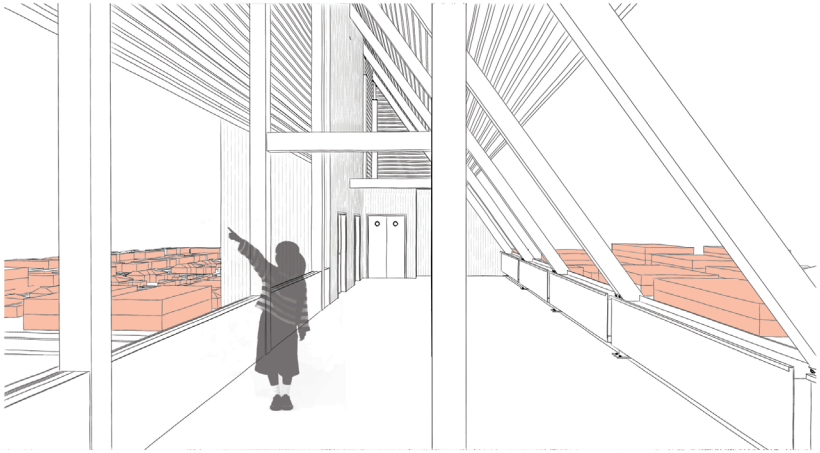



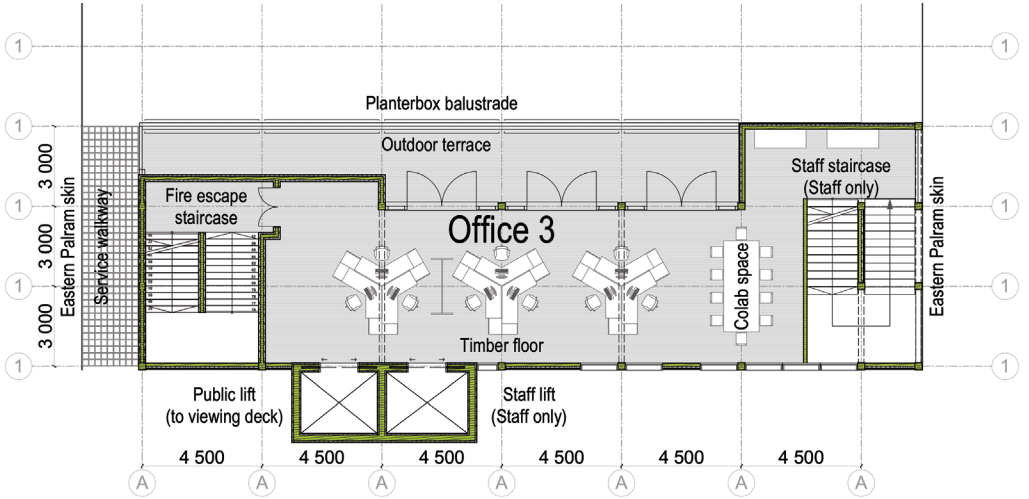

**Figure 173:** Third and fourth floor plan (Author 2020)



**Public viewing deck - Looking north-west**



**Public viewing deck - 360 view**



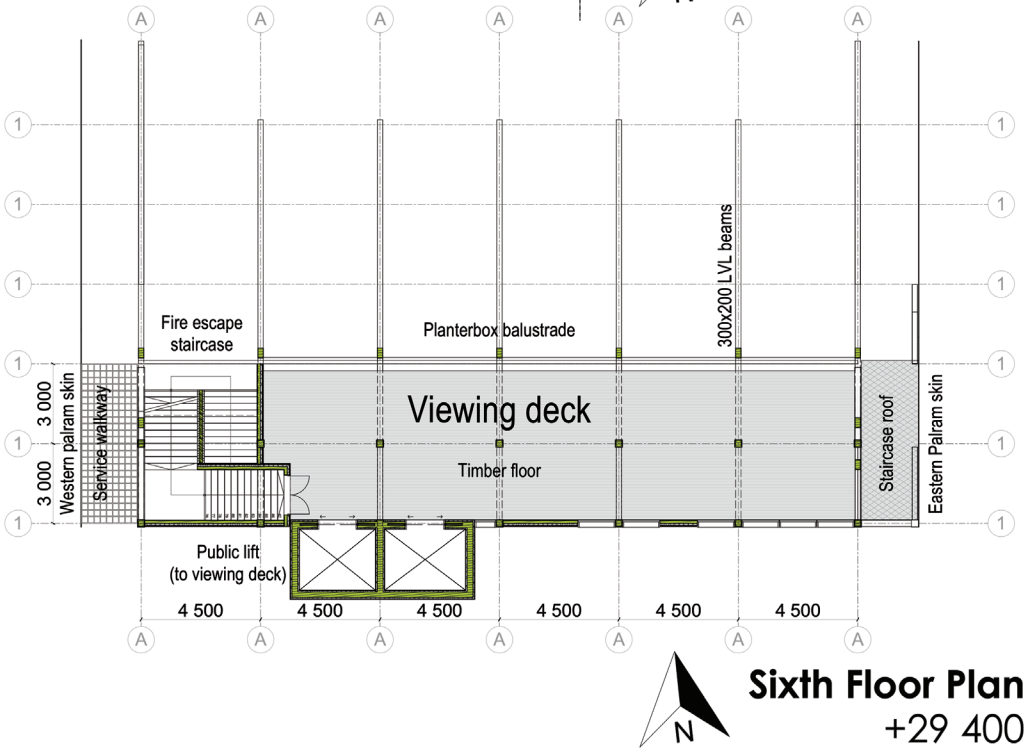




**Figure 174:** Fifth and sixth floor plan (Author 2020)

# Elevation

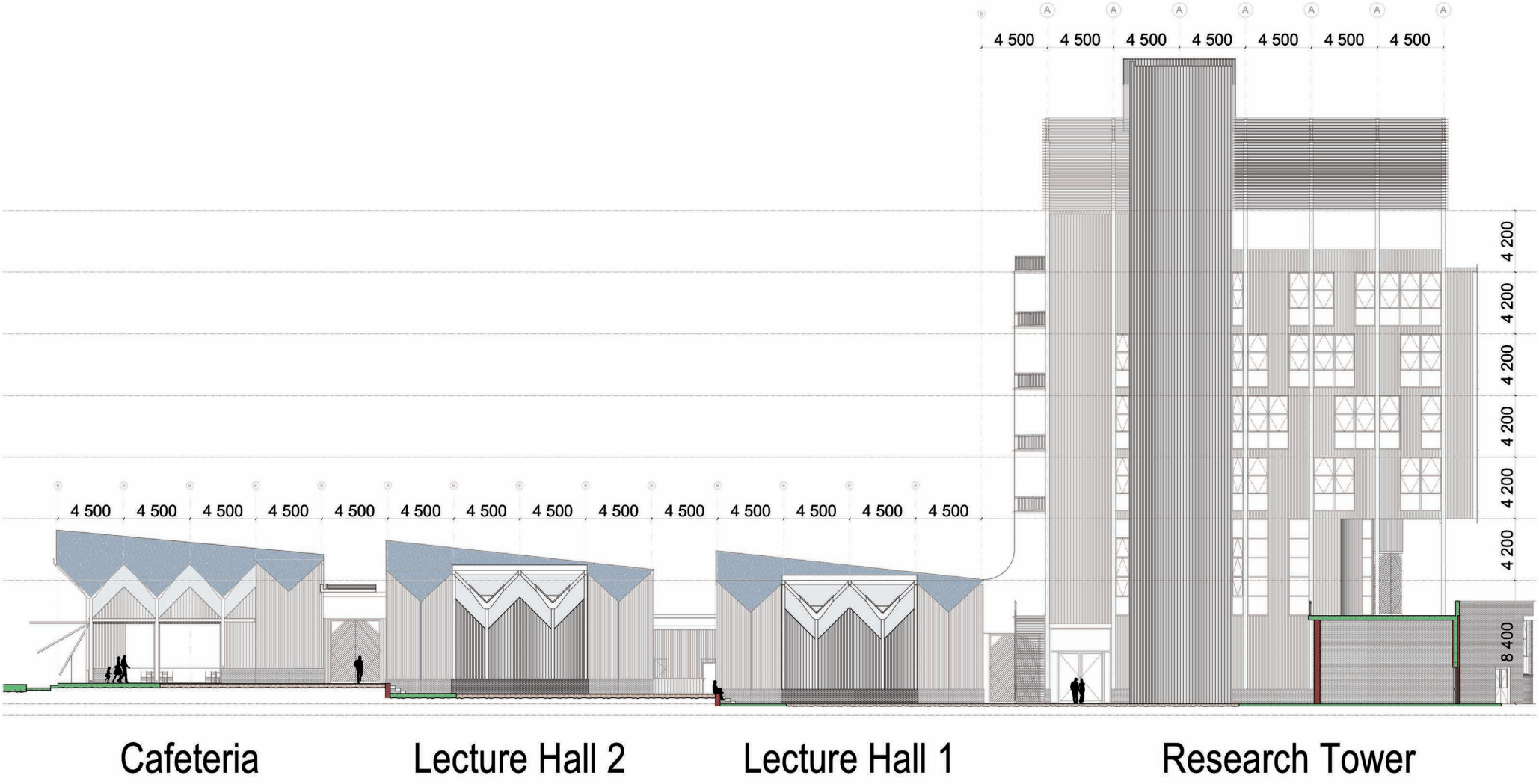



**Figure 175:** South elevation (Author 2020)

# Three different uses of timber

As mentioned before, the different use of timber depends on the program it occupies. There are three distinct uses of timber, but every use has the same triangulation language in common for structural and aesthetical reasons. Firstly, the post and beam construction method of the timber tower will be explained.

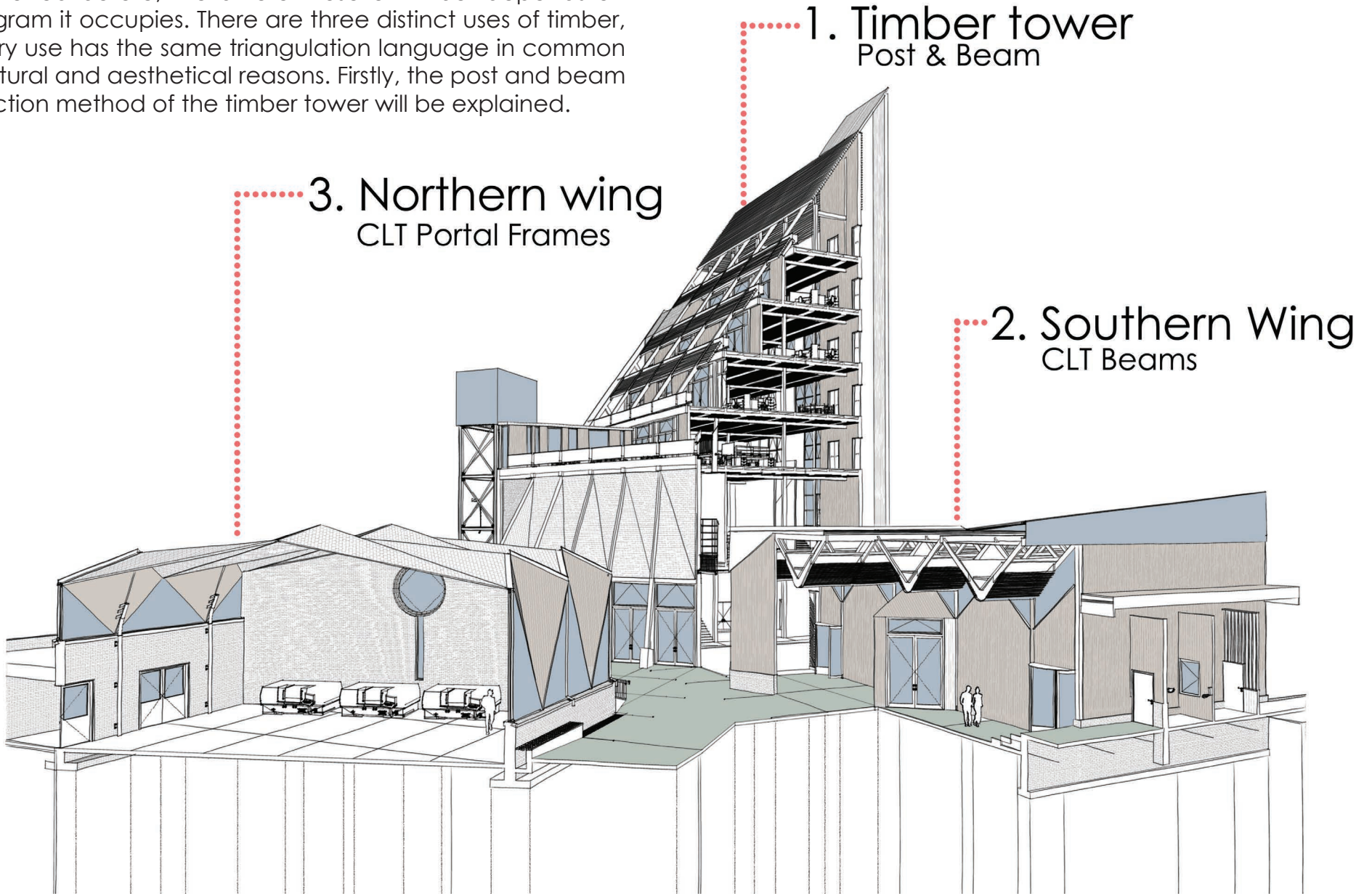
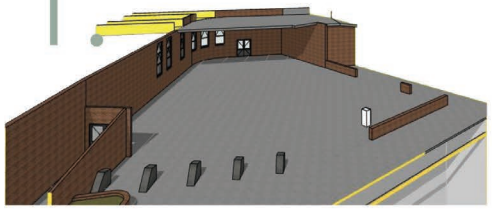
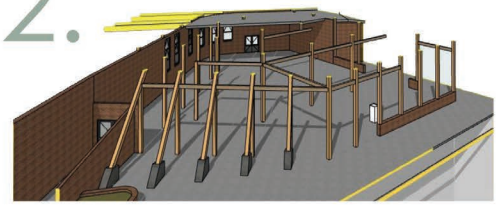



**Figure 176:** The use of timber (Author 2020)

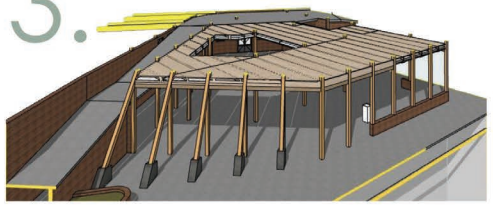
# 1. Timber tower: Post & beam construction

1.


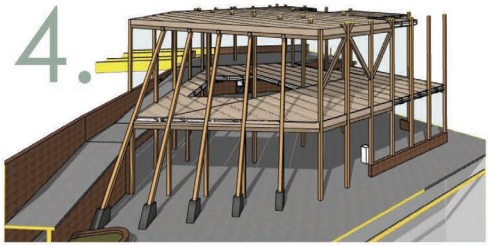
**Ground floor:** Masonry walls and RC stub columns

2.


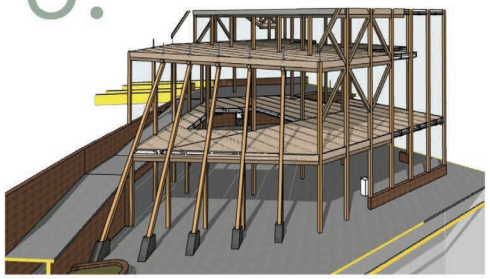
**First floor:** Glu-lam columns and LVL beams

3.


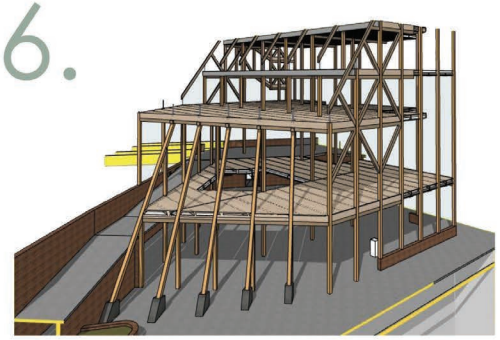
**First floor:** Premanufactured CLT floor panels

4.


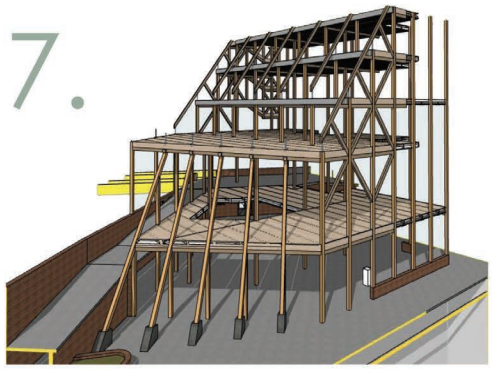
**Second floor:** Post and beam construction & floor installation

5.


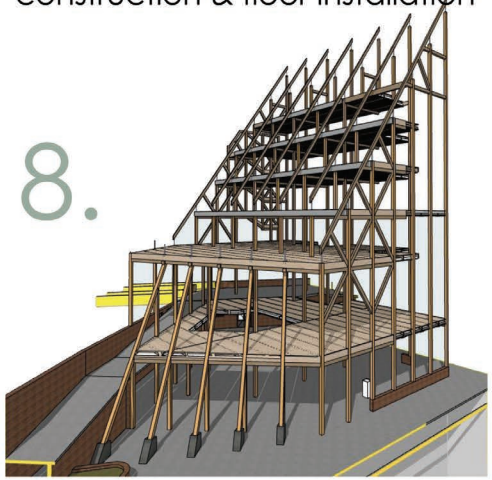
**Third floor:** Post and beam construction & floor installation

6.


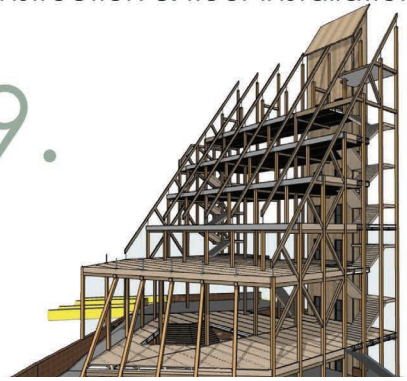
**Fourth floor:** Post and beam construction & floor installation

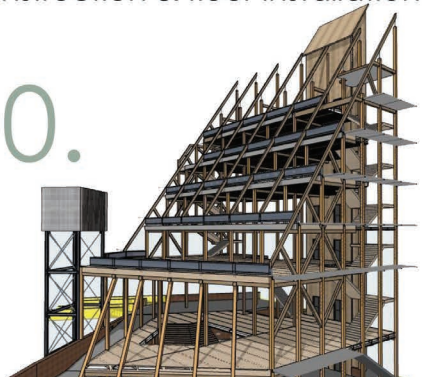
7.


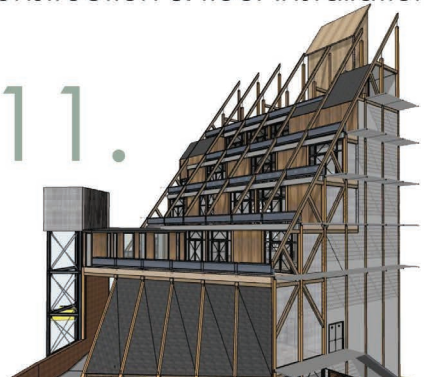
**Fifth floor:** Post and beam construction & floor installation

8.


**6th & 7th floor:** Post and beam construction & floor installation

9.


10.


11.


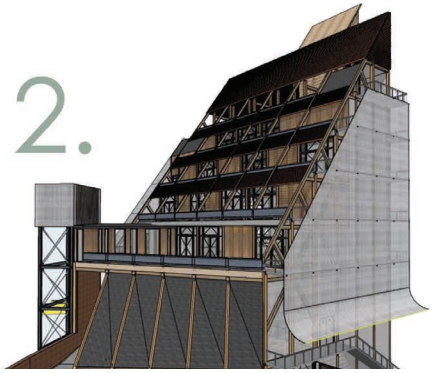
12.


**Figure 177:** Tower construction sequence(Author 2020)

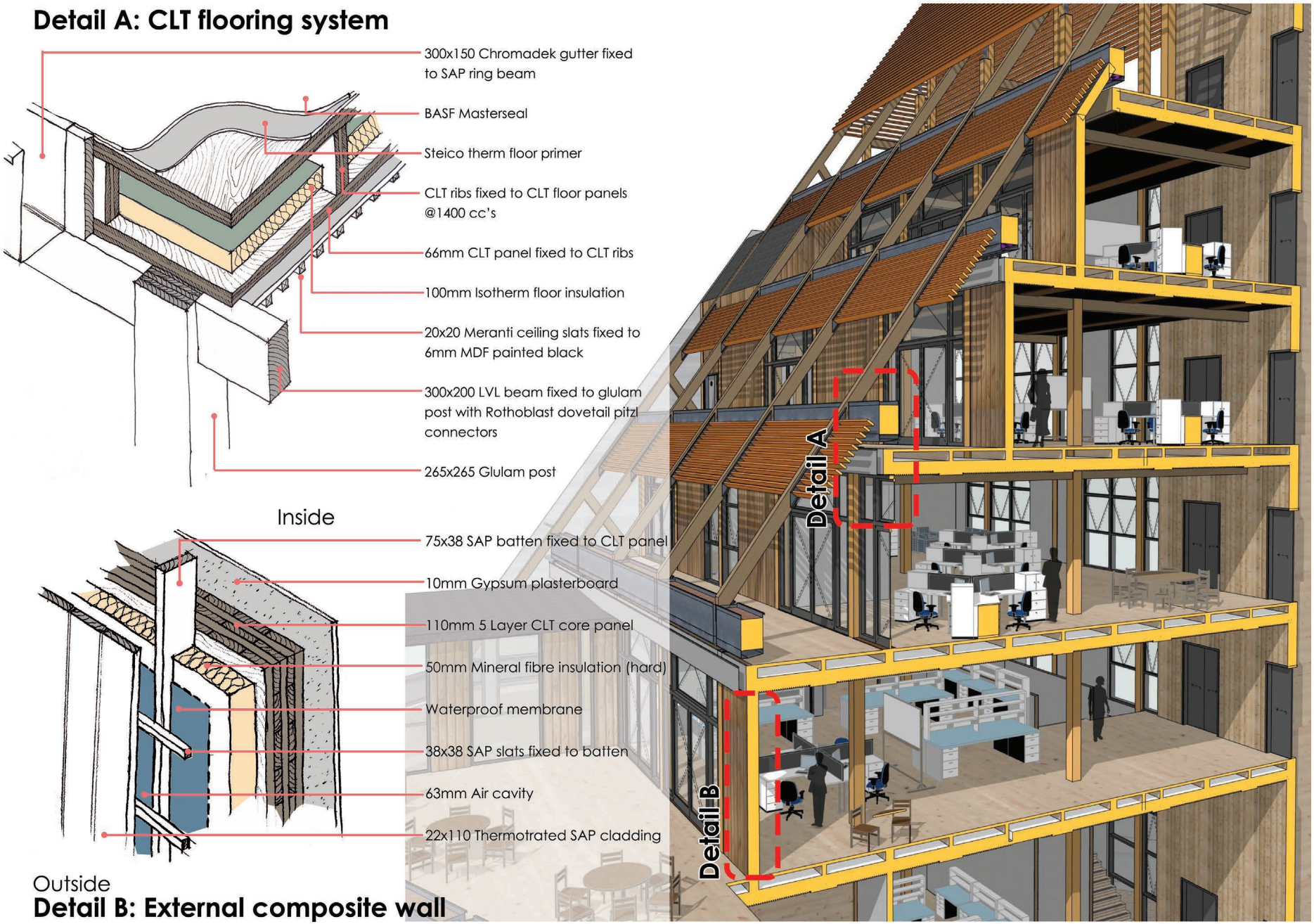



**Figure 178:** Flooring and wall systems (Author 2020)

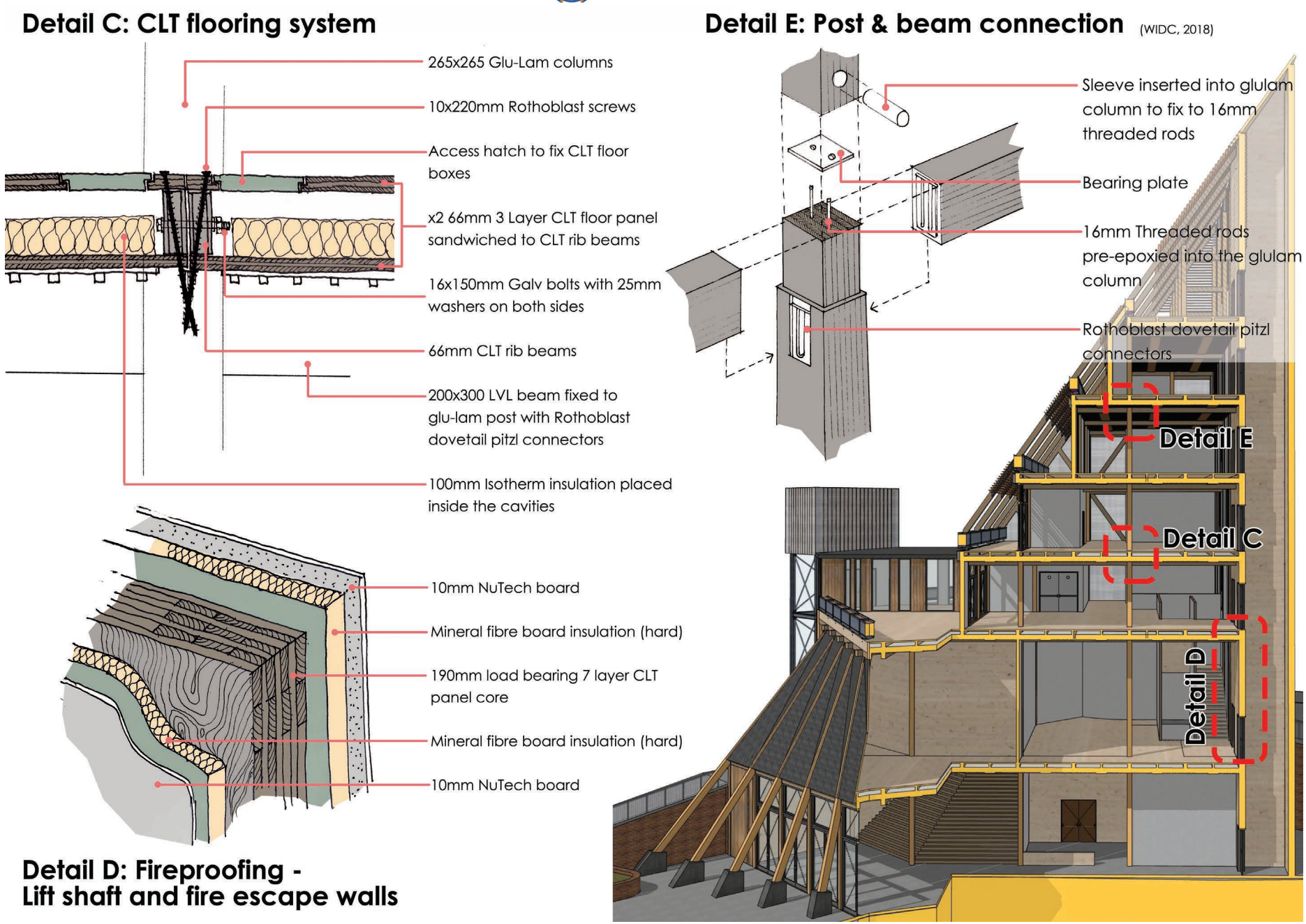



**Figure 179:** Post and beam connection, fireproofing and floor connection detail (Author 2020)



**Figure 180:** Office interior (Author 2020)



**Figure 181:** Reception(Author 2020)

# 2. Southern wing: CLT Beams

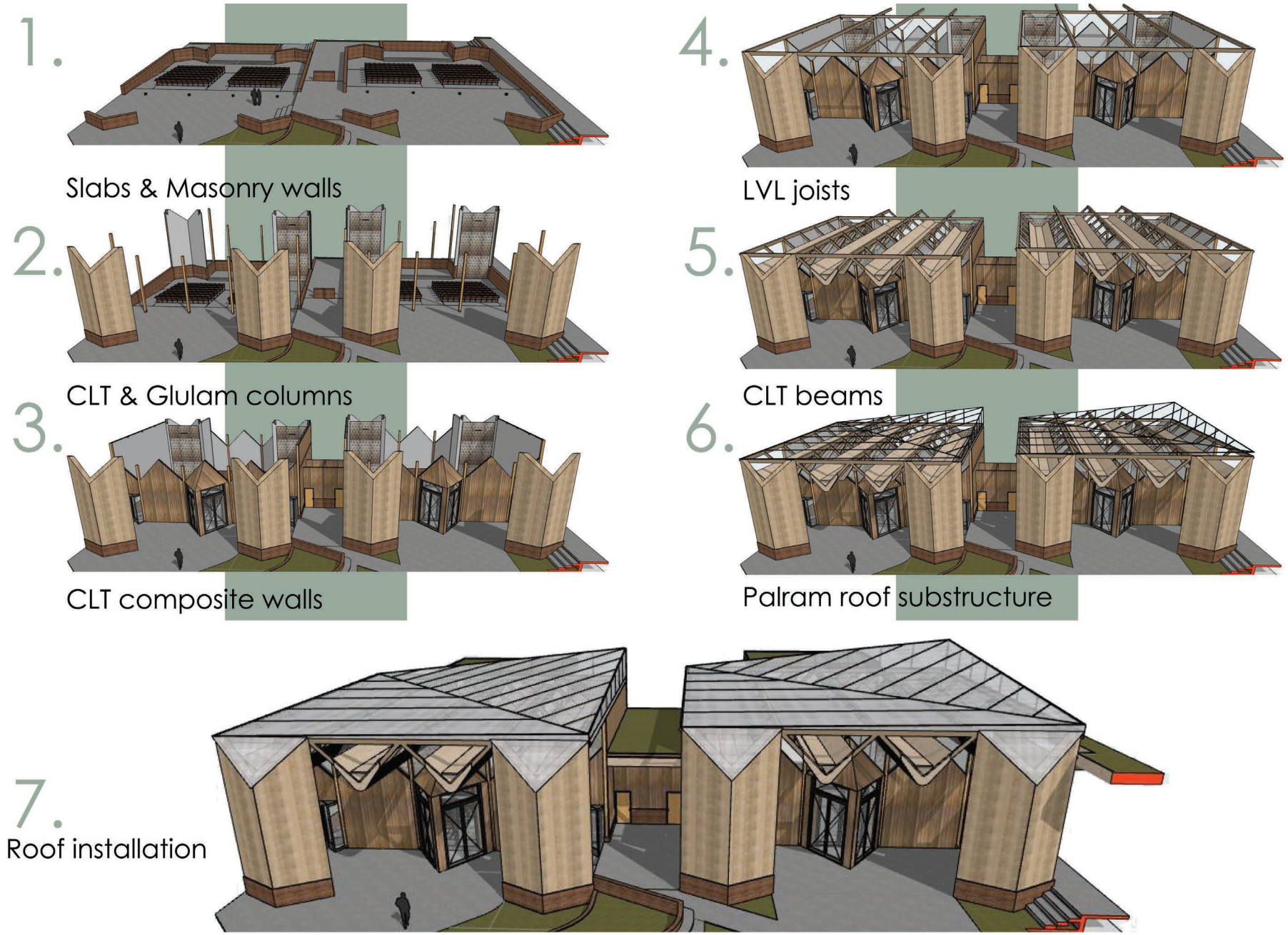



**Figure 182:** Southern wing construction sequence(Author 2020)

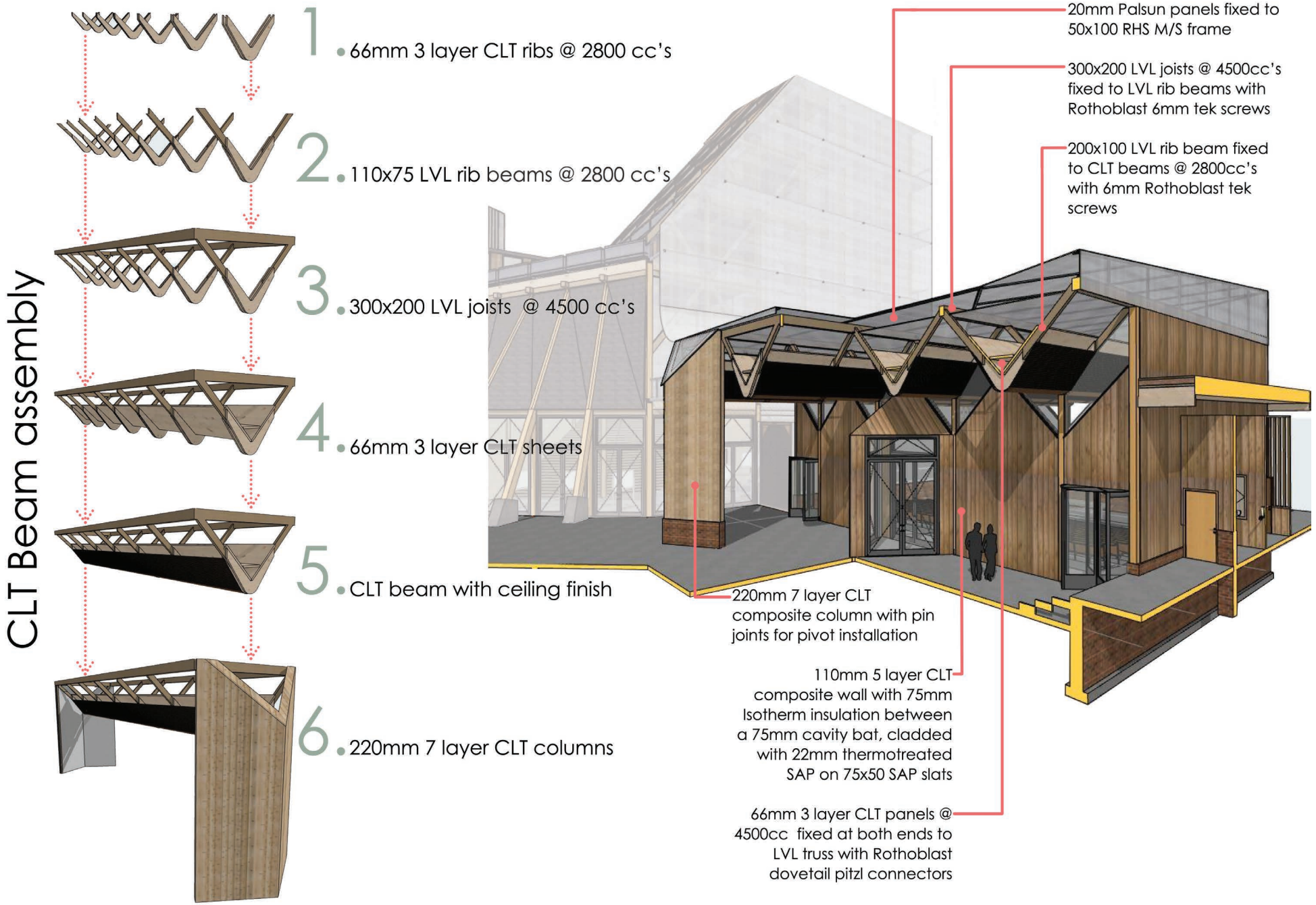



**Figure 183:** CLT beam composition (Author 2020)

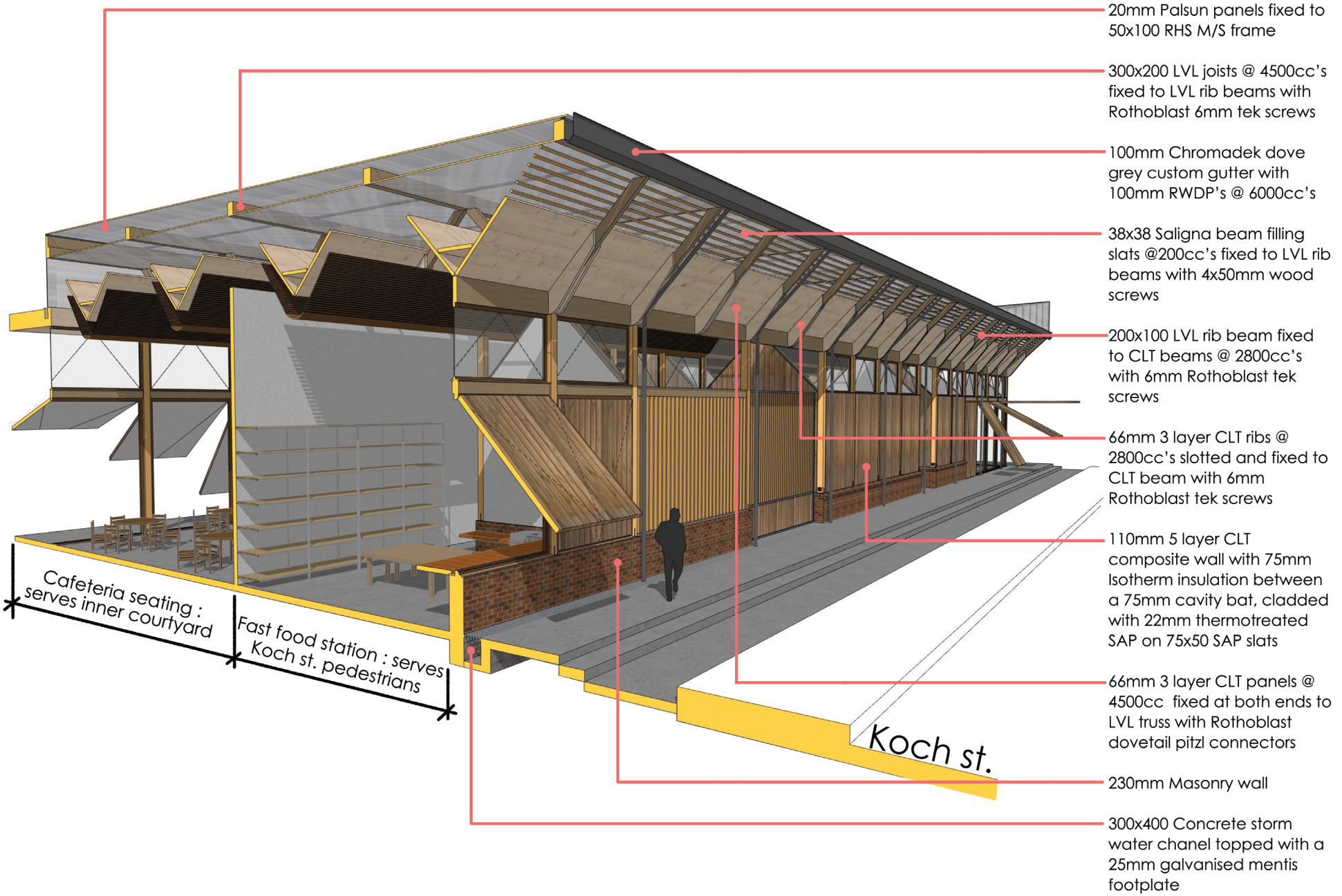



**Figure 184:** Cafeteria sectional perspective (Author 2020)



**Figure 185:** Cafeteria perspective (Author 2020)

# 3. Northern wing: CLT portal frames

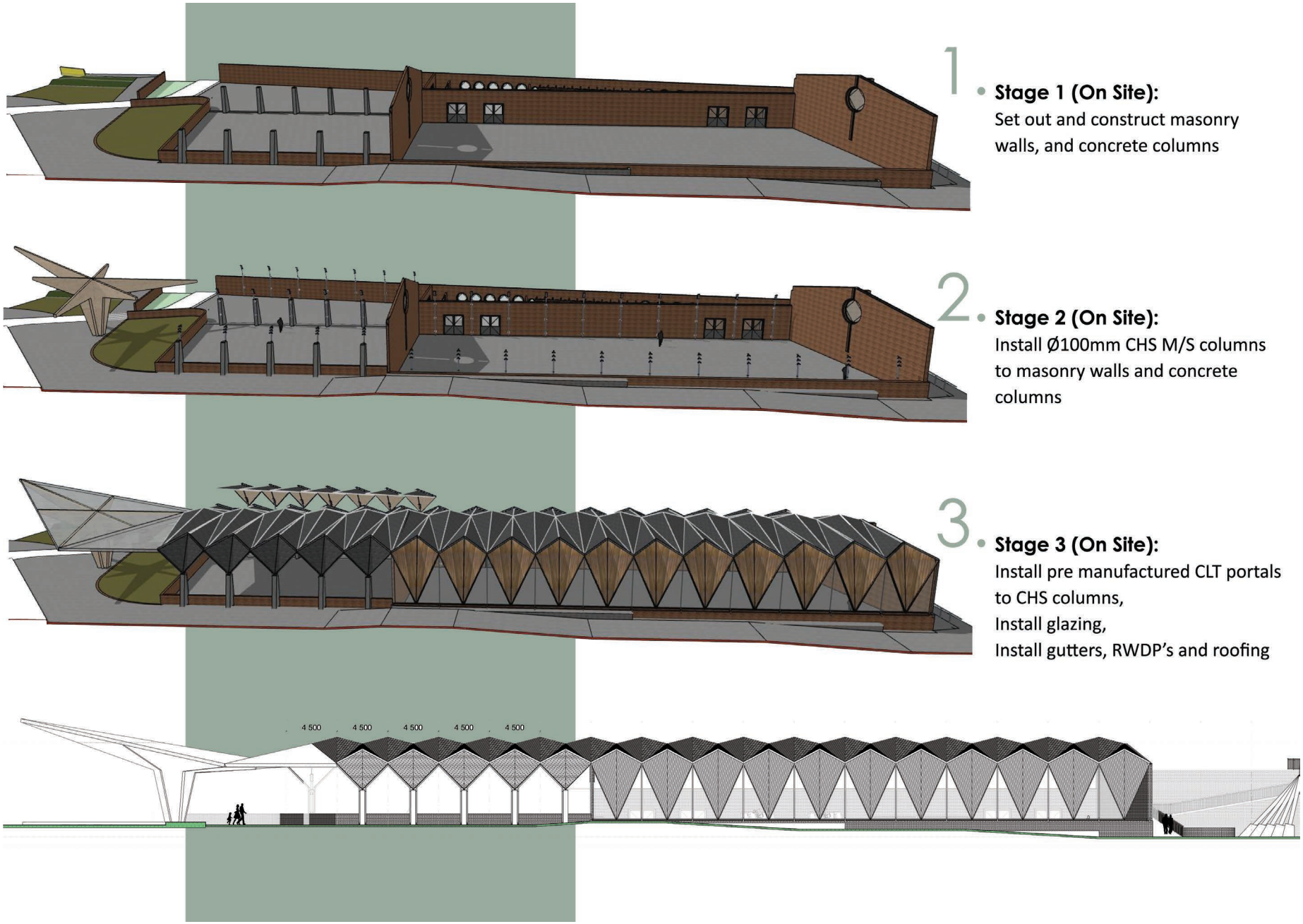



**Figure 186:** Northern wing construction sequence(Author 2020)

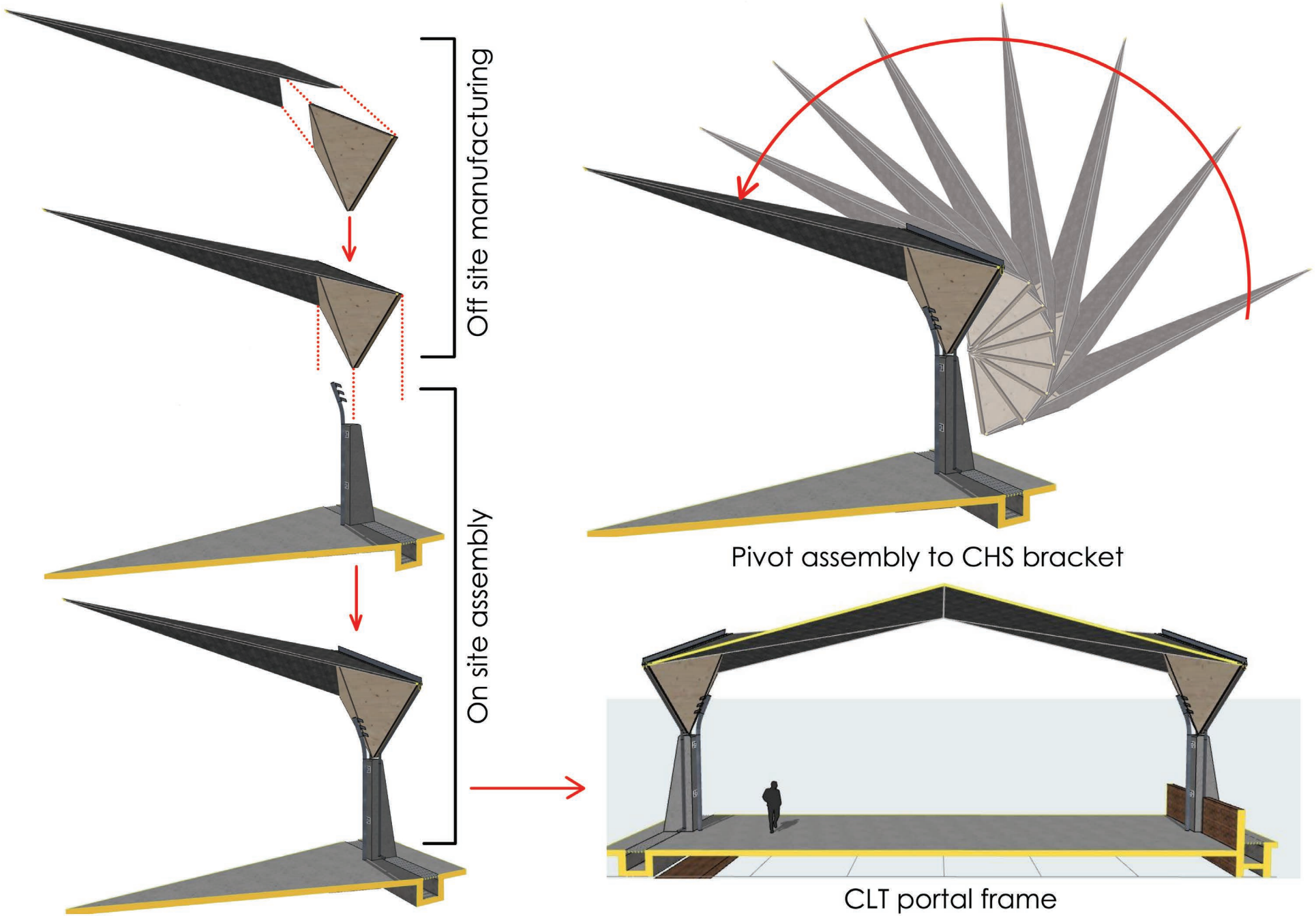



**Figure 187:** CLT portal assembly(Author 2020)

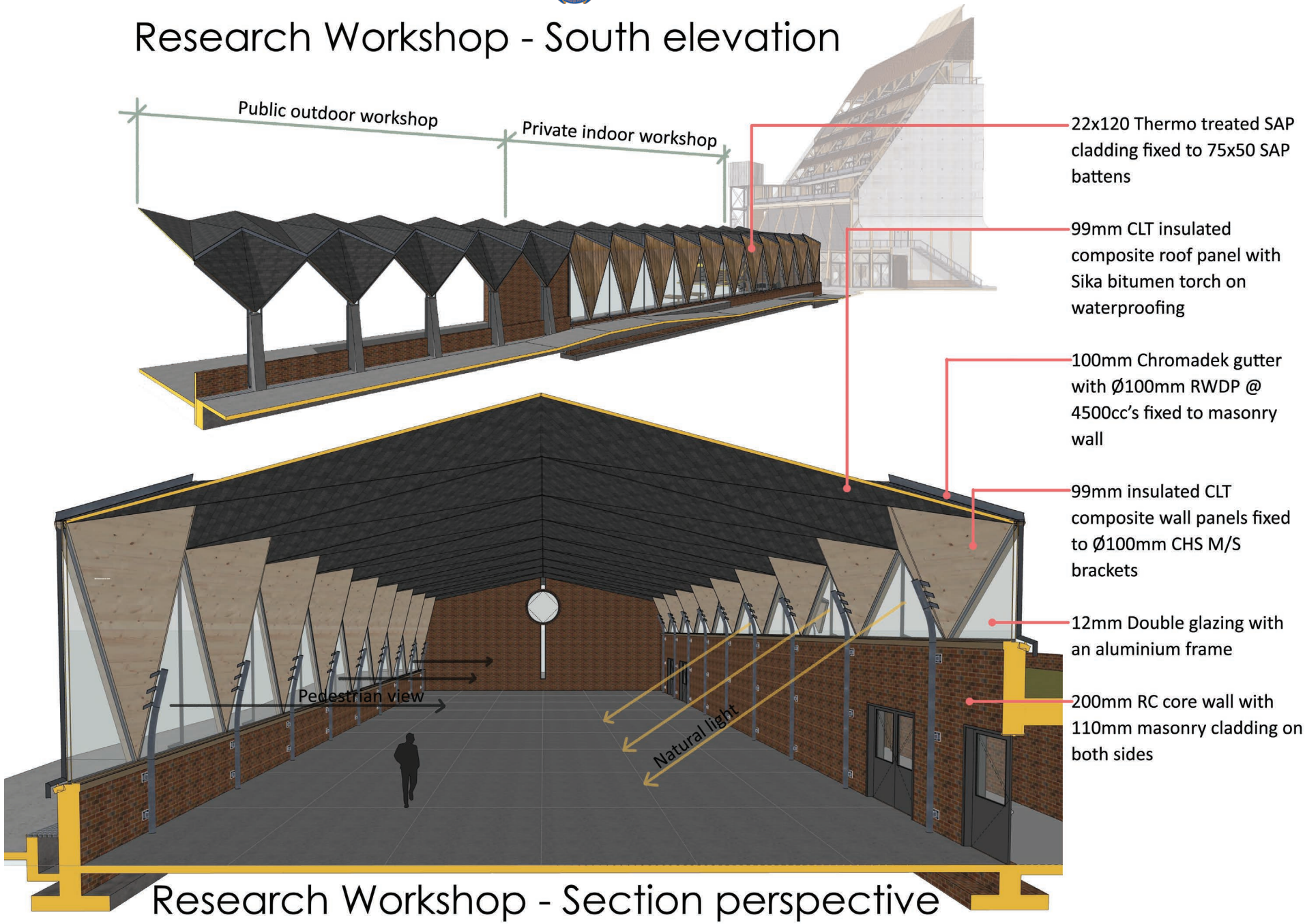



**Figure 188:** Research workshop - Sectional perspective (Author 2020)




**Figure 189:** Research workshopperspective (Author 2020)




**Figure 190:** North elevation (Author 2020)

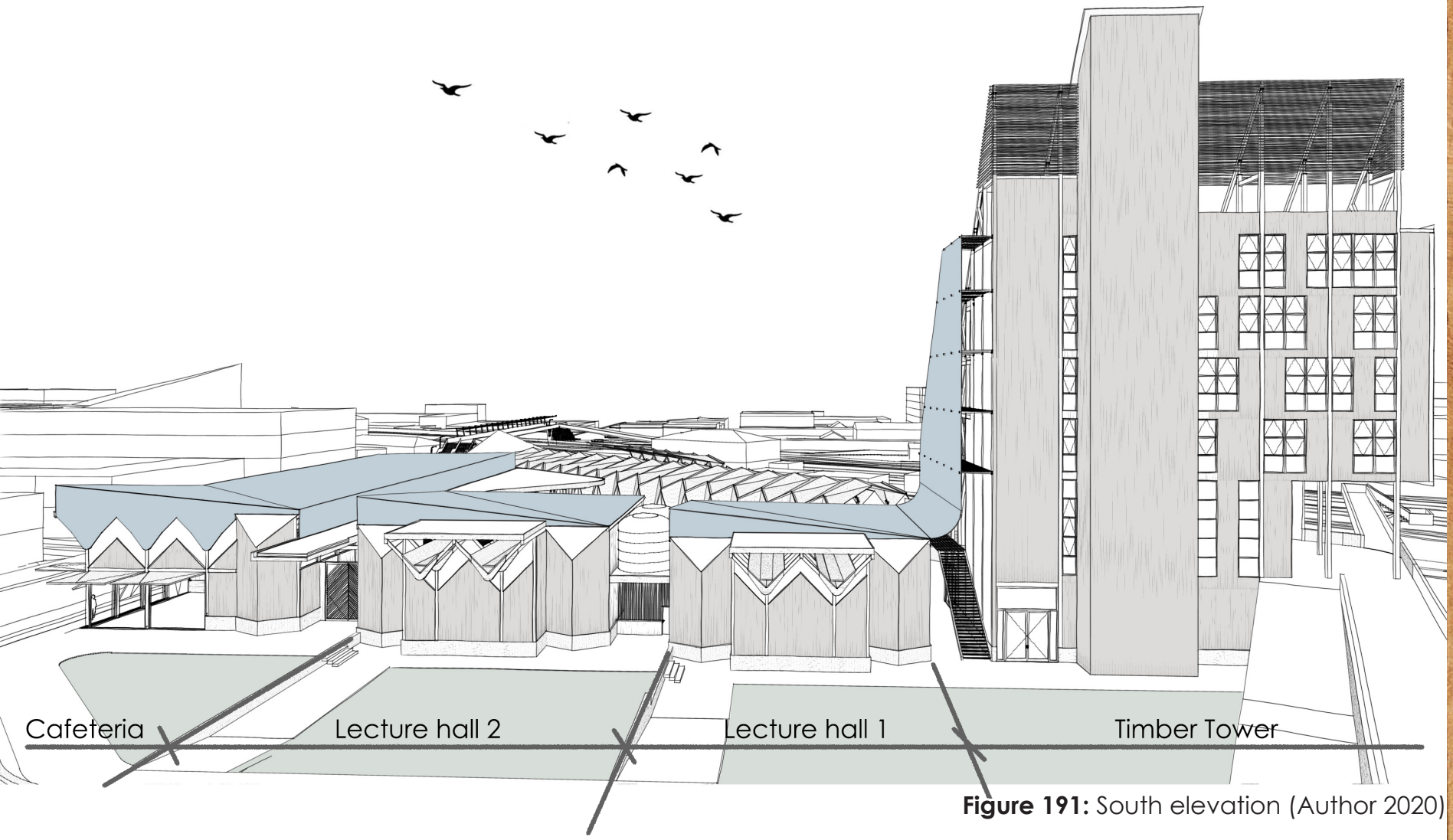



**Figure 191:** South elevation (Author 2020)

# Conclusion

## Summary of findings

It is evident that there is a major skill shortage in the South African built environment and little change can be seen in the way we approach the issue of limited local skills in the construction environment. Furthermore, South Africa's conservative approach to the use of new innovative building materials and methods, along with legislation and the material culture, allow for little room to introduce new construction materials and methods like mass timber construction. Additionally, the use of timber, timber quality and timber availability in South Africa has a bad track record owing to timber mismanagement and processing problems.

## Synthesis of the solution

Digital fabrication and component assembly are suggested as a new construction model, where skill becomes less important during the construction phase of a project due to the assembly nature of pre-manufactured building components. Skill is thus only required during the design phase of the project which involves significantly fewer people. Engineered wood was identified as a suitable material for this kind of construction model, mainly because the material properties are able to be manufactured on CNC machines, as well as the sustainability characteristics of this material.

## Issues that require further attention

The use of timber also raises new questions to be asked, especially in South Africa where timber's bad track record has been poor. It was concluded that South Africa has sufficient natural resources to enhance the forestry sector, thus promoting a stronger timber culture in the country. Hence, a few major concerns like timber processing techniques and ownership of plantations can be addressed. Once these issues are resolved, the hidden potential of the forestry sector can be unlocked to revitalise the industry, as well as to supply all of South Africa's engineered wood products locally.

## Contribution

This dissertation investigated the neglected use of a major construction material, the potential of which has not yet been fully unlocked in South Africa. The potential of this material was explored to facilitate the major concern of limited local skills by means of the already existing architectural paradigm of pre-manufacturing, but reimagined with the new technologies available in the 21st century.

A mass timber construction building with the main notion of "making" was developed and proposed to illustrate how engineered wood can be used in our socioeconomic and climatic context, to create awareness for this kind of construction, as well as to establish a timber culture among the people.
This dissertation also highlighted the events that resulted in the decline in the development of timber in the country, as well as why it is important to reconsider the use of this material to not only tackle local concerns about limited skills, but also to enable our built environment to play a part in the fight against global warming as identified in the goals of the NDP of 2030.

**Figure 192:** Opposite - Northern forecourt (Author 2020)



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# Appendix - Article

**Title**

The gap between limited local skills and high-tech design tools in the South African built environment

**Abstract**

The South African construction industry is an important role-player in job creation. In 2019, the industry provided 11% of jobs in the country (CIDB 2019:12). This figure includes skilled, semi-skilled and unskilled labour, of which the unskilled labour pool is the largest. The minister of Public Works and Infrastructure, Patricia de Lille, states in the CIBD annual report that the next few years will be crucial for South Africa's development, as we will need more than just a burst of speed to meet the goals of the National Development Plan (NDP) Vision of 2030 (CIDB 2019:4).

The Fourth Industrial Revolution has improved society in several ways and the construction industry is no exception. Every day new materials and building techniques are developed to assist designers and construction workers to complete construction projects as cost-effectively as possible and with more efficiency (Diaz 2016:2-3). Although developed countries reap the benefits of these technological advancements, developing countries such as South Africa fall behind. This is mainly due to the low skill level, as well as the lack of awareness of alternative construction materials in the country (Maddock & Maroun 2018).

One current architectural discourse is engineered wood. Although the idea of mass timber construction has been around since the 1990s, it is still a relatively new concept in the South African built environment. Thus far, only a handful of small projects relying on some aspects of engineered wood have been completed, but none have been built completely using mass timber. Not only does a mass timber building offer ecological and environmental advantages, but it also offers immense skill-based advantages because timber allows for component manufacturing and assembly, which in turn allows unskilled workers to complete a wider scope of tasks.

This dissertation aims to challenge local legislation regarding timber construction, empower unskilled workers to make complex/large-scale buildings, change public opinion about timber construction, as well as create a stronger timber culture in South Africa. In addition, this could help meet the demands of the NDP for 2030.

**Problem statement**

**General: Disconnect between technology and skill**

Developing countries such as South Africa appear to have fallen behind to a certain extent in terms of fully utilising high-tech design tools. Several challenges are experienced in this respect such as unemployment, lack of skills, difficulty adapting to alternative building methods, insufficient awareness of alternative construction as well as financial implications (Maddock & Maroun 2018).

**Local: Missing opportunities in the construction industry**

There is a tremendous gap in the South African built environment regarding the use of timber and mass timber construction. This is mainly due to the lack of a timber culture and the influence of the use of dominant materials such as steel and concrete used globally.

**Architectural: Building manufacturing**

The construction process, as stated by the Joint Building Contracts Committee (JBCC), involves an outdated construction approach, where consultants and contractors are disconnected from each other (JBCC 2014). Furthermore, this approach does not accommodate a "making" approach but is instead optimised for a building "construction" approach.

## Introduction - Background information

The latest figures for 2019 indicate that over 60% of the unemployed population have a qualification level of less than a matriculation certificate while 53.8% of employed workers only have a matriculation certificate qualification (Department of Higher Education and Training 2019).

The Construction Industry Development Board (CIDB) views construction labour as all persons involved in physical construction work. This includes skilled, semi-skilled and unskilled labour. Skill can be described as the ability to perform a certain task to a high level of competence (Shah & Burke 2005). The skills required by the construction industry entail the ability to understand the construction process and plan accordingly, to work efficiently in large construction teams and to adapt, learn and use new materials and methods. Unskilled labour, however, lack most of these attributes as well as relevant qualifications, thus limiting the potential of the construction industry as a whole (Shah & Burke 2005).

According to the CIDB (2019), the issue of limited skill is directly linked to the standard and relevance of institutions and programmes such as Further Education and Training (FET) colleges. The curriculum of these institutions does not cater for the needs or required standards of the construction industry and can therefore be judged as almost irrelevant. This issue of limited skills is also a result of the problems in the education system, such as low matric pass rates. Additionally, South Africa's maths and science results are extremely poor (Modisaotsile, 2012) but these subjects are nevertheless required in order to be admitted for higher education in most of the construction trades such as electrical or plumbing courses.

## Research question

How can the gap between limited local skill and high-tech (CNC & BIM) design tools be bridged within the South African built environment?

## Article statement

Considering the above research question, this article will investigate certain issues including questioning the processes and methods followed to construct a building, as well as how high-tech design and manufacturing tools can be utilised to address the major concern of limited skill. The investigation and findings of this article will act as a basis for the broader theme of the dissertation of timber construction and the proposal of a mass timber building in Pretoria.

## Significance of the study

This study aims to provide an alternative solution to building construction. It accordingly proposes alternative construction processes that have been tried and tested in other countries in North America and Europe. Such new processes could address challenges such as limited skills better than the current legislation. This study also aims to emphasise the large gap in the timber construction industry in South Africa, which faces problems like unemployment, low skills and global warming. Current thinking about how we make buildings needs to be reconsidered and mass timber construction can be suggested as a viable solution.

## The global construction industry

### A brief historical overview

From the dawn of architecture, humankind was intrigued and inspired by the materials they used to physically express their ideas and which allowed them to create a building or space (Frampton 2001:2–3). Timber was one of the first materials to be used for building construction, one example being the timber temple of Hera (Hekatompedos) in Samos, Greece, constructed in the mid-8th century BC (Burkert, 2013). Parallel to the use of timber was the use of stone, mainly because of its compressive strength and durability characteristics. Later, the Romans would invent and perfect the use of concrete to create structures never imagined before, such as the Pantheon in Rome constructed in 113–125 AD. The use of concrete allowed for a 43.3-metre span dome capping the rotunda (Jones 2015:182–184). These spans would later be improved as technological knowledge progressed during the Gothic and Renaissance periods.

Fast forward to the Industrial Revolution where a new material was emerging that would change the course of the construction industry for centuries to come – the industrialisation of steel in the 19th century. The potential of this material was explored by pioneer architects like Henri Labrouste (1801–1875). Steel is prominent in his design of the Sainte-Geneviève library in Paris (1850). The barrel-vaulted roof was made up of lightweight iron sheets supported by thin ribs, resting on cast iron columns (Frampton 2001:46).

Joseph Monier's (1823–1906) invention of reinforced concrete in 1849 allowed architects and engineers to develop structural systems like François Hennebique's (1842–1921) reinforced concrete construction system (see Figure 1) and later Le Corbusier's Dom-Ino structural system. This involves the use of thin reinforced concrete slabs and columns to create a free plan interior. The use of steel and reinforced concrete by architects became common and dominated the construction industry for nearly three centuries, leaving the research and development of their counterparts, such as timber, in their wake.

### The use of timber

The use of timber as a structural component can be traced back between one and three million years. Primitive shelters belonging to Peking Man, in what is now China, used timber slats to build dome-like shelters dug in a shallow pit into the earth to protect them from the elements (Smith & Snow 2012:504). Although not contemporaneously, timber construction methods evolved through the ages to what we are accustomed to today, the timber frame method. In the 19th century, methods developed such as George Washington Snow's balloon frame construction system, which is regarded as the first prefabricated building system (Frampton 2001:102). Architects like Frank Lloyd Wright (1867–1959) explored these methods and created modular systems to improve building construction and reduce construction time and material wastage, as can be seen in the summer cottage for George Gerts in Whitetail, Michigan, built in 1902, as well as his famous Usonian houses build across the United States from 1934 to 1958 (Frampton 2001:117).

Various events contributed to the steady decline in the use of timber as the main structural material. The most noteworthy is timber's combustible characteristic. Urban densification during pre-Renaissance periods caused many great urban fires. Historic fires such as the Great Fire of London (1666), the Great Chicago Fire (1871) and the Boston Fire (1872) fuelled the tendency to use more non-combustible materials such as bricks, concrete and steel. These events also resulted in governments passing legislation that limited timber buildings to heights of only four storeys, irrespective of their construction method (Smith & Snow

2012:505).

Urban densification in the 20th century demanded higher buildings to accommodate the influx of people moving to the cities. Because of height restrictions and public perception, architects and engineers resorted to the emerging materials of the time: concrete and steel (Glaeser & Kahn 2003). This led to rapid research and development of these materials and leaving timber only for furniture, interior cladding or ornamentation (Green 2019).

The use of timber as a main structural component in high-rise buildings was not realised during the 19th and most of the 20th century, until 1990. A new concept was developed by European and North American companies, mass timber construction (MTC). MTC utilises engineered wood products such as cross laminated timber (CLT), laminated veneer lumber (LVL) and laminated strand lumber (LSL). This may be used for the entire construction of a building, comprising all the structural and aesthetic elements.

Various mass timber buildings are being built in Europe and North America, with some reaching heights of more than 10 storeys; for example the Stadthaus at 24 Murry Grove in England, built in 2008 by Waugh Thistleton Architects. This was the first high-rise mass timber building in the world that was completely premanufactured and assembled on site, consequently reducing construction time to 49 weeks as opposed to 72 weeks (if the building were to be built out of conventional materials, such as steel and concrete). This building stores more than 181 tonnes of carbon. Additionally, by not using concrete, a further 125 tons of carbon are saved from entering the atmosphere (Waugh 2012).

With legislation being the one major hurdles for tall wood construction, the LifeCycle Tower, which is a concept in development that proposes a 30-storey mass timber skyscraper set to be built in Austria, challenges local authorities to re-examine legislation. Considering the entire carbon footprint and lifecycle, the building aims to be the ultimate, most sustainable building ever constructed. By using prefabrication modules, the construction time of this building will be reduced by 50% as opposed to traditional building techniques (mgb Architecture + Design 2012:30-32). The emerging use of mass timber buildings internationally serves as a valuable example to follow in South Africa.

## The South African construction industry

### A brief historical overview

Architecture in South Africa has been dominated by international influences due to its long colonial past. These influences can be traced back to European countries such as Germany, Holland and Britain. One of the first influences, following the occupation of the Cape by the Dutch in the form of the Dutch East India Company in 1652, was Dutch-Flemish which evolved in a regional architecture known as Cape Dutch. This style comprised thick stone or masonry walls and a thatched gabled roof.

During the mid-19th century, the British Victorian style dominated the built environment with Victorian patterns expressed with corrugated sheet metal and cast iron as the main construction materials. The new prosperity of gold attracted talented architects like Herbert Baker (1862–1946), who designed famous administrative buildings like the Union Building (1909) in Pretoria. Influenced by the international neoclassical style, built with sandstone as the main construction material.

During the 1920s, influences from international contemporary movements influenced the built environment such as the Modern

movement of the early 20th century, which involved the use of reinforced concrete and steel as the main construction materials. These materials along with masonry and glass (because of their availability) would be used as the main construction materials for the rest of the century. In addition, new thinking and influences such as the International style, Little Brazil movement and Regionalism all make use of these materials as a result of their availability, as well as past experience, knowledge and familiarity in the industry. The use of timber as a main construction material was very limited and mostly reserved for use in roof trusses, interior cladding and decorative elements (Prinsloo 1995:302–304), contributing to the decline in a timber culture.

**Local challenges**

Currently, the South African built environment comprises a few skilled workers and consultants and a substantial number of unskilled workers with an education level of matric or less. This places a lot of pressure on the industry much of the work involved is skill intensive.

Other factors relating to skilled worker shortages include the ageing workforce. Research indicates a 30% influx of skilled artisans leaving the workforce (Mukora 2008). These losses of skilled workers are not being filled by a new workforce. This is due to prospective students who are discouraged because they did not obtain a matriculation certificate or had very poor maths and science results (Department of Basic Education 2019:16-18).

This statistic is one of the main reasons why innovative building methods or materials face various hurdles within the South African context; there simply aren't enough skills in the construction workforce pool for architects to specify such methods/materials. The workforce of most contractors consists of workers with limited skills, leading them to resort to known methods that are tried and tested. These contractors rarely overstep the boundaries to explore new materials and methods of construction unless they are given the opportunity (Maddock & Maroun 2018). This phenomenon also explains the building industry's strong conservative belief in traditional materials such as concrete, steel and masonry. This results in limited opportunities to explore alternative construction materials such as engineered wood.

It is also noted that newly developed construction materials and techniques have resulted in a change of demand in certain skills and, in some cases, new skills. According to the Department of Education (2018), the technological advances in the construction industry lead to an ever-changing ecosphere of newly required skills. Curriculums need to be updated, which will redefine the skill requirements for the construction industry (Windapo 2016:3).

**The building process**

Building processes in South Africa are governed by entities such as the Joint Building Contracts Committee (JBCC). Current legislation and building contracts are not compatible with pre manufacturing principles (Green, 2019) as they are optimised for traditional building techniques which require predominantly onsite operation in order to construct a building. Moreover, the consultants and contractors are disconnected from each other and the only line of communication between these two stakeholders is the project manager (PM) who is responsible for all the communication and information between the consultants and the construction team. This approach can have serious consequences such as the misinterpretation of important information, which can result in the project being completed past its due date or over budget (JBCC 2014).

Furthermore, this process disconnects the designers and builders from one another. Traditionally, architects and engineers would design the building and start to issue construction documentation, without the input of the building contractor. This method disconnects the design phase from the building phase. Also, the amount of resources and people required are utilised in the end (build) phase instead of being spread out evenly

between all the phases. This can result in a high risk of change orders (Green 2019).

Katerra, a US-based company, has devised a strategy for a building automation process designed around the use of mass timber construction and building manufacturing automation. This process distributes most of the resources at the beginning of the project to mitigate the risk of change orders as the project progresses. The entire project is created with the aid of a building information management (BIM) program, which is used by all consultants to test building performance and loads, project sequencing, time management and project costs. All these are extremely important aspects and possible issues related to the project are discussed and resolved before the groundwork commences, thus mitigating risks.

**A South African case study**

**Future Africa, Dining Hall, Earthworld Architects, Pretoria, 2018**

Finding a mass timber building case study in South Africa is impossible, simply because there has never been a mass timber building constructed in South Africa in the 30 years of the existence of engineered wood. There are, however, a handful of projects which have been completed using engineered wood and the principles of pre-manufacturing. One such project is the recently completed Dining Hall of the Future Africa campus in Pretoria, completed in 2018 by Earthworld Architects. The principal architect, André Eksteen, saw the immense potential of pre-manufacturing with timber. This allowed him to design a relatively complex structure that was completely designed and "built" in the digital realm of the BIM environment, machined with the help of computer numerical control (CNC) machines and assembled by unskilled workers.

A series of portal frames were used to create the structural system. These portals were constructed out of three layers of 22 mm plywood boards, cut on a CNC machine and assembled off site for installation on site. The build took only 90 days which included manufacturing and assembling the entire structure. The main advantage was that the manufacturing and erection process could happen simultaneously. The contractor assigned to the project had a degree in graphic design but was a joiner and carpenter by trade. This was the first building he had ever built. His team consisted of eight workers, who were all unskilled (Gunter 2020).

The integration of BIM software operated by one skilled architect allowed the manufactured building components to be assembled by unskilled workers, thereby capitalising on the large number of unskilled workers to a ratio of 1:8.

**Hout Bay house, HWZ International, Hout Bay, 2015**

The Hout Bay house was the second CLT house designed and constructed in South Africa with the aim of promoting the use of CLT and timber construction as a sustainable material for housing. The house is a showcase which is accessible to the public. The main aim of this house is to establish the way in which engineered wood performs in the climatic conditions of the Western Cape. The entire house was pre-manufactured in a factory and assembled in just 28 days. Local unskilled helpers were able to assemble the entire house with the help of two CLT construction professionals. Test results also indicated that thermo-treated pine can withstand the elements in the Western Cape. The carefully designed CLT wall and roof systems have cavities and overhangs which can deal with the high humidity of the Cape (HWZ International 2015).

## Research methods and design

Two focus groups are identified as major role players in any construction project: the professional team (architect) and the contractor (construction workers). Accordingly, two different questionnaires were sent to each focus group to identify the current state of the built environment. Additionally, 23 significant buildings were analysed to determine common or new trends used in the construction industry.

This research adopted an overarching or a mixed method (Creswell 2009). It followed a quantitative approach with the use of structured questionnaires, which were sent to several architects in South Africa via Google Forms, as well as qualitative approach that used face-to-face interviews with workers in the construction industry. These included entrepreneurs who get work from the street such as in front of hardware stores. The questions that were formulated for each of the two questionnaires/focus groups were obtained from the literature review where the current state of the built environment was identified. This highlighted important questions that needed to be clarified.

A third method was also undertaken. A desktop study of prominent buildings that have been built in the last 20 years in South Africa was conducted and the following criteria were formulated for selecting and analysing these buildings:

- Buildings had to be located in Gauteng for ease of access to these buildings.
- The buildings had to be publicly accessible in order to allow them to be inspected or there had to be enough information published about the building to analyse it via a desktop study.
- The buildings had to have been built between 2000 and 2020.
- The buildings had to have won the SAIA award for excellence or an award for merit.

The buildings were analysed according to Laughier's principles of the primitive hut, according to which Laughier divides and analyses buildings into three main elements: the column, the entablature and the pediment (Laugier 1755). These elements were adapted in order to be relevant within the context of this study. The adapted elements whereby the selected buildings were analysed are the floor, the wall and the roof.

## Research methods limitations

A number of limitations were identified

**Age groups and experience.** No way was found of contacting a architects in a certain age group with a specific number of years of experience; instead any architect was able to fill in the form. It might have been more beneficial if only architects with 10 years of experience or more could have filled out the forms. However, due to the national COVID-19 crisis this was simply not possible, as I was unable to meet architects in person. I therefore resorted to an electronic medium. One can, however, accept the survey responses provided by more experienced architects into account. For the purposes of this study I used all the feedback, as the results were generally the same.

**Focus group two: unskilled workers.** I was able to approach several workers in person before the national lockdown but was alas unable to interview as many workers as I have hoped for. Most of these workers were found in front of hardware shops and feel a bit intimidated when approached. They feel as if they are being violated in some way or they might get into trouble. Taking the university's ethical guidelines into account, I was only able to interview about 70% of the people that I approached. Although this limited the amount of information, I was still able to get enough information to make an informed conclusion.

**Building analysis.** This study only focuses on award winning buildings in Gauteng. It might have been more beneficial to widen the scope and include more building categories like simple residential dwellings, office blocks and commercial buildings to obtain more detailed information. However, this would have been impossible, given the time, resources and manpower required to inspect such a wide range of buildings. Therefore, the study only focused on award winning buildings which had received an award for a good reason. A simple approach was taken: if a prestigious building did not utilise innovative building or alternative construction materials such as engineered wood, what are the chances that a normal dwelling or office block would utilise these methods or materials?

## Research findings

The three data collection methods conducted revealed interesting results. The three studies will each be analysed individually in order to identify the initial findings.

### Structured questionnaire completed by the architects

The study identified that professional architects acknowledge that the construction industry in South Africa has changed over the past 20 years. They also acknowledge that various new innovative materials and construction methods are available for use. However, most respondents revealed that these new techniques and materials can sometimes be difficult to incorporate in their designs owing to the lack of awareness of new materials and methods, as well as the limited local skills in the country. They also highlighted that the quality of work is not always on par. Most would describe the quality of work as average.

Almost 90% of the architects responded that they already use BIM software to facilitate their designs and documentation. In the light of the use of innovative materials this is a positive result, as BIM programs are the pioneer programs being used for alternative building construction, techniques and building component manufacturing (Volk et al. 2014:1–2). Most of the respondents also said that they are eager to learn more about BIM software and the benefits it has to offer.

Architects prefer a mix of both traditional and innovative building materials and techniques, depending on their own design philosophy, material availability and client requests.

Ninety per cent of architects responded that they had knowledge of engineered wood products, but they seldom specify these materials, as they are unknown among contractors as well as clients. Both contractors and clients prefer more traditional materials they are accustomed with, both in terms of material performance and durability.

### Semi-structured questionnaire administered to the construction workers

The construction workers interviewed ranged from skilled to semi-skilled craftsmen. Most respondents revealed that they were skilled in more than one trade, on average up to three trades. This reflects the context of the South African economy and the healthy sense of entrepreneurship, where an individual is willing to expose themselves to various trades to enhance their chances of getting work.

Ninety-three per cent of the interviewed workers said that they had acquired their skills from a relative or someone they knew. None of these respondents had received any form of formal education. This highlights the lack of institutions where people can learn essential skills relevant to the construction industry in this country (Windapo 2016), as well as the lack of opportunities to study at such an institution.

Most of the construction workers did not have any knowledge of alternative construction methods or materials, knowing only the basic uses for materials. For example, concrete is only used for floor slabs and foundations, bricks are the only material used to construct walls, and timber is the only material used for roof trusses. This identifies the large gap in awareness of the use of alternative building methods and materials, as well as why architects cannot specify the use of these methods and materials.

In addition, these workers had no knowledge of engineered wood products, mainly because they had not been exposed to these materials or they had never been given the opportunity to work with these materials. Timber construction was seen as an elite trade far out of their reach.

**Building analysis: findings**

A total of 23 buildings were analysed, all according to the categories indicated above. These buildings are considered elite buildings in the South African built environment and yet they show signs of mostly having used traditional materials and construction methods. There are however exceptions: the use of innovative methods and materials used can be seen in roofs and walls, where the design of such a system greatly benefits the building's thermal and environmental performance.

In only a few projects (less than 10%) was the use of timber as the main construction material identified. The use of timber is surpassed by the use of more traditional and perhaps more regional materials such as bricks and concrete. This indicates the large gap in the awareness of the use of timber for building construction. Of the five main building materials (concrete, bricks, timber, glass and steel), timber is the material with the lowest total embodied energy and is a completely renewable source (Ching 2014:p. 421). The use of timber should therefore be encouraged to be used.

It is also evident that innovative materials and methods are only applied to buildings of this calibre (as identified in the category by the set limitations). Most of the buildings in our built environment make use of traditional methods and techniques (CIDB, 2019) that do not benefit from the use of innovative methods and materials.

**Findings discussion**

**The link between limited skill and high-tech design**

**Decline in construction skills**

It is evident in this study that there has been a rapid decline in construction skills. To make matters worse, the building industry has not seen significant change in terms of the adaption of new materials or methods to change the way we think about limited skills. Public perception and a conservative approach to traditional building materials make it impossible to explore new means of confronting the problems of limited skills. Consequently, there is no opportunity to explore new materials like engineered wood and construction methods like pre-manufacturing and building in the current built environment. We lack a broad sense of material culture. Material culture, as Sennett (1943–) describes it, "provides in sum a picture of what humans beings are capable of making" (Sennett 2008:15). The bigger the scope of material culture, the bigger the possibilities to consider in the making of our buildings.

The architects interviewed indicated that the overall craftsmanship in the country is deteriorating. These days most people complete work just for the sake of getting paid for the job. In earlier days being a craftsman in your trade was considered the ultimate accomplishment. Today, society has

changed so much that the carpenter and the doctor don't work next to each other anymore as they did centuries ago in classic Medieval and Renaissance cities. Craftsmen these days are located outside the realm of the inner city. At different moments in history, practical activity has been degraded, separated from so-called higher pursuits. Technical skills have been removed from the imagination (Sennett 2008:21). Emerging technologies can assist the designer to enable unskilled workers to participate in the act of making once more.

**Bringing back meaning to the making of a building: enabling an unskilled worker to be a craftsman**

It is certainly possible to get by in life without dedication. Anyone can claim that they are the master of their craft. Sennett describes individuals who complete a task merely for the sake of completion as not worthy of the title of craftsman (Sennett 2008:20). Being a craftsman means to have a skill developed to a very high degree. Acquiring such a level of skill requires immense dedication and diligence. This comes with a reward, both personally and socially. C. Wright Mills (1916–1962) explains:

> The labourer with a sense of craft becomes engaged in the work in and for itself; the satisfactions of working are their own reward. The detail of daily labour is connected in the worker's mind to the product; the worker can control his or her own actions at work; skill develops within the work process; work is connected to the freedom to experiment. Finally, family, community, and politics are measured by the standards of inner satisfaction, coherence, and experiment in craft labour (Wright Mills 1951:220–223).

When interviewing the unskilled construction workers, one prominent phenomenon surfaced. There is a strong will among unskilled workers to learn about their trade or to learn new skills from other trades. Although very limited, they reveal a sense of pride in their work. But because of the competitive market and the limits on their skills, the instinct to survive is bigger than the instinct to produce good work. The labourer struggles to become fully engaged in their work, therefore failing to gain any satisfaction out of their labour.

Bringing back the meaning in the making of a building is an extremely important intangible aspect that is missing from our current construction endeavours. Unskilled workers do not get the opportunity to be involved in the more intricate phases of a building's construction, because due to their skill level the design or construction method does not allow them to be. When a labourer can gain a sense of self-satisfaction, only then will they pursue the ideal of a master craftsman and ultimately be inspired to enhance their skill and bring back a strong sense of meaning in construction and making.

**Art, craft and technology and the skill they entail**

As terms, art and craft overlap as they are both considered to be forms of creativity. A third concept, technology and how technology is used to achieve or aid an individual in their pursuit of art or their craft, may also be considered a skill/craft. Richard Sennett (1943–) explains in his book ,The Craftsman (2008), that a conductor, artist, carpenter and lab technician are all considered craftsman because they are dedicated to good work for its own sake. "They all represent the special human condition of being engaged" (Sennett 2008:20).

Art and craft were founded centuries ago. Back then it was the mediation between the head and mind to enable the artist or craftsman to produce a tangible object/work. But in recent years, since the beginning of the Industrial Revolution, this notion is thought be in jeopardy (Sennett 2008:25–27) because the means of producing and making can now also be accomplished by using machines and technology. Although these machines can produce work that is far more accurate and detailed than most artists or craftsmen, they still require some sort of input/data on what to do. Therefore, operating a machine or program may

also be considered a craft in its own right, just like a conductor or lab technician. Technology will never replace the human connection of being engaged in art or craft, but it can be used as a third tool apart from the mind and hand to assist in the making of meaningful things.

Art is considered to be the expression of emotions while craft is considered to be a form of work completed to a high level/ standard. It results in a tangible output (Baldwin 2017). In the context of this study, art and craft are a single entity. With technology, the hand and mind is used as a tool to achieve these goals of manufacturing and making in a meaningful and economic way.

All media used to create, whether it be virtual/BIM design, laser cut, metalwork, CNC woodwork, 3D printed ceramics, painting or glasswork, can be considered either as utilitarian or artistic. The notions of art and craft are intertwined. The degree of invention and creativity and their investment of beauty and the inspiration of emotion embodies art, but each is expressed through their craftsmanship (Baldwin 2017).

**Rethinking the making of buildings: the pre manufacturing approach**

Pre-manufacturing is not a newfound 21st-century idea. Architects like Frank Lloyd Wright and Le Corbusier explored the possibilities of pre-manufacturing in their respective eras. In Le Corbusier's essay titled "Le Modulor" (1948) he states the following:

> Building should be the concern of heavy industry, and the component parts of houses should be mass – produced.
> A mass – production mentality must be created:
> A frame of mind for building mass – produced houses,
> A frame of mind for living in mass – produced houses,
> A frame of mind for imagining mass – produced houses (Smith 2012:219).

This normative approach was adapted to tie in with the argument of this study.

> Building should be the concern of *manufacturing*, and the component parts *should be machined to be assembled*.
> To *enable anyone to be part of the making where skill becomes less important*.
> *An assembly* mentality must be created:
> A frame of mind for building *prefabricated structures*
> A frame of mind for living in *prefabricated structures*
> A frame of mind for imagining *premanufactured buildings*.

Frank Lloyd Wright's Usonian houses proved the fundamental advantages of the premanufacturing building approach. The idea of pre-manufacturing was further explored by the Usonian automatic houses (1951–1956), which allowed the owner of the house to be involved in the making of their home, cultivating a deeper connection between the building and the user to create meaning through making (Frampton 2001:102–118).

The same approach is followed in this study. Engineered timber was identified as the medium through which premanufacturing can occur to enable unskilled workers to be involved in the making of the building. The idea was that they would not only be engaged during the making process but that it would also promote a sense of self-satisfaction and create meaning.

**Mass timber construction: the pre-manufacturing building process**

Mass timber buildings offer many advantages. Engineered timber can be machined by CNC machines using BIM design programs such as Rhino, Grasshopper, Revit and ArchiCAD. This method of design enables building component manufacturing and pre-manufacturing and allows for efficient and affordable prototyping, as well as small building tolerances. An entire building can be developed and designed in the digital realm

in a BIM environment, where simulations can be conducted to obtain data such as structural and room temperature simulations, material quantities and component cut lists, all before construction has started, thus mitigating the risk of the project being over budget or late (mgb Architecture + Design 2012:36).

A further benefit is that any element or structural component can be modelled and detailed to the finest and most precise perfection. A simple approach can be followed: if a component is modelled in the 3D BIM model, then it will be built. These modelled elements can be exported to various formats for 3D printing, laser cutting or CNC cutting. Building elements can be machined and manufactured the same way cars are manufactured on production lines, where efficiency is everything (Hager, Golonka & Putanowicz 2016). Building elements arrive on site and the building is assembled instead of being built.

With the advent of CAD and modelling software, many professionals have struggled to make the shift to relying solely on these programmes to do their work, finding mastering this skill challenging at first. As time progressed, however, the usability of these programs developed a more user-friendly interface – with some training almost any professional individual can operate and fully utilise them (Kostic et al. 2012), thus limiting the skill level required for building manufacturing. Skill is only required to model these elements with much less skill needed to assemble them, thus limiting the number of skilled staff required and capitalising on unskilled labour to assist in the assembly of buildings.

## Article conclusion

The way we approach construction has remained the same for decades, as have legislation, building contracts and building procedures. What has changed is the availability of skills and funds and a deteriorating education system. We need to change the way we think about building construction.

Technology and manufacturing using engineered wood and various other materials as a medium leads to skill becoming less important, thus enabling anyone to be part of the building process and allowing for a wider scope of people to participate in the act of making.

For this large group of workers, construction has become merely a completing a job just for the sake of surviving. It has lost the intangible aspect of being engaged, creating meaning for the labourer who invests their time and effort in their daily work.

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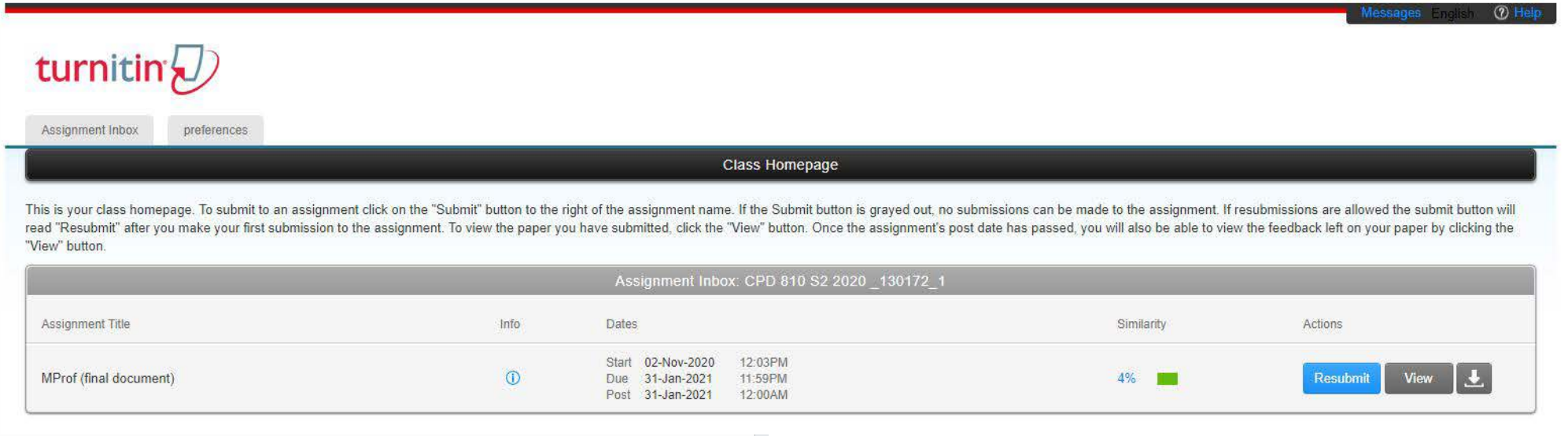
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# Ethics approval

UNIVERSITEIT VAN PRETORIA
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Faculty of Engineering, Built Environment and Information Technology
Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Reference number: EBIT/53/2020

Ms C Karusseit
Department: Architecture
University of Pretoria
Pretoria
0083

Dear Ms C Karusseit

**FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY**

Your recent application to the EBIT Research Ethics Committee refers.

Conditional approval is granted.

This means that the research project entitled "Masters Professional Dissertation in Architecture, Landscape and Interior Architecture" is approved under the strict conditions indicated below. If these conditions are not met, approval is withdrawn automatically.

**Conditions for approval**
Approved based on the summaries provided.
Applications from each student (including application forms and all necessary supporting documents such as questionnaire/interview questions, permission letters, informed consent form, etc) will need to be checked internally by the course coordinator/ supervisor. A checklist will need to be signed off after the checking.
All of the above will need to be archived in the department and at the end of the course a flash disc / CD clearly marked with the course code and the the protocol number of this application will be required to be provided to EBIT REC administrator.
No data to be collected without first obtaining permission letters. The permission letter from the organisation(s) must be signed by an authorized person and the name of the organisation(s) cannot be disclosed without consent.

This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Code of Ethics for Scholarly Activities of the University of Pretoria, or the Policy and Procedures for Responsible Research of the University of Pretoria. These documents are available on the website of the EBIT Ethics Committee.

If action is taken beyond the approved application, approval is withdrawn automatically.

According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of the EBIT Research Ethics Office.

The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

**Prof K.-Y. Chan**
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

UNIVERSITY OF PRETORIA
FACULTY OF ENGINEERING, BUILT ENVIRONMENT & INFORMATION TECHNOLOGY
**DEPARTMENT OF ARCHITECTURE**

**CPD 810 / DPD 801/2/3 / DIT 801/2/3**

Student researcher declaration

(To be signed by each student and kept on record by the supervisor)

1. Title of research project:
   **For the sake of the craft: A research and skills development facility within the Pretoria CBD** (Working title)

2. I Christian Greyling student number 15054013 hereby declare that:

1) I am acquainted with the Code of Ethics for Research and will apply the principles contained in the Codes in all my research activities;
2) I will conduct the study as specified in the application and principally responsible for all matters related to the research;
3) I will communicate all changes to the application/or any other documents before any such is executed in my research with my supervisor;
4) I will explain the objectives and implications of the research to informants;
5) I will indicate to informants that their participation in the research is voluntary and that they can withdraw from the research at any stage;
6) I will obtain written informed consent from each informant;
7) I will not to ask informants any questions requesting personal information (e.g., questions on name, ID number, etc.) or questions beyond the theme of the abovementioned project;
8) I will treat all responses of informants confidentially;
9) I will not engage in any form of research fraud (e.g., falsifying or distorting data);
10) I will obtain written permission letters from organisation(s) that may be contacted as for data related to the abovementioned project; and
11) I will not engage in research that presents conflict of interest or financial benefit, whether for the researcher, company or organisation, that could materially affect the outcome of the investigation or jeopardise the name of the University of Pretoria.

Student signature: _____ Date: 11-03-2020

